Abridged Alternatives Analysis Report on Two-component Low- and High-pressure Spray Polyurethane Foam Systems Containing Unreacted Methylene Diphenyl Diisocyanate

Prepared for
American Chemistry Council
Center for the Polyurethanes Industry
Spray Foam Coalition
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Abbreviations

4,4-MDI	4,4-Methylene Diphenyl Diisocyanate
AA	Alternatives Analysis
ASTM	American Society for Testing and Materials
BPA	Bisphenol A
CAA	Clean Air Act
CalDTSC	California Department of Toxic Substances Control
CalOSHA	California Division of Occupational Safety and Health
CARB	California Air Resources Board
CAS No.	Chemical Abstracts Service Registration Number
CBC	California Building Code
CBES	California Building Efficiency Standard
CBI	Confidential Business Information
CCR	California Code of Regulations
CHDA	1,3- and 1,4-Cyclohexanedicarboxaldehyde
CPI	Center for the Polyurethanes Industry
CPSC	Consumer Product Safety Commission
CRC	California Residential Code
ECHA	European Chemicals Agency
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GPC	Global Product Classification
HDI	Hexamethylene-1,6-diisocyanate
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
Hg	Mercury
HNIPU	Hybrid Non-isocyanate Polyurethane
HSDB	Hazardous Substances Data Bank
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	International Building Code
ICC	International Code Council
ICC-ES	ICC Evaluation Service
IECC	International Energy Conservation Code
IPCC	Intergovernmental Panel on Climate Change
K_{ow}	Octanol-Water Partition Coefficient
Kp	Dermal Permeability Coefficient
LCA	Life Cycle Assessment
MDI	Methylene Diphenyl Diisocyanate
MXDA	Meta Xylene Diamine
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PHT4	Tetrabromophthalate
PPE	Personal Protective Equipment
ppm	Parts Per Million
R&D	Research and Development

RBC	Residential Building Code
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals
RE	Responsible Entity
SCAQMD	South Coast Air Quality Management District
SCP	Safer Consumer Products
SDS	Safety Data Sheet
SFC	Spray Foam Coalition
SPF	Spray-applied Polyurethane Foam
SPFA	Spray Polyurethane Foam Alliance
TBPD	Tetrabromophthalate Diol
TCPP	Tris(2-chloropropylphosphate)
TDI	Toluene Diisocyanate
TEP	Triethyl Phosphate
TMG	N,N,N',N'-Tetramethylguanidine
US DOT	United States Department of Transportation
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

Executive Summary

This Abridged Alternatives Analysis (AA) report was prepared on behalf of each of the responsible entities (RE) participating in the American Chemistry Council's Spray Foam Coalition (SFC). A current list of SFC members is included in Section 1 of this report. The REs participating in the SFC represent a majority of the manufacturers (*i.e.*, systems houses) of two-component spray polyurethane foam (SPF) systems containing unreacted methylene diphenyl diisocyanate (MDI) (organized into four groups, which are referred to herein as the Priority Products). This Abridged AA report was prepared based on the readily available information about the Priority Products and sought to determine whether there are viable candidate alternative chemistries for these products. Important elements of this work were considering the requirements (legal or otherwise) for the Priority Products, determining the function of the chemical of concern (unreacted MDI) in the Priority Products, determining whether simply replacing the chemical of concern in the Priority Products' formulations with one that has reduced health and safety concerns was possible, and assessing relevant factors that indicate a material difference between the Priority Products and potential alternatives.

A two-component SPF product formulated without unreacted MDI or an equivalently effective replacement would not be functional. Thus, simply removing the chemical of concern from the Priority Products' formulations without replacing it with a different ingredient is not an option. We also found that there are currently no viable alternatives to MDI-based SPF. Through a review of patents, we identified several candidate alternative formulations that use alternative chemistries *in lieu* of the chemical of concern. Although such information was limited, to comply with the requirements of the California Safer Consumer Products (SCP) regulations, we used the available ingredient-based hazard and exposure information to evaluate the factors specified in the California SCP regulation to determine those that are relevant for the Priority Products. The relevant factors generally fell under the categories of product hazard, performance, relative exposure potential, and cost. Our analysis indicates that, based on the limited information in available patents, none of the alternative formulations were clearly preferable to the Priority Products. Moreover, none of the alternative formulations are currently commercially available, and data on final formulation and performance of these alternatives that would be needed to support a definitive AA are lacking.

Thus, due to the lack of available alternatives with data sufficient to support an AA, an Abridged AA report is the appropriate outcome.

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This AA was funded by the American Chemistry Council's Spray Foam Coalition (SFC). SFC member companies are:

1. A&B Filling Inc./RHH Foam Systems
2. Albemarle*
3. Arkema*
4. BASF
5. Carlisle Spray Foam Insulation (formerly Accella Polyurethane Systems)
6. Chemours*
7. COIM USA, Inc.*
8. Covestro*

9. Creative Polymer Solutions
10. DAP Products Inc.
11. Demilec, part of the Huntsman group of companies
12. DuPont, Performance Building Solutions (formerly Dow Building Solutions)
13. Evonik Corporation*
14. Firestone
15. Foam Supplies, Inc.
16. General Coatings
17. Graco, Inc.*
18. Henry Company
19. Honeywell*
20. ICL-IP*
21. ICP Adhesives and Sealants
22. Icynene-Lapolla
23. Johns Manville
24. NCFI Polyurethanes
25. SES Foam
26. Solvay Fluorides*
27. Stepan*
28. SWD Urethane
29. Wanhua Chemical (America) Co., LTD*

*Associate Members (Suppliers to the SPF Industry)

Certification and Signatures

Certification of the Abridged AA Report is included in Appendix E or will be made *via* online signature *via* the CalSAFER website during AA submission.

2 Responsible Entity and Supply Chain Information

Manufacturer(s), Importers, and Consortium Participants:

Please see information under responsible entities (REs) in Section 1.

Manufacturer(s), Importer(s), and /or Distributor(s) Listed on the Priority Products' Labels:

These data are regarded as confidential business information (CBI) for each consortium participant. A separate Appendix B will be submitted by each consortium participant and marked as CBI. Information will contain manufacturers', importers', and /or distributors' first and last name, company, email, phone, website, and address.

Purchasers of Priority Products:

These data are regarded as CBI for each consortium participant. A separate Appendix B will be submitted by each consortium participant and marked as CBI. Information will contain purchasers' first and last name, company, email, phone, website, and address.

Manufacturer(s) and/or Importer(s) Retail Sales Outlets:

Not applicable. The manufacturers of the Priority Products do not have their own retail sales outlets. Some spray polyurethane foam (SPF) products (low-pressure SPF) are sold *via* third-party retailers, and other SPF products are restricted for use by commercial applicators who purchase these products directly from the manufacturer or through distribution.

3 Priority Products Information

3.1 Priority Products Made by Responsible Entities Participating in This Alternatives Analysis Report

This RE consortium comprises systems houses[1] of low- and high-pressure two-component SPF products containing unreacted methylene diphenyl diisocyanate (MDI) that intend to continue selling the Priority Products in California. The Priority Products listed on each RE's Priority Product Notifications are shown in Table 3.1. Product safety data sheets (SDSs) for each of these products are provided in Appendix A and will be submitted individually by each RE. Appendix A will include any non-CBI SDSs, if any, or a statement that all of an RE's SDSs are being claimed as CBI. Some REs will submit Appendix A1, which will be an addendum to Appendix A containing SDSs that are considered CBI (*e.g.*, private label products that involve disclosing confidential sales relationships).

In addition, some REs wish to include certain products in this AA that are not sold in California at the time of the Priority Product listing became effective, but may be sold in California in the future as part of expected product development (see Table 3.2). Gradient reviewed these product SDSs and they would fit the criteria for Priority Products (*i.e.*, contains unreacted MDI, two-component) if they were sold in California. Their respective SDSs are included in a second addendum to Appendix A – Appendix A2.

3.2 Chemical(s) of Concern for the Priority Products

The chemicals of concern for the Priority Products are 4,4'-methylenediphenyl diisocyanate, Chemical Abstract Service Registry Number (CAS No.) 101-68-8, and generic methylene diphenyl diisocyanate, mixed isomers, CAS No. 26447-40-5 (CalDTSC, 2014). According to the California Department of Toxic Substance Control (CalDTSC) Revised Priority Products Profile, products using other diisocyanates, such as toluene diisocyanates (TDIs) and hexamethylene-1,6-diisocyanate (HDI), as well as one-component SPF systems typically sold in cans are not included in the scope of this Abridged AA (CalDTSC, 2014).

3.3 Function of the Priority Products

The Priority Products can serve as thermal and acoustic insulation, an air barrier, and a vapor retarder for commercial and residential walls, basements, and roofs (SFC, 2019a). There are three types of two-component high-pressure SPF products: open-cell 0.5-lb and closed-cell 2- and 3-lb SPF,[2] which should each be considered separate products. Closed-cell SPFs provide more resistance to heat transfer (*i.e.*, higher R values), better moisture resistance and better structural support compared to open-cell

[1] The term "systems houses" is used to designate the manufacturers who supply the formulated A side and B side of the SPF to applicators. Systems houses can be distinguished from the chemical suppliers that provide the MDI, polyols, and other chemicals to the systems houses.

[2] The densities given are approximate. For example, 2-lb foam can have a measured density ranging from 1.75-2.5 lbs. In addition, the 3-lb foam category includes certain specialty applications (*e.g.*, chicken coop insulation) that may have higher densities (*e.g.*, up to 10 lbs per cubic foot).

SPFs, whereas open-cell SPFs have greater flexibility and are better acoustic insulators. In addition to these properties, SPF also helps increase building strength and prevents the entry of pollen, dust, and insects into the building where it is applied (SFC, 2019a,b).

Table 3.1 Manufacturers of Low- and High-pressure Two-component SPF Products Containing Unreacted MDI Currently for Sale in California

Manufacturer Name	Product Name
Accella Polyurethane Systems[1]	FOAMSULATE 220 SERIES
Accella Polyurethane Systems	FOAMSULATE 210 SERIES
Accella Polyurethane Systems	Foamsulate 50 NIB
Accella Polyurethane Systems	BAYSEAL OC
Accella Polyurethane Systems	BAYSEAL OC X
Accella Polyurethane Systems	BAYSEAL CC X
Accella Polyurethane Systems	BAYSEAL 2.7 Series[2]
Accella Polyurethane Systems	BAYSEAL 3.0 Series
Accella Polyurethane Systems	QuadForm NatureSeal OCX
Accella Polyurethane Systems	PREMISEAL 305[3]
Accella Polyurethane Systems	PREMISEAL 350[4]
Accella Polyurethane Systems	Bayseal OC HY
Accella Polyurethane Systems	QuadFoam 2.0
Accella Polyurethane Systems	QuadFoam 500
Accella Polyurethane Systems	Premipour 202M
Accella Polyurethane Systems	PREMISEAL 40 SERIES
Accella Polyurethane Systems	PREMISEAL 60 SERIES
Accella Polyurethane Systems	PREMISEAL 70 SERIES
Accella Polyurethane Systems	PREMISEAL 80 SERIES
Accella Polyurethane Systems	PREMISEAL 250 SERIES
Accella Polyurethane Systems	PREMISEAL 255 SERIES
Accella Polyurethane Systems	PREMISEAL 280 SERIES
Accella Polyurethane Systems	PREMISEAL 285 SERIES
Accella Polyurethane Systems	PREMISEAL 300 SERIES
Accella Polyurethane Systems	PREMIR+ 60 SERIES
Accella Polyurethane Systems	PREMIR+ 40 SERIES
Accella Polyurethane Systems	FOAMSULATE CLOSED CELL SERIES
Accella Polyurethane Systems	FOAMSULATE HFO SERIES
Accella Polyurethane Systems	FOAMSULATE 50 HY
Accella Polyurethane Systems	FOAMSULATE 50
Accella Polyurethane Systems	FOAMSULATE OCX
Accella Polyurethane Systems	FOAMSULATE 70
Accella Polyurethane Systems	SEALTITE PRO CLOSED CELL SERIES
Accella Polyurethane Systems	SEALTITE PRO HIGH YIELD
Accella Polyurethane Systems	SEALTITE PRO NO MIX
Accella Polyurethane Systems	SEALTITE PRO NO TRIM
Accella Polyurethane Systems	SEALTITE PRO OCX
Accella Polyurethane Systems	SEALTITE PRO ONE ZERO
Accella Polyurethane Systems	SEALTITE PRO OPEN CELL
A&B Filling Inc.	Brand A Product 1
A&B Filling Inc.	Brand B Product 2
A&B Filling Inc.	Brand C Product 3
A&B Filling Inc.	Brand D Product 4

Manufacturer Name	Product Name
BASF Corp.	Elastospray 81255
BASF Corp.	Elastospray 81285
BASF Corp.	Elastospray 81305
BASF Corp.	Elastospray 8000A[5]
BASF Corp.	ENERTITE G
BASF Corp.	ENERTITE NM
BASF Corp.	FE 348-2.5
BASF Corp.	FE 348-2.8
BASF Corp.	FE 348-3.0
BASF Corp.	SKYTITE 2.5
BASF Corp.	SKYTITE 2.8
BASF Corp.	SKYTITE 3.0
BASF Corp.	SPRAYTITE 158
BASF Corp.	SPRAYTITE 178
BASF Corp.	SPRAYTITE 180
BASF Corp.	SPRAYTITE 81206
BASF Corp.	SPRAYTITE SP
BASF Corp.	WALLTITE US
BASF Corp.	WALLTITE HP+
BASF Corp.	BASF CBI - #1
BASF Corp.	BASF CBI - #2
BASF Corp.	BASF CBI - #3
BASF Corp.	BASF CBI - #4
BASF Corp.	BASF CBI - #5
BASF Corp.	BASF CBI - #6
BASF Corp.	BASF CBI - #7
BASF Corp.	BASF CBI - #8
BASF Corp.	BASF CBI - #9
BASF Corp.	BASF CBI - #10
BASF Corp.	BASF CBI - #11
BASF Corp.	BASF CBI - #12
BASF Corp.	BASF CBI - #13
BASF Corp.	BASF CBI - #14
BASF Corp.	BASF CBI - #15
BASF Corp.	BASF CBI - #16
BASF Corp.	BASF CBI - #17
BASF Corp.	BASF CBI - #18
DAP Products, Inc.	Touch n' Seal Fire-Rated 1.75 PCF Slow Rise Polyurethane Foam Sealant
DAP Products, Inc.	Touch n' Seal 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant
DAP Products, Inc.	Touch n' Seal 2.0 PCF Fire-Rated Polyurethane Foam Sealant
DAP Products, Inc.	Touch n' Seal 3.0 PCF High Density Closed Cell Polyurethane Foam Sealant
DAP Products, Inc.	Touch n' Seal Mine Foam Sealant
DAP Products, Inc.	Touch n' Foam Professional Fire-Rated 1.75 PCF CCMC Closed Cell Polyurethane Foam Sealant
DAP Products, Inc.	Touch n' Foam Fire-Rated 1.75 PCF Closed Cell ICC Polyurethane Foam Sealant
DAP Products, Inc.	Touch n' Seal Fire-Rated Low Density 1.0 PCF Open Cell Polyurethane Foam Sealant

Manufacturer Name	Product Name
DAP Products, Inc.	Touch n' Seal 1.75 PCF Fire Rated PCF CCMC Closed Cell Polyurethane Foam Sealant
Demilec	Agribalance
Demilec	Demilec APX
Demilec	Heatlok HFO High Lift
Demilec	Heatlok HFO Pro
Demilec	Heatlok Soy 200+
Demilec	Heatlok XT
Demilec	Sealection 500
DuPont[6]	FrothPak™ Sealant and Insulation
DuPont	FrothPak™ Ultra Insulation
DuPont	Styrofoam™ Dow 3019 with CM2045
Firestone	F1800 – GacoTrenchFoam – Polyol Component B
Firestone	F-CF2030 – GacoPourFoam CF2030 – Polyol Component B
Firestone	FB28-120 – GacoFlashFoam – Component A & B
Firestone	F10000 – GacoToughFoam – Polyol Component B
Firestone	F183M – Gaco 183M– Polyol Component B
Firestone	F1850R – GacoOnePass – Polyol Component B
Firestone	F052N – Gaco 052N GacoInsulBarrier – Polyol Component B
Firestone	F5001 –GacoFireStop 2 – Polyol Component B
Firestone	F4500R – GacoEZSpray – Polyol Component B
Firestone	FR6500R – GacoProFill – Polyol Component B
Firestone	F1880R – GacoOnePass Low GWP – Polyol Component B
Firestone	F2733R – GacoRoofFoam – Polyol Component B
Firestone	ISO – Isocyanate – Iso Component A[7]
General Coatings Manufacturing Corp.	Brand A 1, 2.5
General Coatings Manufacturing Corp.	Brand A 2, 2.7
General Coatings Manufacturing Corp.	Brand A 3, 3.0
General Coatings Manufacturing Corp.	Brand B 1, 2.5
General Coatings Manufacturing Corp.	Brand B 2, 2.7
General Coatings Manufacturing Corp.	Brand B 3, 3.0
General Coatings Manufacturing Corp.	Ultra-Thane 050
General Coatings Manufacturing Corp.	Ultra-Thane 050 OCX
General Coatings Manufacturing Corp.	Ultra-Thane 170 Pour Foam
General Coatings Manufacturing Corp.	Ultra-Thane 230-2.0[8]
General Coatings Manufacturing Corp.	Ultra-Thane 230-2.5, 2.7, and 3.0 Roof Foam
General Coatings Manufacturing Corp.	Universal Polymers Corp 2.0
General Coatings Manufacturing Corp.	Universal Polymers Corp 500
General Coatings Manufacturing Corp.	Universal Polymers Corp 500 OCX
Henry Company LLC	Permax Closed-cell Foam Insulation
ICP Adhesives & Sealants	Handi-Foam® E84 Spray Foam
ICP Adhesives & Sealants	Handi-Foam® Quick Cure
ICP Adhesives & Sealants	Handi-Foam® Air Seal
ICP Adhesives & Sealants	Handi-Foam® Low Density
ICP Adhesives & Sealants	Handi-Foam® Wall Seal
ICP Adhesives & Sealants	Brand A Product 1
ICP Adhesives & Sealants	Brand B Product 1
ICP Adhesives & Sealants	Brand B Product 2
ICP Adhesives & Sealants	Brand B Product 3

Manufacturer Name	Product Name
Icynene-Lapolla	Icynene Classic Plus™
Icynene-Lapolla	Icynene Classic™
Icynene-Lapolla	Icynene Classic Eco
Icynene-Lapolla	Icynene Classic Max
Icynene-Lapolla	Icynene MDC 200 V6
Icynene-Lapolla	Icynene MDR 210
Icynene-Lapolla	ProSeal Eco
Icynene-Lapolla	Icynene ProSeal
Icynene-Lapolla	Lapolla Foam-LOK FL500
Icynene-Lapolla	Lapolla Foam-LOK FL2000
Icynene-Lapolla	Lapolla Foam-LOK FL2000 – 4G
Icynene-Lapolla	Lapolla Foam-LOK LPA 2500
Icynene-Lapolla	Lapolla Foam-LOK LPA 2800
Johns Manville[9]	JM Corbond III® SPF
Johns Manville	JM Corbond® oc SPF
Johns Manville	JM Corbond® ocx SPF
NCFI Polyurethanes[10]	10-011
NCFI Polyurethanes	10-013
NCFI Polyurethanes	11-016
NCFI Polyurethanes	11-017
NCFI Polyurethanes	11-033
NCFI Polyurethanes	11-035
NCFI Polyurethanes	11-036
NCFI Polyurethanes	11-037
NCFI Polyurethanes	12-008
SES Foam LLC	EasySeal.5 Spray Foam
SES Foam LLC	Nexseal™ 2.0, 2.0W, 2.0 LE, 2.0 LE W
SES Foam LLC	SES 2.5, SES 2.5 S, SES 2.5 W
SES Foam LLC	SES 2.7, SES 2.7 S, SES 2.7W
SES Foam LLC	SES 3.0, SES 3.0 S, SES 3.0W. SES 3.0HCS
SES Foam LLC	Sucraseal™ 0.5 lb Spray Foam
SWD Urethane	Quik-Shield 100X
SWD Urethane	Quik-Shield 106
SWD Urethane	Quik-Shield 108
SWD Urethane	Quik-Shield 112
SWD Urethane	Quik-Shield 118
SWD Urethane	Quik-Shield 125
SWD Urethane	Quik-Shield 450

Notes:

CalDTSC = California Department of Toxic Substances Control; cf = Cubic Foot; dba = Doing Business As; MDI = Methylene Diphenyl Diisocyanate; SDS = Safety Data Sheet; SPF = Spray Foam Polyurethane.

(1) Accella Polyurethane Systems dba Acella Polyurethane Systems, Carlisle Spray Foam Insulation, Carlisle Roof Foam and Coatings.

(2) A single SDS covers both BAYSEAL 2.7 and BAYSEAL 3.0.

(3) PREMISEAL 305 was replaced by PREMISEAL 70.

(4) PREMISEAL 350 was replaced by PREMISEAL 70.

(5) Elastrospray 8000A is the A side SDS for all BASF Priority Products in the Notification.

(6) FROTH-PAK™ Sealant uses "FROTH-PAK™ ISO INT AF HFC" for the A-side and "FROTH-PAK™ Polyol INT 1.75 HFC" for the B-side; FROTH-PAK™ Insulation uses "FROTH-PAK™ ISO INT AF HFC" for the A-side and "FROTH-PAK™ Class A Polyol INT" for the B-side; FROTH-PAK™ Ultra uses "FROTH-PAK™ Ultra 17gal REF ISO" for the A-side and "FROTH-PAK™ Ultra 17gal REF Polyol" for the B-side; STYROFOAM™ SPF uses "Dow 3019" for the A-side and "STYROFOAM™ SPF CM 2045 Polyol" for the B-side.

(7) ISO – Isocyanate – Iso Component A is the A side SDS to all high-pressure Firestone/Gaco products, other than FB28-120 – GacoFlashFoam – Component A & B.
(8) Ultra-Thane 230-2.0 shares the same SDS as Ultra-Thane 230-2.5, 2.7, and 3.0 Roof Foam.
(9) While Johns Manville chooses to include the names of the three Priority Products in the AA, Johns Manville maintains the confidential business information claim on all other information submitted to CalDTSC.
(10) Barnhardt Manufacturing Company dba NCFI® Polyurethanes.

Table 3.2 Manufacturers of Certain Low- and High-pressure Two-component SPF Products Containing Unreacted MDI That Will Potentially Be for Sale in California in the Future

Manufacturer Name	Product Name
Creative Polymer Group	A-Side
Creative Polymer Group	Air Lok 45
Creative Polymer Group	Air-Lok 170
Johns Manville	JM Corbond® IIIe SPF
Johns Manville	JM Corbond® III 2.8 SPF
Johns Manville	JM Corbond IV
Foam Supplies, Inc.	ecospray™ LE
Foam Supplies	ecoroof
Foam Supplies	EcoStar ccSPF
Foam Supplies	Spritzer Family of Products
General Coatings	Ultra-Thane 205 HFO
General Coatings	Ultra-Thane 230 HFO
General Coatings	Universal Polymers Corp UPC 2.0 HFO

Notes:
MDI = Methylene Diphenyl Diisocyanate; SPF = Spray Foam Polyurethane.

3.4 Key Performance Requirements for the Priority Products

As noted above, the Priority Products all serve as insulation and an air barrier for residential and commercial buildings. The key performance requirements for a two-component SPF are as follows:

- The product must be an effective barrier to heat (*i.e.*, the product must have thermal resistance and be an effective insulator). One reason that consumers may choose to use SPF products in a building is because of the high thermal resistance (R values) compared to other insulation products.
- The product must be able to seal a building, serving as an effective barrier to air, moisture (closed-cell foam), and sound where applied.
- The product must resist the spreading of flames and emission of smoke in the case of a fire. Mandatory criteria for surface burning characteristics have been established by building codes to help ensure fire protection. For this reason, SPF products contain flame retardants.
- The product should have a curing or polymerization rate consistent with similar products. For example, polyurethane-based spray foam polymerizes quickly, which prevents slumping, thus providing a good seal for insulated cavities. Similar curing or polymerization rates would be required for any alternatives to maintain the tight barrier properties of SPF.
- The product must have good dimensional stability (<15% change). SPF products should resist structural deterioration/decomposition and resist settling, which improves insulation performance over time.

See Section 3.6 for information on the criteria for various physical characteristics of SPF products for different types and applications.

3.5 Information on SPF Product Grouping

Based on information provided by the REs listed in Table 3.1, there are over 170 different products covered by this Abridged AA. Conducting an assessment of each product individually would be overly complicated and lead to difficulties in understanding comparisons. As a result, we have organized the Priority Products covered by this Abridged AA into four product groups based on their unique product properties and applications (see Table 3.3). The grouping is divided among low- and high-pressure SPF products, further subdivided by product density (*e.g.*, 0.5 lb per cubic foot). Further, this grouping is substantiated by the manner in which the SPF industry views these products – as four distinct products.

Higher weight indicates higher density, and such higher-density SPFs provide better insulation from air and vapor intrusion compared to lower-density SPFs (US EPA, 2016). Low-pressure two-component SPF products can be used by both professionals and do-it-yourself (DIY) applicators for weatherizing and small-scale insulation uses (US EPA, 2016). Only professionals can purchase and use high-pressure two-component SPF products (US EPA, 2016), which are for larger-scale insulation applications such as roofing, filling interior wall cavities, and continuous insulation (*i.e.*, continuous exterior insulation without gaps created by studs, joists, *etc.*) (SFC, 2019a). High-pressure SPF products fall into three groups: open-cell SPF (0.5 lb) used as wall cavity or attic insulation, closed cell 2-lb SPF also used for wall cavity and attic insulation, and 3-lb (or greater density) SPF used for building exteriors or roofs. The last category also includes miscellaneous uses (*e.g.*, chicken coops), and such SPF products have higher densities (up to 10 lbs per cubic foot). While low-pressure SPF products are also available in various densities, we did not further divide the low-pressure product group. It should be noted that the division of products into groups is for clarity of discussion purposes and reflects somewhat different uses, however all products are currently made with MDI and similar B-side chemistries, often at the same production facilities.

Product information that supports the use of these four product groups as Priority Products is available in Appendix C.

Table 3.3 Grouping of Priority Products by Product Type

Group #	Group Name	Applications
1	Low pressure (various densities)	Typically used as air sealants and for small-scale insulation applications
2	High pressure, 0.5 lb/cf, open-cell	Typically used as insulation for above grade interior wall cavities and unvented attics and crawlspaces
3	High pressure, 2 lb/cf, closed-cell	Typically used for exterior continuous insulation, insulation for above and below grade, and unvented attics and crawlspaces
4	High pressure, 3 lb+ lb/cf, closed-cell	Typically used in combination with elastomeric coatings as an insulated roofing system

Notes:
cf = Cubic Foot.
Sources: SFC (2019a).

3.6 Legal Requirements, Standards, and Voluntary Programs Relevant to the Priority Products

The legal requirements relevant to the Priority Products are contained within the International Building Code (IBC), Residential Building Code (RBC), the International Energy Conservation Code (IECC), and various state and local regulations.

Building codes are developed by the International Code Council (ICC) as a minimum set of requirements to ensure the health and safety of building occupants (FEMA, 2019). The ICC codes are referred to as "model codes," as they are adopted by most states and enforced by local agencies, although some agencies may make adaptations or amendments to the model codes. The California Building Standards Code (Title 24 of the California Code of Regulations [CCR]) has 12 parts, including the California Building Code (CBC) and California Residential Code (CRC), which are based on the IBC and RBC, respectively (California Building Standards Commission, 2019a,b). The code chapters relevant to SPF insulation are Chapter 26 of the CBC and Chapter 3 of the CRC, and these chapters are distinct from those relating to non-SPF insulation. In general, the requirements and standards outlined in the codes focus on fire protection, thermal performance, and moisture control.

In addition to the CBC and the CRC, Title 24 includes the California Building Efficiency Standard (CBES) (CCR Title 24, Part 6) (California Building Standards Commission, 2019b). The CBES helps ensure that the most energy-efficient technologies and building practices are used for both newly constructed buildings and alterations and additions to existing buildings (California Energy Commission, 2018). This standard outlines mandatory requirements for thermal insulation, including minimum R values for each climate zone. The CBES specifically references SPF insulation as a material that may be used to meet the specified requirements of an air barrier for building envelopes (California Energy Commission, 2018). The standard also states that all insulation must be certified by the California Department of Consumer Affairs, Bureau of Household Goods and Services (formerly the Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation). As described in the Home Furnishings and Thermal Insulation Act, it is the responsibility of the Bureau of Household Goods and Services to provide licenses for insulation manufacturers and enforce the adopted regulations and standards (see Sections 19164, 19165) (California Dept. of Consumer Affairs, 2019). The Act also requires that insulation manufacturers develop and implement a quality assurance program and maintain a record of performance testing. These standards and enforcement procedures apply to all thermal insulating materials and would extend to any potential SPF alternatives (California Energy Commission, 2018).

A set of specific criteria have been developed that help verify that SPF products conform to the complicated building code requirements for their intended use. All SPF products and potential alternatives must conform to the requirements laid out in the building standards. The ICC Evaluation Service (ICC-ES) developed "Acceptance Criteria for Spray-Applied Foam Plastic Insulation" (AC 377) to help interested parties such as building officials quickly evaluate the compliance of SPF products (ICC-ES, 2018). Similar compliance reports are issued by International Association of Plumbing and Mechanical Officials (IAPMO), Intertek, and others. These product-specific code compliance reports are developed based on the criteria outlined in AC 377 or equivalent criteria. The mandatory physical properties and standard test methods required by AC 377 for different SPF applications are presented in Table 3.4. Code compliance reports for SPF products outline these physical properties and confirm that the product is in compliance with the applicable building codes. In addition, these reports include sections on code compliance (*i.e.*, which version[s] of building codes the report adheres to), packaging and identification, thermal and ignition barrier requirements and special approvals, installation requirements, and quality assurance programs (ICC-ES, 2018). For specific products or systems based on

particular end-uses, AC 377 indicates that alternative or additional quantification methods (*e.g.*, 3-year adhesion, transportation durability/road testing) may be submitted to and approved by ICC-ES prior to testing (ICC-ES, 2018). There are also several optional criteria and large-scale assembly tests outlined in AC 377, including air permeance to qualify as an air-impermeable insulation (ASTM E2178 or E283), vapor permeance to qualify as a water vapor retarder (ASTM E96), and additional fire tests (*e.g.*, National Fire Protection Association [NFPA] Standards 285 and NFPA 286) (ICC-ES, 2018). Many manufacturers also claim conformance to ASTM C1029, which includes compressive strength, water vapor permeability, water absorption, tensile strength, and closed cell content (Massaro, 2019). AC 337 also mentions ASTM C1029 as an alternative set of criteria and tests, specifically for insulation used in roofing (ICC-ES, 2018). In addition to legal requirements, there are various retail-driven requirements and performance expectations for SPF products that would also apply to any alternatives. For example, application systems for low-pressure products should promote safety and ease of use (*e.g.*, preloading of blowing agent in sealed cylinders), and a 12-month shelf life is required by some of DuPont's retail partners (Massaro, 2019).

At the time this report was generated, it was noted that similar criteria (IAPMO ES 1000 and ICC Standard 1100) were under development to replace AC 377 (Wieroniey, 2019).

Table 3.4 Physical Properties of Spray Polyurethane Foam (SPF) Insulation by Application According to AC 377

Application	Test Required	Value
Sealing (nominal core density 0.5-2.5 pcf)	Core Density: ASTM D1622	As reported
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 flame-spread index or less, 450 smoke-developed index or less
	Adhesion: ASTM D1623	5 lbf/in^2, minimum
Low-density insulation (nominal core density 0.5-1.4 pcf)	Thermal resistance at 75°F (24°C) Mean Temperature: ASTM C177, ASTM C518, or ASTM C1363	As reported
	Core Density:[1] ASTM D1622	As reported
	Tensile Strength: ASTM D1623	
	Minimum Closed-cell Content[2] of 90%	5 lbf/in^2, minimum
	Closed-cell Content Less than 90%	3 lbf/in^2, minimum
	Dimensional Stability: ASTM D2126	15% maximum total change
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 flame-spread index or less, 450 smoke-developed index or less
Medium-density insulation (nominal core density 1.5-3.5 pcf)	Thermal Resistance at 75°F (24°C) Mean Temperature: ASTM C177, ASTM C518, or ASTM C1363	As reported
	Core Density: ASTM D1622	As reported
	Tensile Strength: ASTM D1623	15 lbf/in^2, minimum
	Dimensional Stability: ASTM D2126	15% maximum total change
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 flame-spread index or less, 450 smoke-developed index or less
	Compressive Strength: ASTM D1621	15 lbf/in^2, minimum
Roofing (nominal core density 2.5-3.5 pcf)	Thermal Resistance at 75°F (24°C) Mean Temperature: ASTM C177, ASTM C518, or ASTM C1363	As reported
	Core Density: ASTM D1622	As reported
	Tensile Strength: ASTM D1623	40 lbf/in^2 , minimum
	Dimensional Stability: ASTM D2126	15% maximum total change
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 flame-spread index or less
	Compressive Strength: ASTM D1621	40 lbf/in^2, minimum

Notes:
ASTM = American Society for Testing and Materials; cf = Cubic Foot; IBC = International Building Code; lbf = Pound Force; pcf = Pound-force per Cubic Foot; UBC = Uniform Building Code; UL = Underwriters Laboratories Inc.
Table adapted from ICC-ES (2018, Table 1).
"For SI: 1 pfc = 16 02 kg/m^3, 1 lbf/in^2 = 6.89 kPa" (ICC-ES, 2018, Table 1).
(1) "Test specimen density shall be within 10 percent of the nominal density recognized in the evaluation report" (ICC-ES, 2018).
(2) "Closed cell content shall be determined in accordance with ASTM D6226" (ICC-ES, 2018).

Key Definitions:

- **Thermal Resistance (R Value):** A measure of material's resistance to conductive heat flow. The higher the thermal resistance (R value), the more effective the insulating material (US DOE, 2019).
- Surface Burning Characteristics:
  - **Flame Spread Index:** "A comparative measure, expressed as dimensionless number, derived from visual measurements of the spread of flame versus time for a material tested in accordance with ASTM E84 or UL 713" (ICC, 2015).
  - **Smoke-developed Index:** "A comparative measure, expressed as dimensionless number, derived from smoke obscuration versus time for a material tested in accordance with ASTM E84" (ICC, 2015).
- **Core Density:** "Density is expressed most often in pounds per cubic foot… Core density… is the weight from the center of the sample" (Cutcher, 2016).
- **Tensile Strength:** "[T]ensile (pulling or stretching) force necessary to rupture a material sample divided by the sample's original cross sectional area. Units are usually kPa or psi or lb/in^2" (SPFA, 2013).
- **Dimensional Stability:** "[T]he ability of a material to retain its original size and shape. For polyurethane foam, dimensional stability is determined over time under conditions of controlled temperature and humidity. Measured as a percent of original dimension" (SPFA, 2013).
- **Compressive Strength:** "[T]he stress or force applied parallel to the direction of the polyurethane foam rise at 10% deformation or at yield point" (SPFA, 2013).

According to the respiratory protection standards of the United States Occupational Safety and Health Administration (OSHA) (29 CFR 1910.134; OSHA, 2018) and the California Division of Occupational Safety and Health (CalOSHA) (8 CCR 5144; CalOSHA, 2019), SPF applicators are also required to wear appropriate personal protective equipment (PPE) when working with the products. In addition, OSHA's Hazard Communication Standard (29 CFR 1910.1200) requires employers to provide training to employees on chemical safety (OSHA, 2012). The Center for the Polyurethanes Industry (CPI) also offers an online training program for SPF applicators that involves basic information on chemical safety and the proper use of PPE (ACC, 2011). The Spray Polyurethane Foam Alliance (SPFA) has established a certification program for different types of SPF workers (*i.e.*, insulation installer, roofing insulation installer, and field examiner), with differing levels of proficiency (assistant, installer, master installer, project manager) and require progressive training in the proper use of SPF equipment, substrate preparation, equipment repair, codes and standards, *etc.* (SPFA, 2019). These health and safety programs may require modification for any new alternative product.

California air districts may establish and enforce relevant rules and regulations for volatile organic compounds (VOCs). For example, the South Coast Air Quality Management District (SCAQMD), which includes Los Angeles, has established a VOC limit of 250 g/L for foam insulation and foam sealant, which are considered architectural applications under Rule 1168 (SCAQMD, 2017). This limit is scheduled to be reduced to 50 g/L starting on January 1, 2023. This limit would apply to any alternative SPF product.

California has adopted several regulations that aim to reduce hydrofluorocarbon (HFC) emissions by prohibiting certain HFCs in specific product categories, including SPF insulation. The California Cooling Act (Senate Bill 1013) (California State Senate, 2018) and the California Air Resources Board's (CARB)

HFC Regulation (CCR Title 17, Sections 95372) (CARB, 2018) prohibit the use of certain HFCs in SPF products. The following HFCs are unacceptable as of January 1, 2020 for high-pressure rigid polyurethane two-component SPF and as of January 1, 2021 for low-pressure rigid polyurethane two-component SPF: "HFC-134a, HFC-245fa, and blends thereof; blends of HFC-365mfc with at least 4 percent HFC-245fa, and commercial blends of HFC-365mfc with 7 to 13 percent HFC-227ea and the remainder HFC-365mfc; and Formacel TI" (CARB, 2018). These HFCs may still be used in "military or space- and aeronautics-related applications" until January 1, 2025 (CARB, 2018). Any alternatives to high- or low-pressure SPF would have to follow California's HFC ban starting in 2020 as well. Products must be reformulated to work with alternative blowing agents (*e.g*., hydrofluoroolefins [HFOs]), and thus, this CARB requirement adds to the complexity of identifying viable alternatives.

3.7 Role of the Chemical of Concern in the Priority Products

The Priority Products are created from a chemical reaction between two components, the "A side," which contains the unreacted MDI, and a blowing agent in low-pressure systems, and the "B side," which contains polyol, fire retardant, blowing agent, catalysts, and surfactants (CalDTSC, 2014). The two sides combine in the spray applicator, creating polyurethane foam from a chemical reaction of the unreacted MDI and the polyol with the help of the remaining B-side chemicals. Specifically, high-pressure SPF is polymerized upon release, whereas low-pressure SPF is not aerosolized and begins to polymerize prior to release from the spray gun. This polyurethane foam expands to fill the building cavities and will completely cure into rigid foam (SPC, 2019a). An essential attribute of the MDI is its quick reaction time with the polyol, which enables the foam to expand along a surface against the force of gravity, completely filling the space to be insulated rather than slumping to the lowest point of the application site.

3.8 Necessity of the Chemical of Concern or Replacement Chemicals in the Priority Products

As noted above, unreacted MDI is a fundamental component of two-component SPF systems. A two-component SPF product formulated without unreacted MDI or an equivalently effective replacement would not be functional. Thus, simply removing the chemical of concern from the Priority Product formulations without replacing it with a similarly reactive and effective ingredient is not an option.

4 Scoping, Identifying Possible Alternatives, and Relevant Factors

4.1 Philosophy Concerning Stage 1 of an AA

As conceived by Gradient and the RE consortium, the goal of Stage 1 of an AA is to answer the question: Do there exist seemingly viable alternatives to the Priority Products that should be given a more in-depth consideration, or can we be reasonably certain there are no viable alternatives, such that an in-depth AA would be impossible (*i.e.*, due to lack of sufficient information)? Stage 1 of an AA is based on readily available information. The aim is not to definitively identify an alternative to the Priority Products but rather to determine whether there are candidate alternatives that warrant more in-depth evaluation before a decision can be made. We believe this approach is consistent with the California Safer Consumer Products (SCP) regulations (CalDTSC, 2013). Other important elements of Stage 1 include identifying requirements (legal or otherwise) for the product and identifying the function of the chemical of concern in the product to determine whether the chemical can simply be eliminated from the product.

4.2 Optional Relevant Factors Included in Stage 1 of the AA

The SCP regulations do not list performance or cost as required considerations (*i.e.*, relevant factors) for Stage 1 of an AA, but rather include them as required for Stage 2. However, the California SCP regulations (22 CCR § 69505.5[e]) allow an RE to include additional factors that they deem relevant to the AA at their discretion (CalDTSC, 2013). The REs for the Priority Products at issue in this Abridged AA maintain that performance is a critical element for an AA to consider in its initial stage, because an alternative to the Priority Products that has unacceptable performance (*i.e.*, performs poorly compared to the current products by a reasonable metric related to consumer needs or expectations) is not a viable alternative (*i.e.*, consumers will not purchase it) and should therefore not be considered further. Similarly, cost should be a consideration early in the AA process, because an alternative that is not cost-effective, even when possible economies of scale are considered, is not a viable alternative.

That said, we are unable to include the required performance and cost information as relevant factors in this report, because the potential alternatives are not commercialized and we do not have access to such information for any of the potential alternative formulations evaluated in this AA.

4.3 Scoping: Alternatives Outside the Scope of This Abridged AA Report

The first element of an AA involves scoping, or determining the range of alternatives to the Priority Product(s) that will and will not be considered in the AA. "Alternatives" have a narrow definition in the context of the SCP program and are defined under 22 CCR § 69501.1 as consisting of the following options:

A. Removal of Chemical(s) of Concern from a Priority Product, with or without the use of one or more replacement chemicals;

B. Reformulation or redesign of a Priority Product and/or manufacturing process to eliminate or reduce the concentration of Chemical(s) of Concern in the Priority Product;
C. Redesign of a Priority Product and/or manufacturing process to reduce or restrict potential exposures to Chemical(s) of Concern in the Priority Product; or
D. Any other change to a Priority Product or a manufacturing process that reduces the potential adverse impacts and/or potential exposures associated with the Chemical(s) of Concern in the Priority Product, and/or the potential adverse waste and end-of-life effects associated with the Priority Product. (CalDTSC, 2019a)

This Abridged AA is focused on alternatives to two-component high- and low-pressure SPF products containing unreacted MDI. While other types of insulation, such as fiberglass, mineral wool, cellulose, natural fibers, polystyrene, and cementitious foam, would provide some of the same functions as the Priority Products, the REs do not consider these as "alternatives" under California 22 CCR § 69501.1 (CalDTSC, 2019a) and California 22 CCR § 69511.2 (CalDTSC, 2019b). First, they are not based on a reformulation, redesign, or change to the existing Priority Products but rather are wholly different products not providing the multiple functions of SPF. Second, the REs believe they do not meet the definition of the Priority Product as they are not *spray polyurethane* foam. In addition, CalDTSC's "Alternatives Analysis Guide" (CalDTSC, 2017a) indicates that REs are not required to consider alternatives that fall outside their business manufacturing model (CalDTSC, 2017a, p. 26). The SCP regulations also encourage CalDTSC to consider the "practical capacity" of the RE to carry out a regulatory action that CalDTSC may require, such as the mandating of an alternative technology (CalDTSC, 2013). The systems houses that have participated in the preparation and submission of this Abridged AA report view non-spray-foam-based insulation technologies as being outside their manufacturing business model and as technologies that they have no practical capacity to produce. These technologies are therefore considered to be outside the scope of this AA.

4.4 Information on Potential Alternative Formulations

Once the scope of an AA has been identified, the next critical step is to gather information on possible alternatives to the Priority Product(s). To conduct an informative AA, one needs to consider not only those products made by the REs involved in this particular effort but also other similar products that are available, as these may be possible alternatives to the Priority Product(s). To obtain information about potential alternatives to the Priority Products, we first gathered information from SDSs for all the products made by the REs involved in this Abridged AA. We then researched potential alternatives mentioned in CalDTSC's "Revised Priority Product Profile" for SPF products containing unreacted MDI (CalDTSC, 2014).[3] We also conducted an online literature search using terms such as "spray foam insulation," "alternatives," "insulation types," "insulation options," *etc*. In addition, we consulted several recent textbooks on insulation and reviewed CalDTSC's technical document related to the listing of SPF containing unreacted MDI as a Priority Product (CalDTSC, 2017b). Finally, we queried members of the RE consortium, asking that they provide information on any alternative technologies to the Priority Products they are aware of that currently exist, are under development, or have been tried in the past.

[3] Soudal's Soudafoam SMX® is a one-component, non-isocyanate-based canned spray foam that was mentioned in the CalDTSC "Revised Priority Product Profile" for SPF products containing unreacted MDI as a potential commercially available alternative to these products (CalDTSC, 2014). However, because Soudafoam SMX® is a one-component spray foam only available in 500-mL cans (Soudal Australia, 2019), it is not a viable potential alternative for two-component Priority Products and thus is not included in this Abridged AA. In addition, it is unclear whether Soudafoam SMX® is currently commercially available in the US, because the product is not available on Soudal's US website (Soudal Inc., 2019), but is available on its Australian website (Soudal Australia, 2019).

Note that we limited our search to current alternatives to MDI-based *spray polyurethane foams* and not to alternatives to MDI-based *polyurethanes* in general.[4] Polyurethanes are used in a very wide range of products (*e.g.*, coatings, textiles, foam) with very different product characteristics, and alternative chemistries for such applications would not provide useful information about their potential use as spray foam building insulation. Only technologies that are alternatives specific to MDI-based spray foam building insulation were considered.[5]

Through the various approaches outlined above, a number of potential alternative formulations[6] for the Priority Products were identified that appear to replicate some of the current Priority Products' functional abilities (*e.g.*, sprayable, two-component). These formulations are:

1. Firestone/Gaco Canary™;
2. NanoSonic HybridSil™;
3. Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™;
4. Owens Corning Formulation;
5. DuPont Formulations (2); and
6. Dow Formulation.

Additionally, it is worth noting that only four of the seven alternative formulations (*i.e.*, Firestone/Gaco Canary, Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane, DuPont Patent No. WO 2018/005142 A1, and Dow Patent No. WO 2015/142564 A1) appear to be *polyurethane*-based products. It is the REs' position that only these four SPF formulations meet the requirements to be considered as alternatives to the Priority Product as defined under the SCP regulations.[7] However, we are including sprayable non-polyurethane foams as potential alternatives in this Abridged AA, for the sake of completeness.

4.4.1 Firestone/Gaco Canary™

In 2016, Gaco Western patented a two-component, closed-cell, 2.5-lb-per-cubic-foot, non-polyurethane, non-isocyanate-based spray foam formulation that uses the same application equipment and has the same PPE requirements as the current Priority Products, called Canary™ (Gaco Western, 2017; Trumbo, *et al.*,

[4] For example, the Danish Ministry of the Environment studied alternatives to MDI in coatings, adhesives, and sealants but did not address spray foam insulation in that assessment (Danish EPA, 2015).

[5] For example, we found one product (Bautex) that involves making non-MDI-based insulating cement blocks for commercial building construction. Such a product, if adopted as an SPF replacement, would mandate a complete change in construction technology (*e.g.*, from wood or other materials to concrete), which would be outside the scope of the SCP program.

[6] Note that Firestone/Gaco also has a Priority Product, Profill System™, which reduces applicators' exposure to unreacted MDI by installing the spray foam behind plastic membranes (Gaco Western, 2018). However, Profill System is not considered a viable alternative in this Abridged AA, because Profill System is a Priority Product itself, patented under Patent No. US 9481995 B2 (Bemis, 2016), uses the chemical of concern (*i.e.*, unreacted MDI), and requires that workers wear PPE.

[7] 22 CCR Chapter 55 §69511.2 (CalDTSC, 2019b) defines SPF systems containing unreacted MDI as "spray *polyurethane* foam systems containing liquid chemical mixtures in two separate containers that are sold or distributed together. The two separate containers are commonly referred to as Side A and Side B. Side A contains unreacted methylene diphenyl diisocyanates. Side B contains a mixture of polyols and other ingredients which may include catalysts, blowing agents, flame retardants, and surfactants. The chemical mixtures in the sides react when mixed together to form *polyurethane* foam that is used for insulation, roofing, or sealing and filling voids and gaps. This product-chemical combination includes: (1) High-pressure spray polyurethane foam systems, and (2) Low-pressure spray polyurethane foam systems" (emphasis added). Therefore, the REs' interpretation is that any alternative product must have a polyurethane-based chemistry, which can be spray applied, and not a completely alternative chemistry, regardless of its application.

2016). General information on example chemicals (or chemical families) are contained in the patent for this product (Patent No. US 9359471 B2 [Trumbo, *et al*., 2016]), although it is not certain these would be the same chemicals as those in the marketed product. An example formulation contains the following compounds.[8]

Example A Side:

- Sucrose acetoacetate (No CAS No. identified)
- Glycerine acetoacetate (No CAS No. identified)
- Tin catalyst (dimethylbis[(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)

Example B Side:

- Meta xylene diamine (MXDA) (CAS No. 1477-55-0)
- Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)
- Tegostab™ B-8407, a polyether modified siloxane surfactant (CAS No 67762-85-0)
- Tegostab™ B-8221, a silicone surfactant (No CAS No. identified)
- Tris(2-chloropropylphosphate) (TCPP), a fire retardant (CAS No. 1067-98-7)
- HFC-365mfc, a hydrofluorocarbon (HFC) blowing agent (CAS No. 406-58-6)

The hazards and relative exposure potential of these example chemicals can be qualitatively assessed and compared to those of the Priority Products, although ideally such a comparison would involve the actual chemicals found in the marketed product, as composition can change after the patent is filed. While limited data on physical characteristics (*e.g*., density) are available for Canary, complete performance data are not included in the patent. For example, the patent lists R values that the formulation "may" attain (but this is not supported by a publicly available test report) and does not give information on the formulation's compressive strength or flame spread resistance (Trumbo, *et al*., 2016). In addition, this formulation uses HFC-365mfc as a blowing agent, which will be banned in California in 2020 for high-pressure SPF products and alternatives and in 2021 for low-pressure SPF products and alternatives (CARB, 2018). Changing to a new blowing agent (*e.g*., an HFO) would likely require modifying the formulation and could affect product performance. Lastly, all potential alternatives must conform to local VOC emission limits in California and the additional requirements laid out in the building standards outlined in Section 3.6. Recently, Firestone confirmed to Gradient that Canary is not currently commercialized. Overall, Canary is not a viable alternative formulation for the Priority Products that can be further considered in this Abridged AA due to a lack of commercialization, exposure potential, and performance information, and because it is not a polyurethane product.

4.4.2 NanoSonic HybridSil™

HybridSil™ is a two-component, closed-cell, non-isocyanate, silicon-based spray foam insulation that was in part funded by the United States Environmental Protection Agency (US EPA) Small Business Innovation Research Program, in an effort to develop an alternative to SPF (NanoSonic Inc., 2012, 2013).

[8] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for some ingredients.

According to NanoSonic, HybridSil is air-tight and the same traditional SPF equipment can be used for applying HybridSil (NanoSonic Inc., 2012). As of July 30, 2019, NanoSonic does not appear to have a patent for HybridSil. The product is not listed on NanoSonic's website, despite other polyurethane products being described there. Ultimately, no information is available on HybridSil's ingredients, exposure potential, and performance with which to assess whether this product will serve as a viable alternative to the Priority Products. HybridSil is therefore not a viable alternative formulation for the Priority Products that can be further considered in the Abridged AA due to a lack of commercialization, hazard, exposure potential, and performance information, and because it is not a polyurethane product.

4.4.3 Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™

A press release from 2014 stated that Hybrid Coatings Technologies had acquired a hybrid non-isocyanate polyurethane (HNIPU) spray foam technology from a organization called Nanotech Industries, Inc. (Hybrid Coating Technologies Inc., 2014). The press release gave the name of the product as Green Polyurethane™ and claimed that this formulation has similar performance characteristics as an MDI-based spray foam, although no specifics on the chemical components of the formulation were identified in the press release. In 2015, a US patent (Figovsky *et al*., 2015) granted to Nanotech Industries, Inc. (Patent No. US 2015/0024138 A1) for this product indicates that the patented formulation has the following composition.[9]

Example A Side:

- DER 331, a bisphenol A (BPA) epoxy resin (CAS No. 25085-99-8)
- DC-1107 fluid, a silicone surfactant (CAS Nos. 63148-57-2, 68037-53-6, and 142-82-5)
- DC-197, a silicone surfactant (undisclosed CAS No. and CAS No. 34590-94-8)

Example B Side:

- Ancamine 2678, an aliphatic amine curing agent (no CAS No. identified)
- DC-197, a silicone surfactant (undisclosed CAS No. and CAS 34590-94-8)

Other potential A-side ingredients include acrylates or carbonates instead of the epoxy, which could potentially contain renewable sources such as acrylated epoxidized soybean oil or carbonized soybean oil. The patent also implies that a blowing agent (*e.g*., an HFC) was used, but the identity of the blowing agent is not provided. This example formulation is very similar to the Owens Corning product described below. The Hybrid Coatings Technologies website gives no indication that this material has been moved towards the commercialization stage; no insulation products at all are mentioned on the company's website despite other types of polyurethane products being mentioned. Limited data on performance (*e.g*., R value, compressive strength, estimated curing time) are discussed in the patent, but these data are not supported by testing results and in most instances, the test performed is not stated. Other critical information is missing from the patent (*e.g*., flame spread resistance). In addition, all potential alternatives must conform to local VOC emission limits in California and the additional requirements laid out in the building standards outlined in Section 3.6. In summary, Green Polyurethane is not a viable

[9] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

alternative formulation for the Priority Products that can be further considered in the Abridged AA due to a lack of commercialization, exposure potential, and performance information.

4.4.4 Owens Corning Formulation

In 2012, Owens Corning was granted a patent (No. US 2012/0183694 A1) for an open- and closed-cell, non-isocyanate-based polyurethane spray foam "made by reacting cyclo carbonates and di- or polyamines" (Olang, 2012). The patent further states that the formulation contains optional acrylate monomers or epoxy or acrylic resins, as well as rheology modifiers (modifying material flow) and blowing agents. The patent notes that non-isocyanate-based urethanes typically have slow reactivity (which is an issue because the foam needs to quickly form to support itself along the surface it has been applied to rather than slumping downwards), and in this formulation, the reactive acrylates are included to add additional heat to speed the reaction. The temperature range of the applied foam ranges from 120-150°F, which is greater than that typical for the Priority Products (*i.e.*, typical ranges are from 125-130°F). Several formulations are specified in the patent (Olang, 2012). The base formulation contains the following compounds.[10]

Example A Side:

- DER 331, a BPA epoxy resin (CAS No. 25085-99-8)
- Epon™ 8111, a multifunctional epoxy resin (CAS Nos. 25068-38-6 and 15625-89-5)
- Sodium hydroxide (CAS No. 1310-73-2)

Example B Side:

- Cycloate A, an aliphatic amine (CAS No. 1134-23-2)
- Ancamine 2678, an aliphatic amine curing agent (No CAS No. identified)
- Epikure™ 3271, an amine curing agent (CAS Nos. 111-40-0 and 80-05-7)
- DC193, a polysiloxane surfactant (No CAS No. identified)
- Dye (Specific name not stated and no CAS No. identified)

As with the Green Polyurethane patent, the patent for the Owens Corning formulation implies that a blowing agent (*e.g.*, an HFC) was used, but the identity of the blowing agent is not provided. Modifications described in the patent include the addition of a clay-based flow modifier (Garamite-1958) or the use of a different blowing agent (*i.e.*, hexafluorobutene). As with the Firestone/Gaco Canary formulation, the information contained in the patent does not provide specific chemicals that would be used in a marketed version of the formulation, creating uncertainty regarding the accuracy of the AA for this material. An article discussing this formulation (Figovsky *et al*., 2013) suggests that viscosity issues are significant challenges for using this technology in a sprayable product. Limited data on the formulation's performance (*e.g.*, R value range, estimated curing time) are discussed in the patent (but are not supported by provided test results); other critical product information is missing (*e.g.*, anticipated density, compressive strength, flame spread resistance). In addition, all potential alternatives must conform to local VOC emission limits in California and the additional requirements laid out in the

[10] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

building standards outlined in Section 3.6. This Owens Corning formulation is not a viable alternative for the Priority Products due to the lack of performance and exposure information. In addition, a review of the Owens Corning website gives no indication that this formulation has been moved towards the commercialization stage.

4.4.5 DuPont Formulations

DuPont has two patents for non-isocyanate-based spray foam, one granted in 2013 (Patent No. WO 2013/101682 A1) and another in 2018 (Patent No. WO 2018/005142 A1) (Jin *et al*., 2013; Thomas *et al*., 2018).

Patent No. WO 2013/101682 A1 (Jin *et al*., 2013)

The 2013 patent (Patent No. WO 2013/101682 A1) describes an alternative spray foam product produced *via* carbon-Michael chemistry rather than the polyurethane chemistry (Jin *et al*., 2013). A total of 15 potential formulations are listed in this patent, indicating a high degree of uncertainty in regards to a final formulation. This patent does include the following performance information on some, but not all, of the example formulations: compressive strength according to ASTM D1621-10, open cell content according to ASTM D6226-10, density according to ASTM D-1622-03, and flame spread index and smoke development index according to ASTM E84 and E84-12, respectively. However, no information was available on tensile strength, dimensional stability, or thermal resistance. This patent formulation also includes the use of blowing agents (HFC-245fa and -134a), which will be banned in California in 2020 for high-pressure SPF products and alternatives and in 2021 for low-pressure SPF products and alternatives (CARB, 2018). An example of a potential formulation is shown below.[11]

Example A Side:

- Tetrafunctional acrylate (CAS No. 94108-97-1)
- Difunctional acrylate A, a BPA epoxy diacrylate (CAS No. 55818-57-0)
- Tegostab™ B8469, a surfactant (No CAS No. identified)
- HFC-245fa, blowing agent (CAS No. 460-73-1)
- HFC-134a, blowing agent (CAS No. 811-97-2)

Example B Side:

- Trimethylolpropane tris(acetoacetonate) (CAS No. 22208-25-9)
- N,N,N',N'-tetramethylguanidine (TMG) (CAS No. 80-70-6)
- Tri(2-chloropropyl)phosphate (TCPP), a fire retardant (CAS No. 13674-84-5)
- Triethyl phosphate (TEP) (CAS No. 78-40-0)
- Tegostab™ B8469, a surfactant (No CAS No. identified)
- HFC-245fa, blowing agent (CAS No. 460-73-1)

[11] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

- HFC-134a, blowing agent (CAS No. 811-97-2)

Patent No. WO 2018/005142 A1 (Thomas *et al*., 2018)

The 2018 patent (Patent No. WO 2018/005142 A1) (Thomas *et al*., 2018) describes an improved and hydrolytically stable biodegradation polyol-based isocyanate-free polyurethane foam compared to the Dow 2015 patent (Patent No. WO 2015/142564 A1; Foley *et al*., 2015), which is discussed in Section 4.4.6. The A-side MDI equivalent is a polycarbamate, similar to the 2015 patent. Alkali metal oxides (magnesium oxide, magnesium hydroxide, calcium oxide) are added to increase resistance to hydrolysis. The patent mentions a wide range of classes of possible acid catalysts and several possible HFC blowing agents. The patent also indicates that a fire retardant, "such as any of those used in polyurethane", can be used in the product formulation. No performance data are provided in the patent. While the patent seems to be focused on methods for producing the foam and ingredients, no clear formulations were given. An example of a potential formulation is shown below.[12]

Example A Side:

- Polycarbamate 2 (No CAS No. identified)
- Tetrabromophthalate diol (TBPD) (CAS No. 77098-07-8)
- Triethyl phosphate (TEP) (CAS No. 78-40-0)
- Silicone polyether copolymer surfactant (No CAS No. identified)
- P-toluenesulfonic acid, a catalyst (CAS No. 6192-52-5)

Example B Side:

- 1,3- and 1,4-cyclohexanedicarboxaldehyde (CHDA) (CAS Nos. 55309-54-1 and 33424-83-8)
- Magnesium oxide (CAS No. 1309-48-4)
- HFC-245fa, a blowing agent (CAS No. 460-73-1)

As with all of the previous patent formulations, the two DuPont patents reference hundreds of possible ingredient combinations and do not provide specific chemicals that would be used in a marketed version of the formulations, creating uncertainty regarding the accuracy of the AA for this material. These DuPont formulations are not viable alternatives for the Priority Products due to the lack of exposure information and the full suite of required performance data mentioned in Section 3.6. In addition, these formulations rely on blowing agents, which will be banned in California in 2020 for high-pressure SPF products and alternatives and 2021 for low-pressure SPF products and alternatives (CARB, 2018). DuPont's 2013 patent (Jin *et al*., 2013) also describe a non-polyurethane-based foam. Lastly, DuPont has indicated that these formulations are not yet commercially available.

[12] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

4.4.6 Dow Formulation

In 2015, Dow was granted a patent (Patent No. WO 2015/142564 A1) for non-isocyanate-based polyurethane spray foam (Foley *et al.*, 2015). This patent describes a biodegradable and water-soluble polyol-based foam (Foley *et al*., 2015). This foam is subject to hydrolysis and can lose up to 24% weight in tests. A water-soluble alternative formulation is problematic, because current SPFs provide moisture resistance and structural support, and any viable alternative would need to provide similar functionality. The A-side MDI equivalent is stated to be a polycarbamate. The patent describes multiple potential A- and B-side ingredients. Information on density, compressive strength, and open cell content is provided for one potential formulation, but not others. An example of a potential formulation is shown below:[13]

Example A Side:

- Polycarbamate (No CAS No. identified)
- Triethyl phosphate (TEP) (CAS No. 78-40-0)
- Niax L5340, a silicone surfactant (No CAS No. identified)

Example B Side:

- CHDA (CAS No. 2043-61-0)
- Tetrabromophthalate diol (PHT4 Diol), a flame retardant (CAS No. 77098-07-8)
- Niax L5340, a silicone surfactant (No CAS No. identified)

As with all of the previous patent formulations, the Dow patent describes multiple example formulations and does not provide specific chemicals that would be used in a marketed version of the formulations, thus creating uncertainty regarding the accuracy of the AA for this material. The Dow formulation is not a viable alternative for the Priority Products due to the lack of exposure information and the full suite of required performance data mentioned in Section 3.6. In addition, this patent describes a water-soluble foam that can lose up to 24% weight in tests, which is problematic because any viable alternative would need to provide similar moisture resistance and structural support compared to that of the Priority Product. Lastly, the patent holder has indicated that these formulations are not yet commercially available.

4.4.7 Conclusions Regarding Possible Alternative Formulations

None of the identified alternative formulations for the Priority Products have sufficient data available or are sufficiently advanced to support further evaluation in this AA (Table 4.1). However, the California SCP regulations require that, even in the case of an Abridged AA, a comparison of possible alternatives to the Priority Product(s) be performed to determine the factors that are relevant for evaluating the Priority Product(s), presumably in the context of any future research or evaluation (CalDTSC, 2013). This is addressed in Section 4.5.

[13] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

Table 4.1 Potential Alternative Formulations

Potential Alternative Formulation Name	Composition	Corresponding SPF Grouping	Information Available to Support Inclusion in Stage 1 AA?
Firestone/Gaco Canary™	**A Side:** Acetoacetates and tin catalyst **B Side:** Multifunctional amines	Group 3 or 4 (High pressure, closed cell, 2- and/or 3-lb/cf)	No. Not commercially available, still under development, so details on formulation and performance subject to change.
NanoSonic HybridSil™	Silicon-based, but no data on exact composition	Not enough information to assign grouping	No. Not commercially available. No data available to assess.
Hybrid Coatings Tech/ NanoTech Green Polyurethane™	**A Side:** BPA resin and silicone surfactant **B Side:** Amines and silicone surfactant	Closed-cell, but not enough information to assign grouping	No. Development status uncertain. No information on company website.
Owens Corning Formulation	**A Side:** Epoxy resins and sodium hydroxide **B Side:** Cyclo carbonates and di- or polyamines and HFC-245a	Open- and closed-cell, but not enough information to assign grouping	No. Not commercially available. Development status uncertain. No information on company website.
DuPont Formulation Patent No. WO 2013/ 101682 A1	**A Side:** Acrylates, surfactant, HFC-245fa, and HFC-134a **B Side**: Flame retardant, catalysts, surfactant, HFC-245fa, and HFC-134a	High-pressure SPF, but not enough information to assign grouping	No. Not commercially available. Development status uncertain.
DuPont Formulation Patent No. WO 2018/ 005142 A1	**A Side:** Polycarbamate, TBPD, TEP, silicone surfactant, and catalyst **B Side:** CHDA, catalyst, magnesium oxide, and HFC-245fa		
Dow Formulation Patent No. WO 2015/ 142564 A1	**A Side:** Polycarbamate, TEP, and silicone **B Side:** CHDA, flame retardant, and silicone surfactant	High-pressure SPF, but not enough information to assign grouping	No. Not commercially available. Development status uncertain.

Notes:
AA = Alternatives Analysis; BPA = Bisphenol A; cf = Cubic Foot; HFC = Hydrofluorocarbon; SPF = Spray Polyurethane Foam; TBPD = Tetrabromophthalate Diol; TEP = Triethyl Phosphate.
Sources: Bemis (2016); Figovsky *et al*. (2015); Foley *et al*. (2015); Gaco Western (2018); Jin *et al*. (2013); NanoSonic Inc. (2012); Olang (2012); Thomas *et al*. (2018); Trumbo *et al*. (2016).

Because open- and closed-cell SPFs are all currently MDI-based and typically share similar manufacturing equipment, a viable alternative would optimally replace unreacted MDI in all four Priority Product types (*i.e.*, low-pressure, high-pressure 0.5-, 2.0-, and 3-lb SPF). This does not appear to be the case. For example, while Canary could possibly be an alternative high-pressure 2.0- and 3.0-lb SPF if it can be successfully tested and commercialized, it is not an alternative for high-pressure 0.5-lb or low-pressure Priority Products. Having an alternative for only certain types of the Priority Products could adversely complicate product production, requiring additional production facilities (*i.e.*, more land use) and greater raw material transportation. It could also complicate worker training, as all spray foam workers currently only need to receive training regarding the proper use of a single type of material.

4.5 Relevant Factors

We have considered the possibly relevant factors listed in Tables 3-1A and 3-2B of the CalDTSC "Alternatives Analysis Guide" (CalDTSC, 2017a) (which are consistent with those listed in the SCP regulations, 22 CCR § 69505.5[c] [CalDTSC, 2013]). Our review occurred in several stages. For many factors (notably the various toxicities specified in the SCP regulations [CalDTSC, 2013]), we had to tabulate data for the MDI functional replacement chemicals in the A side of the alternative formulations to understand if these factors differed materially among the evaluated products (the results of the data tabulation are discussed in Section 5). Based on our current knowledge of the properties of the different alternatives to the Priority Products we have identified, we have determined which factors are materially different between the Priority Products and any alternatives such that it would inform the conclusion of the Stage 1 AA. The conclusions we have reached in this regard are provided in Table 4.2.

4.6 Relevant Exposure Pathways

We have considered the exposure pathway-related factors listed in Table 3-2C of the CalDTSC "Alternative Analysis Guide" (CalDTSC, 2017a) (which are consistent with those listed in the SCP regulations, 22 CCR § 69505.5[c][3] [CalDTSC, 2013]). Based on our current knowledge of the properties of the different alternatives we have identified, we have determined which exposure pathway-related factors are materially different between the Priority Products and any alternatives such that it would inform the decision conclusion of the Stage 1 AA. The conclusions in this regard we have reached are described in Table 4.3.

The SCP regulations also require information on product use (duration, frequency) as well as the volume of sales in California. With regards to use of the product, SPF application time is highly dependent on the size of the area to be insulated. According to the REs, typically, SPF installation for an attic would take less than a day while installation for a newly constructed whole house could take one to two days; particularly large houses or commercial buildings would take longer, up to a week or more. Spot filling of cracks and voids (an application for low pressure foam often called weatherization) could take minutes. Concerning volume of use (or sales) in California, Gradient and the REs queried online sources (search on "spray foam," "sales" or "volume," and "California"). We determined that these data are not readily available for the Priority Products.

4.6.1 Conceptual Model for Product Life Cycle

In terms of the Priority Products, across the various life cycle stages (*e.g.*, manufacturing, processing, distribution, industrial use, commercial use, disposal), exposure to unreacted MDI (or its replacement) for applicators, other workers or residents *via* inhalation routes and/or dermal routes is possible. The reaction of MDI with polyols is known to be very fast such that MDI emissions from SPF decline very rapidly

with time (and are accounted for in manufacturers' recommended re-entry and re-occupancy times). So for MDI foams, exposures to workers (not wearing PPE) would be the primary concern. Exposure concern for workers applying high-pressure SPF products is primarily related to inhalation of MDI vapors (due to MDI being heated to approximately 120°F during application of the product) and overspray mist (both an inhalation and dermal contact concern). For alternatives that may not cure as quickly, exposures for both workers and residents could be a concern, although this could be accounted for in requiring PPE and longer recommended re-entry and re-occupancy times.

Figure 4.1 shows the conceptual model for the life cycle of the Priority Products. Exposure is expected to be low if PPE is worn. For those not wearing the required PPE, inhalation exposures to vapor are considered the most likely exposure route due to the physical and chemical properties of MDI and SPF (*e.g.*, a semivolatile chemical involved in exothermic curing reactions). Inhalation exposure potential is decreased for low-pressure SPF products, because the SPF is not aerosolized and begins to polymerize prior to leaving the spray gun. However, there is also potential for dermal exposures in various worker scenarios, assuming individuals do not wear appropriate PPE as required by law and stipulated by the manufacturers. Dermal exposures would be concurrent with inhalation exposures. Oral exposures *via* transfer of MDI from hand to mouth is expected to be negligible due to PPE and good work practices. Worker hand contact with foam will be most common during the trimming stage, at which point the foam is largely cured and unreacted MDI is no longer available for volatilization. The potential for exposure during application is expected to be similar for any alternative formulation, as the ingredients have to be quickly reactive (*i.e.*, exhibit high reactivity under exothermic conditions) in order to form an effective foam. It would be important to understand the hazards of alternative formulations in the context of PPE; workers applying the Priority Products are required to wear PPE, and if alternatives are also highly reactive and volatile, one might expect PPE to be required in these cases as well. Thus, this critical question regarding potential worker exposure requires an understanding of the relative chemical hazard of the Priority Products and the possible alternatives. As discussed in Section 4.5, information on this topic is not entirely reliable in the current situation.

Waste handling, treatment, and disposal of the SPF (*e.g.*, trimmed excess material) are expected to be of minimal concern, as the MDI is fully reacted by this stage of the product life cycle. There may be residual, unsprayed material in the drum that could be a source of dermal exposure, but MDI is relatively non-volatile,[14] so inhalation exposure to residual material in a drum would be limited. These types of exposures would be expected to be similar for the alternative formulations, although this is not certain based on the available patent information. For example, if alternative formulations cure more slowly, there may be more exposure in the trimming stage; this cannot be evaluated with the available information.

[14] MDI has an estimated vapor pressure of 4.75E-5 (mm mercury [Hg] at 25°C), according to EPI Suite (US EPA, 2019a).

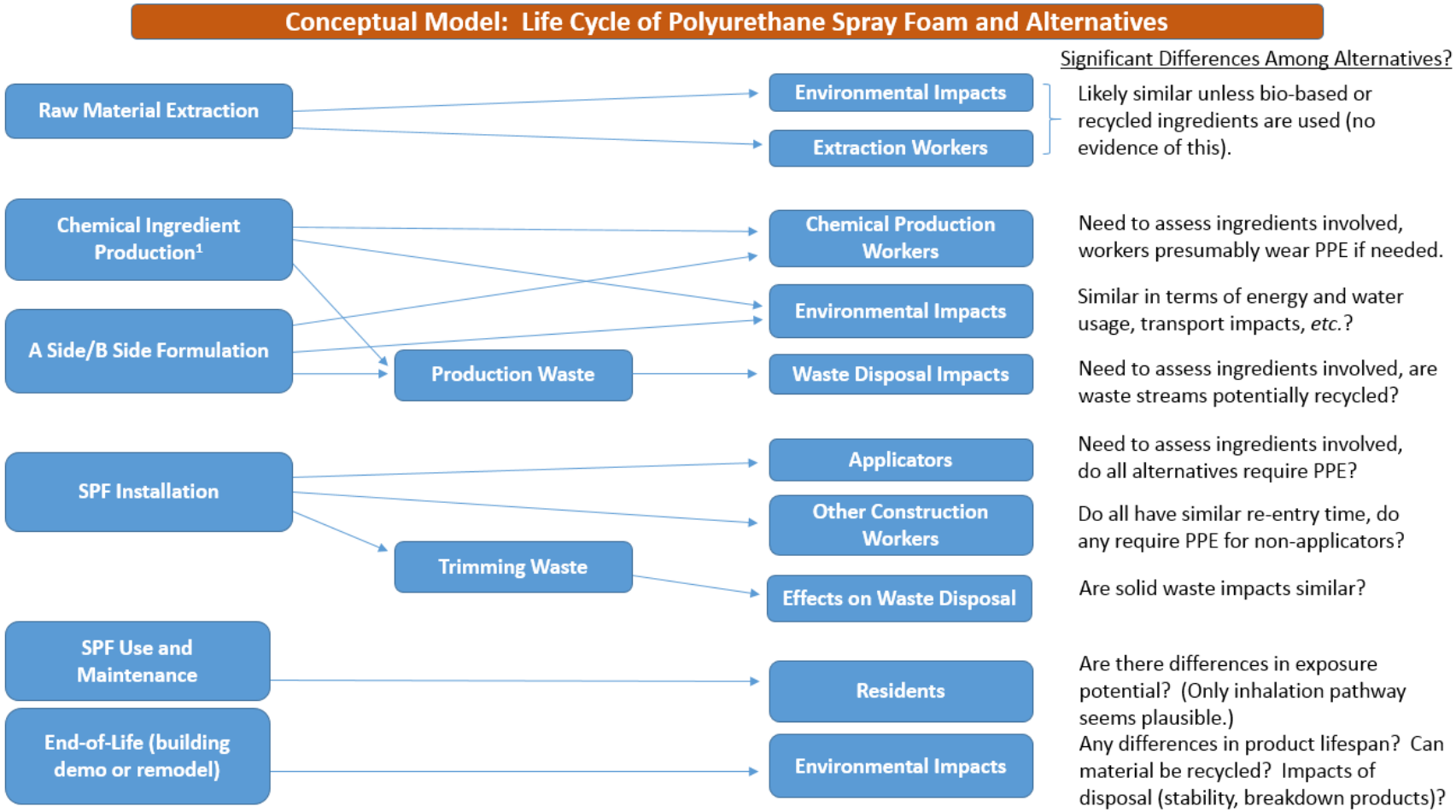

Figure 4.1 Conceptual Exposure Model. (1) Includes monomer (MDI or other), amines, catalysts, flame retardants, surfactants.

4.7 Life Cycle Segments

Consistent with the screening-level nature of the Stage 1 AA, we approached life cycle considerations from the perspective of what is readily known or understood about the alternatives without engaging in extensive analysis. A Stage 2 AA would involve a more detailed effort at substantiating and potentially quantifying life cycle differences among the different products under review.

4.7.1 Raw Materials Extraction

To understand the potential impacts of raw materials extraction, it is necessary to understand how the chemical components of the Priority Products and the potential alternative formulations are produced. MDI is produced *via* reaction of aniline with formaldehyde to produce methylene dianiline, which is in turn reacted with phosgene to produce MDI (ACC, 2019a). Aniline is obtained *via* nitrosation of benzene with subsequent hydrogenation (NLM, 2018a). The benzene can be expected to be derived from fossil fuel sources. Formaldehyde is produced *via* catalytic oxidation of methanol, which is itself typically derived from synthesis gas (syngas), which is produced from fossil fuel sources (NLM, 2015; GSTC, 2019). Thus, the MDI portion of SPF is derived largely from fossil fuel sources. Portions of the B-side components (notably the polyols) of the Priority Products can be derived from recycled and renewable content (Hardcastle, 2014). The A-side components of a number of the alternative formulations variously contain acrylates, polycarbamates, or BPA resins. Most of these chemicals are also synthesized from fossil fuel precursors. For example, BPA is produced by reaction of acetone with phenol (NLM, 2018b) and phenol itself is variously produced from benzene, toluene or cumene (NLM, 2003) all of which are derived from petrochemical sources. Similarly, acrylic acid is formed *via* reactions with propylene-, ethylene-, or other fossil fuel-based (typically natural gas) starting materials (NLM, 2018c). No information could be found regarding the raw materials involved in production of NanoSonic HybridSil (because the specific ingredients of this formulation are unknown). Likewise, no information could be found regarding the base materials used in production of the acetoacetates found in the Firestone/Gaco Canary product (*i.e.*, *via* online searches for "acetoacetate," "production," or "manufacturing").[15]

There is no expectation that raw materials extraction impacts would differ substantially between the Priority Products and the alternative formulations. Based on the available information, they appear to be based on synthetic chemicals, primarily derived from petroleum-based feedstocks. On the B side, some Priority Products have polyols obtained from renewable materials and it is not clear if this would be the case for the alternative formulations. Other B-side ingredients are similar between the Priority Products and possible alternative formulations, such as silicone surfactants, flame retardants, and catalysts. The catalysts in most of the alternative formulations are amines (as with the Priority Products), the Firestone/Gaco Canary formulation uses a tin catalyst (other details about the catalysts used in this product are not specified) and the specific ingredients in NanoSonic's HybridSil are unknown. Based on available information, none of the A-side alternatives are based on recycled inputs, so all of them will involve a qualitatively similar level of impact from raw materials extraction. It must be stressed that the information about the alternative formulations is tentative. Even so, it does not appear that material differences in raw materials extraction impacts would be expected to occur. While a more detailed exploration of relative raw materials extraction impacts could be undertaken, this would require knowing the definitive identities of the chemicals involved and would likely involve substantial effort. Given that

[15] A European Union Risk Assessment Report for ethyl acetoacetate (which is a simpler molecule than the molecules used in the Canary product) indicates the chemical is produced *via* addition of ethanol to diketene (EC, 2002). It is not clear if an analogous process would be involved in the Canary ingredients, but does suggest a synthetic chemical basis.

none of the alternative formulations are in fact credible alternatives, as discussed in Section 4.4.7, engaging in such an effort would be unwarranted.

4.7.2 Resource Inputs and Other Resource Consumption

SPFA previously conducted a life cycle assessment (LCA) of polyurethane-based SPF insulation (thinkstep, 2018). This LCA characterizes resource inputs such as energy, water, and other material requirements associated with SPF. No equivalent LCA or similar document was identified for the potential alternative formulations (*i.e.*, *via* online searches), which is not surprising given that these products appear to still be in the development stage (or potentially no longer under development). As noted above, MDI and the MDI-equivalent chemicals in the alternative formulations are based on synthetic chemicals that are likely produced from petroleum-based feedstocks, and thus, the energy required for petroleum (or natural gas) production and processing for each product would be expected to be similar.

4.7.3 Intermediate Materials Processes

Chemical ingredients for the Priority Products and the possible alternatives are produced from raw materials (*e.g.*, petroleum or natural gas). As discussed above, synthesis of the Priority Products' and the potential alternative formulations' ingredients often involves multiple synthetic stages. Given the very limited information available about the specific ingredients in the potential alternative formulations, understanding the full synthetic pathway for most of the alternative formulations is not possible. There is therefore insufficient data to address this question.

4.7.4 Manufacture

As noted above, MDI is typically produced by the reaction of aniline and formaldehyde to produce aromatic diamines, which are subsequently reacted with phosgene to yield isocyanates. As described above, chemicals in all the identified possible alternative formulations to the Priority Products also appear to be produced industrially from chemical feedstocks and would be produced in facilities that must adhere to occupational exposure standards. This suggests that there is, at least qualitatively, no material difference among the alternatives; however, there is insufficient data to address this question.

4.7.5 Packaging

There appears to be no evidence of any material difference between the Priority Products and the various alternatives in terms of the type of packaging that would be used for them, although none of the alternative formulations are yet commercialized so this is uncertain. All of the proposed alternative formulations consist of two "sides" that must be combined in order to produce spray foam. Several of the patents describe an advantage of the formulation being that existing application equipment can be used, which implies similar pressures and therefore the need for similar containers. All versions of the Priority Products are typically sold in metal cylinders of different sizes. According to the REs, high-pressure SPF products are typically sold in 55-gallon drums for use in special equipment (*i.e.*, spray rig trucks), while low-pressure SPF products are sold in smaller two-cylinder kits, which include the application equipment. There is no expectation that an alternative formulation for the Priority Products would require either more or less packaging than the Priority Products.

4.7.6 Transportation/Distribution

The LCA commissioned by SPFA (thinkstep, 2018) described the transportation impacts associated with SPF. No equivalent LCA (or similar analysis) was located for the alternative formulations, which is again not surprising, given that these products appear to still be in the development stage (or potentially no longer under development). Product-level information on the Priority Products indicates that they are not considered to be "Dangerous Goods" by the United States Department of Transportation (US DOT). However, similar product-level information is not available for the alternative formulations. While product-level information would trump ingredient-level information, all of the products contain at least one chemical that would be classified as a "Dangerous Good" under US DOT regulations (US DOT, 2019). Based on their understanding of the industry, the REs would expect that these would be similar between the Priority Products and the possible alternative formulations, but data are not available to make a definitive determination. In addition, there are no data in the patents indicating that the alternative formulations offer substantially higher efficacy at a reduced weight/volume or eliminate a transportation step in the supply chain.

4.7.7 Use/Application

Use is one area in which the potential alternative formulations could significantly differ from the Priority Products. As noted above, the rate of curing and the volatility of unreacted MDI or alternative chemistry could impact the exposures to applicators, other workers, and residents, although these could be addressed by re-entry and re-occupancy times. A study conducted by CPI (Wood, 2014) reported that MDI was undetectable (detection limit: 0.00014-0.00016 parts per million [ppm]) in the air space of an 8-cubic-foot room after application of a generic formulation SPF within 1 hour after application (the earliest time measured post-application). It is unclear if the same would apply to alternative formulations that have not been studied. Presumably, any viable alternative could not have a significantly longer cure time, because this would adversely impact construction schedules. Similarly, it is expected that all alternative formulations would use the same application equipment as the Priority Products, but we can assume that these (or the Priority Products) could be redesigned to use equipment that minimizes exposure. Such design work would typically be done when products are closer to commercialization.

4.7.8 Operation and Maintenance

This factor is not relevant to this Abridged AA, as the Priority Products are applied and then passively provide insulation without the need for maintenance. SPF used in roofing applications may need to be renewed with a new coating 10 to 15 years after first installation (Schenke, 2014). However, the coating is applied without impacting the roofing material and would not involve unique maintenance factors that would make this stage of the life cycle a relevant concern.

4.7.9 Waste Generation and Management

As all the alternative formulations for the Priority Products are also based on chemicals that have hazardous properties (various degrees of toxicity, flammability, and/or corrosivity), waste management requirements should not differ materially between the alternatives and the Priority Products. We have found no indication that production of the potential alternative formulations involves some other process (*e.g.*, catalysis) that reduces waste generation (*e.g.*, this is not mentioned in the patents reviewed). During the application phase, all excess material is disposed of as solid waste, because the material is fully cured.

4.7.10 Reuse and Recycling

There is no indication that reuse or recycling of the alternative formulations is possible.

4.7.11 End-of-life Disposal

All unused A- and B-side material (for either the identified possible alternatives or the Priority Products) are required to be properly disposed of according to federal, state, and/or local regulations. For high-pressure SPF, because containers can be resealed, unused material can be saved for the next job. For low-pressure SPF, unused A- and B-side material should be disposed of according to manufacturer's recommendations, in addition to federal, state, and/or local regulations. Information from RE representatives suggests this is common practice. CPI recommends that small amounts of residual chemicals be reacted to produce foam, which can then be disposed of, typically as non-hazardous waste/construction debris (ACC, 2019b). As noted above, cured spray foam that is removed from a home is disposed of as solid waste or construction debris, because the foam is fully reacted and would not be a hazardous waste product. It can be expected that any feasible SPF alternative would have similar properties, because an alternative that produced a cured foam that required management as hazardous waste would face substantial hurdles to adoption.

Table 4.2 Consideration of Potentially Relevant Factors Identified in the SCP Regulations

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Life Cycle Segments	Raw material extraction	No	Not likely to be different. As noted in Section 4.7.1-4.7.3, all the products[1] are likely based on petroleum-derived feedstocks. All are produced industrially.
	Resource inputs and other resource consumption	No	
	Intermediate materials production processes	Potentially	All ingredients appear to be based on synthetic chemical processes, but patents for the alternative formulations give no information on possible synthetic pathways.
	Product manufacture	Potentially	As noted in Section 4.7.4, the exact formulations of the possible alternatives are not currently known. However, all appear to be synthetically produced and appear to possess some chemical hazards or have significant data gaps concerning their hazards (refer also to Tables 5.1 and 5.2).
	Packaging	No	As discussed in Section 4.7.5, all the proposed formulations have two sides based on their patent information and the REs have indicated that they would be expected to have similar packaging.
	Transportation during and between all life cycle segments	Potentially	Product-level information on the Priority Products indicates that they are not considered to be "Dangerous Goods" by US DOT. However, similar product-level information is not available for the alternative formulations. While product-level information would trump ingredient-level information, all of the products contain at least one chemical that would be classified as a "Dangerous Good" under US DOT regulations, if shipped individually. Based on their understanding of the industry, the REs would expect that transportation and distribution impacts would be similar between the Priority Products and the possible alternative formulations, but data are not available to make a definitive determination.
	Distribution	Potentially	

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Life Cycle Segments	Use	Potentially	Application of the potential alternatives is expected to be the same as the Priority Products. High-pressure SPF products are typically sold in 55-gallon drums for use in special equipment (*i.e.*, spray rig trucks), while low-pressure SPF products are sold in smaller two-cylinder kits, which include the application equipment. For the alternatives, different formulations may have potential differences in hazard and exposure during application. This will depend on the exact nature of the alternative formulations, which is not certain at this time. However all appear to possess chemical hazards or significant data gaps concerning their hazards.
	Operation and maintenance	NA	Not applicable to this product type. The product is applied and passively provides insulation.
	Waste generation and management	No	There is no indication that production of the potential alternative formulations involves some other process (*e.g.*, catalysis) that reduces waste generation (*e.g.*, this is not mentioned in the patents reviewed). During the application phase, all excess material is disposed of as solid waste, because the material is fully cured.
	Reuse and recycling	Potentially	As noted in Section 4.7.1, some SPF products currently use recycled plastics in production (apparently in the B side). Data are lacking to determine if the same is possible for alternative formulations, but it appears likely, because most have similar B-side chemistries.
	End-of-life disposal	No	Unused A- and B-side material would presumably be disposed of as required by federal, state, and local regulations. Alternatively, for high-pressure foam, they could be retained and used for future work. Unused A- and B-side product could also be combined to produce foam. Once cured, foam is disposed of as inert, solid waste. There is no indication that disposal would be different for the alternative formulations.

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Adverse Air Quality Impacts	Would the product bring any changes to emissions of California Toxic Air Contaminants (*e.g.*, benzene, Cr[VI])?	No	Based on a review of the California regulations and to the best of our knowledge based on patent information, none of the formulations contains chemicals present on the California Toxic Air Contaminants list.
	CO_2 emissions	No	As noted in Section 4.7.2, an LCA exists for SPF that describes CO_2 emissions. However, a similar assessment does not exist for the alternative formulations. Because all of the alternative formulations appear to be based on synthetic chemical feedstocks, it is not expected that CO_2 emissions across the life cycle would be a material differentiator among the formulations, but again, data are very limited.
	HFC emissions	No	Many of the low-pressure and medium- and high-density SPF products as well as some potential alternative products use HFCs as blowing agents. This would be common to the Priority Products and alternative formulations. HFCs are scheduled to be replaced in SPFs sold in California for most uses starting in 2020.
	Methane emissions	No	Based on the known production process for MDI as well as available patent information for the alternative formulations, emissions of these chemicals are not expected to be part of the life cycle of the Priority Products or alternative formulations.
	Nitrogen fluoride emissions	No	
	Perfluorocarbon emissions	No	
	Sulfur hexafluoride emissions	No	
	Other global warming gas emissions	No	All the ingredients of the Priority Products and alternative formulations are produced industrially. Other than HFCs used in foam blowing (being transitioned to low-global-warming-potential HFOs), no other global warming gases are known to be involved in the product life cycle. CO_2 emissions are likely dominated by the transport phase, which, as noted above, will be similar among all the products.
	Nitrogen oxide emissions	No	Based on the known production process for MDI as well as available patent information for the alternative formulations, emissions of these chemicals are not expected to be part of the life cycle of the Priority Products or alternative formulations.
	Particulate matter emissions	No	
	Ozone-depleting substances emissions[2]	No	
	Sulfur dioxide emissions	No	

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Adverse Air Quality Impacts	Would the product bring any changes to emissions of compounds that might lead to tropospheric ozone production?	Potentially	Some, but not all, of the products contain chemicals that could contribute to tropospheric ozone production. However, alternative formulation data are not 100% certain. In addition, while the REs do not consider MDI to be a VOC that contributes to ozone and smog formation, the unreacted MDI in the Priority Products is currently classified under the CAA as such (US EPA, 2018a). According to Tury *et al.* (2003), unreacted MDI is demonstrated to have low ozone-forming potential and does not contribute to smog formation.
Adverse Ecological Impacts	Would the product, its constituents, or its likely breakdown products have any acute or chronic toxicity to impact aquatic, avian, or terrestrial animal or plant organisms or microbes?	No	As shown in Table 5.1 and 5.2, MDI has either a data gap or is not classified for aquatic and terrestrial toxicity. Most of the alternative formulations have chemicals that may pose acute and chronic aquatic toxicity, and one of the alternatives contain a chemical that may pose terrestrial toxicity. However, ecological exposures are unlikely due to product use and disposal patterns. Spray foam insulation products are not used in a manner that would lead to ecological effects (they are used inside structures or on top of roofs, not washed into storm water or surface water, not used on the land surface, *etc*.).
	Would the product bring changes in population size, reduction in biodiversity, or changes in ecological communities?	No	Ecological exposures are unlikely, because spray foam is not used in a manner that would lead to ecological effects (it is used inside structures or on top of roofs, not washed into storm water or surface water, not used on the land surface, *etc*.).
	Would the product bring changes to the abilities of an endangered or threatened species to survive or reproduce?	No	
	Would the product bring changes to deterioration or the loss of environmentally sensitive habitats?	No	
	Would the product bring changes that contribute to or cause vegetation contamination or damage?	No	

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Adverse Soil Quality Impacts	Would the product impact soil compaction or other soil structure changes?	No	Spray foam insulation products are not used in a manner that would lead to effects on these soil characteristics.
	Would the product impact soil erosion?	No	
	Would the product cause loss of organic matter in soil?	No	
	Would the product cause soil sealing?	No	
Adverse Water Quality Impacts	Would the product be expected to directly enter the municipal storm sewer systems (*e.g.*, car wash detergents)?	No	Spray foam insulation products are not used in a manner that would lead to entry into sewer systems. The cured product is a solid and there is no reason that uncured product would be placed into a sewer during its lifespan. Disposal of cured SPF at end-of-life will be as solid or construction waste. Disposal of unused A or B side of the product would follow federal, state, and local regulations.
	Would the product bring any increase in biological oxygen demand within the water system?	No	Spray foam insulation products are not used in a manner that would lead to any of these effects. The cured products should have low water solubility/be insoluble in water in order to provide moisture resistance and structural support.
	Would the product bring any increase in chemical oxygen demand within the water system?	No	
	Would the product bring any increase in the temperature of water systems?	No	
	Would the product bring any increase in total dissolved solids in water systems?	No	
	Increase in California CWA priority pollutants	No	Based on a review of the relevant regulation and to the best of our knowledge, none of the products contain chemicals present on the California CWA priority pollutant list.
	Increase in California CWA pollutants	No	
	Increase in chemicals with drinking water MCLs	No	Based on a review of the relevant regulation and to the best of our knowledge, none of the products contain chemicals that have drinking water MCLs.
	Increase in chemicals with drinking water notification levels	No	Based on a review of the relevant regulation and to the best of our knowledge, none of the products contain chemicals that have drinking water notification levels.
	Increase in chemicals with drinking water public health goals	No	Based on a review of the relevant regulation and to the best of our knowledge, none of the products contain chemicals that have drinking water public health goals.

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Adverse Water Quality Impacts	Exceedance of a standard relating to the protection of the environment	No	To the best of our knowledge, use of the Priority Products or the alternative formulations will not require intentional exceedance of such a standard.
Public Health Impacts	Acute mammalian toxicity	Yes	Out of the ingredients we assessed, many of the products contain chemicals with this property.
	Carcinogenicity	Yes	Out of the ingredients we assessed, some of the products contain chemicals with these properties.
	Developmental toxicity	Yes	
	Reproductive toxicity	No	None of the ingredients we assessed is a chemical with this property.
	Cardiovascular toxicity	Yes	Out of the ingredients we assessed, some of the products contain chemicals with this property.
	Dermatotoxicity	Yes	Out of the ingredients we assessed, most of the products contain chemicals with this property (irritancy).
	Eye irritation	Yes	Out of the ingredients we assessed, most of the products contain chemicals with this property.
	Respiratory sensitization	Yes	Out of the ingredient we assessed, most of the products contain chemicals with these properties, except for those alternative formulations for which there is a data gap for this endpoint.
	Skin sensitization	Yes	
	Organ toxicity	Yes	Out of the ingredients we assessed, most of the products contain chemicals with this property, except for those alternative formulations for which there is a data gap for this endpoint. The severity also differs among the products.
	Endocrine toxicity	Yes	Out of the ingredients we assessed, some of the products contain chemicals with this property.
	Epigenetic toxicity	No	Out of the ingredients we assessed, no data were found indicating that this property is pertinent to the products.
	Genotoxicity/mutagenicity	No	Out of the ingredients we assessed, none of the products contains a chemical with this property.
	Hematotoxicity	Yes	Out of the ingredients we assessed, one of the alternative formulations contains a chemical with this property.
	Hepatotoxicity and digestive system toxicity	Yes	Out of the ingredients we assessed, some of the products contain chemicals with this property, with the exception of the alternatives, for which there is a data gap for this endpoint.

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Public Health Impacts	Immunotoxicity	Yes	Out of the ingredients we assessed, some of the products contain chemicals with this property.
	Musculoskeletal toxicity	Yes	Out of the ingredients we assessed, some of the products have chemicals with these properties.
	Nephrotoxicity	Yes	
	Neurodevelopmental toxicity	Yes	
	Neurotoxicity	Yes	
	Ototoxicity	No	Out of the ingredients we assessed, no data were found indicating that these properties are pertinent to the products.
	Reactivity in biological systems[3]	No	
	Respiratory toxicity	Yes	Out of the ingredients we assessed, most of the products contain chemicals with these properties.
	Exceedance of an enforceable California or federal standard related to public health	No	To the best of our knowledge, use of the Priority Products or alternative formulations will not require intentional exceedance of such a standard.
Waste and End-of-life Effects	Would the product bring any change to the volume or mass of the waste materials and byproducts generated during the life cycle?	No	All the products, once cured, would be disposed of as solid or construction waste at end of life. There is no expectation that alternative formulations would generate more production waste or application waste than the Priority Products, although details on these aspects are scarce because the formulations are not commercialized.
	Would the product need any special handling to mitigate adverse impacts resulting from the waste materials generated during the life cycle?	No	
	Effects on solid waste or wastewater disposal or treatment	No	
	Effects on discharge(s) or disposal(s) to storm drains or sewers adversely affecting wastewater or storm water treatment facilities	No	Spray foam insulation products are very unlikely to be disposed of *via* storm water/wastewater systems. The products are intended to resistant to dissolution in water.
	Release to the environment	No	All spray foam insulation products can be expected to be manufactured, used, and disposed of similarly or *via* analogous processes. A material difference in terms of environmental release potential is not expected.
Environmental Fate	Aerobic and anaerobic half-lives of the product, its constituents, or its likely breakdown products	No	Spray foam insulation products are unlikely to be discharged to soil, surface water, or groundwater. Thus, these factors are not relevant.
	Aqueous hydrolysis half-life of the product, its constituents, or its likely breakdown products	Yes	One of the alternative formulations (Dow Patent No. WO 2015/142564 A1) describes a water-soluble spray foam. The rest of the products are intended to resistant to dissolution in water.

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Environmental Fate	Atmospheric oxidation rate	Yes	Out of the ingredients we assessed, there are differences in the atmospheric lifetime of different chemicals between the Priority Products and alternative formulations. This is captured by environmental half-life in air.
	Bioaccumulation of the product, its constituents, or its likely breakdown products	No	According to Pharos, no bioaccumulation data exist for the chemicals present in the Priority Products and alternative formulations, for the ingredients we assessed. According to a bioconcentration factor study in ECHA (2019a), MDI is not bioaccumulative.
	Mobility in environmental media	Yes	The Priority Products and alternative formulations contain chemicals with different properties related to environmental mobility (*e.g.*, vapor pressure). However, not all environmental media are likely to be relevant (*e.g.*, not soil).
	Persistence	Yes	According to Pharos, some of the alternative formulations contain chemicals that are persistent for the ingredients we assessed, although there are data gaps on this property for other chemicals in the products.
	Photodegradation	Yes	Out of the ingredients we assessed, there are differences in the atmospheric lifetime of different chemicals in the Priority Products and alternative formulations. This is captured by environmental half-life in air.
Materials and Resource Consumption	Impacts on consumption of renewable resources, including energy and raw materials, throughout the product life cycle	No	Some spray foam insulation products (including some variants of the Priority Product) and one of the alternative formulations uses renewable materials in the B side. This should not result in a material difference between the Priority Products and alternative formulations. All of the products could be produced *via* renewable energy, but there is no information indicating that this is currently the case.

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Materials and Resource Consumption	Impacts on consumption of non-renewable resources, including petroleum, coal, metals, minerals, and other finite resources, throughout the product life cycle	No	The Priority Products and alternative formulations are likely produced from petroleum-based chemicals and are not derived from recycled/recovered materials in an amount that would result in a material difference. Other life cycle stage impacts on consumption of non-renewable resources should be similar among all the products.
Physicochemical Hazards	Do the product or the alternatives exhibit oxidizing properties that facilitate combustion?	No	Based on available chemical composition information, none of the products exhibit this property.
	Do the product or the alternatives exhibit explosivity?	No	Based on available chemical composition information, none of the products exhibit this property.
	Do the product or the alternatives exhibit flammability?	No	None of the ingredients we assessed exhibit this property. In addition, most of the products contain flame retardants to suppress inherent flammability.
Physicochemical Properties	Do the product and alternatives have different physical states?	No	The individual ingredients can exist as liquid, semi-liquid, or solid forms but are all applied as a liquid under pressure, so this is not a material difference between the Priority Products and the alternative formulations.
	Molecular weight	No	There is not a material difference between the Priority Products and the alternative formulations in terms of these properties.
	Density	No	
	Vapor pressure	Yes	The Priority Products and alternative formulations differ in the vapor pressures of their ingredients, which could be a relevant factor for exposure.
	Melting point	No	These factors are not relevant to any decision criteria (hazard, exposure, performance, *etc*.) for spray foam insulation products.
	Boiling point	No	
	Water solubility	No	As the Priority Products and alternative formulations are not likely to impact water resources as part of their normal use, this factor is not relevant.
	Lipid solubility	Yes	See octanol-water partition coefficient (log K_{ow}).
	Octanol-water partition coefficient (log K_{ow})	Yes	The Priority Products and alternative formulations differ in the log K_{ow} of their ingredients, which could be a relevant factor for exposure.

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Physicochemical Properties	Octanol-air partition coefficient (K_{oa})	No	Partitioning between lipid-like materials and air should not be significant given the use of spray foam insulation products.
	Organic carbon partition coefficient (K_{oc})	No	Based on K_{oc}, this is not a relevant factor.
	Diffusivity in air and water	No	There is no reason to believe that these properties differ substantially between the Priority Products and the alternative formulations
	Henry's Law constant	No	This parameter describes diffusion of chemicals from water to air and is not relevant for SPF products.
	Sorption coefficient for soil and sediment	No	Spray foam insulation products are not used in a manner that would lead to entry into soil or sediment. The different foams would not be expected to differ in this property.
	Redox potential	No	Not expected to be a significant differentiator. Organic chemicals do not possess this property, and the inorganic chemicals used in the products are not significant redox agents (*i.e.*, in terms of being their defining property).
	Photolysis rates	Yes	The volatile chemicals in spray foam insulation products all have a relatively short half-life in air, which is likely dominated by photolysis. This is captured by the environmental half-life in air.
	Hydrolysis rates	No	Given the low likelihood of the products to impact aquatic media, this factor is not relevant.
	Dissociation constants	No	
	Reactivity, including electrophilicity	No	The products are all chemically reactive as part of their function. To perform adequately, they must be similarly reactive, so this is not materially different among the products.
Product Function and Performance	Are there material differences in terms of the useful life of the product?	Potentially	The available performance information for the potential alternative formulations is inadequate. Performance is certainly an important consideration, but whether this constitutes a material difference among the products cannot be determined based on the available information.
	Are there material differences in terms of the function and performance of the product?	Potentially	
	Are there material differences in terms of the functional acceptability of the product?	Potentially	
	Are there material differences in terms of the technical feasibility of the product?	Potentially	

Category	Factor That Is Relevant if Materially Different Between Priority Products and Alternative Formulations	Relevant?	Basis
Economic Impacts	Will the product and its alternatives have a different cost to consumers or other users?	Potentially	None of the potential alternative formulations are commercially available; thus, the cost of the alternatives is not known.

Notes:
CAA = Clean Air Act; CWA = Clean Water Act; CO_2 = Carbon Dioxide; Cr(VI) = Hexavalent Chromium; HFC = Hydrofluorocarbon; HFO = Hydrofluoroolefin; LCA = Life Cycle Assessment; MCL = Maximum Contaminant Level; SPF = Spray Polyurethane Foam; US DOT = United States Department of Transportation; VOC = Volatile Organic Compound.
SCP regulations: CalDTSC (2013) (22 CCR § 69505.5).
(1) The term "product" is used in this column to refer to the Priority Products and the possible alternatives.
(2) US EPA (2018b).
(3) Any chemical can be reactive in biological systems (*e.g.*, water, oxygen). We interpret this to mean reactivity in some way not captured by the other health-related factors and having an effect that is harmful.

Table 4.3 Life Cycle Elements Considered in Evaluating Potential Exposures

Category	Element	Relevant?	Basis
Chemical Quantity Information	Would the alternative change the quantities of the chemical(s) of concern or other replacement chemicals necessary to manufacture the product?	No	Based on available information from patents, the amount of A-side material is not expected to be materially different between the Priority Products and the alternative formulations.
	Would the alternative change the quantities of the chemical(s) of concern or other replacement chemicals placed into the stream of commerce in California?	No	
Market Presence of Product	Would the alternative change statewide sales of the product by volume?	Potentially	The only way the volume could change would be if an alternative provided greater (or lesser) effectiveness (*e.g.*, insulation) at smaller volume. This is not expected to vary materially between the Priority Products and any viable alternative.
	Would the alternative change statewide sales of the product by number of units?	Potentially	
	Would the alternative change the intended product use(s), and types and age groups of targeted customer base(s)?	No	The Priority Products are defined by their use, and so any replacement product would have to be available for the same use.
Occurrence or Potential Occurrence of Exposure	Will there be a difference in occurrence or potential occurrence of exposure to Candidate Chemicals in the product?	Yes	Some alternative formulations also contain candidate chemicals, while others do not, although information on final formulations for the alternative formulations is lacking.
Household and Workplace Presence	Will the product be used in the home?	Yes	The high-pressure Priority Products are sold to professionals, whereas low-pressure Priority Products can be sold to non-professional DIY applicators, who may use the products at home as air sealants and for small-scale infrequent insulation applications. While none of the alternative formulations are commercially available, we can assume that any viable alternative will be used in homes by professionals and/or DIY applicators.
	Will the product be used in the workplace?	Yes	Potentially, in commercial buildings. Also, installation in homes can be considered as occurring in a temporary workplace.

Category	Element	Relevant?	Basis
Potential Exposure	Are there differences in the manufacturing, use, storage, transportation, waste, or end-of-life management of the product and alternatives?	Yes	There may be differences in exposure potential during manufacture and use/application, although it is likely that applicators will continue to wear PPE due to the use of high-pressure equipment. This will depend on the nature of the chemicals involved. Other life cycle stages (production, transportation, waste management, end-of-life) would be expected to be similar among the products.
	Is the product manufactured, stored, or transported through California but not used in California?	No	The product is used in California.
	Is the product an intermediate product used to manufacture an exempted product?	No	The product is not an intermediate.
	Does the product have household use?	Yes	See above (Household and Workplace Presence).
	Does the product have recreational use?	No	This product is not for recreational use.
	Are there sensitive subpopulations that use the product and alternatives?	Yes	Sensitive populations include workers, sensitized individuals, children, the elderly, and pregnant women. None of these populations, except workers, are likely to be users of the Priority Products.
	Is the product used in homes?	Yes	See above (Household and Workplace Presence).
	Is the product used in schools?	Yes	The product could potentially be used in schools by workers but not by students or teachers and should not be applied when these bystanders are present.
	Is the product used in workplaces?	Yes	See above (Household and Workplace Presence).
	Is the product used in other unusual locations?	No	None are known to the REs involved in this effort.
	Is there a difference in the frequency, extent, level, and duration of exposure potential for the product and its alternatives during use?	Potentially	Performance data for the alternatives are lacking, so it is unclear if the alternative formulations could be applied in the same timeframe as the Priority Products.
	Is there a difference in the frequency, extent, level, and duration of exposure potential for the product and its alternatives at end-of-life?	No	Products should all be disposed of *via* the same process. All cured products would presumably be managed as non-hazardous waste.
	Is there a difference in how the Candidate Chemical is contained within the product and its alternatives?	No	All products are part of a multi-chemical liquid blend prior to application and then a multi-component solid after application.

Category	Element	Relevant?	Basis
Potential Exposure	Is there a difference in terms of engineering and administrative controls to reduce exposure among the product and its alternatives?	No	All products would be governed by the same occupational or consumer product regulations.
	Is there a difference in the potential of the candidate chemical and degradation products to release into, accumulate in, and persist in the environment?	No	This is not believed to be materially different among the products.

Notes:
DIY = Do-it-yourself; PPE = Personal Protective Equipment; RE = Responsible Entity.

5 Comparison of Alternatives

5.1 Hazard

Gradient collected ingredient information for the potential alternative formulations from their respective patents, except in the case of NanoSonic HybridSil, for which no ingredient information or patent could be located. An evaluation of these potential alternative products revealed a similar B-side composition compared to that of the Priority Products (*i.e.*, amines, surfactant, blowing agent) except in the case of the aldehydes in the DuPont (Thomas *et al*., 2018) and Dow (Foley *et al*., 2015) patents. However, the A-side composition was unsurprisingly different. See Section 4.4 for the alternative products' composition information. In order to streamline the assessment for this Abridged AA, we compared the A-side chemicals, in particular MDI and MDI replacement ingredients, of the Priority Products and the potential alternatives to screen for potential hazards (*i.e*., relevant factors). We did not evaluate the B-side ingredients (*e.g*., amines, catalysts, blowing agents, and surfactants), because the B-side hazards should be comparable due to the similarity of ingredients and because MDI is the chemical of concern in the Priority Product Notification, not any of the B-side ingredients. Some of the alternative formulations include what would be typically B-side ingredients in their A sides, such as surfactants and blowing agents; however, we did not assess their hazards because they are found in the B side of the Priority Products as well, and thus the hazards would be equivalent.

It should be noted that "hazard" refers to a chemical's inherent potential to produce an adverse effect. Hazard does not consider exposure, something that is essential to estimate health risk. The California SCP regulations (and AA in general) do not allow for the consideration of risk (*i.e.*, adjusting hazard for exposure potential) in making decisions about selecting alternative products (CalDTSC, 2013). However, it is important to note when reviewing chemical hazard data on products that the indication of a high hazard does not necessarily equate to an actual health risk. Risk and hazard are different concepts.

To conduct this analysis in a transparent and consistent manner, we screened each chemical contained in the Priority Products and alternative formulations for hazard properties using the Pharos website (Healthy Building Network, 2019; Table 5.1). The Pharos outputs for all of the Priority Products' ingredients for which CAS Nos. were available can be found in Appendix D. For example, if an ingredient is classified as a Globally Harmonized System of Classification and Labelling of Chemicals (GHS) Category 1A or 1B Reproductive Toxicant by regions or countries such as the European Union, Australia, or Japan, then the ingredient would be considered a "High" reproductive hazard under GreenScreen® and Pharos. The hazard interpretation guide for every hazard endpoint is also included Appendix D (Clean Production Action, 2018). For expediency, we adopted the same scoring and color coding system used by Clean Production Action in the GreenScreen® hazard evaluation system (Clean Production Action, 2019). In addition, we added light maroon shading to the endpoints for which no data were found (*i.e*., data gaps). It should be noted that data gaps do not indicate lack of toxicity; they merely indicate that no information was found. While Pharos lists most of the hazard endpoints required by the SCP regulation (*e.g.*, acute mammalian toxicity; CalDTSC, 2013), it does not address some of the relevant factors such as nephrotoxicity and cardiovascular toxicity. To address these remaining factors, we reviewed the US National Library of Medicine's Hazardous Substances Data Bank (HSDB) files for each of the chemicals to determine whether we could obtain information on these other types of hazards from this source (NLM, 2005-2013; Appendix D). See Table 5.1 for the results of this analysis. For the endpoints evaluated *via* the HSDB, we scored a factor as "D" if it was discussed as a potential hazard of the chemical and as "ND"

if there was no discussion of this hazard in the chemical's HSDB profile. This is a fairly crude approach, but we believe that the alternative approach (creating a novel GreenScreen-like scoring rubric for all of the additional SCP hazard endpoints) would be outside the scope of responding to the Priority Product listing. To address global warming potential, we compared the chemicals of interest to the global warming gases listed in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013). To assess potential for contribution to tropospheric ozone formation, we first assessed whether the chemical is a VOC with a vapor pressure equal to or greater than 0.1 mm mercury (Hg) or if it is listed as a substance exempted under California regulations (CARB, 2009). Some VOCs have negligible contributions to tropospheric ozone formation (40 CFR § 51.100[s]) and are exempted from Clean Air Act (CAA) VOC status (US EPA, 2018a), such as the two A-side HFCs (HFC-245fa and HFC-134a) in DuPont's Patent No. WO 2013/101682 A1 formulation.

Table 5.1 also shows the number of "high" or "very high" hazard scores for a particular product or alternative formulation, as well as the number of endpoints with data gaps. It should be noted that the hazards in Table 5.1 are for individual ingredients and are not representative of the hazards or risk of a cured SPF product based on either the Priority Product ingredients or any alternative formulation.

As shown in Table 5.1, of the MDI replacement chemicals we assessed, two of the six potential alternative products for which we have at least some chemical formulation details (*i.e.*, Hybrid Coatings Technology/Nanotech Industries Green Polyurethane and the Owens Corning formulation) contain ingredients that share the same respiratory sensitization concern as the MDI in the Priority Products. Considering the fact that respiratory sensitization and workplace asthma are the primary reasons why pressurized two-component SPF products were selected as Priority Products by CalDTSC (2014), Hybrid Coatings Technology/Nanotech Industries Green Polyurethane and the Owens Corning formulation may not be suitable replacements for the Priority Products under the SCP program. Because we have no composition information for NanoSonic HybridSil, it is unclear if this potential alternative would also contain respiratory sensitizing chemicals. As for the other four potential alternative formulations (*i.e.*, Firestone/Gaco Canary, Dow Patent No. WO 2015/142564 A1, and DuPont Patent Nos. WO 2018/005142 A1 and WO 2013/101682 A1), no information was found in Pharos or HSDB on the MDI replacement ingredients to indicate whether these alternatives would contain respiratory sensitizer(s) or not. As mentioned above, a lack of data does not indicate a lack of toxicity; it merely indicates that no information was located, perhaps due to lack of testing.

According to Table 5.1, the Priority Products A-side ingredients have 3 relevant factors with "High" or "Very High" hazard scores (*i.e.*, dermatotoxicity, respiratory sensitization, and eye irritation) compared to 0 for Firestone/Gaco Canary due mostly to a lack of data, 2 for Hybrid Coatings Technology/Nanotech Industries Green Polyurethane (*i.e.*, persistence and chronic aquatic toxicity), 17[16] for the Owens Corning formulation (*i.e.*, dermatotoxicity, eye irritation, organ toxicity, respiratory sensitization, skin sensitization, persistence, acute and chronic aquatic toxicity), 3 for DuPont's Patent No. WO 2013/101682 A1 formulation (*i.e.*, dermatotoxicity [irritation], eye irritation, and persistence), 0 for Dow's Patent No. WO 2015/142564 A1 formulation due to a complete lack of data, and 3 for DuPont's Patent No. WO 2018/005142 A1 formulation (*i.e.*, eye irritation, dermatotoxicity [irritation], and persistence). While this crude scoring makes the Owens Corning and DuPont Patent No. WO 2013/101682 A1 formulations appear more hazardous compared to the Priority Products, it should be noted that the number of A-side ingredients described in the patents for these two potential alternatives are greater than for the A side of the Priority Products (*i.e.*, two to four ingredients *versus* one ingredient), and thus, a direct comparison would be misleading. In addition, while the REs do not consider MDI to be a VOC that contributes to

[16] This count include the number of times "High" or "Very High" appear for a product. Because some products contain multiple ingredients that scored "High" or "Very High" on the same endpoint, that same endpoint is counted multiple times.

ozone and smog formation, the unreacted MDI in the Priority Products is currently classified under the CAA as such (US EPA, 2018a). According to Tury *et al*. (2003), unreacted MDI is demonstrated to have low ozone-forming potential and does not contribute to smog formation. Comparatively, none of the MDI replacement chemicals we assessed are VOCs that contribute to smog formation.

In an attempt to fill the data gaps according to Pharos, Gradient queried the European Chemicals Agency (ECHA) Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) database (ECHA, 2019c) for additional hazard information on the same ingredients in Table 5.1. These results are available in Table 5.2. Gradient did not color code Table 5.2, because ECHA and the GHS do not use colors in their hazard assignments. It is also important to note that Gradient reported the hazard classifications reported by ECHA dossiers and did not evaluate the underlying toxicity studies to verify the hazard classifications. This is the same approach we took with Pharos. While not all ingredients have ECHA dossiers, we were able to find hazard classifications for some endpoints for certain chemicals that were identified as data gaps in Pharos. For MDI, its ECHA dossier reported no hazard or not classified according to GHS for the following endpoints that were data gaps under Pharos: reproductive toxicity, mutagen, acute and chronic aquatic toxicity, and flammability. For the tin catalyst in the Firestone/Gaco Canary formulation, we were able to fill most of the data gaps as "not classified," but we also identified additional hazards (*e.g*., skin sensitizer and irritation). For the three ingredients in the Owens Corning formulation that had ECHA dossiers (*i.e*., Epon™ 8111, Multifunctional Epoxy Resin [CAS Nos. 25068-38-6 and 15625-89-5] and sodium hydroxide), we were able to fill most of the data gaps as "not classified," but we also identified one additional hazard for sodium hydroxide (*e.g*., corrosive to metal); however, this endpoint is not a relevant factor in the AA. For the two DuPont patents, we were able to populate many of the data gaps as "not classified" for the difunctional acrylate A in the Patent No. WO 2013/101682 A1 formulation and the p-toluenesulfonic acid in the Patent No. WO 2018/005142 A1 formulation. No additional hazards were identified for either ingredient. Lastly, no ECHA dossiers are available (*i.e*., no data available) for MDI replacement ingredients in the Hybrid Coatings Technology/Nanotech Industries Green Polyurethane and the Dow Patent No. WO 2015/142564 A1 formulations.

Although data on chemical composition are available from the patents for Firestone/Gaco Canary, Technology/Nanotech Industries Green Polyurethane, the Owens Corning formulation, the Dow formulation, and the DuPont formulations, which allows some comparison of these alternatives' potential hazard, there is substantial uncertainty in this assessment, due to the lack of CAS Nos. for some of the ingredients and because other additional (or fewer) chemicals could be present in a final commercial formulation of these alternatives. Overall, the available data suggest that there is no alternative formulation that is conclusively preferable to the Priority Products in terms of chemical hazard. Certain data gaps (*e.g*., for Firestone/Gaco Canary, Dow Patent No. WO 2015/142564 A1, and DuPont Patent No. WO 2018/005142 A1) would need to be filled in order to reach more definitive conclusions.

5.2 Performance

We could not evaluate performance parameters between the Priority Products and the potential alternative formulations, because a complete set of necessary performance information was lacking for each formulation (and some had no information at all). As outlined in Section 3.6, AC 377 outlines the mandatory physical properties and standard test methods required for all SPF products, including any alternatives. These properties include thermal resistance (ASTM C177, C518, or C1363), core density (ASTM D1622), tensile strength (ASTM D1623), dimensional stability (ASTM D2126), and surface burning characteristics (ASTM E84 or UL 723). While the patents for Hybrid Coatings Technology/Nanotech Industries Green Polyurethane (Figovsky *et al*., 2015) and the Owens Corning formulation (Olang, 2012) reported limited information on R value range and estimated curing time; these

claims were not supported by test data. In addition, no information on anticipated density, compressive strength, or flame spread resistance was provided in these products' patents. DuPont's 2013 patent (Patent No. WO 2013/101682 A1) reported information on compressive strength, open cell content, density, flame index, and smoke development index for some, but not all, of the example formulations (Jin *et al*., 2013). However, no information was provided on tensile strength, dimensional stability, or thermal resistance in this patent. The two other patents, Dow Patent No. WO 2015/142564 A1 and DuPont Patent No. WO 2018/005142 A1, contained very limited performance data, such as for density, compressive strength, and open cell content, or no such data (Foley *et al*., 2015; Thomas *et al*., 2018). The lack of standardized performance information for SPFs is to be expected, because none of the potential alternative products are commercially available, and it is also unclear if all of the products have moved beyond the research and development (R&D) phase into commercialization and official product testing.

In addition to those requirements outlined in AC 377, all SPFs, including any alternative formulations, must conform to local VOC emission limits in California and all additional requirements laid out in the building standards, as mentioned in Section 3.6 (none of which are addressed in the alternative formulations' patents). Lastly, in addition to performance, many of the patents include the use of blowing agents (HFC-245fa, HFC-134a, and HFC-365mfc), which will be banned in California in 2020 for high-pressure SPF products and alternatives and in 2021 for low-pressure SPF products and alternatives (CARB, 2018).

5.3 Relative Exposure Potential

We could not evaluate product-level exposure parameters between the Priority Products and the potential alternative formulations, because no product-level exposure information was located for any of the alternatives. However, we did gather data for all physicochemical properties (*i.e*., exposure-relevant factors) outlined in CalDTSC's "Alternatives Analysis Guide" (CalDTSC, 2017a). The last factor (dermal permeability coefficient [Kp]) is not part of the SCP list (CalDTSC, 2013) but was added because of the dermal irritation and sensitization potential of the Priority Products and some alternative formulations.

Due to data availability and in order to be consistent among the Priority Products and alternative formulations, we consulted first experimental, then modelled data from the US EPA database EPI Suite (US EPA, 2019a). When EPI Suite was not able to provide a value, we consulted other literature sources, such as the HSDB (NLM, 2005-2013), and US EPA's CompTox Chemicals Dashboard (US EPA, 2019b). Dermal permeability values were calculated using Formula 3.8 from the US EPA's Risk Assessment Guidance for Superfund, Part E ("Supplemental Guidance for Dermal Risk Assessment") if the log octanol-water partition coefficient (K_{ow}) and molecular weights were available for a chemical (US EPA, 2004). The tabulated data are shown in Table 5.3 and all experimental values are bolded to differentiate between experimental and modelled data. Similar to the hazard tables, there are many physicochemical data gaps for the ingredients. In addition, Gradient did not color code this exposure-relevant factors table, because no color coding was provided by the various data sources and because it would be difficult to assign relative preference for many of the relevant factors (*i.e*., physical state and molecular weight).

Many of the physicochemical parameters are not materially relevant (*e.g*., molecular weight, density, physical state), because their exposure potentials are better described by other parameters in Table 5.3. For example, differences in molecular weights are not materially relevant among the ingredients, but molecular weight does impact vapor pressure and dermal penetration, which are materially relevant.

For the few endpoints that would be materially relevant (*i.e*., log K_{ow}, vapor pressure, environmental half-life, and dermal penetration potential), the exposure potential of MDI and MDI replacement ingredients in Firestone/Gaco Canary, the Owens Corning formulation, and the DuPont Patent No. WO 2013/101682

A1 example formulation were either comparable or somewhat preferable to that of the Priority Products. However, we could not find exposure information for one or more ingredients in these alternatives. The exposure potentials of ingredients in Hybrid Coatings Technology/Nanotech Industries Green Polyurethane and the DuPont Patent No. WO 2018/005142 A1 example formulation were comparable, somewhat preferable to, and somewhat undesirable compared to those of the Priority Products (depending on the ingredient). Lastly, no information was found at all for the MDI replacement ingredient in the Dow Patent No. WO 2015/142564 A1 example formulation. Again, it should be stressed that the ingredient-specific exposure information in Table 5.2 is for individual ingredients and is not representative of the exposure potential of a final product or formulations.

Although some data on chemical composition are available from the alternative formulation patents, which allows some comparison of these alternatives' relative exposure potentials, there is substantial uncertainty, because other additional (or fewer) chemicals could be present in a final commercial formulation of these alternatives. Overall, the exposure potentials of the MDI replacement ingredients in Firestone/Gaco Canary, the Owens Corning example formulation, and the Patent No. DuPont WO 2013/101682 A1 example formulation appear to be slightly better than that of the Priority Products. While this qualitative exercise provided some insight into the ingredient-level exposure potential of the alternative products, ideally, we would compare the product-level exposure data, because the ingredients are meant to react and create a foam structure that is distinctly different than the individual ingredients. Unfortunately, no product-level exposure information are available at this time for the alternative formulations.

5.4 Cost

We could not evaluate costs between the Priority Products and the potential alternative products, because none of the potential alternative products are commercially available. There may be cost differences and potential economic impacts on consumers and industry.

6 Conclusions of This Abridged AA

6.1 Potential Alternatives to Priority Products

There are no potential alternatives to the Priority Products that can be appropriately explored in an AA.

Several potential non-isocyanate-based, sprayable, two-component alternative formulations were identified: Firestone/Gaco Canary, Hybrid Coatings Technology/Nanotech Industries Green Polyurethane, the Owens Corning formulation, NanoSonic HybridSil, the Dow formulation, and the two DuPont formulations. However, it is the REs' position that only *polyurethane* alternatives can be considered as potential alternatives to the Priority Products. Nonetheless Gradient included non-polyurethane alternatives for review in the Abridged AA. From the limited information available, the identified potential alternatives products use BPA resins, silicon-based technologies, acetoacetate and tin catalyst, acrylates, or polycarbamates to replace the unreacted MDI in the Priority Products. However, the ingredient information may be subject to change, because we only identified example formulations in patents rather than actual commercial products. In addition, no product-level exposure or standardized SPF performance information could be found for any of the alternatives. This lack of information is a concern because several sources suggest challenges with alternative formulations in terms of curing time and application. Without actual performance data, we cannot be sure that the formulations covered by the patents are actually viable products.

6.2 Decision Concerning an Abridged AA or Stage 2 AA

The conclusion of this Abridged AA is that there are no commercially available alternatives to the Priority Products. A proposed R&D plan to seek and make available a safer product to replace the Priority Products is outlined in Section 7.

7 Potential Regulatory Responses

There are a number of potential regulatory responses CalDTSC may take following the submission of a Stage 1 or Abridged AA (CalDTSC, 2019c). These include the Agency requiring or imposing:

- Supplemental AA Report Information and Regulatory Response Revisions;
- Product Information for Consumers;
- Use Restrictions;
- Product Sales Prohibition;
- Engineering or Administrative Controls;
- End-of-Life Product Management Program;
- Advancement of Green Chemistry and Green Engineering; or
- No Regulatory Response. (CalDTSC, 2019c)

A number of these potential regulatory responses are already in place for the Priority Products (*i.e.*, engineering or administrative controls, use restrictions, product information for consumers, end-of-life product management program). SPF products are extremely effective at providing insulation and energy conservation at a reasonable price. Further use restrictions or product sales prohibitions would significantly affect commercial buildings and residential homes' energy efficiency and lead to increased greenhouse gas emissions, due to increased heating and cooling needs, thus impeding some of California's climate change goals.

Under the SCP program, an Abridged AA, at a minimum, must address two potential regulatory responses: provision of product information for consumers, as defined under 22 CCR § 69506.3, and a proposal for an R&D project to make a safer product available (CalDTSC, 2013).

7.1 Product Information for Consumers

22 CCR § 69506.3 requires manufacturers to disclose certain information to consumers.

High-pressure SPF systems are not a traditional consumer product. There is no retail location or product for the consumer to interact with to review the information required by 22 CCR § 69506.3 (CalDTSC, 2013). Therefore, 22 CCR § 69506.3 is not applicable to manufacturers of high-pressure SPF systems. The information required under 22 CCR § 69506.3 is required to be provided to SPF applicators under OSHA's Hazard Communication Standard.[17]

[17] 29 CFR 1910.1200 (OSHA, 2017).

Manufacturers of low-pressure SPF systems will comply with 22 CCR § 69506.3 by posting the required information on their websites (CalDTSC, 2013). In addition to posting the required information online, manufacturers of low-pressure SPF systems will determine if they will comply with 22 CCR § 69506.3I(2) by posting the required information at the point of sale or on the product or product package (CalDTSC, 2013).

7.2 Proposed Potential Research and Development Plan

The Advancement of Green Chemistry and Green Engineering regulatory response (22 CCR § 69506.8) requires REs to fund a research program to:

(a) Design a safer alternative to the Priority Product;
(b) Improve the performance of a safer alternative to the Priority Product;
I Decrease the cost of the safer alternative to the Priority Product; and/or
(d) Increase the market penetration of a safer alternative to the Priority Product. (CalDTSC, 2013)

The SPF industry has concluded that a functionally acceptable and technically feasible alternative is not available for low-pressure SPF, open-cell SPF, closed-cell SPF, or roofing SPF. Therefore, the REs believe that Options B, C, and D are not suitable for a research program.

Within 12 months of CalDTSC approving the Abridged AA report, SFC and CalDTSC will agree to a mutually acceptable research project.

7.3 Applicability to Possible Future Products Based on Similar Chemistry

This Abridged AA report was developed in response to CalDTSC listing SPF systems with unreacted MDI as a Priority Product under the SCP regulation (CalDTSC, 2013). The REs covered by this Abridged AA report frequently modify their products' B-side formulations (or in the case of low-pressure SPF, may modify the propellant or blowing agent on the A-side) and update product names, without making changes relevant to the concern identified in the Priority Product listing.

Because formulation changes to Priority Products do not impact the hazards associated with the unreacted MDI (*i.e.*, the A-side formulation) it is not appropriate to submit new Priority Product notifications under 22 CCR § 69503.7 or to submit new or updated AAs for each newly branded product placed into commerce in California under 22 CCR § 69505.1(b)(2)(c) (CalDTSC, 2013). Doing so would be excessively burdensome and achieve no benefit to public health.

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Tables

Table 5.1 Data for Relevant Factors – Ingredient-specific Hazards (Primarily from Pharos), Does Not Represent Hazard or Risk Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Factors with High/Very High Scores from MDI and MDI Replacement Ingredients Per Product	No. of Factors with Data Gaps from MDI and MDI Replacement Ingredients Per Product	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Group A Endpoints									
					Acute Mammalian Toxicity	Carcinogenicity	Developmental Toxicity	Reproductive Toxicity	Dermatotoxicity (Irritation)	Endocrine Toxicity	Mutagen	Neurotoxicity	Eye Irritation	Organ Toxicity
Priority Product														
MDI in Priority Product	3	17	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 101-68-8 and 26447-40-5)	30-70 (excluding pMDI, which is not a Priority Product)	Moderate	Moderate	CAS No. 101-68-8: Moderate CAS No. 26447-40-5: DG	DG	High	DG	DG	DG	High	Moderate
Alternative Formulations (as Compared to the Priority Product Above)														
Firestone/Gaco Canary™ Example Formulation	0	86	Sucrose Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
			Glycerine Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
			Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	Potential Concern	DG	Potential Concern	DG	DG	DG	DG	DG	DG	Potential Concern
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	2	24	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	Moderate	Potential Concern	DG	DG	Potential Concern	Moderate	Potential Concern	DG	DG	DG
Owens Corning Example Formulation	17	80	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	Moderate	Potential Concern	DG	DG	Potential Concern	Moderate	Potential Concern	DG	DG	DG
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	DG	DG	DG	DG	High	DG	DG	DG	High	High
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	Low	Moderate	DG	DG	High	DG	DG	DG	High	DG
			Sodium Hydroxide (CAS No. 1310-73-2)	0.7	Moderate	DG	DG	DG	Very High	DG	DG	Potential Concern	Very High	Very High
DuPont Patent No. WO 2013/101682 A1 Example Formulation	3	43	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	Low	Potential Concern	DG	DG	High	DG	DG	DG	High	Potential Concern
			Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	DG	DG	DG	DG	Potential Concern	DG	DG	DG	Potential Concern	Potential Concern
Dow Patent No. WO 2015/142564 A1 Example Formulation	0	31	Polycarbamate (No CAS No., reaction product)	90	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
DuPont Patent No. WO 2018/005142 A1 Example Formulation	3	55	Polycarbamate 2 (No CAS No., reaction product)	No data	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
			P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	Moderate	DG	DG	DG	High	DG	DG	DG	High	Moderate

Notes:

CAA = Clean Air Act; DG = Data Gap; ECHA = European Chemicals Agency; HFC = Hydrofluorocarbon; Hg = Mercury; RE = Responsible Entity; SPF = Spray Polyurethane Foam; VOC = Volatile Organic Compound.

Chemicals reviewed include MDI and potential replacement ingredients for MDI in the respective alternative formulations. In the case of Firestone/Gaco Canary™ example formulation, we kept tin catalyst, because it appears to be a different catalyst compared to those typically found in SPF products. In the case of the Owens Corning example formulation, we kept sodium hydroxide, because it is listed as an A side ingredient and is not a chemical typically found in SPF products.

Because a few of the chemicals are polymers or resin, Pharos reported both the hazards of the chemical of interest and that of the potential residual chemicals or other substances used in the manufacturing of the chemical. We did not report the hazards of these residual chemicals, because the amount of residuals and impurities can differ greatly among different manufacturers. However, the inclusion of hazards from these residual chemical may impact the hazards of the associated product.

All data for Group A hazards were obtained *via* Pharos (Healthy Building Network, 2019), except CAA VOC status and global warming potential. For CAA VOC status, substances were determined to be a VOC if vapor pressure is equal to or greater than 0.1 mm Hg or listed as a substance applying to be exempted (CARB, 2009). Exempted VOC status data were taken from 40 CFR § 51.100 (US EPA, 2018a). For global warming potential, chemicals were checked against the IPCC Fifth Report List of Greenhouse Gases (IPCC, 2013). HFC-245fa and HFC 134a are listed as having a global warming potential of 858 and 1,300 (relative to CO^2 on a 100-year time horizon). The HFCs are classified as "High" based on their global warming potential and California regulatory ban in spray foam starting in 2020. Data for Group B hazards are from the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013).

Scoring for Group A Hazards:

Very High
High
Moderate
Low
Very Low
Potential Concern
DG

All category scores are based on the GreenScreen® scoring system (Clean Production Action, 2019).

Potential Concern = Hazards reported in sources that are not GreenScreen® authoritative or screening sources.

Scoring for Group B Hazards:

D	Data in HSDB implying the effect is associated with the chemical at some level.
ND	

Table 5.1 Data for Relevant Factors – Ingredient-specific Hazards (Primarily from Pharos), Does Not Represent Hazard or Risk Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Factors with High/Very High Scores from MDI and MDI Replacement Ingredients Per Product	No. of Factors with Data Gaps from MDI and MDI Replacement Ingredients Per Product	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Group A Endpoints									
					Respiratory Sensitization	Skin Sensitization	Persistent	Acute Aquatic Toxicity	Chronic Aquatic Toxicity	Terrestrial Ecotoxicity	Global Warming Potential	Bioaccumulative	Flammable	CAA VOC Contributing to Smog Formation
Priority Product														
MDI in Priority Product	3	17	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 101-68-8 and 26447-40-5)	30-70 (excluding pMDI, which is not a Priority Product)	CAS No. 101-68-8: High CAS No. 26447-40-5: Moderate	Moderate	DG	DG	DG	DG	No	DG	DG	VOC and not on 40 CFR § 51.100 exempted list
Alternative Formulations (as Compared to the Priority Product Above)														
Firestone/Gaco Canary™ Example Formulation	0	86	Sucrose Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
			Glycerine Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
			Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	DG	DG	DG	Potential Concern	Potential Concern	DG	No	DG	DG	Not a VOC (low vapor pressure)
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	2	24	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	Potential Concern	Potential Concern	High	Potential Concern	High	DG	No	DG	DG	Not a VOC (low vapor pressure)
Owens Corning Example Formulation	17	80	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	Potential Concern	Potential Concern	High	Potential Concern	High	DG	No	DG	DG	Not a VOC (low vapor pressure)
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	DG	Moderate	High	Very High	High	DG	No	DG	DG	Not a VOC (low vapor pressure)
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	High	High	DG	Moderate	High	DG	No	DG	DG	Not a VOC (low vapor pressure)
			Sodium Hydroxide (CAS No. 1310-73-2)	0.7	DG	DG	High	Moderate	DG	Moderate	No	DG	DG	Not a VOC (low vapor pressure)
DuPont Patent No. WO 2013/101682 A1 Example Formulation	3	43	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	DG	DG	DG	DG	Potential Concern	DG	No	DG	DG	Not a VOC (low vapor pressure)
			Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	DG	Potential Concern	High	DG	Potential Concern	DG	No	DG	DG	Not a VOC (low vapor pressure)
Dow Patent No. WO 2015/142564 A1 Example Formulation	0	31	Polycarbamate (No CAS No., reaction product)	90	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
DuPont Patent No. WO 2018/005142 A1 Example Formulation	3	55	Polycarbamate 2 (No CAS No., reaction product)	No data	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.									
			P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	DG	DG	High	DG	DG	DG	No	DG	DG	Not a VOC (low vapor pressure)

Notes:

CAA = Clean Air Act; DG = Data Gap; ECHA = European Chemicals Agency; HFC = Hydrofluorocarbon; Hg = Mercury; RE = Responsible Entity; SPF = Spray Polyurethane Foam; VOC = Volatile Organic Compound.

Chemicals reviewed include MDI and potential replacement ingredients for MDI in the respective alternative formulations. In the case of Firestone/Gaco Canary™ example formulation, we kept tin catalyst, because it appears to be a different catalyst compared to those typically found in SPF products. In the case of the Owens Corning example formulation, we kept sodium hydroxide, because it is listed as an A side ingredient and is not a chemical typically found in SPF products.

Because a few of the chemicals are polymers or resin, Pharos reported both the hazards of the chemical of interest and that of the potential residual chemicals or other substances used in the manufacturing of the chemical. We did not report the hazards of these residual chemicals, because the amount of residuals and impurities can differ greatly among different manufacturers. However, the inclusion of hazards from these residual chemical may impact the hazards of the associated product.

All data for Group A hazards were obtained *via* Pharos (Healthy Building Network, 2019), except CAA VOC status and global warming potential. For CAA VOC status, substances were determined to be a VOC if vapor pressure is equal to or greater than 0.1 mm Hg or listed as a substance applying to be exempted (CARB, 2009). Exempted VOC status data were taken from 40 CFR § 51.100 (US EPA, 2018a). For global warming potential, chemicals were checked against the IPCC Fifth Report List of Greenhouse Gases (IPCC, 2013). HFC-245fa and HFC 134a are listed as having a global warming potential of 858 and 1,300 (relative to CO^2 on a 100-year time horizon). The HFCs are classified as "High" based on their global warming potential and California regulatory ban in spray foam starting in 2020. Data for Group B hazards are from the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013).

Scoring for Group A Hazards:

Very High
High
Moderate
Low
Very Low
Potential Concern
DG

All category scores are based on the GreenScreen® scoring system (Clean Production Action, 2019).

Potential Concern = Hazards reported in sources that are not GreenScreen® authoritative or screening sources.

Scoring for Group B Hazards:

D	Data in HSDB implying the effect is associated with the chemical at some level.
ND	

Table 5.1 Data for Relevant Factors – Ingredient-specific Hazards (Primarily from Pharos), Does Not Represent Hazard or Risk Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Factors with High/Very High Scores from MDI and MDI Replacement Ingredients Per Product	No. of Factors with Data Gaps from MDI and MDI Replacement Ingredients Per Product	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Group B Endpoints										
					Respiratory Toxicity	Cardiovascular Toxicity	Epigenetic Toxicity	Hematotoxicity	Reactive in Biological Systems	Hepatotoxicity and Digestive System Toxicity	Immunotoxicity	Musculoskeletal Toxicity	Nephrotoxicity	Neurotoxicity	Ototoxicity
Priority Product															
MDI in Priority Product	3	17	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 101-68-8 and 26447-40-5)	30-70 (excluding pMDI, which is not a Priority Product)	D	ND	ND	ND	ND	D	D	ND	ND	D	ND
Alternative Formulations (as Compared to the Priority Product Above)															
Firestone/Gaco Canary™ Example Formulation	0	86	Sucrose Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.										
			Glycerine Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.										
			Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	Not reviewed in HSDB.										
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	2	24	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	Not reviewed in HSDB.										
Owens Corning Example Formulation	17	80	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	Not reviewed in HSDB.										
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	Not reviewed in HSDB.										
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	ND	ND	ND	ND	ND	D	D	ND	ND	ND	ND
			Sodium Hydroxide (CAS No. 1310-73-2)	0.7	D	D	ND	D	ND	D	ND	D	D	ND	ND
DuPont Patent No. WO 2013/101682 A1 Example Formulation	3	43	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	Not reviewed in HSDB.										
			Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	Not reviewed in HSDB.										
Dow Patent No. WO 2015/142564 A1 Example Formulation	0	31	Polycarbamate (No CAS No., reaction product)	90	Unable to assess due to generic name and lack of CAS No.										
DuPont Patent No. WO 2018/005142 A1 Example Formulation	3	55	Polycarbamate 2 (No CAS No., reaction product)	No data	Unable to assess due to generic name and lack of CAS No.										
			P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	D	D	ND	ND	ND	D	ND	ND	ND	ND	ND

Notes:

CAA = Clean Air Act; DG = Data Gap; ECHA = European Chemicals Agency; HFC = Hydrofluorocarbon; Hg = Mercury; RE = Responsible Entity; SPF = Spray Polyurethane Foam; VOC = Volatile Organic Compound.

Chemicals reviewed include MDI and potential replacement ingredients for MDI in the respective alternative formulations. In the case of Firestone/Gaco Canary™ example formulation, we kept tin catalyst, because it appears to be a different catalyst compared to those typically found in SPF products. In the case of the Owens Corning example formulation, we kept sodium hydroxide, because it is listed as an A side ingredient and is not a chemical typically found in SPF products.

Because a few of the chemicals are polymers or resin, Pharos reported both the hazards of the chemical of interest and that of the potential residual chemicals or other substances used in the manufacturing of the chemical. We did not report the hazards of these residual chemicals, because the amount of residuals and impurities can differ greatly among different manufacturers. However, the inclusion of hazards from these residual chemical may impact the hazards of the associated product.

All data for Group A hazards were obtained *via* Pharos (Healthy Building Network, 2019), except CAA VOC status and global warming potential. For CAA VOC status, substances were determined to be a VOC if vapor pressure is equal to or greater than 0.1 mm Hg or listed as a substance applying to be exempted (CARB, 2009). Exempted VOC status data were taken from 40 CFR § 51.100 (US EPA, 2018a). For global warming potential, chemicals were checked against the IPCC Fifth Report List of Greenhouse Gases (IPCC, 2013). HFC-245fa and HFC 134a are listed as having a global warming potential of 858 and 1,300 (relative to CO^2 on a 100-year time horizon). The HFCs are classified as "High" based on their global warming potential and California regulatory ban in spray foam starting in 2020. Data for Group B hazards are from the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013).

Scoring for Group A Hazards:

Very High
High
Moderate
Low
Very Low
Potential Concern
DG

All category scores are based on the GreenScreen® scoring system (Clean Production Action, 2019).

Potential Concern = Hazards reported in sources that are not GreenScreen® authoritative or screening sources.

Scoring for Group B Hazards:

D	Data in HSDB implying the effect is associated with
ND	the chemical at some level.

Table 5.2 Ingredient-specific Hazards According to ECHA – Does Not Represent Hazard or Risk Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Endpoints with Cat. 1 Classifications from MDI and MDI Replacement Ingredients Per Product	No. of Endpoints with Data Gaps from MDI and MDI Replacement Ingredients Per Product	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Human Health											
					Acute Mammalian Toxicity	Aspiration Hazard	Carcinogenicity	Eye Irritation/ Corrosion	Skin Irritation/ Corrosion	Germ Cell Mutagenicity	Target Organ Toxicity – Single Exposure	Target Organ Toxicity – Repeated Exposure	Reproductive/ Developmental Toxicity	Effects on or *via* Lactation	Sensitizer – Respiration	Sensitizer – Skin
Priority Product																
MDI in Priority Product	2	2	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 101-68-8 and 26447-40-5)	30-70 (excluding pMDI, which is not a Priority Product)	Oral: Not classified; Dermal: Not classified; Inhalation: Cat. 4	Inconclusive	Cat. 2	Cat. 2	Cat. 2	Not classified	Cat. 3 (respiratory irritation)	Cat. 2 (inhalation)	Not classified	Not classified	Cat. 1	Cat. 1B
Alternative Formulations (as Compared to the Priority Product Above)																
Firestone/Gaco Canary™ Example Formulation	1	74	Sucrose Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			Glycerine Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	Oral: Cat. 3; Dermal: DG; Inhalation: DG	Not classified	DG	Not classified	Cat. 2	Not classified	DG	DG	DG	DG	DG	Cat. 1A
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	DG	32	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	No ECHA dossier available.											
Owens Corning Example Formulation	7	53	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	No ECHA dossier available.											
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	Oral/Dermal/Inhalation: Not classified	Not classified	DG	Cat. 2	Cat. 2	DG	DG	DG	Not classified	Not classified	Not classified	Cat. 1
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	Oral/Dermal/Inhalation: Not classified	Not classified	Not classified	Cat. 2	Cat. 2	Not classified	Not classified	Not classified	Not classified	DG	DG	Cat. 1
			Sodium Hydroxide (CAS No. 1310-73-2)	0.7	Oral/Dermal/Inhalation: Not classified	Not classified	Not classified	Cat. 1	Cat. 1A	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified
DuPont Patent No. WO 2013/101682 A1 Example Formulation	1	37	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	ECHA dossier available, but no hazard information.											
			Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	Oral/Dermal/Inhalation: Not classified	Not classified	DG	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	DG	DG	Cat. 1
Dow Patent No. WO 2015/142564 A1 Example Formulation	DG	32	Polycarbamate (No CAS No., reaction product)	90	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
DuPont Patent No. WO 2018/005142 A1 Example Formulation	2	34	Polycarbamate 2 (No CAS No., reaction product)	No data	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	Oral/Dermal/Inhalation: Not classified	DG	Not classified	Cat. 1	Cat. 1C	Not classified	Not classified	Not classified	Not classified	Not classified	DG	Not classified

Notes:

Cat. = Category; CLP = Classification, Labelling, and Packaging Regulation; DG = Data Gap; ECHA = European Chemicals Agency; pMDI = Polymeric Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam.

All hazard information was obtained *via* ECHA (2019c). If a dossier has both an European Union CLP Annex VI classification and a self-classification, the self-classifications were recorded in this table, because the European Union CLP Annex VI classifications are already captured under Pharos in Table 5.1. For MDI, we recorded the ECHA classifications of CAS No. 101-68-8, because it is a more complete ECHA dossier compared to that of CAS No. 26447-40-5. In addition, the hazard classifications match between the two dossiers.

Chemicals reviewed include MDI and potential replacement ingredients for MDI in the respective alternative formulations. In the case of the Firestone/Gaco Canary™ example formulation, we kept tin catalyst, because it appears to be a different catalyst compared to those typically found in SPF products. In the case of the Owens Corning example formulation, we kept sodium hydroxide, because it is listed as an A side ingredient and is not a chemical typically found in SPF products.

Legend:

Category 1	Category 1 is most hazardous classification for all endpoints. For a minority of endpoints (*i.e.,* acute mammalian and chronic aquatic toxicity), Category 4 is the least hazardous. For the rest of the endpoints, excluding physical endpoints, Category 2 is the least hazardous.
Category 2	
Category 3	
Category 4	

Table 5.2 Ingredient-specific Hazards According to ECHA – Does Not Represent Hazard or Risk Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Endpoints with Cat. 1 Classifications from MDI and MDI Replacement Ingredients Per Product	No. of Endpoints with Data Gaps from MDI and MDI Replacement Ingredients Per Product	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Environmental			Physical							
					Aquatic Toxicity – Acute	Aquatic Toxicity – Chronic	Hazardous to Ozone Layer	Corrosive to Metals	Explosiveness	Desensitized Explosives	Flammable Aerosols	Flammable Gas	Flammable Liquid	Flammable Solid	Emit Flammable Gases in Contact with Water
Priority Product															
MDI in Priority Product	2	2	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 101-68-8 and 26447-40-5)	30-70 (excluding pMDI, which is not a Priority Product)	Not classified	Not classified	DG	Not classified	Not classified	DG	Not classified	Not classified	Not classified	Not classified	Not classified
Alternative Formulations (as Compared to the Priority Product Above)															
Firestone/Gaco Canary™ Example Formulation	1	74	Sucrose Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.							
			Glycerine Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.							
			Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	DG	Cat. 2	DG	DG	Not classified	DG	Not classified	Not classified	Not classified	Not classified	Not classified
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	DG	32	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	No ECHA dossier available.			No ECHA dossier available.							
Owens Corning Example Formulation	7	53	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	No ECHA dossier available.			No ECHA dossier available.							
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	Not classified	Cat. 2	Not classified	Not classified	Not classified	DG	Not classified	Not classified	Not classified	Not classified	Not classified
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	Cat. 1	Cat. 1	DG	DG	Not classified	DG	DG	DG	Not classified	DG	Not classified
			Sodium Hydroxide (CAS No. 1310-73-2)	0.7	Not classified	Not classified	Not classified	Cat. 1	Not classified	DG	Not classified	Not classified	Not classified	Not classified	Not classified
DuPont Patent No. WO 2013/101682 A1 Example Formulation	1	37	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	ECHA dossier available, but no hazard information.			ECHA dossier available, but no hazard information.							
			Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	Not classified	Not classified	Not classified	DG	Not classified	DG	Not classified	Not classified	Not classified	Not classified	Not classified
Dow Patent No. WO 2015/142564 A1 Example Formulation	DG	32	Polycarbamate (No CAS No., reaction product)	90	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.							
DuPont Patent No. WO 2018/005142 A1 Example Formulation	2	34	Polycarbamate 2 (No CAS No., reaction product)	No data	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.							
			P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified

Notes:
Cat. = Category; CLP = Classification, Labelling, and Packaging Regulation; DG = Data Gap; ECHA = European Chemicals Agency; pMDI = Polymeric Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam.
All hazard information was obtained *via* ECHA (2019c). If a dossier has both an European Union CLP Annex VI classification and a self-classification, the self-classifications were recorded in this table, because the European Union CLP Annex VI classifications are already captured under Pharos in Table 5.1. For MDI, we recorded the ECHA classifications of CAS No. 101-68-8, because it is a more complete ECHA dossier compared to that of CAS No. 26447-40-5. In addition, the hazard classifications match between the two dossiers.
Chemicals reviewed include MDI and potential replacement ingredients for MDI in the respective alternative formulations. In the case of the Firestone/Gaco Canary™ example formulation, we kept tin catalyst, because it appears to be a different catalyst compared to those typically found in SPF products. In the case of the Owens Corning example formulation, we kept sodium hydroxide, because it is listed as an A side ingredient and is not a chemical typically found in SPF products.

Legend:

Category 1	Category 1 is most hazardous classification for all endpoints. For a minority of endpoints (*i.e.,* acute mammalian and chronic aquatic toxicity), Category 4 is the least hazardous. For the rest of the endpoints, excluding physical endpoints, Category 2 is the least hazardous.
Category 2	
Category 3	
Category 4	

Table 5.2 Ingredient-specific Hazards According to ECHA – Does Not Represent Hazard or Risk Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Endpoints with Cat. 1 Classifications from MDI and MDI Replacement Ingredients Per Product	No. of Endpoints with Data Gaps from MDI and MDI Replacement Ingredients Per Product	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Physical								
					Organic Peroxide	Oxidizing Gas	Oxidizing Liquid	Oxidizing Solid	Pyrophoric Liquid	Pyrophoric Solid	Self-heating Substance	Self-reactive Substance	Gas Under Pressure
Priority Product													
MDI in Priority Product	2	2	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 101-68-8 and 26447-40-5)	30-70 (excluding pMDI, which is not a Priority Product)	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified
Alternative Formulations (as Compared to the Priority Product Above)													
Firestone/Gaco Canary™ Example Formulation	1	74	Sucrose Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.								
			Glycerine Acetoacetate (No CAS No. identified)	48.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.								
			Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	DG	32	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	No ECHA dossier available.								
Owens Corning Example Formulation	7	53	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	No ECHA dossier available.								
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified
			Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	DG	DG	Not classified	DG	Not classified	DG	DG	DG	DG
			Sodium Hydroxide (CAS No. 1310-73-2)	0.7	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified
DuPont Patent No. WO 2013/101682 A1 Example Formulation	1	37	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	ECHA dossier available, but no hazard information.								
			Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified
Dow Patent No. WO 2015/142564 A1 Example Formulation	DG	32	Polycarbamate (No CAS No., reaction product)	90	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.								
DuPont Patent No. WO 2018/005142 A1 Example Formulation	2	34	Polycarbamate 2 (No CAS No., reaction product)	No data	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.								
			P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified	Not classified

Notes:
Cat. = Category; CLP = Classification, Labelling, and Packaging Regulation; DG = Data Gap; ECHA = European Chemicals Agency; pMDI = Polymeric Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam.
All hazard information was obtained *via* ECHA (2019c). If a dossier has both an European Union CLP Annex VI classification and a self-classification, the self-classifications were recorded in this table, because the European Union CLP Annex VI classifications are already captured under Pharos in Table 5.1. For MDI, we recorded the ECHA classifications of CAS No. 101-68-8, because it is a more complete ECHA dossier compared to that of CAS No. 26447-40-5. In addition, the hazard classifications match between the two dossiers.
Chemicals reviewed include MDI and potential replacement ingredients for MDI in the respective alternative formulations. In the case of the Firestone/Gaco Canary™ example formulation, we kept tin catalyst, because it appears to be a different catalyst compared to those typically found in SPF products. In the case of the Owens Corning example formulation, we kept sodium hydroxide, because it is listed as an A side ingredient and is not a chemical typically found in SPF products.

Legend:

Category 1	Category 1 is most hazardous classification for all endpoints. For a minority of endpoints (*i.e.,* acute mammalian and chronic aquatic toxicity), Category 4 is the least hazardous. For the rest of the endpoints, excluding physical endpoints, Category 2 is the least hazardous.
Category 2	
Category 3	
Category 4	

Table 5.3 Data for Relevant Factors – Ingredient-specific Exposure Information, Does Not Represent Exposure Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Endpoints with Data Gaps from MDI and MDI Replacement Ingredients Per Product	No. of Factors as Data Gaps	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Molecular Weight	Density (g/cm^3)	Log K_{ow} (Octanol-Water Partition Coefficient, Describes Lipid Solubility)	Log K_{oa} (Octanol-Air Partition Coefficient)	Log K_{oc} (Organic Carbon Partition Coefficient, Describes Sorption in Soil and Sediment)	K_H (Henry's Law Constant at 25°C)
Priority Product										
MDI in Priority Product	4	5	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 26447-40-5 or 101-68-8)	30-70 (excluding pMDI, which is not a Priority Product)	250.252	**1.2**	5.22	9.657	5.455	8.95E-07
Alternative Formulations (as Compared to the Priority Product Above)										
Firestone/Gaco Canary™ Example Formulation	44	19	Sucrose Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.					
		19	Glycerine Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.					
		7	Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	491.3	DG	5.5	5.911	3.751	9.49E-03
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	20	16	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	DG	DG	DG	DG	DG	DG
Owens Corning Example Formulation	35	16	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	DG	DG	DG	DG	DG	DG
		17	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	DG	DG	DG	DG	DG	DG
		5	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	296.32	**1.11 at 20°C**	**2.75**	10.47	3.179	6.01E-10
		8	Sodium Hydroxide (CAS No. 1310-73-2)	0.7	40	**2.13 at 25°C**	Not Applicable (inorganic)	DG	DG	DG
DuPont Patent No. WO 2013/ 101682 A1 Example Formulation	21	6	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	466.53	1.08	4.34	16.167	5.291	3.64E-14
		17	Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	DG	DG	DG	DG	DG	DG
Dow Patent No. WO 2015/ 142564 A1 Example Formulation	19	19	Polycarbamate (No CAS No., reaction product)	90	Unable to assess due to generic name and lack of CAS No.					
DuPont Patent No. WO 2018/ 005142 A1 Example Formulation	24	19	Polycarbamate 2 (No CAS No., reaction product)	No data	Unable to assess due to generic name and lack of CAS No.					
		6	P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	172.2	**1.45 at 25°C**	-0.62	6.324	1.206	2.78E-09

Notes:

CAS No. = Chemical Abstracts Service Registration Number; DG = Data Gap; Hg = Mercury; Kp = Equilibrium Constant.

Bolded text indicates experimental values. Non-bolded text indicates modelled or calculated values.

Data were obtained from US EPA's EPI Suite (US EPA, 2019a), the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013), Haz-Map (NLM, 2018d), OECD (2002), and US EPA's CompTox Chemicals Dashboard (US EPA, 2019b).

(1) To provide context, we also give the dermal penetration potential Kp (cm/hour) values for a few common substances: 5.0E-04 (water), 7.9E-04 (ethanol), 1.5E-02 (m-cresol), and 1.4E-01 (chloroform). The Kp values in this table were calculated using Formula 3.8 in US EPA (2004), if the log K_{ow} and molecular weights were available. This formula was used for all ingredients to ensure consistency.

Table 5.3 Data for Relevant Factors – Ingredient-specific Exposure Information, Does Not Represent Exposure Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Endpoints with Data Gaps from MDI and MDI Replacement Ingredients Per Product	No. of Factors as Data Gaps	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Vapor Pressure (Saturated, mm Hg at 25°C)	Melting Point (°C at 1 atm)	Boiling Point (°C at 1 atm)	Water Solubility (mg/L at 25 °C)	Physical State	Hydrolysis Rate Constant ($M^{-1}s^{-1}$)	Dissociation Constant	Photolysis Rate Constant (s^{-1})
Priority Product												
MDI in Priority Product	4	5	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 26447-40-5 or 101-68-8)	30-70 (excluding pMDI, which is not a Priority Product)	5.00E-06	**40**	**235**	1.836	**Solid**	DG	DG	DG
Alternative Formulations (as Compared to the Priority Product Above)												
Firestone/Gaco Canary™ Example Formulation	44	19	Sucrose Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.							
		19	Glycerine Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.							
		7	Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	1.06E-06	133.85	391.820	0.010	**Liquid**	DG	DG	DG
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	20	16	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	**3.45E-10**	DG	DG	DG	**Liquid**	DG	DG	DG
Owens Corning Example Formulation	35	16	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	**3.45E-10**	DG	DG	DG	**Liquid**	DG	DG	DG
		17	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	DG	DG	DG	DG	**Liquid**	DG	DG	DG
		5	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	**5.63E-04**	27.19	322.42	74.317	**Liquid**	DG	DG	DG
		8	Sodium Hydroxide (CAS No. 1310-73-2)	0.7	**1.82E-21**	**318**	**1,388**	DG	**Solid**	Not applicable	Not applicable	DG
DuPont Patent No. WO 2013/ 101682 A1 Example Formulation	21	6	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	2.13E-08	148.97	454.15	1.0675	Solid	DG	DG	DG
		17	Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	DG	DG	DG	DG	**Liquid**	DG	DG	DG
Dow Patent No. WO 2015/ 142564 A1 Example Formulation	19	19	Polycarbamate (No CAS No., reaction product)	90	Unable to assess due to generic name and lack of CAS No.							
DuPont Patent No. WO 2018/ 005142 A1 Example Formulation	24	19	Polycarbamate 2 (No CAS No., reaction product)	No data	Unable to assess due to generic name and lack of CAS No.							
		6	P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	2.90E-06	**105**	**140**	**6.20E+05**	Solid	DG	DG	DG

Notes:

CAS No. = Chemical Abstracts Service Registration Number; DG = Data Gap; Hg = Mercury; Kp = Equilibrium Constant.

Bolded text indicates experimental values. Non-bolded text indicates modelled or calculated values.

Data were obtained from US EPA's EPI Suite (US EPA, 2019a), the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013), Haz-Map (NLM, 2018d), OECD (2002), and US EPA's CompTox Chemicals Dashboard (US EPA, 2019b).

(1) To provide context, we also give the dermal penetration potential Kp (cm/hour) values for a few common substances: 5.0E-04 (water), 7.9E-04 (ethanol), 1.5E-02 (m-cresol), and 1.4E-01 (chloroform). The Kp values in this table were calculated using Formula 3.8 in US EPA (2004), if the log K_{ow} and molecular weights were available. This formula was used for all ingredients to ensure consistency.

Table 5.3 Data for Relevant Factors – Ingredient-specific Exposure Information, Does Not Represent Exposure Associated with Final Product(s)

Priority Product and Alternative Formulations	No. of Endpoints with Data Gaps from MDI and MDI Replacement Ingredients Per Product	No. of Factors as Data Gaps	MDI and Potential Replacement Ingredient(s) for MDI	Percentage in A Side Product (% by weight)	Standard Reduction Potential (V)	Air Diffusion Coefficient (Diffusivity) (cm^2/s)	Water Diffusion Coefficient (Diffusivity) (cm^2/s)	Reactivity/ Electrophilicity Index	Environmental Half-life in Air (Days)	Dermal Penetration Potential Kp[1] (cm/hour)
Priority Product										
MDI in Priority Product	4	5	Unreacted Methylene Diphenyl Diisocyanate (MDI) (CAS No. 26447-40-5 or 101-68-8)	30-70 (excluding pMDI, which is not a Priority Product)	Not applicable	Not applicable since ingredient is a solid	DG	DG	**0.46**	1.8E-01
Alternative Formulations (as Compared to the Priority Product Above)										
Firestone/Gaco Canary™ Example Formulation	44	19	Sucrose Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.					
		19	Glycerine Acetoacetate (No CAS No. identified)	48.5	Unable to assess due to generic name and lack of CAS No.					
		7	Tin Catalyst (Dimethylbis [(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)	3	Not applicable	Not applicable since ingredient is a liquid	DG	DG	DG	1.2E-02
Hybrid Coatings Technology/Nanotech Industries Green Polyurethane™ Example Formulation	20	16	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8	Not applicable	Not applicable since ingredient is a liquid	DG	DG	DG	DG
Owens Corning Example Formulation	35	16	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7	Not applicable	Not applicable since ingredient is a liquid	DG	DG	DG	DG
		17	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	8.15-11.4	Not applicable	Not applicable since ingredient is a liquid	DG	DG	DG	DG
		5	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	5.7-8.15	Not applicable	Not applicable since ingredient is a liquid	DG	DG	**0.46**	2.3E-03
		8	Sodium Hydroxide (CAS No. 1310-73-2)	0.7	Not applicable	Not applicable since ingredient is a solid	DG	DG	**1.50E-04**	DG
DuPont Patent No. WO 2013/ 101682 A1 Example Formulation	21	6	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30	Not applicable	Not applicable since ingredient is a solid	DG	DG	DG	2.8E-03
		17	Difunctional Acrylate A (CAS No. 55818-57-0)	10.9	Not applicable	Not applicable since ingredient is a liquid	DG	DG	DG	DG
Dow Patent No. WO 2015/ 142564 A1 Example Formulation	19	19	Polycarbamate (No CAS No., reaction product)	90	Unable to assess due to generic name and lack of CAS No.					
DuPont Patent No. WO 2018/ 005142 A1 Example Formulation	24	19	Polycarbamate 2 (No CAS No., reaction product)	No data	Unable to assess due to generic name and lack of CAS No.					
		6	P-toluenesulfonic Acid (CAS No. 104-15-4)	No data	Not applicable	DG	DG	DG	**11.8**	6.70625E-05

Notes:

CAS No. = Chemical Abstracts Service Registration Number; DG = Data Gap; Hg = Mercury; Kp = Equilibrium Constant.

Bolded text indicates experimental values. Non-bolded text indicates modelled or calculated values.

Data were obtained from US EPA's EPI Suite (US EPA, 2019a), the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013), Haz-Map (NLM, 2018d), OECD (2002), and US EPA's CompTox Chemicals Dashboard (US EPA, 2019b).

(1) To provide context, we also give the dermal penetration potential Kp (cm/hour) values for a few common substances: 5.0E-04 (water), 7.9E-04 (ethanol), 1.5E-02 (m-cresol), and 1.4E-01 (chloroform). The Kp values in this table were calculated using Formula 3.8 in US EPA (2004), if the log K_{ow} and molecular weights were available. This formula was used for all ingredients to ensure consistency.

Appendix C

Product Grouping Information on Existing Priority Products

Table C.1 Manufacturers of Low- and High-pressure Two-component SPF Products Containing Unreacted MDI Currently for Sale in California

Manufacturer Name	Product Name	Density (lb/cf)	Pressure	Group[1]
Accella Polyurethane Systems[2]	FOAMSULATE 200 SERIES	2	High	3
Accella Polyurethane Systems	FOAMSULATE 210 SERIES	2	High	3
Accella Polyurethane Systems	Foamsulate 50 NIB	0.5	High	2
Accella Polyurethane Systems	BAYSEAL OC	0.45-5	High	2
Accella Polyurethane Systems	BAYSEAL OC X	0.6	High	2
Accella Polyurethane Systems	BAYSEAL CC X	2	High	3
Accella Polyurethane Systems	BAYSEAL 2.7 Series[3]	2.7	High	3
Accella Polyurethane Systems	BAYSEAL 3.0 Series	3	High	4
Accella Polyurethane Systems	QuadForm NatureSeal OCX	0.5	High	2
Accella Polyurethane Systems	PREMISEAL 305[4]	3	High	4
Accella Polyurethane Systems	PREMISEAL 350[5]	3	High	4
Accella Polyurethane Systems	Bayseal OC HY	0.45-5	High	2
Accella Polyurethane Systems	QuadFoam 2.0	2	High	3
Accella Polyurethane Systems	QuadFoam 500	0.5	High	2
Accella Polyurethane Systems	Premipour 202M	2.0	High	3
Accella Polyurethane Systems	PREMISEAL 40 SERIES	2.5	High	3
Accella Polyurethane Systems	PREMISEAL 60 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMISEAL 70 SERIES	3	High	4
Accella Polyurethane Systems	PREMISEAL 80 SERIES	3	High	4
Accella Polyurethane Systems	PREMISEAL 250 SERIES	2.5	High	3
Accella Polyurethane Systems	PREMISEAL 255 SERIES	2.5	High	3
Accella Polyurethane Systems	PREMISEAL 280 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMISEAL 285 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMISEAL 300 SERIES	3	High	4
Accella Polyurethane Systems	PREMIR+ 60 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMIR+ 40 SERIES	2.5	High	3
Accella Polyurethane Systems	FOAMSULATE CLOSED CELL SERIES	2	High	3
Accella Polyurethane Systems	FOAMSULATE HFO SERIES	2	High	3
Accella Polyurethane Systems	FOAMSULATE 50 HY	0.5	High	2
Accella Polyurethane Systems	FOAMSULATE 50	0.5	High	2
Accella Polyurethane Systems	FOAMSULATE OCX	0.5	High	2
Accella Polyurethane Systems	FOAMSULATE 70	0.75	High	2
Accella Polyurethane Systems	SEALTITE PRO CLOSED CELL SERIES	2	High	3

Manufacturer Name	Product Name	Density (lb/cf)	Pressure	Group[1]
Accella Polyurethane Systems	SEALTITE PRO OCX	0.5	High	2
Accella Polyurethane Systems	SEALTITE PRO NO MIX	0.5	High	2
Accella Polyurethane Systems	SEALTITE PRO NO TRIM	0.75	High	2
Accella Polyurethane Systems	SEALTITE PRO HIGH YIELD	0.45	High	2
Accella Polyurethane Systems	SEALTITE PRO ONE ZERO	2	High	3
Accella Polyurethane Systems	SEALTITE PRO OPEN CELL	0.5	High	2
A&B Filling Inc.	Brand A Product 1	0.75-2.8	Low	1
A&B Filling Inc.	Brand B Product 2	1.75	Low	1
A&B Filling Inc.	Brand C Product 3	2.5	Low	1
A&B Filling Inc.	Brand D Product 4	NA	Low	1
BASF Corp.	Elastospray 81255	2.5	High	3
BASF Corp.	Elastospray 81285	2.8	High	4
BASF Corp.	Elastospray 81305	3.0	High	4
BASF Corp.	Elastospray 8000A[6]	NA	High	NA
BASF Corp.	ENERTITE G	0.50	High	2
BASF Corp.	ENERTITE NM	0.50	High	2
BASF Corp.	FE 348-2.5	2.5	High	3
BASF Corp.	FE 348-2.8	2.8	High	4
BASF Corp.	FE 348-3.0	3.0	High	4
BASF Corp.	SKYTITE 2.5	2.5	High	3
BASF Corp.	SKYTITE 2.8	2.8	High	4
BASF Corp.	SKYTITE 3.0	3.0	High	4
BASF Corp.	SPRAYTITE 158	2.0	High	3
BASF Corp.	SPRAYTITE 178	2.0	High	3
BASF Corp.	SPRAYTITE 180	2.0	High	3
BASF Corp.	SPRAYTITE 81206	2.0	High	3
BASF Corp.	SPRAYTITE SP	2.0	High	3
BASF Corp.	WALLTITE US	2.0	High	3
BASF Corp.	WALLTITE HP+	2.0	High	3
BASF Corp.	BASF CBI - #1	NA	Low	1
BASF Corp.	BASF CBI - #2	0.5	Low	1
BASF Corp.	BASF CBI - #3	2.0	Low	1
BASF Corp.	BASF CBI - #4	NA	High	NA
BASF Corp.	BASF CBI - #5	2.5	High	3

Manufacturer Name	Product Name	Density (lb/cf)	Pressure	Group[1]
BASF Corp.	BASF CBI - #6	2.8	High	4
BASF Corp.	BASF CBI - #7	3.0	High	4
BASF Corp.	BASF CBI - #8	NA	High	NA
BASF Corp.	BASF CBI - #9	2.5	High	3
BASF Corp.	BASF CBI - #10	2.8	High	4
BASF Corp.	BASF CBI - #11	3.0	High	4
BASF Corp.	BASF CBI - #12	NA	High	NA
BASF Corp.	BASF CBI - #13	2.8	High	4
BASF Corp.	BASF CBI - #14	3.0	High	4
BASF Corp.	BASF CBI - #15	NA	High	NA
BASF Corp.	BASF CBI - #16	2.5	High	3
BASF Corp.	BASF CBI - #17	2.8	High	4
BASF Corp.	BASF CBI - #18	3.0	High	4
DAP Products, Inc.	Touch n' Seal Fire-Rated 1.75 PCF Slow Rise Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Seal 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Seal 2.0 PCF Fire-Rated Polyurethane Foam Sealant	2	Low	1
DAP Products, Inc.	Touch n' Seal 3.0 PCF High Density Closed Cell Polyurethane Foam Sealant	3	Low	1
DAP Products, Inc.	Touch n' Seal Mine Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Foam Professional Fire-Rated 1.75 PCF CCMC Closed Cell Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Foam Fire-Rated 1.75 PCF Closed Cell ICC Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Seal Fire-Rated Low Density 1.0 PCF Open Cell Polyurethane Foam Sealant	1	Low	1
DAP Products, Inc.	Touch n' Seal 1.75 PCF Fire Rated PCF CCMC Closed Cell Polyurethane Foam Sealant	1.75	Low	1
Demilec	Agribalance	0.6-0.8	High	2
Demilec	Demilec APX	0.45-0.5	High	2
Demilec	Heatlok HFO High Lift	2-2.4	High	3
Demilec	Heatlok HFO Pro	2-2.4	High	3
Demilec	Heatlok XT	2.2	High	3
Demilec	Heatlok Soy 200+	2.1	High	3
Demilec	Sealection 500	0.52	High	2
DuPont[7]	FrothPak™ Sealant and Insulation	1.75	Low	3
DuPont	FrothPak™ Ultra Insulation	2.3	Low	1

Manufacturer Name	Product Name	Density (lb/cf)	Pressure	Group[1]
DuPont	Styrofoam™ Dow 3019 with CM2045	2.3	High	3
Firestone	F1800 – GacoTrenchFoam – Polyol Component B	No info. provided	High	No info. provided
Firestone	F-CF2030 – GacoPourFoam CF2030 – Polyol Component B	2	High	3
Firestone	FB28-120 – GacoFlashFoam – Component A & B	2.5	Low	1
Firestone	F10000 – GacoToughFoam – Polyol Component B	10	High	4
Firestone	F183M – Gaco 183M– Polyol Component B	1.8	High	3
Firestone	F1850R – GacoOnePass – Polyol Component B	1.8	High	3
Firestone	F052N – Gaco 052N GacoInsulBarrier – Polyol Component B	0.5	High	2
Firestone	F5001 –GacoFireStop 2 – Polyol Component B	0.6	High	2
Firestone	F4500R – GacoEZSpray – Polyol Component B	0.5	High	2
Firestone	FR6500R – GacoProFill – Polyol Component B	0.6	High	2
Firestone	F1880R – GacoOnePass Low GWP – Polyol Component B	1.8	High	3
Firestone	F2733R – GacoRoofFoam – Polyol Component B	2.7	High	4
Firestone	ISO – Isocyanate – Iso Component A[8]	NA	High	NA
General Coatings Manufacturing Corp.	Brand A 1, 2.5	2.5	High	3
General Coatings Manufacturing Corp.	Brand A 2, 2.7	2.7	High	4
General Coatings Manufacturing Corp.	Brand A 3, 3.0	3.0	High	4
General Coatings Manufacturing Corp.	Brand B 1, 2.5	2.5	High	3
General Coatings Manufacturing Corp.	Brand B 2, 2.7	2.7	High	4
General Coatings Manufacturing Corp.	Brand B 3, 3.0	3.0	High	4
General Coatings Manufacturing Corp.	Ultra-Thane 050	0.5	High	2
General Coatings Manufacturing Corp.	Ultra-Thane 050 OCX	0.5	High	2
General Coatings Manufacturing Corp.	Ultra-Thane 170 Pour Foam	2	Low	1
General Coatings Manufacturing Corp.	Ultra-Thane 230-2.0[9]	2	High	3
General Coatings Manufacturing Corp.	Ultra-Thane 230-2.5, 2.7, and 3.0 Roof Foam	2	High	3
General Coatings Manufacturing Corp.	Universal Polymers Corp 2.0	2.15	High	3
General Coatings Manufacturing Corp.	Universal Polymers Corp 500	0.5	High	2
General Coatings Manufacturing Corp.	Universal Polymers Corp 500 OCX	0.5	High	2
Henry Company LLC	Permax Closed-cell Foam Insulation	1.8-2.5	High	3
ICP Adhesives & Sealants	Handi-Foam® E84 Spray Foam	2.12	Low	1
ICP Adhesives & Sealants	Handi-Foam® Quick Cure	2.12	Low	1
ICP Adhesives & Sealants	Handi-Foam® Air Seal	2.12	Low	1
ICP Adhesives & Sealants	Handi-Foam® Low Density	0.75	Low	1

Manufacturer Name	Product Name	Density (lb/cf)	Pressure	Group[1]
ICP Adhesives & Sealants	Handi-Foam® Wall Seal	0.75	Low	1
ICP Adhesives & Sealants	Brand A Product 1	2.12	Low	1
ICP Adhesives & Sealants	Brand B Product 1	2.12	Low	1
ICP Adhesives & Sealants	Brand B Product 2	2.12	Low	1
ICP Adhesives & Sealants	Brand B Product 3	1.12	Low	1
Icynene-Lapolla	Icynene Classic Plus™	0.7	High	2
Icynene-Lapolla	Icynene Classic™	0.5	High	2
Icynene-Lapolla	Icynene Classic Eco	0.5	High	2
Icynene-Lapolla	Icynene Classic Max	0.5	High	2
Icynene-Lapolla	Icynene MDC 200 V6	2.4	High	3
Icynene-Lapolla	Icynene MDR 210	2.2	High	2
Icynene-Lapolla	ProSeal Eco	2.2	High	3
Icynene-Lapolla	Icynene ProSeal	2-2.4	High	3
Icynene-Lapolla	Lapolla Foam-LOK FL500	0.5	High	2
Icynene-Lapolla	Lapolla Foam-LOK FL2000	2.0	High	3
Icynene-Lapolla	Lapolla Foam-LOK FL2000 – 4G	2.0	High	3
Icynene-Lapolla	Lapolla Foam-LOK LPA 2500	2.5	High	3
Icynene-Lapolla	Lapolla Foam-LOK LPA 2800	2.8	High	4
Johns Manville[10]	JM Corbond III® SPF	2	High	3
Johns Manville	JM Corbond® oc SPF	0.5	High	2
Johns Manville	JM Corbond® ocx SPF	0.5	High	2
NCFI Polyurethanes[11]	10-011	2.8	High	4
NCFI Polyurethanes	10-013	2.8	High	4
NCFI Polyurethanes	11-016	2	High	3
NCFI Polyurethanes	11-017	2	High	3
NCFI Polyurethanes	11-033	1.7	High	3
NCFI Polyurethanes	11-035	2	High	3
NCFI Polyurethanes	11-036	2	High	3
NCFI Polyurethanes	11-037	2	High	3
NCFI Polyurethanes	12-008	0.4-0.5	High	2
SES Foam LLC	EasySeal.5 Spray Foam	0.5	High	2
SES Foam LLC	Nexseal™ 2.0, 2.0W, 2.0 LE, 2.0 LE W	2	High	3
SES Foam LLC	SES 2.5, SES 2.5 S, SES 2.5 W	2.5	High	3
SES Foam LLC	SES 2.7, SES 2.7 S, SES 2.7W	2.7	High	4

Manufacturer Name	Product Name	Density (lb/cf)	Pressure	Group[1]
SES Foam LLC	SES 3.0, SES 3.0 S, SES 3.0W. SES 3.0HCS	3.0	High	4
SES Foam LLC	Sucraseal™ 0.5 lb Spray Foam	0.5	High	2
SWD Urethane	Quik-Shield 100X	0.5	High	2
SWD Urethane	Quik-Shield 106	0.5	High	2
SWD Urethane	Quik-Shield 108	0.4	High	2
SWD Urethane	Quik-Shield 112	2	High	3
SWD Urethane	Quik-Shield 118	2	High	3
SWD Urethane	Quik-Shield 125	3	High	4
SWD Urethane	Quik-Shield 450	2	High	3

Notes:

CalDTSC = California Department of Toxic Substances Control; cf = Cubic Foot; dba = Doing Business As; MDI = Methylene Diphenyl Diisocyanate; NA = Not Applicable (due to A side SDS); SDS = Safety Data Sheet; SPF = Spray Polyurethane Foam.

(1) Groups: 1 = Low Pressure; 2 = High Pressure, 0.5 lb/cf, Open Cell; 3 = High Pressure, 2 lb/cf, Closed Cell; 4 = High Press., 3 lb+/cf, Closed Cell.

(2) Accella Polyurethane Systems dba Acella Polyurethane Systems, Carlisle Spray Foam Insulation, Carlisle Roof Foam and Coatings.

(3) A single SDS covers both BAYSEAL 2.7 and BAYSEAL 3.0.

(4) PREMISEAL 305 was replaced by PREMISEAL 70.

(5) PREMISEAL 350 was replaced by PREMISEAL 70.

(6) Elastrospray 8000A is the A side SDS for all BASF Priority Products in the notification.

(7) FROTH-PAK™ Sealant uses "FROTH-PAK™ ISO INT AF HFC" for the A side and "FROTH-PAK™ Polyol INT 1.75 HFC" for the B side; FROTH-PAK™ Insulation uses "FROTH-PAK™ ISO INT AF HFC" for the A side and "FROTH-PAK™ Class A Polyol INT" for the B side; FROTH-PAK™ Ultra uses "FROTH-PAK™ Ultra 17gal REF ISO" for the A side and "FROTH-PAK™ Ultra 17gal REF Polyol" for the B side; STYROFOAM™ SPF uses "Dow 3019" for the A side and "STYROFOAM™ SPF CM 2045 Polyol" for the B side

(8) ISO – Isocyanate – Iso Component A is the A side SDS to all high-pressure Firestone/Gaco products, other than FB28-120 – GacoFlashFoam – Component A & B.

(9) Ultra-Thane 230-2.0 shares the same SDS as Ultra-Thane 230-2.5, 2.7, and 3.0 Roof Foam.

(10) While Johns Manville choose to include the names of the three Priority Products in the AA, Johns Manville maintains the confidential business information claim on all other information submitted to CalDTSC.

(11) Barnhardt Manufacturing Company dba NCFI® Polyurethanes.

Appendix D

Hazard Sources and GreenScreen® Hazard Interpretation Guide

Pharos Results

[101-68-8] METHYLENE BISPHENYL DIISOCYANATE (PURE MDI)

- General Information
- Hazards
- Compound Groups
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 101-68-8

Synonyms: [153986-89-1] 4,4'-Diphenylmethane diisocyanate; [201528-77-0] 4,4'-Diphenylmethane diisocyanate; [53633-14-0] 4,4'-Diphenylmethane diisocyanate; [57460-66-9] 4,4'-Diphenylmethane diisocyanate; [77090-48-3] 4,4'-Diphenylmethane diisocyanate; [88001-94-9] 4,4'-Diphenylmethane diisocyanate; [97568-33-7] 4,4'-Diphenylmethane diisocyanate; [1211266-59-9] 4,4'-Diphenylmethane diisocyanate; [1220313-65-4] 4,4'-Diphenylmethane diisocyanate; [1400594-70-8] 4,4'-Diphenylmethane diisocyanate; [1533423-48-1] 4,4'-Diphenylmethane diisocyanate (primary CASRN is 101-68-8); [1588489-56-8] 4,4'-Diphenylmethane diisocyanate (primary CASRN is 101-68-8); [2031250-39-0] 4,4'-Diphenylmethane diisocyanate (primary CASRN is 101-68-8); [2056146-02-0] 4,4'-Diphenylmethane diisocyanate (primary CASRN is 101-68-8); [142690-07-1] 4,4'-Diphenylmethane diisocyanate; [55157-41-0] 4,4'-Diphenylmethane diisocyanate; [1211316-64-1] 4,4'-Diphenylmethane diisocyanate; (S)-9,10-Difluro-3-methyl-7-oxo-2,3-dihydro-7H-pyrido[1,2,3-de][1,4]benzoxazine-6-carboxylic acid; 1-Isocyanato-4-(4-isocyanatobenzyl)benzene #; 1-isocyanato-4-[(4-isocyanatophenyl)methyl] benzene; 1,1'-Methylenebis(4-isocyanatobenzene); 4-[(4-isocyanatophenyl)methyl]benzenisocyanate; 4-4'-Diisocyanate de diphenylmethane; 4-4'-Diisocyanate de diphenylmethane [French]; 4,4'- diphenylmethane diisocyanate; 4,4'-,2,4'-,2,2'-Diisocyanatodiphenylmethane; 4,4'-Diisocyanate de diphenylmethane; 4,4'-Diisocyanatodiphenylmethane; 4,4'-Diphenylmethane Diisocyanate; 4,4'-Diphenylmethanediisocyanate; 4,4'-Diphenylmethanediisocyante; 4,4'-MDI; 4,4'-MDI, analytical standard; 4,4'-Methylene diphenyl diisocyanate; 4,4'-Methylenebis(phenyl isocyanate); 4,4'-methylenebis(phenylisocyanate); 4,4'-Methylenebis[phenyl isocyanate]; 4,4'-Methylenedi-p-phenylene diisocyanate; 4,4'-Methylenedi(phenyl diisocyanate); 4,4'-Methylenedi(phenyl isocyanate); 4,4'-Methylenedi(phenylene isocyanate); 4,4'-Methylenediphenyl diisocyanate; 4,4'-Methylenediphenyl isocyanate; 4,4'-Methylenediphenylene diisocyanate; 4,4'-Methylenediphenylene isocyanate; 4,4"-Diphenylmethane diisocyanate; 4,4'diisocyanatodiphenylmethane; 4,4'diphenylmethane diisocyanate; 4,4’-MDI; 4,4/'-Methylenediphenyldiisocyanate; Bayer Desmodur 44; Benzene, 1,1'-methylenebis(4-isocyanato-; Benzene, 1,1'-methylenebis[4-isocyanato-; Benzene,1'-methylenebis[4-isocyanato-; Bis(1,4-isocyanatophenyl)methane; Bis (4-isocyanatophenyl)methane; Bis(p-isocyanatophenyl)methane; Bis(para-isocyanatophenyl)methane; Caradate 30; Crude MDI; Desmodur 44; Di-(4-isocyanatophenyl)methane; Difenil-metan-diisocianato; Difenil-metan-diisocianato [Italian]; Difenylmethaan-diisocyanaat; Difenylmethaan-dissocyanaat; Difenylmethaan-dissocyanaat [Dutch];

Diphenyl methane diisocyanate; diphenyl-methane-diisocyanate; Diphenylmethan-4,4'-diisocyanat; Diphenylmethan-4,4'-diisocyanat [German]; diphenylmethan-4,4'-diisocyanate; Diphenylmethane 4,4-diisocyanate; Diphenylmethane 4,4'-diisocyanate; Diphenylmethane diisocyanate; Diphenylmethane p,p'-diisocyanate; Diphenylmethane-4,4'- Diisocyanate, Methylene Diphenyl Isocyanate; diphenylmethane-4,4'-diisocyanate; Diphenylmethyl diisocyanate; diphenylmethylene diisocyanate; Generic MDI; Hylene M 50; Hylene M-50; Hylene M50; Isocyanic acid, diphenylmethylene ester; Isocyanic acid, ester with diphenylmethane; Isocyanic acid, methylenedi-p-phenylene ester; Isocyanic acid, methylenediphenylene ester; Isonate; MDI; MDR; Methylbisphenyl isocyanate; Methylene bisphenyl isocyanate; Methylene di-p-phenylene isocyanate; Methylene diphenyl diisocyanate; Methylene Diphenyl Diisocyanate and polymeric Methylene Diphenyl Diisocyanate; Methylenebis (4-isocyanatobenzene); Methylenebis(4-phenyl isocyanate); Methylenebis(4-phenylene isocyanate); Methylenebis (4-Phenylisocyanate); Methylenebis(4,4'-phenyl isocyanate); Methylenebis(p-phenyl isocyanate); Methylenebis (p-phenylene isocyanate); Methylenebis(para-phenyl isocyanate); Methylenebis(para-phenylene isocyanate); methylenebis(phenyl isocyanate); Methylenebis(phenylisocyanate); Methylenebis(phenylisocyanate) [Diisocyanates]; Methylenebis[4-isocyanatobenzene]; Methylenebis[4-phenyl isocyanate]; Methylenebis [4-phenylene isocyanate]; Methylenebis[p-phenyl isocyanate]; Methylenebis[p-phenylene isocyanate]; Methylenebisphenyl diisocyanate; methylenebisphenylene diisocyanate; Methylenedi-p-phenyl diisocyanate; Methylenedi-p-phenylene diisocyanate; Methylenedi-para-phenylene diisocyanate; Methylenedi(p-phenyl isocyanate); Methylenedi(p-phenylene diisocyanate); Methylenedi(p-phenylene isocyanate); Methylenediphenyl 4,4'-Diisocyanate; Methylenediphenyl diisocyanate; Methylenediphenyl diisocyanate, 4,4'-; Non-isomeric-specific MDI; p,p'-Diphenylmethane diisocyanate; p,p'-Methylenebis(phenyl isocyanate); p,p'-Methylenebis[phenyl isocyanate]; para,para'-Diphenylmethane diisocyanate; para,para'-Methylenebis(phenyl isocyanate); Para'-Diphenylmethane Diisocyanate; PMDI; Polymeric 4,4-methylenediphenyl diisocyanate; Polymeric mdi; Polymethylene polyphenyl isocynate; Pure MDI; Rubinate 44

PubChem CID: 7570

Used in Product Categories: **Thermal Insulation**, **Resilient Flooring**, **Adhesives**, Foamed-in-Place Insulation, Flooring, Resilient Flooring Adhesives, **Carpet - Tile and Sheet**, Carpet Backing, Wood Flooring Adhesives, Casework Adhesives, **Fluid-Applied Flooring Systems**, MDF, Foamed-in-Place Insulation Components, Resilient Flooring Adhesive Components, Wood Flooring Adhesive Components, **Wood Flooring**, Carpet Backing Components, Engineered Wood Flooring, **Composite Wood**, Casework Adhesive Components, Particle Board, Fluid-Applied Flooring Components (Wet)

Description:

Used as a binder in composite wood products
See also PMDI 9016-87-9 - a polymeric version of MDI that can contain up to 50% MDI

Manufacturing method: Benzene and nitric acid are reacted to produce nitrobenzene. Nitrobenzene is reacted with hydrogen to form aniline. Aniline is reacted with formaldehyde to form 4,4'-methylene dianiline, which is then phosgenated to produce MDI. The phosgenation process is a reaction of carbon monoxide and chlorine. From Figure 2, Polyurethane MDI Handbook, BASF, February 2000 (p.5) available at:
http://www2.basf.us/urethanechemicals/Specialty_Systems/pdfs/2000mdihandbook.pdf

Website (if applicable): *Not provided*

Functional Uses:

- Unknown function in elmers probond polyurethane glue p9401,9402,9405,9406 1 (arts and crafts), percentage: 10-30% (CPDat). Added on 06/29/18.
- Unknown function in great stuff gaps & cracks 1 (home maintenance) (CPDat). Added on 06/29/18.
- Unknown function in liquid nails rhino ultra glue 1 (personal care), percentage: 5-10% (CPDat). Added on 06/30/18.
- manufacture of lacquer coatings, polyurethane resins, and spandex fibers (CA Office of Environmental Health Hazard Assessment (OEHHA)). Added on 08/15/18.

- not reported in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/17/18.
- preparation of polyurethane resin and spandex fibers; bonding rubber to rayon and nylon (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.

VOC designation: SVOC (Boiling point: 314 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

CANCER	EU - Annex VI CMRs - Carcinogen Category 2 - Suspected human Carcinogen EU - GHS (H-Statements) - H351 - Suspected of causing cancer MAK - Carcinogen Group 4 - Non-genotoxic carcinogen with low risk under MAK/BAT levels GHS - Australia - H351 - Suspected of causing cancer GHS - New Zealand - 6.7B - Suspected human carcinogens IARC - Group 3 - Agent is not classifiable as to its carcinogenicity to humans US EPA - IRIS Carcinogens - (1986) Group D - Not classifiable as to human carcinogenicity US EPA - IRIS Carcinogens - (1996) Carcinogenic potential cannot be determined	+ 7
DEVELOPMENTAL	MAK - Pregnancy Risk Group C	
RESPIRATORY	MAK - Sensitizing Substance Sah - Danger of airway & skin sensitization EU - GHS (H-Statements) - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled CHE - Toxicant Database - Asthma - allergen, sensitizer - strong evidence CHE - Toxicant Database - Rhinitis – allergic - strong evidence GHS - Japan - Respiratory sensitizer - Category 1 GHS - Australia - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled GHS - Korea - Respiratory sensitization - Category 1 [H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled] GHS - New Zealand - 6.5A (respiratory) - Respiratory sensitisers (Cat. 1) US EPA - PPT Chemical Action Plans - Inhalation sensitizer causing asthma and lung damage AOEC - Asthmagens - Asthmagen (G) - generally accepted	+ 9
MAMMALIAN	EU - GHS (H-Statements) - H332 - Harmful if inhaled GHS - Australia - H330 - Fatal if inhaled GHS - Japan - Acute toxicity (inhalation: dust, mist) - Category 2	+ 8

	GHS - New Zealand - 6.1B (inhalation) - Acutely toxic Québec CSST - WHMIS 1988 - Class D1A - Very toxic material causing immediate and serious toxic effects GHS - Korea - Acute toxicity (inhalation) - Category 4 [H332 - Harmful if inhaled] GHS - New Zealand - 6.1D (inhalation) - Acutely toxic GHS - New Zealand - 6.1E (oral) - Acutely toxic EU - Manufacturer REACH hazard submissions - H331 - Toxic if inhaled (unverified) EU - GHS (H-Statements) - H319 - Causes serious eye irritation	
EYE IRRITATION	GHS - Korea - Serious eye damage/irritation - Category 2 [H319 - Causes serious eye irritation] GHS - Australia - H319 - Causes serious eye irritation GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A) GHS - Japan - Serious eye damage / eye irritation - Category 2B EU - GHS (H-Statements) - H315 - Causes skin irritation	+ 4
SKIN IRRITATION	GHS - Japan - Skin corrosion / irritation - Category 2 GHS - Australia - H315 - Causes skin irritation GHS - Korea - Skin corrosion/irritation - Category 2 [H315 - Causes skin irritation] GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2) EU - Manufacturer REACH hazard submissions - H314 - Causes severe skin burns and eye damage (unverified) EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction	+ 5
SKIN SENSITIZE	GHS - Japan - Skin sensitizer - Category 1 GHS - Korea - Skin sensitization - Category 1 [H317 - May cause an allergic skin reaction] GHS - New Zealand - 6.5B (contact) - Contact sensitisers (Cat. 1) GHS - Australia - H317 - May cause an allergic skin reaction	+ 4
ORGAN TOXICANT	EU - GHS (H-Statements) - H335 - May cause respiratory irritation EU - GHS (H-Statements) - H373 - May cause damage to organs through prolonged or repeated exposure GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 1 GHS - New Zealand - 6.9A (inhalation) - Toxic to human target organs or systems (Cat. 1) GHS - Australia - H372 - Causes damage to organs through prolonged or repeated exposure GHS - Japan - Specific target organs/systemic toxicity following repeated exposure - Category 1 GHS - Korea - Specific target organ toxicity - Single exposure - Category 3 [H335 - May cause respiratory irritation] GHS - Australia - H335 - May cause respiratory irritation GHS - Korea - Specific target organ toxicity - Repeated exposure - Category 2	+ 10

	[H373 - May cause damage to organs through prolonged or repeated exposure] EU - Manufacturer REACH hazard submissions - H370 - Causes damage to organs (unverified) EU - Manufacturer REACH hazard submissions - H371 - May cause damage to organs (unverified) Québec CSST - WHMIS 1988 - Class D2A - Very toxic material causing other toxic effects	
MULTIPLE	Québec CSST - WHMIS 1988 - Class D2B - Toxic material causing other toxic effects EC - CEPA DSL - Inherently Toxic to Humans (iTH) EC - CEPA Toxic Substances (Sched 1) - CEPA Toxics German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters EU - SVHC Authorisation List - May use an Annex XIV chemical in its life cycle - banned unless authorized	+ 4
RESTRICTED LIST	CA SCP - Candidate Chemicals - Candidate Chemical List CA SCP - Candidate Chemicals - Chemicals of Concern EU - PACT-RMOA Substances - Substances selected for RMOA or hazard assessment EU - REACH Annex XVII non-CMRs - Substances restricted under REACH HBN - Priority Asthmagens - Priority Asthmagen to Avoid MDH - Chemicals of High Concern and Priority Chemicals - Chemicals of High Concern P+W - Precautionary List - Precautionary list of asthma triggers P+W - Precautionary List - Precautionary list of asthmagens SCHF - Hazardous 100 - Chemicals of high concern US EPA - Hazardous Air Pollutants - HAPs subject to the Clean Air Act US EPA - PPT Chemical Action Plans - EPA Chemical of Concern - Action Plan published	+ 11

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Compound Groups (3):

- ISOCYANATES *
- METHYLENE DIPHENYL DIISOCYANATE (MDI) COMPOUNDS
- POLYISOCYANATE COMPOUNDS

Process Chemistry Research Status: Preliminary literature review drafted

Process Chemistry - Other:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[101-77-9] 4,4'-METHYLENE DIANILINE (MDA)				Reactant	Integral	Unknown	

[62-53-3] ANILINE	Reactant	Integral	Unknown
[71-43-2] BENZENE	Reactant	Integral	Unknown
[7782-50-5] CHLORINE	Reactant	Frequent	Unknown
[50-00-0] FORMALDEHYDE	Reactant	Integral	Unknown
[1333-74-0] HYDROGEN	Reactant	Integral	Unknown
[7697-37-2] NITRIC ACID	Reactant	Integral	Unknown
[98-95-3] NITROBENZENE	Reactant	Integral	Unknown
[75-44-5] PHOSGENE	Reactant	Frequent	Unknown

This material is used in the process chemistry of:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[25686-28-6] 4,4'-MDI HOMOPOLYMER				Monomer	Integral (known)	Unknown	
[9016-87-9] POLYMERIC MDI (PMDI)				Monomer	Integral	Unknown	
[9017-01-0] POLYMERIC TDI				Component	Frequent (known)	Unknown	
[64440-88-6] POLYURETHANE				Monomer	Frequent (known)	Unknown	
[9009-54-5] POLYURETHANE FOAMS				Reactant	Frequent	Unknown	
[68083-75-0] Propylene oxide, ethylene oxide, 1,2-propanediol, diphenylmethane-4,4'-diisocyanate polymer				Monomer	Integral	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-UNK (Benchmark Unknown)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.										Acute Aquatic Tox.				Chronic Aquatic Tox.								
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Organoh
R	-	R/Y/G	-	?	-	R	R	-	Y	R	-	-	-	-	-	-	-	-	-	-	G	NL

Full Hazard List By Endpoint:

Carcinogenicity	EU - Annex VI CMRs - Carcinogen Category 2 - Suspected human Carcinogen: Red EU - GHS (H-Statements) - H351 - Suspected of causing cancer: Red GHS - Australia - H351 - Suspected of causing cancer: Red IARC - Group 3 - Agent is not classifiable as to its carcinogenicity to humans: Red, Yellow, or Green US EPA - IRIS Carcinogens - (1986) Group D - Not classifiable as to human carcinogenicity: Red, Yellow, or Green US EPA - IRIS Carcinogens - (1996) Carcinogenic potential cannot be determined: Red, Yellow, or Green MAK - Carcinogen Group 4 - Non-genotoxic carcinogen with low risk under MAK/BAT levels: Yellow GHS - New Zealand - 6.7B - Suspected human carcinogens: Not rated
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	MAK - Pregnancy Risk Group C: Red, Yellow, or Green
Endocrine Disruption	not listed
Oral Toxicity	GHS - New Zealand - 6.1E (oral) - Acutely toxic: Not rated
Dermal Toxicity	not listed
Inhalative Toxicity	GHS - Australia - H330 - Fatal if inhaled: Red GHS - Japan - Acute toxicity (inhalation: dust, mist) - Category 2: Red EU - GHS (H-Statements) - H332 - Harmful if inhaled: Red or Yellow EU - GHS (H-Statements) - H335 - May cause respiratory irritation: Yellow GHS - Australia - H335 - May cause respiratory irritation: Yellow GHS - Korea - Acute toxicity (inhalation) - Category 4 [H332 - Harmful if inhaled]: Yellow GHS - Korea - Specific target organ toxicity - Single exposure - Category 3 [H335 - May cause respiratory irritation]: Yellow GHS - New Zealand - 6.1B (inhalation) - Acutely toxic: Not rated GHS - New Zealand - 6.1D (inhalation) - Acutely toxic: Not rated GHS - New Zealand - 6.9A (inhalation) - Toxic to human target organs or systems (Cat. 1): Not rated
Oral, Dermal, and/or Inhalative Toxicity	GHS - Australia - H372 - Causes damage to organs through prolonged or repeated exposure: Red GHS - Japan - Specific target organs/systemic toxicity following repeated

	exposure - Category 1: Red GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 1: Red Québec CSST - WHMIS 1988 - Class D1A - Very toxic material causing immediate and serious toxic effects: Red EU - GHS (H-Statements) - H373 - May cause damage to organs through prolonged or repeated exposure: Yellow GHS - Korea - Specific target organ toxicity - Repeated exposure - Category 2 [H373 - May cause damage to organs through prolonged or repeated exposure]: Yellow
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	EU - GHS (H-Statements) - H315 - Causes skin irritation: Yellow EU - GHS (H-Statements) - H319 - Causes serious eye irritation: Yellow GHS - Australia - H315 - Causes skin irritation: Yellow GHS - Australia - H319 - Causes serious eye irritation: Yellow GHS - Japan - Serious eye damage / eye irritation - Category 2B: Yellow GHS - Japan - Skin corrosion / irritation - Category 2: Yellow GHS - Korea - Serious eye damage/irritation - Category 2 [H319 - Causes serious eye irritation]: Yellow GHS - Korea - Skin corrosion/irritation - Category 2 [H315 - Causes skin irritation]: Yellow GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2): Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated
Skin and Respiratory Sensitization	EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction: Red EU - GHS (H-Statements) - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled: Red GHS - Australia - H317 - May cause an allergic skin reaction: Red GHS - Australia - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled: Red GHS - Japan - Respiratory sensitizer - Category 1: Red GHS - Japan - Skin sensitizer - Category 1: Red GHS - Korea - Respiratory sensitization - Category 1 [H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled]: Red GHS - Korea - Skin sensitization - Category 1 [H317 - May cause an allergic skin reaction]: Red AOEC - Asthmagens - Asthmagen (G) - generally accepted: Red, Yellow, or Green GHS - New Zealand - 6.5A (respiratory) - Respiratory sensitisers (Cat. 1): Not rated GHS - New Zealand - 6.5B (contact) - Contact sensitisers (Cat. 1): Not rated CHE - Toxicant Database - Rhinitis – allergic - strong evidence: Not rated CHE - Toxicant Database - Asthma - allergen, sensitizer - strong evidence: Not rated US EPA - PPT Chemical Action Plans - Inhalation sensitizer causing asthma and lung damage: Not rated
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	not listed

Chronic Aquatic Toxicity (Invertibrates)	not listed
Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	not listed
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic to Humans (iTH): Red EC - CEPA Toxic Substances (Sched 1) - CEPA Toxics: Red German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters: Red MAK - Sensitizing Substance Sah - Danger of airway & skin sensitization: Red Québec CSST - WHMIS 1988 - Class D2A - Very toxic material causing other toxic effects: Red Québec CSST - WHMIS 1988 - Class D2B - Toxic material causing other toxic effects: Red

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Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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[26447-40-5] DIPHENYLMETHANE DIISOCYANATE (MDI) - NON ISOMER SPECIFIC

- General Information
- Hazards
- Compound Groups
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 26447-40-5

Synonyms: [12125-47-2] 4,4'-Diphenylmethane diisocyanate; [156580-59-5] 4,4'-Diphenylmethane diisocyanate; [28515-38-0] 4,4'-Diphenylmethane diisocyanate; [65916-89-4] 4,4'-Diphenylmethane diisocyanate; [327155-87-3] 4,4'-Diphenylmethane diisocyanate; (S)-9,10-Difluro-3-methyl-7-oxo-2,3-dihydro-7H-pyrido[1,2,3-de][1,4]benzoxazine-6-carboxylic acid; 1-Isocyanato-4-(4-isocyanatobenzyl)benzene #; 1-isocyanato-4-[(4-isocyanatophenyl)methyl]benzene; 1,1'-Methylenebis(4-isocyanatobenzene); 1,1'-METHYLENEBIS(ISOCYANATOBENZENE); 4-[(4-isocyanatophenyl) methyl]benzenisocyanate; 4-4'-Diisocyanate de diphenylmethane; 4-4'-Diisocyanate de diphenylmethane [French]; 4,4'-diphenylmethane diisocyanate; 4,4'-,2,4'-,2,2'-Diisocyanatodiphenylmethane; 4,4'-Diisocyanate de diphenylmethane; 4,4'-Diisocyanatodiphenylmethane; 4,4'-Diphenylmethane diisocyanate; 4,4'-Diphenylmethanediisocyanate; 4,4'-Diphenylmethanediisocyante; 4,4'-MDI; 4,4'-MDI, analytical standard; 4,4'-methylene diphenyl diisocyanate; 4,4'-Methylenebis(phenyl isocyanate); 4,4'-methylenebis(phenylisocyanate); 4,4'-Methylenebis[phenyl isocyanate]; 4,4'-Methylenedi-p-phenylene diisocyanate; 4,4'-Methylenedi(phenyl diisocyanate); 4,4'-Methylenedi(phenyl isocyanate); 4,4'-Methylenedi(phenylene isocyanate); 4,4'-Methylenediphenyl diisocyanate; 4,4'-Methylenediphenyl isocyanate; 4,4'-Methylenediphenylene diisocyanate; 4,4'-Methylenediphenylene isocyanate; 4,4"-Diphenylmethane diisocyanate; 4,4'diisocyanatodiphenylmethane; 4,4'diphenylmethane diisocyanate; 4,4/'-Methylenediphenyldiisocyanate; Bayer Desmodur 44; Benzene, 1,1'-methylenebis(4-isocyanato-; Benzene, 1,1'-methylenebis[4-isocyanato-; Benzene,1'-methylenebis[4-isocyanato-; Bis(1,4-isocyanatophenyl)methane; Bis(4-isocyanatophenyl)methane; Bis (p-isocyanatophenyl)methane; Bis(para-isocyanatophenyl)methane; Caradate 30; Crude MDI; Desmodur 44; Di-(4-isocyanatophenyl)methane; Difenil-metan-diisocianato; Difenil-metan-diisocianato [Italian]; Difenylmethaan-diisocyanaat; Difenylmethaan-dissocyanaat; Difenylmethaan-dissocyanaat [Dutch]; Diphenyl methane diisocyanate; diphenyl-methane-diisocyanate; Diphenylmethan-4,4'-diisocyanat; Diphenylmethan-4,4'-diisocyanat [German]; diphenylmethan-4,4'-diisocyanate; Diphenylmethane 4,4-diisocyanate; Diphenylmethane 4,4'-diisocyanate; Diphenylmethane diisocyanate; Diphenylmethane p,p'-diisocyanate; diphenylmethane-4,4'-diisocyanate; Diphenylmethyl diisocyanate; diphenylmethylene diisocyanate; Generic MDI; Hylene M 50; Hylene M-50; Hylene M50; Isocyanic acid, diphenylmethylene ester; Isocyanic acid, ester with diphenylmethane; Isocyanic acid, methylenedi-p-phenylene ester; Isocyanic acid, methylenediphenylene ester; Isonate; MDI; MDR; Methylbisphenyl isocyanate; Methylene bisphenyl isocyanate; Methylene di-p-phenylene isocyanate; Methylene diphenyl diisocyanate; Methylene Diphenyl Diisocyanate and polymeric Methylene Diphenyl Diisocyanate; Methylenebis(4-isocyanatobenzene); Methylenebis(4-phenyl isocyanate); Methylenebis(4-phenylene isocyanate); Methylenebis(4,4'-phenyl isocyanate);

Methylenebis(p-phenyl isocyanate); Methylenebis(p-phenylene isocyanate); Methylenebis(para-phenyl isocyanate); Methylenebis(para-phenylene isocyanate); Methylenebis(phenyl isocyanate); Methylenebis(phenylisocyanate); Methylenebis(phenylisocyanate) [Diisocyanates]; Methylenebis[4-isocyanatobenzene]; Methylenebis[4-phenyl isocyanate]; Methylenebis[4-phenylene isocyanate]; Methylenebis[p-phenyl isocyanate]; Methylenebis[p-phenylene isocyanate]; Methylenebisphenyl diisocyanate; methylenebisphenylene diisocyanate; Methylenedi-p-phenyl diisocyanate; Methylenedi-p-phenylene diisocyanate; Methylenedi-para-phenylene diisocyanate; Methylenedi(p-phenyl isocyanate); Methylenedi(p-phenylene diisocyanate); Methylenedi(p-phenylene isocyanate); Methylenediphenyl 4,4'-Diisocyanate; Methylenediphenyl diisocyanate; Methylenediphenyl diisocyanate, 4,4'-; Non-isomeric-specific MDI; p,p'-Diphenylmethane diisocyanate; p,p'-Methylenebis(phenyl isocyanate); p,p'-Methylenebis[phenyl isocyanate]; para,para'-Diphenylmethane diisocyanate; para,para'-Methylenebis(phenyl isocyanate); PMDI; Polymeric 4,4-methylenediphenyl diisocyanate; Polymeric mdi; Polymethylene polyphenyl isocynate; Pure MDI; Rubinate 44

PubChem CID: 7570

Used in Product Categories: **Thermal Insulation**, **Adhesives**, Foamed-in-Place Insulation, Flooring, Casework Adhesives, **Fluid-Applied Flooring Systems**, **Resilient Flooring**, **Carpet - Tile and Sheet**, Foamed-in-Place Insulation Components, Resilient Flooring Adhesives, Carpet Backing, Wood Flooring Adhesives, **Composite Wood**, Casework Adhesive Components, Particle Board, Fluid-Applied Flooring Components (Wet)

Description: *Not provided*

Website (if applicable): *Not provided*

Functional Uses:

- Unknown function in liquid nails rhino ultra glue 1 (personal care), percentage: 5-10% (CPDat). Added on 06/30/18.

VOC designation: SVOC (Boiling point: 314 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

CANCER	EU - Annex VI CMRs - Carcinogen Category 2 - Suspected human Carcinogen	+ 3
RESPIRATORY	EU - GHS (H-Statements) - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled	+ 6
MAMMALIAN	EU - GHS (H-Statements) - H332 - Harmful if inhaled	+ 6
EYE IRRITATION	EU - GHS (H-Statements) - H319 - Causes serious eye irritation	+ 3
SKIN IRRITATION	EU - GHS (H-Statements) - H315 - Causes skin irritation	+ 3
SKIN SENSITIZE	EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction	+ 4
ORGAN TOXICANT	EU - GHS (H-Statements) - H335 - May cause respiratory irritation	+ 5
RESTRICTED LIST	EU - SVHC Authorisation List - May use an Annex XIV chemical in its life cycle - banned unless authorized	+ 8
MULTIPLE		

EC - CEPA DSL - Inherently Toxic to Humans (iTH) + 1

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Compound Groups (3):

- ISOCYANATES *
- METHYLENE DIPHENYL DIISOCYANATE (MDI) COMPOUNDS
- POLYISOCYANATE COMPOUNDS

Process Chemistry Research Status: Preliminary literature review done

Process Chemistry - Other:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[101-77-9] 4,4'-METHYLENE DIANILINE (MDA)				Reactant	Integral	Unknown	
[75-44-5] PHOSGENE				Reactant	Frequent	Unknown	

This material is used in the process chemistry of:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[39420-98-9] POLY[OXY(METHYL-1,2-ETHANEDIYL)], .ALPHA.-HYDRO-.OMEGA.-HYDROXY-, POLYMER WITH 1,1'-METHYLENEBIS [ISOCYANATOBENZENE]				Monomer	Integral	Unknown	
[9009-54-5] POLYURETHANE FOAMS				Reactant	Frequent (known)	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-UNK (Benchmark Unknown)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

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(Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic	Acute Aquatic Tox.	Chronic Aquatic Tox.

C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish Inv. Alg.	Any	Fish Inv. Alg.	Any	T	P	B	Climate	Organohalog
R	-	-	-	?	-	R	R	-	Y		R	-	-	-	-	-	-	-	-	-	G		NL

Full Hazard List By Endpoint:

Carcinogenicity	EU - Annex VI CMRs - Carcinogen Category 2 - Suspected human Carcinogen: Red EU - GHS (H-Statements) - H351 - Suspected of causing cancer: Red GHS - Australia - H351 - Suspected of causing cancer: Red GHS - New Zealand - 6.7B - Suspected human carcinogens: Not rated
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	GHS - New Zealand - 6.1E (oral) - Acutely toxic: Not rated
Dermal Toxicity	not listed
Inhalative Toxicity	GHS - Australia - H330 - Fatal if inhaled: Red GHS - Japan - Acute toxicity (inhalation: dust, mist) - Category 2: Red EU - GHS (H-Statements) - H332 - Harmful if inhaled: Red or Yellow EU - GHS (H-Statements) - H335 - May cause respiratory irritation: Yellow GHS - Australia - H335 - May cause respiratory irritation: Yellow GHS - New Zealand - 6.1B (inhalation) - Acutely toxic: Not rated GHS - New Zealand - 6.1D (inhalation) - Acutely toxic: Not rated GHS - New Zealand - 6.9A (inhalation) - Toxic to human target organs or systems (Cat. 1): Not rated
Oral, Dermal, and/or Inhalative Toxicity	GHS - Australia - H372 - Causes damage to organs through prolonged or repeated exposure: Red EU - GHS (H-Statements) - H373 - May cause damage to organs through prolonged or repeated exposure: Yellow
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	EU - GHS (H-Statements) - H315 - Causes skin irritation: Yellow EU - GHS (H-Statements) - H319 - Causes serious eye irritation: Yellow GHS - Australia - H315 - Causes skin irritation: Yellow GHS - Australia - H319 - Causes serious eye irritation: Yellow GHS - Japan - Serious eye damage / eye irritation - Category 2B: Yellow GHS - Japan - Skin corrosion / irritation - Category 2: Yellow GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2): Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated
Skin and Respiratory Sensitization	EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction: Red EU - GHS (H-Statements) - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled: Red GHS - Australia - H317 - May cause an allergic skin reaction: Red GHS - Australia - H334 - May cause allergy or asthma symptoms or breathing difficulties if inhaled: Red GHS - Japan - Skin sensitizer - Category 1: Red GHS - New Zealand - 6.5A (respiratory) - Respiratory sensitisers (Cat. 1): Not rated GHS - New Zealand - 6.5B (contact) - Contact sensitisers (Cat. 1): Not rated Quebec CSST - Asthma Agents - Agent Causing Occupational Asthma: Not rated CHE - Toxicant Database - Rhinitis – allergic - strong evidence: Not rated CHE - Toxicant Database - Asthma - allergen, sensitizer - strong evidence: Not rated US EPA - PPT Chemical Action Plans - Inhalation sensitizer causing asthma and lung damage: Not rated

Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	not listed
Chronic Aquatic Toxicity (Invertibrates)	not listed
Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	not listed
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic to Humans (iTH): Red German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters: Red

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers

- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown

- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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A new version of Pharos is scheduled for release on Sept 6. Click her for details.

1. Dashboard
2. Chemicals and Materials
3. [104-15-4] P-TOLUENESULFONIC ACID

[104-15-4] P-TOLUENESULFONIC ACID

- General Information
- Hazards
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 104-15-4

Synonyms: [100901-72-2] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [114213-96-6] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [126033-27-0] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [144647-92-7] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [210357-81-6] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [402-47-1] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [185568-48-3] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [227313-49-7] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [369371-25-5] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [51506-29-7] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [1023356-14-0] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [128739-80-0] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [156627-46-2] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [613262-31-0] p-Toluenesulfonic acid (primary CASRN is 104-15-4); [119314-18-0] p-Toluenesulfonic acid (primary CASRN is 104-15-4); p-Toluenesulfonic acid; Toluene-4-sulphonic acid

PubChem CID: 6101

Description: *Not provided*

Website (if applicable): *Not provided*

Functional Uses:

- /used as reagent in/ kirsten modification of kleber method (for lemon oil) (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- antimicrobial pesticide (US EPA Pesticide Database). Added on 07/10/18.
- catalyst in coatings, paint, polymer, and textile industries. stabilizer for monomers and polymers, pharmaceutical intermediate, cleaning agents, plating additive (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- effect solubility of disperse dyes, initiator for catalytic polymerization of caprolactam, catalyst for dimerization of alpha-methylstyrene (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- hydrotrope in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.

- manufacture of 4-formylbenzenesulfonic acid, p-sulfobenzoic acid, 2-chlorotoluene-4-sulfonic acid, and 4-(chloromethyl)phenylmethanesulfonic acid (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- manufacture of dyes and oral antidiabetic drugs; conversion to sodium and ammonium salts for manufacture of hydrotropes (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- surfactant in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.

VOC designation: VOC (Boiling point: 116 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

PERSISTENT	EC - CEPA DSL - Persistent	
MAMMALIAN	GHS - Japan - Acute toxicity (oral) - Category 4	+ 1
EYE IRRITATION	EU - GHS (H-Statements) - H319 - Causes serious eye irritation	+ 3
SKIN IRRITATION	EU - GHS (H-Statements) - H315 - Causes skin irritation	+ 3
ORGAN TOXICANT	EU - GHS (H-Statements) - H335 - May cause respiratory irritation	+ 2
REACTIVE	Québec CSST - WHMIS 1988 - Class E - Corrosive materials	
MULTIPLE	EC - CEPA DSL - Inherently Toxic to Humans (iTH)	+ 1

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Process Chemistry Research Status: No life cycle research started

This material is used in the process chemistry of:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[103-23-1] DI(2-ETHYLHEXYL)ADIPATE (DEHA)				Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown	
[117-81-7] DI(2-ETHYLHEXYL)PHTHALATE (DEHP) (primary CASRN)				Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-UNK (Benchmark Unknown)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.											Acute Aquatic Tox.				Chronic Aquatic Tox.							
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Organohalogen
-	-	-	-	Y	-	Y	Y	-	R	-	-	-	-	-	-	-	-	-	-	R/Y	-	G	NL

Full Hazard List By Endpoint:

Carcinogenicity	not listed
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	GHS - Japan - Acute toxicity (oral) - Category 4: Yellow
Dermal Toxicity	not listed
Inhalative Toxicity	EU - GHS (H-Statements) - H335 - May cause respiratory irritation: Yellow GHS - Australia - H335 - May cause respiratory irritation: Yellow
Oral, Dermal, and/or Inhalative Toxicity	GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 2: Yellow
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	GHS - Japan - Serious eye damage / eye irritation - Category 1: Red GHS - Japan - Skin corrosion / irritation - Category 1: Red EU - GHS (H-Statements) - H315 - Causes skin irritation: Yellow EU - GHS (H-Statements) - H319 - Causes serious eye irritation: Yellow GHS - Australia - H315 - Causes skin irritation: Yellow GHS - Australia - H319 - Causes serious eye irritation: Yellow GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2): Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated
Skin and Respiratory Sensitization	not listed
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	not listed
Chronic Aquatic Toxicity (Invertibrates)	not listed
Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	EC - CEPA DSL - Persistent: Red or Yellow
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*

Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic to Humans (iTH): Red German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters: Red Québec CSST - WHMIS 1988 - Class E - Corrosive materials: Red

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

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For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

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For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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GreenScreen

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GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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1. Dashboard
2. Chemicals and Materials
3. [1310-73-2] Sodium hydroxide

[1310-73-2] Sodium hydroxide

- General Information
- Hazards
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 1310-73-2

Synonyms: [8012-01-9] Sodium hydroxide (primary CASRN is 1310-73-2); [1418731-95-9] Sodium hydroxide (primary CASRN is 1310-73-2); Caustic soda; Soda lye; Sodium hydroxide; Sodium hydroxide (Na(OH)); White caustic

PubChem CID: 14798

Used in Product Categories: **Resilient Flooring**, Flooring, **Carpet - Tile and Sheet**, **Composite Wood**, **Sanitary Ware**, **Wallboard**, MDF, **Decorative Laminates**, **Adhesives**, Resilient Flooring Components, Carpet Backing, **Wood Flooring**, Countertops, Engineered Wood Flooring, Plywood, **Composite Wood Components**, Particle Board, Wheatboard, Peel & Stick Adhesives, Toilet Seats, Sanitary Ware Components

Description:

"The organic chemical industry uses sodium hydroxide for saponification reactions, production of nucleophilic anionic intermediates, etherification and esterification, basic catalysis, and the production of free organic bases. Sodium hydroxide solution is used for scrubbing waste gases and neutralizing wastewater....

In the paper industry ... sodium hydroxide solution is used for cooking wood (removal of lignin).... The textile industry uses sodium hydroxide solution to manufacture viscose and viscose staple fibers. The sodium hydroxide solution used must contain only traces of chloride ions (rayon quality). The surface of cotton can be improved by treatment with sodium hydroxide solution (mercerization). [Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006]

Website (if applicable): cameochemicals.noaa.gov/chemical/9073

Functional Uses:

- Unknown function in vo5 hot oil (nourish my shine), manufacturer: Unilever (CPDat). Added on 06/29/18.
- Unknown function in scotch craft stick 1 (arts and crafts), percentage: 0-1% (CPDat). Added on 06/29/18.
- Unknown function in c16 radiator stop leak 1 (auto products), percentage: 0-0% (CPDat). Added on 06/29/18.
- Unknown function in Fabrics, textiles and apparel (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in instant power main line cleaner 1 (home maintenance) (CPDat). Added on 06/29/18.
- Unknown function in mr clean professional floor finish stripper 1 (home maintenance), manufacturer: procter & gamble, percentage: 1-1% (CPDat). Added on 06/29/18.

- Unknown function in for dummies inkjet cartridges - various 1 (home office), percentage: 0-0% (CPDat). Added on 06/30/18.
- Unknown function in lysol brand disinfectant all purpose cleaner trigger w/ bleach 4in1 1 (inside the home) (CPDat). Added on 06/29/18.
- Unknown function in clorox ropa blancos intensos cloro 1 (inside the home), percentage: 0-1% (CPDat). Added on 06/29/18.
- Unknown function in lysol brand disinfectant all purpose cleaner trigger w- bleach 4in1 1 (inside the home), percentage: 0-0% (CPDat). Added on 06/29/18.
- Unknown function in sos steel wool soap pads 1 (inside the home), percentage: 0-0% (CPDat). Added on 06/29/18.
- Unknown function in clorox clean up cleaner with bleach - spray formula 1 (inside the home), manufacturer: clorox, percentage: 0-2% (CPDat). Added on 06/29/18.
- Unknown function in hth 5-way test kit - alkalinity indicator 1 (landscape/yard), percentage: 1-1% (CPDat). Added on 06/29/18.
- Unknown function in Leather articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in Metal articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in crest pro-health [hd] step 2 whitening gel 2 (personal care), manufacturer: proctor and gamble, percentage: 0-1% (CPDat). Added on 06/29/18.
- Unknown function in olay smooth finish hair removal duo - medium to coarse hair 2 (personal care), manufacturer: proctor and gamble, percentage: 1-5% (CPDat). Added on 06/29/18.
- Unknown function in bonide termite and carpenter ant, gallon rtu 1 (pesticides), percentage: 10-30% (CPDat). Added on 06/29/18.
- Unknown function in pet odor eliminator 1 (pet care), percentage: 0-0% (CPDat). Added on 06/29/18.
- Unknown function in Stone, plaster, cement, glass and ceramic articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- alkalinity source in domestos grotbuster bleach cleaning gel, manufacturer: Unilever (CPDat). Added on 06/29/18.
- antibacterial agent in mr clean your home pro liquid antibacterial summer citrus, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- antimicrobial pesticide (US EPA Pesticide Database). Added on 07/10/18.
- buffering in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.
- buffering agent in badedas bath original, manufacturer: Unilever (CPDat). Added on 06/29/18.
- chemical base, acid neutralizer, caustic cleaning agent, solvent, production of paper or fibers (kraft pulping), tissue digestion, dissolving amphoteric metals, saponification (production of hard soap), manufacture of fabric and plastic, food processing, livestock management (cattle dehorning) (CA Office of Environmental Health Hazard Assessment (OEHHA)). Added on 08/15/18.
- conventional chemical pesticide (US EPA Pesticide Database). Added on 07/10/18.
- denaturant in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.
- fragrance or fragrance accessory (IFRA Volume of Use Survey 2016: Transparency List). Added on 04/03/19.
- gelling agent (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/11/18.
- in inorganic chemistry, sodium hydroxide is used in the manufacture of sodium salts, for alkaline ore digestion, and for ph regulation (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- in the aluminum industry, sodium hydroxide is used mainly for the treatment of bauxite (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- in the food industry, sodium hydroxide is used for degreasing, cleaning, and for peeling potatoes (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- in the paper industry ... sodium hydroxide solution is used for cooking wood (removal of lignin) (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- it is used in the manufacture of rayon, mercerized cotton, soap, paper, aluminum, petroleum, chemicals, and dye-stuffs. it is also used for metal cleaning, electrolytic extraction of zinc, tin plating, oxide coating, laundering, and bleaching (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- medication: vet (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- no function in cif antibacterial liquid lemon and green tea, manufacturer: Unilever (CPDat). Added on 06/29/18.
- ph adjuster in kaboom stainbuster mold mtr ing en, manufacturer: Arm & Hammer (CPDat). Added on 06/29/18.
- ph adjuster in oxiclean max force liqui el mtr ing en, manufacturer: Arm & Hammer (CPDat). Added on 06/29/18.
- ph adjuster in xtra powdered laundry detergent mtr ing en, manufacturer: Arm & Hammer (CPDat). Added on 06/29/18.
- ph adjuster in scrub free mildew stain remover mtr ing en, manufacturer: Arm & Hammer (CPDat). Added on 06/29/18.
- ph adjuster in arm & hammer oxy-strength pet odor and stain remover, manufacturer: Arm & Hammer (CPDat). Added on 06/29/18.

- ph adjuster in xtra powdered laundry detergent bucket formula mtr ing en, manufacturer: Arm & Hammer (CPDat). Added on 06/29/18.
- ph adjuster in mr clean your home pro spray with bleach, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph adjusting agent in cascade gel except cascade complete gel, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph adjustment in tide to go, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph control in palmolive ecoand citrus apple splash, manufacturer: Palmolive (CPDat). Added on 06/29/18.
- ph control in palmolive ecoand lemon splash, manufacturer: Palmolive (CPDat). Added on 06/29/18.
- ph neutralizer in 2x ulra era crystal springs, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in 2x ultra era, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in 2x ultra era with oxi booster, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in 2x ultra era he liquid, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in cheer brightclean liq, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in cheer brightclean liquid bounce fresh linen, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in dreft he ultra liquid detergent, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in liquid tide with bleach alternative vivid white and bright, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide coldwater liquid mountain spring, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide he liquid with febreze freshness spring and renewal, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide liquid original, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide liquid with febreze freshness meadows and rain, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in cheer free gentle hdl he, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide totalcare he liquid renewing rain, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide totalcare liquid cool cotton, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- ph neutralizer in tide totalcare liquid renewing rain, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- processing aid in tide stain release pre treater spray, manufacturer: Proctor & Gamble (CPDat). Added on 06/30/18.
- processing aids-additives (EPA Design For the Environment Safer Chemicals Ingredients List). Added on 07/10/18.
- used for sodium phosphate production in the detergent industry. soaps are manufactured by the saponification of fats and oils with sodium hydroxide solution, and detergents are produced from organic sulfonic acids and sodium hydroxide (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- used to maintain safe ph for your fabrics in febreze fabric refresher all varieties, manufacturer: Proctor & Gamble (CPDat). Added on 06/29/18.
- vegetable oil refining; regenerating ion exchange resins; organic fusions; peeling of fruits and vegetables in food industry; etching and electroplating (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.
- waterworks use dilute sodium hydroxide solution to regenerate ion exchangers for water purification and wastewater treatment (TOXNET Hazardous Substances Data Bank (HSDB)). Added on 07/17/18.

VOC designation: Non-volatile (Boiling point: 1388 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

PERSISTENT	EC - CEPA DSL - Persistent	
EYE IRRITATION	GHS - Japan - Serious eye damage / eye irritation - Category 1	+ 3
SKIN IRRITATION	EU - GHS (H-Statements) - H314 - Causes severe skin burns and eye damage	+ 7
ORGAN		+ 1

TOXICANT	GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 1	
MAMMALIAN	GHS - Korea - Acute toxicity (dermal) - Category 4 [H312 - Harmful in contact with skin]	+ 5
ACUTE AQUATIC	GHS - Japan - Hazardous to the aquatic environment (acute) - Category 3	+ 2
TERRESTRIAL	GHS - New Zealand - 9.3C - Harmful to terrestrial vertebrates	
REACTIVE	GHS - Korea - H290 - May be corrosive to metals	+ 2
RESTRICTED LIST	CA SCP - Candidate Chemicals - Candidate Chemical List	+ 1
NEUROTOXICITY	Boyes - Neurotoxicants - Neurotoxic	
MULTIPLE	EC - CEPA DSL - Inherently Toxic to Humans (iTH)	+ 1
POSITIVE LIST	US EPA - DfE SCIL - Green Circle - Verified Low Concern	

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Process Chemistry Research Status: Preliminary literature review drafted

Process Chemistry - Other:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[1305-62-0] CALCIUM HYDROXIDE				Reactant	Occasional/Rare	Unknown	
[497-19-8] Sodium carbonate				Reactant	Occasional/Rare	Unknown	
[7647-14-5] SODIUM CHLORIDE				Reactant	Frequent	Unknown	
[7440-23-5] Sodium metal				Reactant	Occasional/Rare	Unknown	

This material is used in the process chemistry of:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[482-89-3] (2,2'-BIINDOLINE)-3,3'-DIONE				Reactant	Frequent	Unknown	
[67762-26-9] (C14-C18) AND (C16-C18) UNSATURATED ALKYLCARBOXYLIC ACID METHYL ESTER				Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown	
[2426-08-6] 1-BUTOXY-2,3-EPOXYPROPANE				Reactant	Integral	Unknown	
[77-99-6] 1,1,1-TRI(HYDROXYMETHYL)PROPANE				Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown	

[58-36-6] 10,10'-BIS(PHENOXYARSINYL) OXIDE	Reactant	Frequent	Unknown
[68891-38-3] ALCOHOLS, (C12-14), ETHOXYLATED, MONOETHERS WITH SULFURIC ACID, SODIUM SALTS	Reactant	Frequent	Unknown
[68439-57-6] ALKENES, C14-16 ALPHA-, SULFONATED, SODIUM SALTS	Reactant	Frequent	Unknown
[106-92-3] ALLYL GLYCIDYL ETHER	Reactant	Frequent	Unknown
[1344-28-1] ALUMINUM OXIDE	Reactant	Frequent	Unknown
Aluminum oxide, fibrous dust (variant of 1344-28-1)	Reactant	Frequent	Unknown
[140-31-8] Aminoethylpiperazine	Reactant	Integral	Unknown
[7440-36-0] ANTIMONY	Process Aid	Occasional/Rare	Unknown
[94-36-0] BENZOYL PEROXIDE	Reactant	Integral	Unknown
Benzoyl peroxide 70%	Reactant	Integral	Unknown
[298-07-7] BIS(2-ETHYLHEXYL) PHOSPHATE	Reactant	Frequent	Unknown
[1675-54-3] BISPHENOL A DIGLYCIDYL ETHER (BADGE)	Catalyst (homogeneous/ unstructured/ unknown)	Integral	Unknown
[25085-99-8] BISPHENOL A DIGLYCIDYL ETHER (BADGE)	Catalyst (homogeneous/ unstructured/ unknown)	Integral	Unknown
[12447-61-9] BORON ZINC OXIDE (B6ZN2O11), HYDRATE	Reactant	Occasional/Rare	Unknown
[25013-16-5] BUTYLATED HYDROXYANISOLE (BHA)	Reactant	Frequent	Unknown
[471-34-1] CALCIUM CARBONATE	Reactant	Occasional/Rare	Unknown
[9004-34-6] Cellulose, microcrystalline	Reactant	Frequent	Unknown
[57583-35-4] DIMETHYLTIN BIS(2-ETHY1HEXYL MERCAPTOACETATE)	Reactant	Frequent	Unknown
[25067-34-9] Ethenol, polymer with ethene	Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown
[111-76-2] Ethylene glycol monobutyl ether (EGBE)	Reactant	Integral	Unknown
[56-81-5] GLYCERIN	Reactant	Occasional/Rare	Unknown
[9004-62-0] HYDROXYETHYL CELLULOSE	Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown
[9004-65-3] HYDROXYPROPYL METHYL CELLULOSE	Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown
[1215036-04-6] Isosorbide Diesters	Reactant	Frequent	Unknown
[9032-42-2]	Catalyst	Frequent	Unknown

Methylhydroxyethylcellulose	Catalyst (homogeneous/ unstructured/ unknown)		
Nano silver	Reactant	Frequent	Unknown
[91-20-3] NAPHTHALENE	Reactant	Occasional/Rare	Unknown
[90-43-7] O-PHENYLPHENOL	Reactant	Integral	Unknown
[144-62-7] OXALIC ACID	Reactant	Frequent	Unknown
[122-60-1] PHENYL GLYCIDYL ETHER	Reactant	Frequent	Unknown
[25037-45-0] POLYCARBONATE	Reactant	Frequent	Unknown
[9002-86-2] POLYVINYL CHLORIDE (PVC)	Byproduct	Frequent	Unknown
[75-55-8] PROPYLENEIMINE	Reactant	Occasional/Rare	Unknown
[9010-10-0] Proteins, soy	Reactant	Frequent (known)	Unknown
[130328-20-0] Silver Zinc Zeolites	Reactant	Frequent	Unknown
[532-32-1] SODIUM BENZOATE	Reactant	Frequent	Unknown
[9004-32-4] SODIUM CARBOXYMETHYL CELLULOSE	Reactant	Frequent	Unknown
[9004-82-4] Sodium dodecylpoly(oxyethylene) sulfate	Reactant	Integral	Unknown
[7681-53-0] SODIUM HYPOPHOSPHITE	Reactant	Frequent	Unknown
[151-21-3] SODIUM LAURYL SULFATE	Reactant	Frequent	Unknown
[7775-19-1] SODIUM METABORATE	Reactant	Frequent	Unknown
[7631-99-4] SODIUM NITRATE	Reactant	Frequent	Unknown
[7632-00-0] SODIUM NITRITE	Reactant	Frequent	Unknown
[1313-59-3] SODIUM OXIDE	Reactant	Frequent	Unknown
[7558-80-7] SODIUM PHOSPHATE, MONOBASIC	Reactant	Occasional/Rare	Unknown
[7601-54-9] SODIUM PHOSPHATE, TRIBASIC	Reactant	Frequent	Unknown
[54193-36-1] SODIUM POLYMETHACRYLATE	Reactant	Integral	Unknown
[9084-06-4] SODIUM POLYNAPTHALENESULFONATE	Reactant	Integral	Unknown
[67784-80-9] Soybean oil, Me ester	Catalyst (homogeneous/ unstructured/ unknown)	Frequent	Unknown
[8002-26-4] TALL OIL	Reactant	Frequent	Unknown
[7440-28-0] THALLIUM	Reactant	Frequent	Unknown
[8042-47-5] WHITE MINERAL OIL	Reactant	Frequent	Unknown
[7440-66-6] ZINC	Reactant	Frequent	Unknown
Zinc (powder)	Reactant	Frequent	Unknown

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-P1 (Possible Benchmark 1)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level

?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.										Acute Aquatic Tox.				Chronic Aquatic Tox.								
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Organoh
-	-	-	-	?	Y	Y	R	R/Y/G	R	-	-	-	-	Y	?	?	-	-	?	R/Y	-	G	NL	

Full Hazard List By Endpoint:

Carcinogenicity	not listed
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	GHS - New Zealand - 6.1D (oral) - Acutely toxic: Not rated GHS - New Zealand - 6.1E (oral) - Acutely toxic: Not rated
Dermal Toxicity	GHS - Korea - Acute toxicity (dermal) - Category 4 [H312 - Harmful in contact with skin]: Yellow GHS - New Zealand - 6.1D (dermal) - Acutely toxic: Not rated GHS - New Zealand - 6.1E (dermal) - Acutely toxic: Not rated
Inhalative Toxicity	GHS - Australia - H335 - May cause respiratory irritation: Yellow
Oral, Dermal, and/or Inhalative Toxicity	GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 1: Red
Neurotoxicity	Boyes - Neurotoxicants - Neurotoxic: Red, Yellow, or Green
Skin, Eye, and Respiratory Corrosion/Irritation	EU - GHS (H-Statements) - H314 - Causes severe skin burns and eye damage: Red GHS - Australia - H314 - Causes severe skin burns and eye damage: Red GHS - Japan - Serious eye damage / eye irritation - Category 1: Red GHS - Japan - Skin corrosion / irritation - Category 1: Red GHS - Korea - Skin corrosion/irritation - Category 1 [H314 - Causes severe skin burns and eye damage]: Red GHS - Malaysia - H314 - Causes severe skin burns and eye damage: Red GHS - Malaysia - H318 - Causes serious eye damage: Red GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2): Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated GHS - New Zealand - 8.2B - Corrosive to dermal tissue (Cat. 1B): Not rated GHS - New Zealand - 8.2C - Corrosive to dermal tissue (Cat. 1C): Not rated GHS - New Zealand - 8.3A - Corrosive to ocular tissue (Cat. 1): Not rated
Skin and Respiratory Sensitization	not listed
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	GHS - Japan - Hazardous to the aquatic environment (acute) - Category 3: Yellow
Chronic Aquatic Toxicity (Fish)	GHS - New Zealand - 9.1D (fish) - Slightly harmful in the aquatic environment or are otherwise designed for biocidal action: Not rated
Chronic Aquatic Toxicity (Invertibrates)	GHS - New Zealand - 9.1D (crustacean) - Slightly harmful in the aquatic environment or are otherwise designed for biocidal action: Not rated

Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	GHS - New Zealand - 9.3C - Harmful to terrestrial vertebrates: Not rated
Persistence	EC - CEPA DSL - Persistent: Red or Yellow
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	GHS - New Zealand - 8.1A - Corrosive to metals: Not rated
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic to Humans (iTH): Red German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters: Red Québec CSST - WHMIS 1988 - Class E - Corrosive materials: Red

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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3. [15625-89-5] TRIMETHYLOLPROPANE TRIACRYLATE

[15625-89-5] TRIMETHYLOLPROPANE TRIACRYLATE

- General Information
- Hazards
- Compound Groups
- Process Chemistry Research
- GreenScreen
- C2C
- Sources

CAS RN: 15625-89-5

Synonyms: [100465-65-4] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [116335-81-0] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [159251-16-8] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [162193-38-6] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [58998-51-9] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [72269-91-1] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [117079-82-0] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [199685-35-3] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [255831-11-9] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [352031-28-8] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [1186622-07-0] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [1199921-30-6] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); [1798797-17-7] Trimethylolpropane triacrylate (primary CASRN is 15625-89-5); 1,3-PROPANEDIOL, 2-ETHYL-2-(HYDROXYMETHYL)-, TRIACRYLATE ; 1,1,1-Trimethylol propane triacrylate; 1,1,1-Trimethylolpropane triacrylate; 1,1,1-Tris(acryloyloxymethyl)propane; 1,3-Propanediol, 2-ethyl-2-(hydroxymethyl)-, triacrylate; 2-(acryloyloxymethyl)-2-ethylpropane-1,3-diyl diacrylate; 2-Ethyl-2-(((1-oxoallyl)oxy)methyl)-1,3-propanediyl diacrylate; 2-Ethyl-2-(hydroxymethyl)-1,3-propanediol triacrylate; 2-Propenoic acid, 1,1'-(2-ethyl-2-(((1-oxo-2-propen-1-yl)oxy)methyl)-1,3-propanediyl) ester; 2-Propenoic acid, 1,1'-[2-ethyl-2-[[(1-oxo-2-propen-1-yl)oxy]methyl]-1,3-propanediyl] ester; 2-Propenoic acid, 2-ethyl-2-(((1-oxo-2-propenyl)oxy)methyl)-1,3-propanediyl ester; 2-Propenoic acid, 2-ethyl-2-[[(1-oxo-2-propenyl)oxy]methyl]-1,3-propanediyl ester; 2,2-bis(prop-2-enoyloxymethyl)butyl prop-2-enoate; Acrylate monomer ; Acrylic acid, 1,1,1-(trihydroxymethyl)propane triester; Acrylic acid, triester with 2-ethyl-2-(hydroxymethyl)-1,3- propanediol; Acrylic acid, triester with 2-ethyl-2-(hydroxymethyl)-1,3-propanediol; MFM; NK Ester A TMPT; TMPTA ; TMPTA; TMPTA (Trimethylol propane triacrylate); Trimethylolpropane triacrylate

PubChem CID: 27423

Used in Product Categories: **High Performance Coatings**, **Resilient Flooring**, Flooring, High Performance Coating Components, Resilient Flooring Components, **Wood Flooring**, Floor Sealants and Coatings, Engineered Wood Flooring, Solid Unfinished Wood Flooring, Solid PreFinished Wood Flooring, **Flooring Finishes**, **Composite Wood**, Plywood, UV-Cured Finishes

Description:

Organic liquid used in polymers, paints, inks, lacquers and varnishes. (IUCLID)

"Trimethylolpropane triacrylate has wide industrial application based on its use as a cross-linker in radiation curing. It is used to produce inks and coatings for wood, paper, glass, metal, textiles, vinyl and other plastics, and as an ingredient in coating formulations, print varnishes, inks, and other polymer systems. Trimethylolpropane triacrylate is used in colloidal dispersions for industrial baked coatings. Non-radiation curing uses of trimethylolpropane triacrylate include paper and wood impregnates, rubber crosslinking, wire and cable extrusion, and anaerobic adhesives. Trimethylolpropane triacrylate is also used as a chemical intermediate. Consumers are at potential risk of exposure from the many consumer products which contain trimethylolpropane triacrylate." (NTP)

Website (if applicable): ecb.jrc.ec.europa.eu/iuclid-datasheet/15625895.pdf

Functional Uses:

- Unknown function in Plastic articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- emulsion stabilising in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/17/18.
- film forming in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.
- hair conditioning in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.
- hair fixing in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/18/18.

VOC designation: VOC (Boiling point: 200 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

CANCER	IARC - Group 2B - Possibly carcinogenic to humans	
RESPIRATORY	AOEC - Asthmagens - Asthmagen (Rs) - sensitizer-induced	+ 1
SKIN SENSITIZE	MAK - Sensitizing Substance Sh - Danger of skin sensitization	+ 4
EYE IRRITATION	EU - GHS (H-Statements) - H319 - Causes serious eye irritation	+ 3
SKIN IRRITATION	EU - GHS (H-Statements) - H315 - Causes skin irritation	+ 3

ACUTE AQUATIC	GHS - New Zealand - 9.1D (crustacean) - Slightly harmful in the aquatic environment or are otherwise designed for biocidal action	+ 1
CHRON AQUATIC	GHS - New Zealand - 9.1B (algal) - Very ecotoxic in the aquatic environment	+ 4
MULTIPLE	Québec CSST - WHMIS 1988 - Class D2B - Toxic material causing other toxic effects	+ 1
RESTRICTED LIST	HBN - Priority Asthmagens - Priority Asthmagen to Avoid	
MAMMALIAN	GHS - New Zealand - 6.1E (dermal) - Acutely toxic	

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

EYE IRRITATION	GHS - Japan - Serious eye damage / eye irritation - Category 1 - *from ACRYLIC ACID*	+ 3
SKIN IRRITATION	EU - GHS (H-Statements) - H314 - Causes severe skin burns and eye damage - *from ACRYLIC ACID*	+ 5
ORGAN TOXICANT	GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 1 - *from ACRYLIC ACID*	+ 3
ACUTE AQUATIC	EU - GHS (H-Statements) - H400 - Very toxic to aquatic life - *from ACRYLIC ACID*	+ 7
CHRON AQUATIC	GHS - Japan - Hazardous to the aquatic environment (chronic) - Category 2 - *from ACRYLIC ACID*	+ 1
RESPIRATORY	AOEC - Asthmagens - Suspected asthmagen (R) - but does not meet AOEC criteria) - *from ACRYLIC ACID*	
MAMMALIAN	EU - GHS (H-Statements) - H302 - Harmful if swallowed - *from ACRYLIC ACID*	+ 20
SKIN SENSITIZE	GHS - New Zealand - 6.5B (contact) - Contact sensitisers (Cat. 1) - *from ACRYLIC ACID*	
TERRESTRIAL	GHS - New Zealand - 9.3B - Ecotoxic to terrestrial vertebrates - *from ACRYLIC ACID*	
FLAMMABLE	EU - GHS (H-Statements) - H226 - Flammable liquid and vapour - *from ACRYLIC ACID*	+ 5
RESTRICTED LIST	CA SCP - Candidate Chemicals - Candidate Chemical List - *from ACRYLIC ACID*	+ 3
CANCER	IARC - Group 3 - Agent is not classifiable as to its carcinogenicity to humans - *from ACRYLIC ACID*	
NEUROTOXICITY	Boyes - Neurotoxicants - Neurotoxic - *from ACRYLIC ACID*	
MULTIPLE	EC - CEPA DSL - Inherently Toxic to Humans (iTH) - *from ACRYLIC ACID*	+ 1

Compound Groups (1):

- ACRYLATES

Process Chemistry Research Status: Preliminary literature review drafted

Process Chemistry - Known or Potential Residuals:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[79-10-7] ACRYLIC ACID				Pollutant/ Contaminant	Integral	Unknown	

Process Chemistry - Other:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[77-99-6] 1,1,1-TRI(HYDROXYMETHYL)PROPANE				Reactant	Integral	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-P1 (Possible Benchmark 1)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.												Acute Aquatic Tox.				Chronic Aquatic Tox.								
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Organ
R	-	-	-	-	?	-	-	-	Y	R	-	-	-	-	?	?	?	-	-	-	G	NL	

Full Hazard List By Endpoint:

Carcinogenicity	IARC - Group 2B - Possibly carcinogenic to humans: Red
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	not listed
Dermal Toxicity	GHS - New Zealand - 6.1E (dermal) - Acutely toxic: Not rated
Inhalative Toxicity	not listed
Oral, Dermal, and/or Inhalative Toxicity	not listed
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	EU - GHS (H-Statements) - H315 - Causes skin irritation: Yellow EU - GHS (H-Statements) - H319 - Causes serious eye irritation: Yellow GHS - Australia - H315 - Causes skin irritation: Yellow GHS - Australia - H319 - Causes serious eye irritation: Yellow GHS - Japan - Serious eye damage / eye irritation - Category 2A: Yellow GHS - Japan - Skin corrosion / irritation - Category 2: Yellow GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2): Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated
Skin and Respiratory Sensitization	AOEC - Asthmagens - Asthmagen (Rs) - sensitizer-induced: Red EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction: Red GHS - Australia - H317 - May cause an allergic skin reaction: Red GHS - Japan - Skin sensitizer - Category 1: Red MAK - Sensitizing Substance Sh - Danger of skin sensitization: Red GHS - New Zealand - 6.5B (contact) - Contact sensitisers (Cat. 1): Not rated CHE - Toxicant Database - Asthma - allergen, sensitizer - strong evidence: Not rated
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	GHS - New Zealand - 9.1B (fish) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Invertibrates)	GHS - New Zealand - 9.1D (crustacean) - Slightly harmful in the aquatic environment or are otherwise designed for biocidal action: Not rated
Chronic Aquatic Toxicity (Algae)	GHS - New Zealand - 9.1B (algal) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	not listed
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may*

	have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters: Red Québec CSST - WHMIS 1988 - Class D2B - Toxic material causing other toxic effects: Red

- National Toxicology Program (NTP, 1991): Trimethylolpropane triacrylate

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Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2

- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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1. Dashboard
2. Chemicals and Materials
3. [25068-38-6] EPICHLOROHYDRIN-BISPHENOL A RESIN

[25068-38-6] EPICHLOROHYDRIN-BISPHENOL A RESIN

- General Information
- Hazards
- Compound Groups
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 25068-38-6

Synonyms: [103599-14-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [104364-97-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [104491-99-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [105521-57-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [108556-05-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [108728-21-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11097-80-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11098-13-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11098-40-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11100-23-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11108-41-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11120-31-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11121-19-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [11126-36-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [111517-59-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [114013-37-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [120146-74-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [120797-43-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [121273-37-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [123939-44-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [125147-87-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [128281-71-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [132893-73-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [138157-20-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [138361-18-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [144855-66-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [161937-12-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [167972-06-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [37184-50-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [37184-52-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [37208-29-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [37217-92-8] Bisphenol A epichlorohydrin polymer (primary

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[60202-19-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [60267-31-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [60382-89-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [60606-56-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [60800-54-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [60831-77-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [60894-16-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [61036-82-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [61287-42-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [61356-27-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [61711-38-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [61991-18-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [62169-28-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [62169-29-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [62601-75-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [62601-76-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [62887-23-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [63055-40-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [63172-55-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [63799-24-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [63993-57-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [63993-58-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [64086-14-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [64086-16-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [64176-52-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [64176-61-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [64176-66-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [64177-03-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [65931-38-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [65931-39-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [66995-96-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [67185-62-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [68821-97-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [69899-40-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [70179-83-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [70213-44-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [848887-61-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [9015-99-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [9083-76-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [139554-29-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [65233-49-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [917483-69-3] Bisphenol A epichlorohydrin

polymer (primary CASRN is 25068-38-6); [922728-11-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [934588-09-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [97568-16-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [102256-87-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1033821-54-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1034342-45-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [103599-13-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1068160-75-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1082736-74-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1096473-97-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1114797-08-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1189565-70-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1190235-62-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1190729-68-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1192045-32-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1195324-26-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1196030-95-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1199811-18-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1203835-26-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1206700-05-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1228639-00-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1245563-83-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1271727-39-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1300093-58-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1300102-07-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1305321-17-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [135976-90-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [61763-30-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [74504-20-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [913745-83-2] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [945610-97-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [950907-45-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [111367-08-9] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1198291-96-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1338071-08-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1365383-44-3] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1446691-72-0] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1450839-98-1] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1620807-39-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1641551-32-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1803435-34-8] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1807886-27-6] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1807886-28-7] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1815624-46-4] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [1815624-47-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); [2170564-75-5] Bisphenol A epichlorohydrin polymer (primary CASRN is 25068-38-6); (Chloromethyl)oxirane,4'-(1-methylethylidene)bisphenol copolymer; 2-(chloromethyl)oxirane; 4-[2-(4-hydroxyphenyl)propan-2-yl]phenol; 2,2-Bis(4-hydroxyphenyl)propane-epichlorohydrin copolymer; 2,2-Bis(4-hydroxyphenyl)propane-epichlorohydrin polymer; 2,2-Bis(hydroxyphenyl)propane-epichlorohydrin copolymer; 2,2-Bis(p-hydroxyphenyl)propane-epichlorohydrin condensate; 2,2-Bis(p-hydroxyphenyl)propane-epichlorohydrin copolymer; 2,2-Bis(p-hydroxyphenyl)propane-epichlorohydrin polymer; 2,2-Diphenylolpropane-epichlorohydrin polymer; 4, polymer with (chloromethyl)oxirane; 4,4'-Dihydroxydiphenylpropane-epichlorohydrin polymer; 4,4'-Isopropylidenediphenol-epichlorohydrin polymer; 4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-Chloro-2,3-epoxypropane; 4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane, reaction products with fatty acids, C18-unsatd., dimers; Bakelite PAHJ; Bakelite PKDA; Bakelite PKHH; Bis(p-hydroxyphenyl)dimethylmethane-epichlorohydrin copolymer; Bisphenol A - epichlorohydrin condensate; BISPHENOL A DIGLYCIDYL ETHER RESIN; bisphenol A epichlorohydrin; Bisphenol A epichlorohydrin polymer; Bisphenol A-epichlorohydrin condensate; Bisphenol A-epichlorohydrin copolymer; Bisphenol A-epichlorohydrin epoxy resin; Bisphenol A-epichlorohydrin polymer; Bisphenol A-epichlorohydrin resin; Bisphenol A, (chloromethyl)oxirane polymer; Bisphenol A, epichlorohydrin polymer; Bisphenol A, epichlorohydrin, dimer fatty acids polymer; Casting Resin F; CHLOROMETHYL)OXIRANE, 4,4'-(1-

METHYLETHYLIDENE)BISPHENOL COPOLYMER; ChS 1/33; ChS 15; ChS 15 (epoxy resin); D04FGX; DER 66; Dian-epichlorohydrin polymer; Diphenylolpropane-epichlorohydrin copolymer; Diphenylolpropane-epichlorohydrin polymer; E 40; E 44; E 44 (resin); ED 20; ED 22; ED 24; ED 5; ED 8; ED-8; ED-L; ED-NSP; Epichlorohydrin-2,2-bis(4-hydroxyphenyl)propane copolymer; Epichlorohydrin-2,2-bis(4-hydroxyphenyl)propane polymer; Epichlorohydrin-4,4'-dihydroxydiphenylpropane copolymer; Epichlorohydrin-4,4'-isopropylidenediphenol polymer; Epichlorohydrin-bisphenol A copolymer; Epichlorohydrin-bisphenol A epoxy resin; Epichlorohydrin-bisphenol A polymer; Epichlorohydrin-bisphenol A resin; Epichlorohydrin-diphenylolpropane polymer; Epidian 1; Epidian 12; Epidian 14; Epidian 2; Epidian 3; Epidian 4; Epidian 5; Epikote DX 57; Epikote OL 53L32; Epiterm; Epiterm 1; Epiterm W; Epiterm W 20; Epiterm W 30; Epiterm W 40; Epiterm W 5; Epomic A 3; Eponol 53B40; Eponol 53L32; Eponol 55; Eponol 55B40; Eponol 55L32; Epoxy 15; Fatty acids, C18-unsatd., dimers, polymers with bisphenol A and epichlorohydrin; Fatty acids, C18-unsaturated, dimers, polymer with (chloromethyl)oxirane and 4,4'-(1-methylethylidene)bis(phenol); Genepoxide; Grilonit G 16.05; Nucleolin binding domain/CLIP 71 conjugate (cancer), Esperance; Oxirane, (chloromethyl)-, polymer with fatty acids and 4,4'-(1-methylethylidene)bis(phenol); Oxirane, polymer with 4,4'-(1-methylethylidene)bis[phenol]; PAHJ; Phenol, 4,4'-(1-methylethylidene)bis-, polymer with 2-(chloromethyl)oxirane; Phenol,4'-(1-methylethylidene)bis-, polymer with (chloromethyl)oxirane; Phenol,4'-isopropylidenedi-, polymer with 1-chloro-2,3-epoxypropane; Phenoxy PKHH; PKHH; Technical bisphenol A diglycidyl ether

PubChem CID: 62790

Used in Product Categories: Flooring, **Fluid-Applied Flooring Systems**, **Tile Installation Products**, **High Performance Coatings**, High Performance Coating Components, Fluid-Applied Flooring Components (Wet), Grout, Tile Installation Components (Wet), Thin Sets & Mortars

Description:

epoxy resin

Website (if applicable): *Not provided*

Functional Uses:

- Unknown function in jb kwik weld 1 (arts and crafts), manufacturer: j-b weld, percentage: 30-40% (CPDat). Added on 06/29/18.
- Unknown function in loctite 5 min epoxy tubes 1 (auto products), percentage: 30-60% (CPDat). Added on 06/29/18.
- Unknown function in 3m bondo leather and vinyl repair kit part a 46091 1 (auto products), percentage: 40-60% (CPDat). Added on 06/29/18.
- Unknown function in bumper repair syringe kit 1 (auto products), percentage: 50-60% (CPDat). Added on 06/29/18.
- Unknown function in quiksteel epoxy putty 1 (auto products), percentage: 30-60% (CPDat). Added on 06/29/18.
- Unknown function in 3m bondo bumper repair kit, pn 280, 1 (auto products), percentage: 40-60% (CPDat). Added on 06/29/18.
- Unknown function in patch kit 1 (home maintenance), percentage: 30-60% (CPDat). Added on 06/29/18.
- Unknown function in jb weld original cold weld epoxy 1 (home maintenance), manufacturer: j-b weld, percentage: 30-40% (CPDat). Added on 06/29/18.
- Unknown function in Machinery, mechanical appliances, electrical/electronic articles covered by the Waste Electrical and Electronic Equipment (WEEE) directive (e.g. refrigerators, washing machines, vacuum cleaners, computers, telephones, drills, saws, smoke detectors, ...) (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in Metal articles (ECHA Registered Substances Article Categories). Added on 07/09/18.

- Unknown function in Paper articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in Plastic articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in Stone, plaster, cement, glass and ceramic articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in Vehicles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- Unknown function in Wood articles (ECHA Registered Substances Article Categories). Added on 07/09/18.
- film forming in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/17/18.

VOC designation: Non-volatile (Boiling point: 401 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

PERSISTENT	EC - CEPA DSL - Persistent	
ACUTE AQUATIC	GHS - Japan - Hazardous to the aquatic environment (acute) - Category 1	
EYE IRRITATION	EU - GHS (H-Statements) - H319 - Causes serious eye irritation	+ 3
SKIN IRRITATION	EU - GHS (H-Statements) - H315 - Causes skin irritation	+ 3
SKIN SENSITIZE	EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction	+ 3
ORGAN TOXICANT	GHS - New Zealand - 6.9B (dermal) - Harmful to human target organs or systems (Cat. 2)	
CHRON AQUATIC	EU - GHS (H-Statements) - H411 - Toxic to aquatic life with long lasting effects	+ 5
MULTIPLE	Québec CSST - WHMIS 1988 - Class D2B - Toxic material causing other toxic effects	+ 3
RESTRICTED LIST	EU - PACT-RMOA Substances - Substances selected for RMOA or hazard assessment	+ 2

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Compound Groups (2):

- Chlorinated Organic Compounds
- HALOGENATED ORGANIC COMPOUNDS *

Process Chemistry Research Status: Preliminary literature review drafted

Process Chemistry - Other:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[80-05-7] BISPHENOL A (BPA)				Monomer	Integral	Unknown	
[106-89-8] EPICHLOROHYDRIN				Monomer	Integral	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-P1 (Possible Benchmark 1)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol,

there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.											Acute Aquatic Tox.				Chronic Aquatic Tox.								
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Or
-	-	-	-	-	?	-	-	-	Y	R	-	-	-	R	?	?	?	R	-	R/Y	-	G	R

Full Hazard List By Endpoint:

Carcinogenicity	not listed
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed

Oral Toxicity	not listed
Dermal Toxicity	GHS - New Zealand - 6.9B (dermal) - Harmful to human target organs or systems (Cat. 2): Not rated
Inhalative Toxicity	not listed
Oral, Dermal, and/or Inhalative Toxicity	not listed
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	EU - GHS (H-Statements) - H315 - Causes skin irritation: Yellow EU - GHS (H-Statements) - H319 - Causes serious eye irritation: Yellow GHS - Australia - H315 - Causes skin irritation: Yellow GHS - Australia - H319 - Causes serious eye irritation: Yellow GHS - Japan - Serious eye damage / eye irritation - Category 2B: Yellow GHS - Japan - Skin corrosion / irritation - Category 2: Yellow GHS - New Zealand - 6.3B - Mildly irritating to the skin: Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated
Skin and Respiratory Sensitization	EU - GHS (H-Statements) - H317 - May cause an allergic skin reaction: Red GHS - Australia - H317 - May cause an allergic skin reaction: Red GHS - Japan - Skin sensitizer - Category 1: Red GHS - New Zealand - 6.5B (contact) - Contact sensitisers (Cat. 1): Not rated
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	GHS - Japan - Hazardous to the aquatic environment (acute) - Category 1: Red
Chronic Aquatic Toxicity (Fish)	GHS - New Zealand - 9.1B (fish) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Invertibrates)	GHS - New Zealand - 9.1B (crustacean) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Algae)	GHS - New Zealand - 9.1B (algal) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	EU - GHS (H-Statements) - H411 - Toxic to aquatic life with long lasting effects: Red GHS - Australia - H411 - Toxic to aquatic life with long lasting effects: Red GHS - Japan - Hazardous to the aquatic environment (chronic) - Category 1: Not rated
Terrestrial	not listed
Persistence	EC - CEPA DSL - Persistent: Red or Yellow
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	HALOGENATED ORGANIC COMPOUNDS
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic in the Environment (iTE): Red

EC - CEPA DSL - Inherently Toxic to Humans (iTH): Red
German FEA - Substances Hazardous to Waters - Class 2 - Hazard to Waters: Red
Québec CSST - WHMIS 1988 - Class D2B - Toxic material causing other toxic effects: Red

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Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

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Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

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GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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A new version of Pharos is scheduled for release on Sept 6. Click here f details.

[25085-99-8] BISPHENOL A DIGLYCIDYL ETHER (BADGE)

- General Information
- Hazards
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 25085-99-8

Synonyms: [100629-69-4] Araldite B (primary CASRN is 25085-99-8); [104137-75-9] Araldite B (primary CASRN is 25085-99-8); [107461-90-5] Araldite B (primary CASRN is 25085-99-8); [110737-21-8] Araldite B (primary CASRN is 25085-99-8); [112603-15-3] Araldite B (primary CASRN is 25085-99-8); [115566-93-3] Araldite B (primary CASRN is 25085-99-8); [116469-81-9] Araldite B (primary CASRN is 25085-99-8); [118815-21-7] Araldite B (primary CASRN is 25085-99-8); [122157-02-2] Araldite B (primary CASRN is 25085-99-8); [122538-86-7] Araldite B (primary CASRN is 25085-99-8); [123584-39-4] Araldite B (primary CASRN is 25085-99-8); [125005-11-0] Araldite B (primary CASRN is 25085-99-8); [131151-70-7] Araldite B (primary CASRN is 25085-99-8); [132325-44-1] Araldite B (primary CASRN is 25085-99-8); [135668-53-0] Araldite B (primary CASRN is 25085-99-8); [137086-94-3] Araldite B (primary CASRN is 25085-99-8); [137545-84-7] Araldite B (primary CASRN is 25085-99-8); [137802-59-6] Araldite B (primary CASRN is 25085-99-8); [141093-30-3] Araldite B (primary CASRN is 25085-99-8); [145849-86-1] Araldite B (primary CASRN is 25085-99-8); [148092-60-8] Araldite B (primary CASRN is 25085-99-8); [150872-30-3] Araldite B (primary CASRN is 25085-99-8); [152059-80-8] Araldite B (primary CASRN is 25085-99-8); [161107-52-4] Araldite B (primary CASRN is 25085-99-8); [168759-37-3] Araldite B (primary CASRN is 25085-99-8); [171264-64-5] Araldite B (primary CASRN is 25085-99-8); [179530-03-1] Araldite B (primary CASRN is 25085-99-8); [181493-44-7] Araldite B (primary CASRN is 25085-99-8); [185702-25-4] Araldite B (primary CASRN is 25085-99-8); [26142-22-3] Araldite B (primary CASRN is 25085-99-8); [37217-54-2] Araldite B (primary CASRN is 25085-99-8); [37294-19-2] Araldite B (primary CASRN is 25085-99-8); [39378-82-0] Araldite B (primary CASRN is 25085-99-8); [39475-40-6] Araldite B (primary CASRN is 25085-99-8); [41178-38-5] Araldite B (primary CASRN is 25085-99-8); [51280-98-9] Araldite B (primary CASRN is 25085-99-8); [51374-21-1] Araldite B (primary CASRN is 25085-99-8); [51394-05-9] Araldite B (primary CASRN is 25085-99-8); [51910-45-3] Araldite B (primary CASRN is 25085-99-8); [52229-16-0] Araldite B (primary CASRN is 25085-99-8); [52350-20-6] Araldite B (primary CASRN is 25085-99-8); [52737-84-5] Araldite B (primary CASRN is 25085-99-8); [53637-50-6] Araldite B (primary CASRN is 25085-99-8); [55963-67-2] Araldite B (primary CASRN is 25085-99-8); [56690-61-0] Araldite B (primary CASRN is 25085-99-8); [56730-71-3] Araldite B (primary CASRN is 25085-99-8); [56832-64-5] Araldite B (primary CASRN is 25085-99-8); [58128-07-7] Araldite B (primary CASRN is 25085-99-8); [58615-59-1] Araldite B (primary CASRN is 25085-99-8); [58799-17-0] Araldite B (primary CASRN is 25085-99-8); [59979-12-3] Araldite B (primary CASRN is 25085-99-8); [59979-27-0] Araldite B (primary CASRN is 25085-99-8); [60202-18-8] Araldite B (primary CASRN is 25085-99-8); [60371-12-2] Araldite B (primary CASRN is 25085-99-8); [60825-75-4] Araldite B (primary CASRN is 25085-99-8); [61287-89-6] Araldite B (primary CASRN is 25085-99-8); [62362-68-9] Araldite B (primary CASRN is 25085-99-8); [62494-59-1] Araldite B (primary CASRN is 25085-99-8); [64083-68-7] Araldite B (primary CASRN is 25085-99-8); [64083-69-8] Araldite B (primary CASRN is 25085-99-8); [65098-97-7] Araldite B (primary

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Used in Product Categories: **Resilient Flooring**, **Adhesives**, Flooring, Resilient Flooring Adhesives, Wood Flooring Adhesives, Casework Adhesives, **Fluid-Applied Flooring Systems**, **Tile Installation Products**, **High Performance Coatings**, High Performance Coating Components, Resilient Flooring Adhesive Components, Wood Flooring Adhesive Components, **Wood**

Flooring, Engineered Wood Flooring, Casework Adhesive Components, Fluid-Applied Flooring Components (Wet), Grout, Tile Installation Components (Wet), Thin Sets & Mortars, Tile Installation Components (Dry)

Description:

An epoxy polymer. The primary CAS number used for BADGE is 1675-54-3.

Website (if applicable): householdproducts.nlm.nih.gov/cgi-bin/household/brands?tbl=chem&id=1948

Functional Uses:

- Unknown function in quiksteel epoxy putty 1 (auto products), percentage: 8-16% (CPDat). Added on 06/29/18.
- Unknown function in 4 minute multi metal epoxy 8413 1 (home maintenance), manufacturer: permatex inc, percentage: 40-50% (CPDat). Added on 06/29/18.
- pre-polymer resin in Common Product (Epoxy Flooring Adhesive), percentage: 11.56%. Added on 08/08/19.

VOC designation: Non-volatile

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

PERSISTENT	EC - CEPA DSL - Persistent	
ENDOCRINE	EU - Priority Endocrine Disruptors - Category 2 - In vitro evidence of biological activity related to Endocrine Disruption	
MAMMALIAN	GHS - New Zealand - 6.1D (dermal) - Acutely toxic	± 2
CHRON AQUATIC	GHS - New Zealand - 9.1B (algal) - Very ecotoxic in the aquatic environment	± 2
RESTRICTED LIST	HBN - Priority Asthmagens - Priority Asthmagen to Avoid	± 2
CANCER	DK-EPA - Danish Advisory List - Carc. 2; H351 - Suspected of causing cancer (modeled)	
GENE MUTATION	DK-EPA - Danish Advisory List - Muta. 2; H341 - Suspected of causing genetic defects (modeled)	
SKIN IRRITATION	DK-EPA - Danish Advisory List - Skin Irrit. 2 - Causes skin irritation (modeled)	
SKIN SENSITIZE	DK-EPA - Danish Advisory List - Skin Sens. 1 - May cause an allergic skin reaction (modeled)	
ACUTE AQUATIC	DK-EPA - Danish Advisory List - Aquatic Acute1 - Very toxic to aquatic life (modeled)	± 1
MULTIPLE	EC - CEPA DSL - Inherently Toxic to Humans (iTH)	

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

PERSISTENT	EC - CEPA DSL - Persistent - *from Sodium hydroxide*	
EYE IRRITATION	GHS - Japan - Serious eye damage / eye irritation - Category 1 - *from Sodium hydroxide*	± 3
SKIN IRRITATION	EU - GHS (H-Statements) - H314 - Causes severe skin burns and eye damage - *from Sodium hydroxide*	± 7

ORGAN TOXICANT	GHS - Japan - Specific target organs/systemic toxicity following single exposure - Category 1 - *from Sodium hydroxide*	+ 1
MAMMALIAN	GHS - Korea - Acute toxicity (dermal) - Category 4 [H312 - Harmful in contact with skin] - *from Sodium hydroxide*	+ 5
ACUTE AQUATIC	GHS - Japan - Hazardous to the aquatic environment (acute) - Category 3 - *from Sodium hydroxide*	+ 2
TERRESTRIAL	GHS - New Zealand - 9.3C - Harmful to terrestrial vertebrates - *from Sodium hydroxide*	
REACTIVE	GHS - Korea - H290 - May be corrosive to metals - *from Sodium hydroxide*	+ 2
RESTRICTED LIST	CA SCP - Candidate Chemicals - Candidate Chemical List - *from Sodium hydroxide*	+ 1
NEUROTOXICITY	Boyes - Neurotoxicants - Neurotoxic - *from Sodium hydroxide*	
MULTIPLE	EC - CEPA DSL - Inherently Toxic to Humans (iTH) - *from Sodium hydroxide*	+ 1
POSITIVE LIST	US EPA - DfE SCIL - Green Circle - Verified Low Concern - *from Sodium hydroxide*	

Process Chemistry Research Status: Preliminary literature review drafted

Process Chemistry - Known or Potential Residuals:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[1310-73-2] Sodium hydroxide				Catalyst (homogeneous/ unstructured/ unknown)	Integral	Unknown	

Process Chemistry - Other:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[80-05-7] BISPHENOL A (BPA)				Reactant	Integral	Unknown	
[106-89-8] EPICHLOROHYDRIN				Reactant	Integral	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-P1 (Possible Benchmark 1)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

			Acute and Chronic Tox.								Acute Aquatic Tox.				Chronic Aquatic Tox.									
C	**M**	**R+D**	**E**	**O**	**D**	**I**	**O/D/I**	**N**	**IrS+IrE**	**SnS+SnR**	**Fish**	**Inv.**	**Alg.**	**Any**	**Fish**	**Inv.**	**Alg.**	**Any**	**T**	**P**	**B**	**Climate**	**Organohalogen**	**Tox Met**
-	-	-	R/Y	?	?	?	-	-	-	-	-	-	-	-	?	?	?	-	-	R/Y	-	G	NL	NL

Full Hazard List By Endpoint:

Carcinogenicity	not listed

Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	EU - Priority Endocrine Disruptors - Category 2 - In vitro evidence of biological activity related to Endocrine Disruption: Red or Yellow
Oral Toxicity	GHS - New Zealand - 6.1D (oral) - Acutely toxic: Not rated
Dermal Toxicity	GHS - New Zealand - 6.1D (dermal) - Acutely toxic: Not rated
Inhalative Toxicity	GHS - New Zealand - 6.1D (inhalation) - Acutely toxic: Not rated
Oral, Dermal, and/or Inhalative Toxicity	not listed
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	not listed
Skin and Respiratory Sensitization	not listed
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	GHS - New Zealand - 9.1B (fish) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Invertibrates)	GHS - New Zealand - 9.1B (crustacean) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Algae)	GHS - New Zealand - 9.1B (algal) - Very ecotoxic in the aquatic environment: Not rated
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	EC - CEPA DSL - Persistent: Red or Yellow
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic to Humans (iTH): Red

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

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For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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A new version of Pharos is scheduled for release on Sept 6. Click here f details.

[55818-57-0] BISPHENOL A-EPICHLOROHYDRIN ACRYLATE

CAS RN: 55818-57-0

Synonyms: [100358-45-0] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [112326-85-9] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [148165-73-5] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [187619-12-1] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [64176-47-2] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [65742-46-3] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [67383-21-5] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [68551-02-0] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [69771-15-9] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [72348-14-2] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [74315-70-1] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [90598-46-2] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [193226-76-5] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [395069-06-4] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [934588-10-0] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [1190729-69-1] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [1228639-01-7] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [1215270-98-6] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); [2120399-29-1] Bisphenol A-epichlorohydrin acrylate (primary CASRN is 55818-57-0); 2-(chloromethyl)oxirane; 4-[2-(4-hydroxyphenyl)propan-2-yl]phenol; prop-2-enoic acid; 2-Propenoic acid, polymer with (chloromethyl)oxirane and 4,4'-(1-methylethylidene)bis(phenol); 2-Propenoic acid, polymer with 2-(chloromethyl) oxirane and 4,4'-(1-methylethylidene)bis(phenol); 4,4'-(1-Methylethylidene)bisphenol, chloromethyloxirane polymer, acrylic acid adduct; 4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-Chloro-2,3-epoxypropane, Esters with Acrylic acid; Acrylic acid bisphenol A epichlorohydrin polymer; acrylic acid; 2-(chloromethyl)oxirane; 4-[1-(4-hydroxyphenyl)-1-methyl-ethyl] phenol; AED 30; AED 60; Bisphenol A - epichlorohydrin acrylate; Bisphenol A - epichlorohydrin copolymer acrylate; Bisphenol A - epichlorohydrin polymer acrylate; BISPHENOL A DIGLYCIDYL DIACRYLATE; Bisphenol A-epichlorohydrin acrylate; Bisphenol A, (chloromethyl)oxirane, acrylic acid polymer; Bisphenol A, epichlorohydrin, acrylic acid polymer; E 44, acrylate; EAS 20A; EAS 8A; ED 20 acrylate; Epoxy Resin; NEO 20A; Oxirane, (chloromethyl)-, polymer with 4,4'-(1-methylethylidene)bis (phenol), 2-propenoate; Phenol, 4,4'-(1-methylethylidene)bis-, polymer with (chloromethyl)oxirane, 2-propenoate; Phenol, 4,4'-(1-methylethylidene)bis-, polymer with 2-(chloromethyl)oxirane, 2-propenoate

PubChem CID: 169944

Used in Product Categories: **Resilient Flooring**, Flooring, Resilient Flooring Components, **Wood Flooring**, Floor Sealants and Coatings, Engineered Wood Flooring, Solid Unfinished Wood Flooring, Solid PreFinished Wood Flooring, **Flooring Finishes**, **Composite Wood**, Plywood, UV-Cured Finishes

Description:

"Epoxy resins are used in a range of applications including the electrical and electronic industry, building and construction industry, powder coatings, and can and coil coatings.... The residual monomer content of bisphenol-A in the epoxy resin as produced is a maximum of 1,000 ppm. The residual bisphenol-A will be further reacted when the product is used (i.e. when the epoxy resin is cured)." (EU Risk Assessment, 2003)

Website (if applicable): www.ourstolenfuture.org/newscience/oncompounds/bisphenola/bpauses.htm

Functional Uses:

- film forming in cosmetics (CosIng - European Commission's Cosmetic Ingredient Database). Added on 03/17/18.

VOC designation: Non-volatile (Boiling point: 401 degrees Celsius)

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

PERSISTENT	EC - CEPA DSL - Persistent	
RESTRICTED LIST	Living Future - Living Building Red List 3.0 - Red List substances to avoid in Living Building Challenge V3 projects	+ 1
EYE IRRITATION	EU - Manufacturer REACH hazard submissions - H319 - Causes serious eye irritation (unverified)	
SKIN IRRITATION	EU - Manufacturer REACH hazard submissions - H315 - Causes skin irritation (unverified)	
SKIN SENSITIZE	EU - Manufacturer REACH hazard submissions - H317 - May cause an allergic skin reaction (unverified)	
ORGAN TOXICANT	EU - Manufacturer REACH hazard submissions - H335 - May cause respiratory irritation (unverified)	
CHRON AQUATIC	EU - Manufacturer REACH hazard submissions - H413 - May cause long lasting harmful effects to aquatic life (unverified)	
MULTIPLE	EC - CEPA DSL - Inherently Toxic in the Environment (iTE)	+ 1

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

CANCER	CA EPA - Prop 65 - Carcinogen - *from EPICHLOROHYDRIN*	+ 14
DEVELOPMENTAL	US NIH - Reproductive & Developmental Monographs - Clear Evidence of Adverse Effects - Developmental Toxicity - *from BISPHENOL A (BPA)*	+ 4
REPRODUCTIVE	CA EPA - Prop 65 - Reproductive Toxicity - Female - *from BISPHENOL A (BPA)*	+ 11
ENDOCRINE	EU - SVHC Authorisation List - Equivalent Concern - Candidate List: endocrine disrupting properties cause probable serious effects to the environment or human health - *from BISPHENOL A (BPA)*	+ 4
GENE MUTATION	GHS - Australia - H340 - May cause genetic defects - *from EPICHLOROHYDRIN*	+ 4
PERSISTENT	EC - CEPA DSL - Persistent - *from HYDROGEN CHLORIDE (HCl)*	+ 1

RESPIRATORY	AOEC - Asthmagens - Asthmagen (Rr) - irritant-induced - *from HYDROGEN CHLORIDE (HCl)*	+ 1
MAMMALIAN	EU - GHS (H-Statements) - H311 - Toxic in contact with skin - *from EPICHLOROHYDRIN*	+ 28
EYE IRRITATION	EU - GHS (H-Statements) - H318 - Causes serious eye damage - *from BISPHENOL A (BPA)*	+ 6
SKIN IRRITATION	EU - GHS (H-Statements) - H314 - Causes severe skin burns and eye damage - *from HYDROGEN CHLORIDE (HCl)*	+ 7
SKIN SENSITIZE	MAK - Sensitizing Substance Sh - Danger of skin sensitization - *from EPICHLOROHYDRIN*	+ 7
ACUTE AQUATIC	GHS - Japan - Hazardous to the aquatic environment (acute) - Category 1 - *from HYDROGEN CHLORIDE (HCl)*	+ 7
CHRON AQUATIC	GHS - Japan - Hazardous to the aquatic environment (chronic) - Category 2 - *from BISPHENOL A (BPA)*	+ 3
TERRESTRIAL	GHS - New Zealand - 9.3A - Very ecotoxic to terrestrial vertebrates - *from EPICHLOROHYDRIN*	+ 1
ORGAN TOXICANT	EU - GHS (H-Statements) - H335 - May cause respiratory irritation - *from BISPHENOL A (BPA)*	+ 7
FLAMMABLE	EU - GHS (H-Statements) - H226 - Flammable liquid and vapour - *from EPICHLOROHYDRIN*	+ 6
REACTIVE	GHS - New Zealand - 8.1A - Corrosive to metals - *from HYDROGEN CHLORIDE (HCl)*	+ 1
RESTRICTED LIST	US EPA - DfE SCIL - Yellow Triangle - best available in class but some hazard profile issues - *from HYDROGEN CHLORIDE (HCl)*	+ 24
MULTIPLE	Québec CSST - WHMIS 1988 - Class D2A - Very toxic material causing other toxic effects - *from BISPHENOL A (BPA)*	+ 9
NEUROTOXICITY	Boyes - Neurotoxicants - Neurotoxic - *from EPICHLOROHYDRIN*	
BIOACCUMULATIVE	US EPA - PPT Chemical Action Plans - Low bioaccumulation potential - TSCA Criteria met - *from BISPHENOL A (BPA)*	

Compound Groups (2):

- Chlorinated Organic Compounds
- HALOGENATED ORGANIC COMPOUNDS *

Process Chemistry Research Status: Preliminary literature review drafted

Process Chemistry - Known or Potential Residuals:

Material	Hazard			Type	Frequency	Percentage	Notes
	Substance	Residual	Manufacturing				
[80-05-7] BISPHENOL A (BPA)				Monomer	Integral (known)	Unknown	
[106-89-8] EPICHLOROHYDRIN				Monomer	Integral (known)	Unknown	

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-UNK (Benchmark Unknown)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

×

How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level

?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.											Acute Aquatic Tox.				Chronic Aquatic Tox.								
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Organohalogen	Toxic Metal
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R/Y	-	G	R	NL

Full Hazard List By Endpoint:

Carcinogenicity	not listed
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	not listed
Dermal Toxicity	not listed
Inhalative Toxicity	not listed
Oral, Dermal, and/or Inhalative Toxicity	not listed
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	not listed
Skin and Respiratory Sensitization	not listed
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	not listed
Chronic Aquatic Toxicity (Invertibrates)	not listed
Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	EC - CEPA DSL - Persistent: Red or Yellow
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	HALOGENATED ORGANIC COMPOUNDS
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic in the Environment (iTE): Red German FEA - Substances Hazardous to Waters - Class 1 - Low Hazard to Waters: Red

- Agilent Technologies: Trace Level Analysis of Epichlorohydrin
- EU Risk Assessment - Bisphenol A - 2003

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

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For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

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GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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- Building Products
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1. Dashboard
2. Chemicals and Materials
3. [68928-76-7] Stannane, dimethylbis[(1-oxoneodecyl)oxy]-

[68928-76-7] Stannane, dimethylbis[(1-oxoneodecyl)oxy]-

- General Information
- Hazards
- Compound Groups
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 68928-76-7

Synonyms: Bis[(2-ethyl-2,5-dimethylhexanoyl)oxy](dimethyl)stannane; Neodecanoic acid, 1,1'-(dimethylstannylene) ester; Stannane, dimethylbis((1-oxoneodecyl)oxy)-

Description: *Not provided*

Website (if applicable): *Not provided*

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

RESTRICTED LIST	CPA - Chemical Footprint - CoHC List (non SVHC)	+ 6
DEVELOPMENTAL	EU - Manufacturer REACH hazard submissions - H361 - Suspected of damaging fertility or the unborn child (unverified)	
MAMMALIAN	EU - Manufacturer REACH hazard submissions - H302 - Harmful if swallowed (unverified)	
ORGAN TOXICANT	EU - Manufacturer REACH hazard submissions - H372 - Causes damage to organs through prolonged or repeated exposure (unverified)	+ 1
ACUTE AQUATIC	EU - Manufacturer REACH hazard submissions - H400 - Very toxic to aquatic life	

	(unverified)	
CHRON AQUATIC	EU - Manufacturer REACH hazard submissions - H410 - Very toxic to aquatic life with long lasting effects (unverified)	+ 2
MULTIPLE	EC - CEPA DSL - Inherently Toxic in the Environment (iTE)	

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Compound Groups (3):

- Dimethyltin derivatives
- ORGANOTIN COMPOUNDS *
- Tin Compounds *

Process Chemistry Research Status: No life cycle research started

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-P1 (Possible Benchmark 1)

Cradle to Cradle Certified™ List Hazards

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The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

Acute and Chronic Tox.												Acute Aquatic Tox.				Chronic Aquatic Tox.								
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Orga
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	NL	

Full Hazard List By Endpoint:

Carcinogenicity	not listed
Mutagenicity	not listed

Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	not listed
Dermal Toxicity	not listed
Inhalative Toxicity	not listed
Oral, Dermal, and/or Inhalative Toxicity	not listed
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	not listed
Skin and Respiratory Sensitization	not listed
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	not listed
Chronic Aquatic Toxicity (Invertibrates)	not listed
Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	not listed
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*
Toxic Metal	ORGANOTIN COMPOUNDS
Other (Human Health)	not listed
Multiple Endpoints	EC - CEPA DSL - Inherently Toxic in the Environment (iTE): Red

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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Pharos FROM HBN

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- Chemicals and Materials
- Certifications
- CompAIR
- Dashboard
- Logout

A new version of Pharos is scheduled for release on Sept 6. Click here f details.

1. Dashboard
2. Chemicals and Materials
3. [94108-97-1] Di(trimethylolpropane) tetraacrylate

[94108-97-1] Di(trimethylolpropane) tetraacrylate

- General Information
- Hazards
- Process Chemistry Research
- GreenScreen
- C2C

CAS RN: 94108-97-1

Synonyms: [124449-58-7] Ditrimethylolpropane tetraacrylate (primary CASRN is 94108-97-1); [171903-28-9] Ditrimethylolpropane tetraacrylate (primary CASRN is 94108-97-1); [173939-98-5] Ditrimethylolpropane tetraacrylate (primary CASRN is 94108-97-1); [1220696-46-7] Ditrimethylolpropane tetraacrylate (primary CASRN is 94108-97-1); [1235721-89-7] Ditrimethylolpropane tetraacrylate (primary CASRN is 94108-97-1); [2097923-15-2] Ditrimethylolpropane tetraacrylate (primary CASRN is 94108-97-1); [2-[2,2-bis(prop-2-enoyloxymethyl)butoxymethyl]-2-(prop-2-enoyloxymethyl)butyl] prop-2-enoate; 2-((2,2-Bis(((1-oxoallyl)oxy)methyl)butoxy)methyl)-2-ethyl-1,3-propanediyl diacrylate; 2-Propenoic acid, 1,1'-(2-((2,2-bis(((1-oxo-2-propen-1-yl)oxy)methyl)butoxy)methyl)-2-ethyl-1,3-propanediyl) ester; 2-Propenoic acid, 1,1'-[2-[[2,2-bis[[(1-oxo-2-propen-1-yl)oxy]methyl]butoxy]methyl]-2-ethyl-1,3-propanediyl] ester; 2-Propenoic acid, 2-((2,2-bis(((1-oxo-2-propenyl)oxy)methyl) butoxy)methyl)-2-ethyl-1,3-propanediyl ester; di- TMPTA (Di -Trimethylol propane tetraacrylate); Ditrimethylolpropane tetraacrylate

PubChem CID: 175585

Description: *Not provided*

Website (if applicable): *Not provided*

- View products containing this material

My Project Lists

No project lists available. Lists can be added to existing projects on your account. Visit your dashboard for more information.

Direct Hazards:

EYE IRRITATION	GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A)	+ 1
SKIN IRRITATION		

	GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2)	+ 1
ORGAN TOXICANT	EU - Manufacturer REACH hazard submissions - H335 - May cause respiratory irritation (unverified)	
CHRON AQUATIC	EU - Manufacturer REACH hazard submissions - H411 - Toxic to aquatic life with long lasting effects (unverified)	
MAMMALIAN	GHS - New Zealand - 6.1E (inhalation) - Acutely toxic	

Potential Residual Hazards:

See Process Chemistry Research tab for details on residuals and other substances used in manufacture.

None identified

Process Chemistry Research Status: No life cycle research started

GreenScreen for Safer Chemicals Full Assessment: *None available*

Highest concern GreenScreen score : LT-UNK (Benchmark Unknown)

Cradle to Cradle Certified™ List Hazards

What are C2C hazards and what do these colors mean?

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What are C2C hazards and what do these colors mean?

What are the C2C Hazards? The Cradle to Cradle Certified Product Standard establishes a Material Health Assessment Methodology which assigns hazard ratings to 24 individual human and environmental health endpoints. Roll your cursor over the abbreviations (C, M, R+D, etc) in the table to see the full name of each endpoint (Carcinogenicity, Mutagenicity, Reproductive Toxicity, etc). Organohalogen and Toxic Metal are classes of chemicals generally associated with significant human and environmental health issues and are specially treated in the C2C Standard.

The hazard rating is a Green-Yellow-Red-Grey color scheme based upon available toxicity and fate information:

- Green: no hazard identified for the endpoint
- Red: hazard identified for the endpoint
- Yellow: borderline
- Grey: no data available for the endpoint

This tab shows the preliminary hazard ratings based upon hazard lists tracked in the Pharos Chemical & Material Library. During full assessment for certification purposes, Grey hazards must be filled by an accredited assessor and other list-based hazards may be overridden.

Why are these rating colors sometimes different from the GreenScreen or Pharos rating colors? The C2C hazard rating colors are similar to those used in the GreenScreen system and in Pharos, with some distinctions. Pharos has two additional rating colors - orange and purple - not used in the C2C or GreenScreen systems. Pharos orange, red and purple ratings generally encompass the C2C & GreenScreen red ranges. There are some distinctions between the GreenScreen and C2C thresholds that result in different color assignments that are under consideration for harmonization. See the Material Health Evaluation Programs Harmonization Opportunities Report for details. For substances that have been fully assessed under the GreenScreen protocol, there may be different colors due to the application of data from studies that provide information beyond that in the hazard lists.

If interested in assessing the chemicals in a product, please also review the link below describing "How to Use These Scores in a C2C Assessment".

How to Use These Scores in a C2C Assessment

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How to Use These Scores in a C2C Assessment

The top table displays preliminary hazard ratings for individual endpoints based on the hazard lists a given chemical appears on. During the assessment, an accredited Cradle to Cradle Certified Material Health Assessor may override these list-based hazard ratings based on information from other sources. Additionally, a red hazard rating in any one endpoint does not automatically mean that a substance will be x-assessed and targeted for phase-out, as exposure relevant to the endpoint may be deemed non-plausible for the substance depending on the material and product context in which it is being assessed.

The bottom table (Full Hazard List by Endpoint) includes all warnings associated with the substance from each of the authoritative hazard lists used by C2C, as well as additional lists in the Pharos Chemical and Material Library. C2C lists are labeled with their C2C hazard rating (Red, Yellow, or Green), while non-C2C lists are labeled as "not rated".

The ratings for the hazard lists used in this tool are based on Table 9 in the Material Assessment Methodology, Cradle to Cradle Certified Version 3.0 with a few minor adjustments/additions to allow for direct mapping from GreenScreen list translator results for a subset of the covered lists. The v3.0 Material Assessment Methdology document can be found on the C2C Resources page at http://www.c2ccertified.org/resources/collection-page/cradle-to-cradle-certified-resources.

Key
R: Red hazard level
Y: Yellow hazard level
G: Green hazard level
?: On a hazard list that has not been rated by C2C
-: Not listed on any C2C or Pharos hazard lists

										Acute and Chronic Tox.				Acute Aquatic Tox.				Chronic Aquatic Tox.										
C	M	R+D	E	O	D	I	O/D/I	N	IrS+IrE	SnS+SnR	Fish	Inv.	Alg.	Any	Fish	Inv.	Alg.	Any	T	P	B	Climate	Organohalogen	Toxic Metal	Ot
-	-	-	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	-	-	G	NL	NL	-

Full Hazard List By Endpoint:

Carcinogenicity	not listed
Mutagenicity	not listed
Reproductive Toxicity (Repro + Dev)	not listed
Endocrine Disruption	not listed
Oral Toxicity	not listed
Dermal Toxicity	not listed
Inhalative Toxicity	GHS - New Zealand - 6.1E (inhalation) - Acutely toxic: Not rated
Oral, Dermal, and/or Inhalative Toxicity	not listed
Neurotoxicity	not listed
Skin, Eye, and Respiratory Corrosion/Irritation	GHS - New Zealand - 6.3A - Irritating to the skin (Cat. 2): Not rated GHS - New Zealand - 6.4A - Irritating to the eye (Cat. 2A): Not rated
Skin and Respiratory Sensitization	not listed
Acute Aquatic Toxicity (Fish)	not listed
Acute Aquatic Toxicity (Invertibrates)	not listed
Acute Aquatic Toxicity (Algae)	not listed
Acute Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Chronic Aquatic Toxicity (Fish)	not listed
Chronic Aquatic Toxicity (Invertibrates)	not listed

Chronic Aquatic Toxicity (Algae)	not listed
Chronic Aquatic Toxicity (Fish, Invertibrates, and/or Algae)	not listed
Terrestrial	not listed
Persistence	not listed
Bioaccumulation	not listed
Climatic Relevance	not listed
Organohalogen	not listed - *This chemical is not on the Pharos list of organohalogens, but we may have missed a few. Please double-check the chemical structure to confirm there are no carbon-halogen bonds.*
Toxic Metal	not listed - *This chemical is not on the Pharos list of toxic metals, but we may have missed a few. Please double-check the chemical structure to confirm there are no toxic metals.*
Other (Human Health)	not listed
Multiple Endpoints	not listed

×

Substance Hazard

This color reflects the highest hazard associated directly with this substance by an authoritative hazard list.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the authoritative hazard list that is the source of this hazard color, see the "Hazard" tab on the chemical / material's page.

×

Residual Hazard

This color reflects the highest hazard associated with residual chemicals that our research indicates may be present with the chemical. These residuals consist of all process chemicals in the following categories:

- Monomers
- Catalysts
- Non-reactive Additives
- Pollutants and Contaminants
- Other known residuals

Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

Manufacturing Hazard

This color reflects the highest hazard associated with chemicals that our research categorizes as “frequent” or “integral” to the production of a chemical. The manufacturing score is included to surface potential hazards upstream in the manufacturing process that may or may not be present as residuals. Hazards are drawn from process chemicals far upstream in the manufacturing process as well as the immediate precursors to this chemical.

The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern).

Grey indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels.

Blue indicates that the substance is referenced on a restricted substance list (RSL) rather than an authoritative hazard list.

For a full description of authoritative hazard lists used in Pharos and of the derivation of the hazard level indicators, see the complete Pharos Chemical and Material Library Description.

For the source of this hazard, see the "Process Chemistry Research" tab on the chemical's page.

×

GreenScreen

The Pharos scoring system is informed by the GreenScreen® for Safer Chemicals, a benchmarking system to rank the safety of chemicals on a 4 point hazard scale and encourage progress toward safer alternatives. Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a Benchmark score, which is the most authoritative. Chemicals that have been assessed using an automated comparison to hazard lists are given a List Translator score, which is less authoritative. Full GreenScreen assessments trump results from List Translator scoring.

GreenScreen Scores in order from highest concern to lowest concern are:

- Benchmark 1
- LT-1 - List Translator Likely Benchmark 1
- LT-P1 - List Translator Possible Benchmark 1
- LT-UNK - List Translator Benchmark Unknown
- Benchmark U
- Benchmark 2
- Benchmark 3
- Benchmark 4

For more information, see the "GreenScreen" tab on the chemical's page or visit www.greenscreenchemicals.org.

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GreenScreen® Hazard Interpretation Guide

SECTION V — ANNEX 1

GreenScreen Chemical Hazard Criteria™

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GreenScreen Chemical Hazard Criteria

SINGLE HAZARD ENDPOINTS

Group I Human Health Effects (Group I Human)

TABLE A1.1: Carcinogenicity (C)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Carcinogenicity (C)	Data	GHS Criteria & Guidance		GHS Category 1A (Known) or 1B (Presumed) for any route of exposure	GHS Category 2 (Suspected) for any route of exposure or limited or marginal evidence of carcinogenicity in animals	· Adequate data available and negative studies; and · GHS not classified
	A Lists	US EPA – IRIS Carcinogens (1986)	Authoritative	Group A or B1 or B2	Group C	Group E
		US EPA – IRIS Carcinogens (1996, 1999, 2005)	Authoritative	Known or Likely		Not Likely
		EU – REACH Annex XVII CMRs	Authoritative	Category 1 or 2	Category 3	
		EU – Annex VI CMRs	Authoritative	Carc 1A or 1B	Carc 2	
		EU – GHS (H-Statements)	Authoritative	H350 or H350i	H351	
		EU – R-Phrases[1]	Authoritative	R45 or R49	R40	
		EU – SVHC Candidate List	Authoritative	Carcinogenic – Candidate list		
		EU – SVHC Prioritisation List	Authoritative	Carcinogenic – Prioritized for listing		
		EU – SVHC Authorisation List	Authoritative	Carcinogenic – Banned unless Authorised		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1A or 1B or H350 or H350i	Category 2 or H351	Not Classified
		GHS – [NEW ZEALAND]	Screening	6.7A	6.7B	Not Classified
		IARC	Authoritative	Group 1 or 2a	Group 2b	Group 4
		MAK	Authoritative	Carcinogen Group 1 or 2	Carcinogen Group 3A or 3B or 4 or 5	
		US CDC – Occupational Carcinogens	Authoritative	Occupational Carcinogen		
		US NIH – Report on Carcinogens	Authoritative	Known or Reasonably Anticipated		
		CA EPA – Prop 65	Authoritative	Carcinogen		
	B Lists	US EPA – IRIS Carcinogens (1986)	Authoritative	Group D		
		US EPA – IRIS Carcinogens (1999)	Authoritative	Suggestive Evidence, but not sufficient to assess human carcinogenic potential		
		US EPA – IRIS Carcinogens (2005)	Authoritative	Suggestive evidence of carcinogenic potential		
		IARC	Authoritative	Group 3		
		CA EPA – Prop 65 (with qualifications)[2]	Authoritative	Carcinogen – specific to chemical form or exposure route		

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TABLE A1.2: Mutagenicity/Genotoxicity (M)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Mutagenicity/Genotoxicity (M)	Data	GHS Criteria & Guidance		GHS Category 1A (Known) or 1B (Presumed) for any route of exposure	GHS Category 2 (Suspected) for any route of exposure or limited or marginal evidence of mutagenicity in animals	· Adequate data available and negative studies for both chromosomal aberrations and gene mutations; and · GHS not classified
	A Lists	EU – REACH Annex XVII CMRs	Authoritative	Category 1 or 2	Category 3	
		EU – Annex VI CMRs	Authoritative	Mutagen 1A or 1B	Mutagen 2	
		EU – GHS (H-Statements)	Authoritative	H340	H341	
		EU – R-Phrases[1]	Authoritative	R46	R68	
		EU – SVHC Candidate List	Authoritative	Mutagenic – Candidate list		
		EU – SVHC Prioritisation List	Authoritative	Mutagenic – Prioritized for listing		
		EU – SVHC Authorisation List	Authoritative	Mutagenic – Banned unless Authorised		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1A or 1B or H340	Category 2 or H341	Not Classified
		GHS – [NEW ZEALAND]	Screening	6.6A	6.6B	Not Classified
	B Lists	MAK	Authoritative	Germ Cell Mutagen 1 or 2 or 3a		
		MAK	Authoritative	Germ Cell Mutagen 3b or 5		

TABLE A1.3: Reproductive Toxicity (R)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Reproductive Toxicity (R)	Data	GHS Criteria & Guidance Note: GHS Reproductive Toxicity includes both reproductive and developmental effects, while GreenScreen separates them into two distinct hazard endpoints. This classification must be based on reproductive effects alone.		GHS Category 1A (Known) or 1B (Presumed) for any route of exposure	GHS Category 2 (Suspected) for any route of exposure or limited or marginal evidence of reproductive toxicity in animals	· Adequate data available and negative studies; and · GHS not classified
	A Lists	EU – GHS (H-Statements)	Authoritative	H360F or H360FD or H360Fd	H360Df or H361f or H361fd	
		EU – R-Phrases[1]	Authoritative	R60	R62	
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1A (Known) or Category 1B (Presumed) or H360F or H360FD or H360Fd	Category 2 (Suspected) or H360Df or H361f or H361fd	Not Classified for reproductive effects
		GHS – [NEW ZEALAND]	Screening	6.8A	6.8B	Not Classified for reproductive effects
		US NIH – Reproductive & Developmental Monographs	Authoritative	Clear Evidence of Adverse Effects – Reproductive		Clear Evidence of No Adverse Effects – Reproductive
		CA EPA – Prop 65	Authoritative	Reproductive Toxicity – Male or Female		
	B Lists	US NIH – Reproductive & Developmental Monographs	Authoritative	Limited Evidence of Adverse Effects – Reproductive or Some Evidence of Adverse Effects – Reproductive		
					Limited Evidence of No Adverse Effects – Reproductive or Some Evidence of No Adverse Effects – Reproductive	
				Insufficient Evidence for a Conclusion – Reproductive Toxicity		
		CA EPA – Prop 65 (with qualifications)[2]	Authoritative	Reproductive Toxicity – Male or Female		

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SECTION V — ANNEX 1

GreenScreen Chemical Hazard Criteria

TABLE A1.4: Developmental Toxicity (D)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Developmental Toxicity (D)	Data	GHS Criteria & Guidance Note: GHS Reproductive Toxicity includes both reproductive and developmental effects, while GreenScreen separates them into two distinct hazard endpoints. This classification must be based on developmental effects alone.		GHS Category 1A (Known) or 1B (Presumed) for any route of exposure or effects on or via lactation	GHS Category 2 (Suspected) for any route of exposure or limited or marginal evidence of developmental toxicity in animals	· Adequate data available and negative studies; and · GHS not classified
	A Lists	EU – GHS (H-Statements)	Authoritative	H360FD or H360D or H360Df or H362	H360Fd or H361d or H361fd	
		EU – R-Phrases[1]	Authoritative	R61 or R64	R63	
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1A or 1B or effects on or via lactation or H360FD or H360D or H360Df or H362	Category 2 or H360Fd or H361d or H361fd	Not Classified for developmental effects
		GHS – [NEW ZEALAND]	Screening	6.8A or 6.8C	6.8B	Not Classified for developmental effects
		US NIH – Reproductive & Developmental Monographs	Authoritative	Clear Evidence of Adverse Effects – Developmental		Clear Evidence of No Adverse Effects – Developmental
		CA EPA – Prop 65	Authoritative	Developmental toxicity		
	B Lists	G&L – Neurotoxic Chemicals	Screening	Developmental Neurotoxicant		
		Boyes – Neurotoxicants	Screening	Developmental Neurotoxicity		
		MAK	Authoritative	Pregnancy Risk Group A or B		
					Pregnancy Risk Group C	
				Pregnancy Risk Group D		
		US NIH – Reproductive & Developmental Monographs	Authoritative	Limited Evidence of Adverse Effects – Developmental or Some Evidence of Adverse Effects – Developmental		
					Limited Evidence of No Adverse Effects – Reproductive or Some Evidence of No Adverse Effects – Developmental	
				Insufficient Evidence for a Conclusion – Developmental Toxicity		
		CA EPA – Prop 65 (with qualifications)[2]	Authoritative	Developmental toxicity		

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TABLE A1.5: Endocrine Activity (E)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Endocrine Activity (E)	Data	All Available Data		Evidence of endocrine activity and related human health effect	Evidence of endocrine activity	Adequate data available and negative studies
	A Lists	EU – Priority Endocrine Disrupters	Screening			Category 3a
		EU – SVHC Candidate List	Authoritative	Equivalent Concern – Candidate List: endocrine disrupting properties cause probable serious effects to the environment or human health		
		EU – SVHC Prioritisation List	Authoritative	Equivalent Concern – Prioritized for Listing: endocrine disrupting properties cause probable serious effects to the environment or human health		
		EU – SVHC Authorisation List	Authoritative	Equivalent Concern – Banned Unless Authorized: endocrine disrupting properties cause probable serious effects to the environment or human health		
	B Lists	EU – Priority Endocrine Disrupters	Screening	Category 1 or 2		
				Category 3b		
		OSPAR	Authoritative	Endocrine Disruptor – chemical for priority action		
		OSPAR	Screening	Endocrine Disruptor – substance of possible concern		
		ChemSec – SIN List	Screening	Endocrine Disruption		
		TEDX – Potential Endocrine Disruptors	Screening	Potential Endocrine Disruptor		

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SINGLE HAZARD ENDPOINTS

Group II and II* Human Health Effects (Group II and II* Human)

TABLE A1.6: Acute Mammalian Toxicity (AT)

	Information Type	Information Source	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Acute Mammalian Toxicity (AT)	Data	GHS Criteria & Guidance		GHS Category 1 or 2 for any route of exposure	GHS Category 3 for any route of exposure	GHS Category 4 for any route of exposure	· GHS Category 5; or · Adequate data available and negative studies; and · GHS not classified
	Guidance Values for Animal Data (see GHS for further information)	Oral LD50 (mg/kg)		≤50	>50 – 300	>300 – 2000	>2000
		Dermal LD50 (mg/kg)		≤200	>200 – 1000	>1000 – 2000	>2000
		Inhalation – Gas or Vapor LC50(mg/L)		≤2	>2 – 10	>10 – 20	>20
		Inhalation – Dust/Mist/Fumes LC50 (mg/L)		≤0.5	>0.5 – 1.0	>1 – 5	>5
	A Lists	DOT[1]	Authoritative	Class 2.3 Group A, or Class 6.1 Group 1 or Group 2	Class 6.1 Group 3		
		EU – GHS (H-Statements)	Authoritative	H300 or H310 or H330	H301 or H311or H331	H302 or H312 or H332	
		EU – R-Phrases[1]	Authoritative	R26 or R27 or R28			
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1 or 2 or H300 or H310 or H330	Category 3 or H301 or H311 or H331	Category 4 or H302 or H312 or H332	Category 5 or H303 or H313 or H333 or Not Classified
		GHS – [NEW ZEALAND]	Screening	6.1A or 6.1B	6.1C	6.1D	6.1E or Not Classified
	B Lists	US EPA – EPCRA Extremely Hazardous Substances	Authoritative	Extremely Hazardous Substance			
		EU – R-Phrases	Authoritative			R20 or R21 or R22	
				R23 or R24 or R25			
		Québec CSST – WHMIS 1988	Screening	D1A Toxic			
				D1B Toxic			

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TABLE A1.7: **Systemic Toxicity/Organ Effects (ST)**

		Information Type	Information Source	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Systemic Toxicity/Organ Effects (ST)	Single Exposure	Data Note: GHS includes neurotoxicity under Systemic Toxicity, while GreenScreen separates them into two distinct hazard endpoints. This classification must be based on any effects other than neurological/ neurobehavioral effects.	GHS Criteria & Guidance		GHS Category 1 Single Exposure for any route of exposure	GHS Category 2 Single Exposure for any route of exposure	GHS Category 3 Single Exposure for any route of exposure	· Adequate data available and negative studies; and · GHS not classified
		GHS Guidance Values for Animal Data (see GHS for further information) Note above applies here too.	Oral (mg/kg-bw)		≤300	>300 – 2000		
			Dermal (mg/kg-bw)		≤1000	>1000 – 2000		
			Inhalation-Gas or Vapor (mg/L/4h)		≤10	>10 – 20		
			Inhalation-Dust/Mist/Fumes (mg/L/4h)		≤1.0	>1.0 – 5.0		
		A Lists	EU – GHS (H-Statements)	Authoritative			H335	
			EU – R-Phrases[1]	Authoritative			R37	
			GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening			H335	
	Single Exposure - Aspiration Hazards	Data	GHS Criteria & Guidance			GHS Category 1	GHS Category 2	· Adequate data available and negative studies; and · GHS not classified
		A Lists	EU – GHS (H-Statements)	Authoritative		H304		
			EU – R-Phrases[1]	Authoritative		R65		
			GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening		Category 1 or H304	Category 2 or H305	"Not Classified"
		B Lists	GHS – [NEW ZEALAND]	Screening		6.1E		
	Repeated* Exposure	Data Note: GHS includes neurotoxicity under Systemic Toxicity, while GreenScreen separates them into two distinct hazard endpoints. This classification must be based on any effects other than neurological/neu-robehavioral effects.	GHS Criteria & Guidance			GHS Category 1 Repeated Exposure for any route of exposure	GHS Category 2 Repeated Exposure for any route of exposure	· Adequate data available and negative studies; and · GHS not classified
		GHS Guidance Values for Animal Data (see GHS for further information) Note above applies here too.	Oral (mg/kg-bw/day)			≤10	>10 – 100	>100
			Dermal (mg/kg-bw/day)			≤20	>20 – 200	>200
			Inhalation-Gas or Vapor (mg/L/6h/day)			≤0.2	>0.2 – 1.0	>1.0
			Inhalation-Dust/Mist/Fumes (mg/L/6h/day)			≤0.02	>0.02 – 0.2	>0.2
		A Lists	EU – SVHC Candidate List	Authoritative		Equivalent Concern – Candidate List		
			EU – SVHC Prioritisation List	Authoritative		Equivalent Concern – Prioritized for Listing		
			EU – SVHC Authorisation List	Authoritative		Equivalent Concern – Banned Unless Authorized		

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TABLE A1.8: Neurotoxicity (N)

		Information Type	Information Source	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Neurotoxicity (N)	Single Exposure	Data Note: GHS includes neurotoxicity under Systemic Toxicity, while GreenScreen separates them into two distinct hazard endpoints. This classification must be based on neurological/ neurobehavioral effects alone.	GHS Criteria Systemic Toxicity/ Organ Effects using USEPA Risk Assessment Guidance to define applicable neurotoxic effects.		GHS Category 1 Single Exposure for any route of exposure	GHS Category 2 Single Exposure for any route of exposure	GHS Category 3 Single Exposure for any route of exposure	· Adequate data available and negative studies; and · GHS not classified
		GHS Guidance Values for Animal Data (see GHS for further information). Note above applies here too	Oral (mg/kg-bw)		≤300	>300 – 2000		
			Dermal (mg/kg-bw)		≤1000	>1000 – 2000		
			Inhalation-Gas or Vapor (mg/L/4h)		≤10	>10 – 20		
			Inhalation-Dust/Mist/Fumes (mg/L/4h)		≤1.0	>1.0 – 5.0		
		B Lists	EU – GHS (H-Statements)	Authoritative			H336	
			EU – R-Phrases[1]	Authoritative			R67	
			GHS –[COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening			H336	
	Repeated* Exposure	Data Note: GHS includes neurotoxicity under Systemic Toxicity, while GreenScreen separates them into two distinct hazard endpoints. This classification must be based on neurological/ neurobehavioral effects alone.	GHS Criteria Systemic Toxicity/ Organ Effects using USEPA Risk Assessment Guidance to define applicable neurotoxic effects.			GHS Category 1 Repeated Exposure for any route of exposure	GHS Category 2 Repeated Exposure for any route of exposure	· Adequate data available and negative studies; and · GHS not classified
		GHS Guidance Values for Animal Data (see GHS for further information). Note above applies here too.	Oral (mg/kg-bw/day)			≤10	>10 – 100	>100
			Dermal (mg/kg-bw/day)			≤20	>20 – 200	>200
			Inhalation-Gas or Vapor (mg/L/6h/day)			≤0.2	>0.2 – 1.0	>1.0
			Inhalation-Dust/Mist/Fumes (mg/L/6h/day)			≤0.02	>0.02 – 0.2	>0.2
	Either	B Lists	Boyes – Neurotoxicants	Screening	Neurotoxic[3]			
			G&L – Neurotoxic Chemicals	Screening	Neurotoxic[3]			

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TABLE A1.9: Skin Sensitization (SnS*)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Skin Sensitization (SnS*)	Data	GHS Criteria & Guidance		GHS Category 1A (high frequency of occurrence)	GHS Category 1B (low to moderate frequency of occurrence)	· Adequate data available and negative studies; and · GHS not classified
	A Lists	GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1A	Category 1B	Not Classified
	B Lists	MAK	Authoritative	Sensitizing Substance Sh – Danger of skin sensitization or Sah – Danger of airway & skin sensitization		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	H317		
		EU – GHS (H-Statements)	Authoritative	H317		
		EU – R-Phrases[1]	Authoritative	R43		
		GHS – [NEW ZEALAND]	Screening	6.5B		

TABLE A1.10: Respiratory Sensitization (SnR*)

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)
Respiratory Sensitization (SnR*)	Data	GHS Criteria & Guidance		GHS Category 1A (high frequency of occurrence)	GHS Category 1B (low to moderate frequency of occurrence)	· Adequate data available and negative studies; and · GHS not classified
	A Lists	EU – SVHC Candidate List	Authoritative	Equivalent Concern – Candidate List: Respiratory sensitizing		
		EU – SVHC Prioritisation List	Authoritative	Equivalent Concern – Prioritized for Listing: Respiratory sensitizing		
		EU – SVHC Authorisation List	Authoritative	Equivalent Concern – Banned Unless Authorized: Respiratory sensitizing		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1A	Category 1B	Not Classified
	B Lists	MAK	Authoritative	Sensitizing Substance Sa – Danger of airway sensitization or Sah – Danger of airway & skin sensitization		
		AOEC – Asthmagens	Authoritative	Asthmagen (G)		
				Asthmagen (Rr) and/ or (Rs) and/or (Rrs)		
		EU – GHS (H-Statements)	Authoritative	H334		
		EU – R-Phrases[1]	Authoritative	R42		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	H334		
		GHS – [NEW ZEALAND]	Screening	6.5A		

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TABLE A1.11: Skin Irritation (IrS)

	Information Type	Information Source	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Skin Irritation (IrS)	Data	GHS Criteria & Guidance		GHS Category 1 (Corrosive)	GHS Category 2 (Irritant)	GHS Category 3 (Mild irritant)	· Adequate data available and negative studies; and · GHS not classified
	A Lists	EU – GHS (H-Statements)	Authoritative	H314	H315		
		EU – R-Phrases[1]	Authoritative	R34 or R35	R38		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1 or H314	Category 2 or H315	Category 3 or H316	Not Classified
		GHS – [NEW ZEALAND]	Screening	8.2A or 8.2B or 8.2C	6.3A	6.3B	Not Classified

TABLE A1.12: Eye Irritation (IrE)

	Information Type	Information Source	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Eye Irritation (IrE)	Data	GHS Criteria & Guidance		GHS Category 1 (Irreversible)	GHS Category 2A (Irritating)	GHS Category 2B (Mildly irritating)	· Adequate data available and negative studies; and · GHS not classified
	A Lists	EU – GHS (H-Statements)	Authoritative	H318	H319	H320	
		EU – R-Phrases[1]	Authoritative	R41			
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1	Category 2A	Category 2B	Not Classified
		GHS – [NEW ZEALAND]	Screening	8.3A			Not Classified
	B Lists	EU – R-Phrases[1]	Authoritative		R36		
		GHS – [NEW ZEALAND]	Screening		6.4A		

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SINGLE HAZARD ENDPOINTS
Ecotoxicity (Ecotox)

TABLE A1.13: Acute Aquatic Toxicity (AA)

	Information Type	Measurement	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Acute Aquatic Toxicity (AA)	Data	GHS Criteria & Guidance		GHS Category 1	GHS Category 2	GHS Category 3	· Adequate data available and negative studies; and · GHS not classified
	Guidance Values (see GHS for further information)	LC50 or EC50 (mg/L)		≤1	>1 to 10	> 10 to 100	>100
	A Lists	EU – GHS (H-Statements)	Authoritative	H400			
		EU – R-Phrases[1]	Authoritative	R50			
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1 or H400	Category 2 or H401	Category 3 or H402	Not Classified
		GHS – [NEW ZEALAND]	Screening	9.1A			Not Classified
	B Lists	EU – R-Phrases[1]	Authoritative		R51 or R52		
		GHS – [NEW ZEALAND]	Screening		9.1D		

TABLE A1.14: Chronic Aquatic Toxicity (CA)

	Information Type	Measurement	Very High (vH)	High (H)	Moderate (M)	Low (L)
Chronic Aquatic Toxicity (CA)	Data	Guidance Value (mg/L)	≤0.1	>0.1 to 1.0	> 1.0 to 10	>10

TABLE A1.15: Persistence (P)

	Information Type	Media & Measurement	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)	Very Low (vL)
Persistence (P)	Data	Soil or Sediment		>180 or recalcitrant	>60 to 180	16 to 60	< 16 OR GHS "Rapid degradability"	Meets 10-day window in "Ready Biodegradation Test"
		(1/2 life in days OR Result)						
		Water		> 60 or recalcitrant	> 40 to 60	16 to 40	< 16 OR GHS "Rapid degradability"	Meets 10-day window in "Ready Biodegradation Test"
		(1/2 life in days OR Result)						
		Air		> 5 or recalcitrant	>2 to 5		< 2	
		(1/2 life in days OR Result)						
		Long-Range Environmental Transport			Evidence	Suggestive Evidence		
	B Lists	EC - CEPA DSL	Screening	Persistent				

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TABLE A1.16: Bioaccumulation Potential (B)

	Information Type	Measurement		Very High (vH)	High (H)	Moderate (M)	Low (L)	Very Low (vL)
Bioaccumulation Potential (B)	Data	BAF		> 5000	> 1000 to 5000	> 500 to 1000	> 100 to 500	≤ 100
		(Bioaccumulation Factor)						
		BCF		> 5000	> 1000 to 5000	> 500 to 1000	> 100 to 500	≤ 100
		(Bioconcentration Factor)						
		Log Kow		> 5.0	> 4.5 to 5.0	> 4.0 to 4.5		≤ 4
		(Log octanol-water partition coefficient)						
		Monitoring Data			Evidence	Suggestive Evidence		
		(Presence in humans or wildlife)						
	A Lists	EC – CEPA DSL	Screening	Bioaccumulative				

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SINGLE HAZARD ENDPOINTS
Physical Hazards

TABLE A1.17: **Reactivity (Rx)**

	Information Type	Measurement	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)
Reactivity (Rx)	Data - GHS Criteria & Guidance	Explosives		GHS Unstable	GHS Division 1.1, 1.2, or 1.3	GHS Division 1.4 or 1.5	Division 1.6 or Adequate data available and GHS not classified
		Self-reactive Substances		GHS Type A or B	GHS Type C or D	GHS Type E or F	Type G or Adequate data available and GHS not classified
		Substances which on contact with water emit flammable gases		GHS Category 1	GHS Category 2	GHS Category 3	Adequate data available and GHS not classified
		Oxidizing Gases			GHS Category 1		Adequate data available and GHS not classified
		Oxidizing Liquids and Solids		GHS Category 1	GHS Category 2	GHS Category 3	Adequate data available and GHS not classified
		Organic Peroxides		GHS Type A or B	GHS Type C or D	GHS Type E or F	Type G or Adequate data available and GHS not classified
		Self-heating Substances			GHS Category 1	GHS Category 2	Adequate data available and GHS not classified
		Substances Corrosive to Metal				GHS Category 1	Adequate data available and GHS not classified
		Desensitized Explosives			GHS Category 1 or 2	GHS Category 3 or 4	Adequate data available and GHS not classified
	A Lists	DOT[1]	Authoritative		Class 1 Group 1.1, 1.2, or 1.3	Class 1 Group 1.4, 1.5, or 1.6	
					Class 4.2 Group 2	Class 4.2 Group 3	
				Class 4.3 Group 1	Class 4.3 Group 2	Class 4.3 Group 3	
				Class 5.1 Group 1	Class 5.1 Group 2	Class 5.1 Group 3	
				Class 5.2 Type B	Class 5.2 Type C or D	Class 5.2 Type E or F	Class 5.2 Type G
		EU – GHS (H-Statements)	Authoritative	H200, H240, H241, H260, H271, EU-H032	H201, H202, H203, H251, H270	H204, H205, H252, H290	
		EU – R-Phrases[1]	Authoritative	R09, R32			
		GHS – [NEW ZEALAND]	Screening	4.1.2A or 4.1.2B or 4.3A or 5.1.1A or 5.2A or 5.2B	1.1 or 1.2 or 1.3, or 4.1.2C or 4.1.2D, 4.2B, or 4.3B, or 5.1.2A, or 5.1.1B, or 5.2C or 5.2D	1.4 or 1.5, or 4.1.2E or 4.1.2F, or 4.2C, or 4.3C, or 5.1.1C, or 5.2E or 5.2F, 8.1A	1.6, 4.1.2G, or 5.2G
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	See GreenScreen List Translator Map in Annex 12			
	B Lists	DOT[1]	Authoritative	Class 4.1, Class 5.2 Type A			
		EU – GHS (H-Statements)	Authoritative	EU-H029, EU-H031			
					H261, H272		
				H242			
		EU – R-Phrases[1]	Authoritative	R29, R31			
				R01, R06, R07, R15			
				R02, R04, R05, R08, R14, R16, R19, R44			
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	H242			
					H206, H207, H261, H272		
		Québec CSST – WHMIS 1988	Screening	B6, C, or F			

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TABLE A1.18: Flammability (F)

	Information Type	Measurement		Very High (vH)	High (H)	Moderate (M)	Low (L)
Flammability (F)	Data – GHS Criteria & Guidance	Flammable Liquid		GHS Category 1	GHS Category 2	GHS Category 3 or 4	Adequate data available and GHS not classified
		Flammable Gases (including pyrophoric gases and chemically unstable gases)		GHS Category 1A, or pyrophoric gas, or chemically unstable gas	GHS Category 1B	GHS Category 2	Adequate data available and GHS not classified
		Flammable Solids			GHS Category 1	GHS Category 2	Adequate data available and GHS not classified
		Aerosols			GHS Category 1	GHS Category 2	GHS Category 3 or Adequate data available and GHS not classified
		Pyrophoric Liquids			GHS Category 1		Adequate data available and GHS not classified
		Pyrophoric Solids			GHS Category 1		Adequate data available and GHS not classified
	A Lists	DOT[1]	Authoritative	Class 3 Group 1	Class 3 Group 2 or Class 4.2 Group 1	Class 3 Group 3	
		EU – GHS (H-Statements)	Authoritative	H220, H224, H230, H231	H222, H225, H250	H223, H226, H227	
		EU – R-Phrases[1]	Authoritative		R17		
		Québec CSST – WHMIS 1988	Screening		B1	B3	
		GHS – [NEW ZEALAND]	Screening	3.1A	3.1B, or 4.1.1A or 4.2A	2.1.1B or 3.1C or 3.1D, or 4.1.1B	
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	See GreenScreen List Translator Map in Annex 12			
	B Lists	DOT[1]	Authoritative		Class 2.1		
		EU – GHS (H-Statements)	Authoritative		H221, H228		
		EU – R-Phrases[1]	Authoritative	R10 (Gas or Solid), R11 (Solid)			
				R10 (Liquid only)			
				R11 (Liquid only)			
					R12 (Gas only)		
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening		H221, H228		
		GHS – [NEW ZEALAND]	Screening	2.1.1A, 2.1.2A			
		Québec CSST – WHMIS 1988	Authoritative		B4 or B5		
				B2			

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MULTIPLE HAZARD ENDPOINTS

TABLE A1.19: Carcinogens, Mutagens, Reproductive Toxins (CMR)

	Information Type	Information Source	List Category	List Type	High (H)	Moderate (M)	Low (L)	LT Score	Hazard Endpoints Addressed
Carcinogens, Mutagens, Reproductive Toxins (CMR)	A Lists	ChemSec – SIN List	CMR – Carcinogen, Mutagen &/or Reproductive Toxicant	Screening				P1	One or more of the following: Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity.

TABLE A1.20: Reproductive and/or Developmental Toxicity

	Information Type	Information Source	List Type	High (H)	Moderate (M)	Low (L)	LT Score	Hazard Endpoints Addressed
Reproductive and/or Developmental Toxicity	A Lists	EU – R-Phrases[1]	Authoritative	R60/61 "May impair fertility" and "May cause harm to the unborn child"			1	Reproductive and Developmental Toxicity
	B Lists	EU – REACH Annex XVII CMRs	Authoritative	Toxic to Reproduction Category 1 – Substances known to impair fertility or cause Developmental Toxicity in humans			1	Reproductive and/or Developmental Toxicity
			Authoritative	Toxic to Reproduction Category 2 – Substances which should be regarded as if they impair fertility or cause Developmental Toxicity in humans			1	
			Authoritative		Reproduction Category 3 – possible		UNK	
		EU – Annex VI CMRs	Authoritative	Reproductive Toxicity 1A			1	
			Authoritative	Reproductive Toxicity 1B			1	
			Authoritative		Reproductive Toxicity – Category 2		UNK	
		EU – GHS (H-Statements)	Authoritative	H360 (with no letters) "May damage fertility or the unborn child <state specific effect if known > <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard >."			1	
			Authoritative		H361 (with no letters) "Suspected of damaging fertility or the unborn child <state specific effect if known> <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>."		UNK	
		EU – SVHC Candidate List	Authoritative	Toxic to reproduction – Candidate list			1	
		EU – SVHC Prioritisation List	Authoritative	Toxic to reproduction – Prioritized for listing			1	
		EU – SVHC Authorisation List	Authoritative	Toxic to reproduction – Banned unless Authorised			1	

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TABLE A1.21: Systemic Toxicity/Organ Effects and/or Neurotoxicity

		Information Type	Information Source	List Type	Very High (vH)	High (H)	Moderate (M)	Low (L)	LT Score
Systemic Toxicity/Organ Effects and/or Neurotoxicity	Single Exposure	A Lists	EU – GHS (H-Statements)	Authoritative	H370	H371			LT-UNK
			EU – R-Phrases[1]	Authoritative	R39 or R39/23 or R39/24 or R39/25 or R39/26 or R39/27 or R39/28	R68/20 or R68/21 or R68/22			LT-UNK
			GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening	Category 1 or H370	Category 2 or H371	Category 3	Not Classified	LT-UNK
			GHS – [NEW ZEALAND]	Screening	6.9A	6.9B		Not Classified	LT-UNK
	Repeated* Exposure	A Lists	EU – GHS (H-Statements)	Authoritative		H372	H373		LT-UNK
			EU – R-Phrases[1]	Authoritative		R48/23 or R48/24 or R48/25	R33 or R48/20 or R48/21 or R48/22		LT-UNK
			GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Screening		Category 1 or H372	Category 2 or H373	Not Classified	LT-UNK
			GHS – [NEW ZEALAND]	Screening		6.9A	6.9B	Not Classified	LT-UNK
		B Lists	EU – R-Phrases[1]	Authoritative		R48 – Danger of serious damage to health by prolonged exposure			LT-UNK

TABLE A1.22: Various Combinations of Group I, II and II* Human Health Endpoints

	Information Type	Information Source	List Category	List Type	High (H)	Moderate (M)	Low (L)	LT Score	Hazard Endpoints Addressed
Various Combinations of Group I, II and II* Endpoints	B Lists	EC – CEPA DSL	Inherently Toxic to Humans (iT human)	Screening				UNK	One or more of the following Human Health Effects: Carcinogenicity, Mutagenicity/ Genotoxicity, Reproductive Toxicity, Developmental Toxicity, Acute Mammalian Toxicity, System Toxicity/Organ Effects.
		MAK		Authoritative	Sensitizing Substance Sah – Danger of airway & skin sensitization			UNK	Respiratory and Skin Sensitization
				Authoritative	Sensitizing Substance SP – Danger of photo-contact sensitization			UNK	Skin and/or Respiratory Sensitization
		Québec CSST – WHMIS 1988	D2A and D2B Toxic and Very Toxic – With other effects	Screening				UNK	One or more of the following Chronic Human Health Effects: Carcinogenicity, Mutagenicity/ Genotoxicity, Reproductive Toxicity, Developmental Toxicity, Skin Sensitization, Respiratory Sensitization, Systemic Toxicity/ Organ Effects, Eye Irritation, Skin Irritation.
			E Corrosive	Screening				UNK	Reactivity and/or Eye Irritation/Corrosivity and/or Skin Irritation/Corrosivity

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TABLE A1.23: **PBTs, vPvBs and other combinations of Persistence, Bioaccumulation and Toxicity**

PBTs, vPvBs and other combinations of Persistence, Bioaccumulation and Toxicity

Information Type	Information Source	List Category	List Type	High (H)	Moderate (M)	Low (L)	LT Score	Hazard Endpoints Addressed
A Lists	EC – CEPA DSL	Persistent, Bioaccumulative and inherently Toxic (PBiTH) to humans	Screening				P1	PBT [Persistence, Bioaccumulation and Human Toxicity (Human Health Effects)]
		Persistent, Bioaccumulative and inherently Toxic (PBiTE) to the Environment (based on aquatic organisms)	Screening				P1	PBT [Persistence, Bioaccumulation, and Acute Aquatic Toxicity or Chronic Aquatic Toxicity
	EU – ESIS PBT	vPvB	Screening				P1	vPvB [Persistence, Bioaccumulation]
		PBT	Screening				P1	PBT [Persistence, Bioaccumulation and any of the following: Ecotoxicity and/or Human Toxicity (Human Health Effects)]
		POP	Screening				P1	Persistent Organic Pollutant [Persistence, Bioaccumulation and any of the following: Ecotoxicity and/or Human Toxicity (Human Health Effects)]
	EU – SVHC Candidate List	PBT – Candidate list	Authoritative				1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity]
		vPvB – Candidate list	Authoritative				1	vPvB [Persistence, Bioaccumulation]
	EU – SVHC Prioritisation List	PBT – Prioritized for listing	Authoritative				1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity]
		vPvB – Prioritized for listing	Authoritative				1	vPvB [Persistence, Bioaccumulation]
	EU – SVHC Authorisation List	PBT – Banned unless Authorised	Authoritative				1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity]
		vPvB – Banned unless Authorised	Authoritative				1	vPvB [Persistence, Bioaccumulation]
	US EPA – Priority PBTs (NWMP)	Priority PBT	Authoritative				1	PBT [Persistence, Bioaccumulation and any of the following: Ecotox and/or Human Toxicity (Human Health Effects)]
	OR DEQ – Priority Persistent Pollutants	Priority Persistent Pollutant – Tier 1 and Tier 2	Screening				P1	PBT [Persistence, Bioaccumulation and any of the following: Ecotox and/or Human Toxicity (Human Health Effects)]
	OSPAR	PBT – substance of possible concern	Screening				P1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity, Systemic Toxicity/Organ Effects repeated exposure)]
		PBT – chemical for priority action	Authoritative				1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity, Systemic Toxicity/Organ Effects repeated exposure)]
		Equivalent Concern – substance of possible concern	Screening				P1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity, Systemic Toxicity/Organ Effects repeated exposure)]
		Equivalent Concern – chemical for priority action	Authoritative				P1	PBT [Persistence, Bioaccumulation, and any of the following: Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Carcinogenicity, Mutagenicity, Reproductive Toxicity, Developmental Toxicity, Systemic Toxicity/Organ Effects repeated exposure)]
	ChemSec – SIN List	vPvB	Screening				P1	Persistence and Bioaccumulation
		PBT	Screening				P1	Persistence, Bioaccumulation and any of the following: Ecotoxicity and/or Human Toxicity (Human Health Effects)
	UNEP Stockholm Conv – Persistent Organic Pollutants	Priority POP	Authoritative				1	PBT [Persistence, Bioaccumulation and any of the following: Ecotoxicity and/or Human Toxicity (Human Health Effects)]
	US EPA – Toxics Release Inventory PBTs	PBT	Authoritative				1	PBT [Persistence, Bioaccumulation, and Acute Aquatic Toxicity]
	WA DoE – PBT	PBT	Screening				P1	PBT [Persistence, Bioaccumulation and any of the following: Ecotoxicity and/or Human Toxicity (Human Health Effects)]

CONTINUED

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TABLE A1.23: **PBTs, vPvBs and other combinations of Persistence, Bioaccumulation and Toxicity** CONTINUED

	Information Type	Information Source	List Category	List Type	High (H)	Moderate (M)	Low (L)	LT Score	Hazard Endpoints Addressed
PBTs, vPvBs and other combinations of Persistence, Bioaccumulation and Toxicity	B Lists	EC – CEPA Toxic Substances (Sched 1)	CEPA Toxic	Screening				UNK	One or more of the following: Human Health Effects, Ecotoxicity, and/or Fate endpoints.
		EC – CEPA DSL	Inherently Toxic to the Environment (iT environment)	Screening				UNK	Acute Aquatic Toxicity or Chronic Aquatic Toxicity
		EU – GHS (H-Statements)	H410 – Very toxic to aquatic life with long lasting effects	Authoritative				P1	T & P and/or B [(Chronic Aquatic Toxicity and Persistence) or (Acute Aquatic Toxicity and Persistence and/or Bioaccumulation)]
			H411 – Toxic to aquatic life with long lasting effects	Authoritative				P1	
			H412 – Harmful to aquatic life with long lasting effects	Authoritative				UNK	
			H413 – May cause long-lasting harmful effects to aquatic life	Authoritative				UNK	
		EU – R-Phrases[1]	R50/53 – Very Toxic to Aquatic Organisms, May cause long-term adverse effects in the aquatic environment	Authoritative				P1	
			R51/53 – Toxic to Aquatic Organisms, May cause long-term adverse effects in the aquatic environment	Authoritative				P1	
			R52/53 – Harmful to Aquatic Organisms, May cause long-term adverse effects in the aquatic environment	Authoritative				UNK	
			R53 – May cause long-term adverse effects in the aquatic environment	Authoritative				UNK	
		GHS – [COUNTRY] Lists (Australia, Indonesia, Japan, Korea, Malaysia, Taiwan and Thailand)	Category 1 or H410	Screening				P1	
			Category 2 or H411	Screening				P1	
			Category 3 or H412	Screening				UNK	
			Category 4 or H413	Screening				UNK	
		GHS – [NEW ZEALAND]	9.1A	Screening				P1	
			9.1B	Screening				P1	
			9.1C	Screening				UNK	
			9.1D	Screening				UNK	
		German FEA – Substances Hazardous to Waters	Class 1 – Low Hazard to Waters	Screening				UNK	Any combination of the following: Acute Mammalian Toxicity, Systemic Toxicity/Organ Effects, Carcinogenicity, Reproductive Toxicity, Developmental Toxicity, Acute Aquatic Toxicity, Chronic Aquatic Toxicity, Persistence, Bioaccumulation.
			Class 2 – Hazard to Waters	Screening				P1	
			Class 3 – Severe Hazard to Waters	Screening				P1	

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TABLE A1.24: Reactivity and/or Flammability

	Information Type	Information Source	List Category	List Type	High (H)	Moderate (M)	Low (L)	LT Score	Hazard Endpoints Addressed
Reactivity and/or Flam-	B Lists	EU – R-Phrases[1]	R12 – Extremely Flammable Liquid	Authoritative				UNK	Reactivity and/or Flammability
			R03 – Extreme risk of explosion by shock, friction, fire or other sources of ignition	Authoritative				UNK	
			R18 – In use, may form flammable/explosive vapour-air mixture	Authoritative				UNK	
			R30 – Can become highly flammable in use	Authoritative				UNK	

1 List is considered an information source and is used as a line of evidence to classify a hazard in a GreenScreen assessment. List is not considered a GreenScreen Specified List and is not required to be searched for a GreenScreen List Translator assessment. See Annex 10 Information Sources.

2 See Annex 11 GreenScreen Specified Lists for more information about these lists.

3 List includes consideration of both acute and chronic neurotoxic impacts. To facilitate List Translator scoring, hazards are considered under the repeated exposure sub-endpoint. This does not impact List Translator scoring, as the list can only be translated to a range of hazard levels resulting in an "UNK" designation.

4 If a country does not designate between Category 1A and Category 1B for evaluating Skin or Respiratory Sensitization, then the list should be treated as a Screening B list, with a High to Moderate hazard level in GreenScreen for GHS Category 1 classifications.

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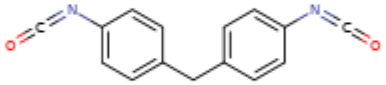
Hazardous Substances Data Bank (HSDB) Results

4,4'-Methylenediphenyl Diisocyanate

CASRN: 101-68-8
UNII: B0LO6BBS8C
Reviewed by SRP on 5/17/2012



FULL RECORD DISPLAY
Displays all fields in the record.
For other data, click on the Table of Contents

Human Health Effects:

Toxicity Summary:

IDENTIFICATION AND USE: This chemical exists as a colorless or light yellow fused solid. 4,4'-Methylenediphenyl diisocyanate (MDI) is miscible in water, and soluble in acetone, benzene, kerosene, and nitrobenzene. The product is used to make rigid and semi-rigid polyurethane foams. Pure MDI is distilled from the reaction mixture and is used for reaction injection molding, thermoplastic elastomers, and adhesives. HUMAN EXPOSURE AND TOXICITY: MDI is irritating to skin, eyes, and respiratory passages. Nose and throat irritation has also been observed. A few cases of alveolitis have been reported in workers exposed to MDI vapors. Contact allergy and allergic contact eczema have been reported in workers exposed to MDI. Cases of asthmatic breathing have been observed in workers. Lung fibrosis is also been observed in workers exposed to MDI. Children living in proximity of an accidental MDI release had signs of sore throat, dizziness, nausea and breathing difficulties MDI is an allergic sensitizer. Workers in occupational settings have the potential for inhalation or skin contact with particles of MDI. There is inadequate evidence for the carcinogenicity of MDI in humans. ANIMAL STUDIES: There is limited evidence in experimental animals for the carcinogenicity of MDI. MDI has low oral toxicity in rats. Repeated doses of MDI for 5 days in corn oil produced slight spleen enlargement in rats. In male and female rats exposed to polymeric MDI aerosol there was increased incidences of pulmonary adenomas in high dose males. Accumulation of alveolar macrophages containing polymeric MDI were associated with retractile yellowish material, localized fibrosis and alveolar duct epithelialization and increased alveolar bronchiolization were observed in the lungs of the high dose group. A 2 yr inhalation study using a mixture of MDI and higher weight oligomers showed both male and female rats had treatment related histological changes in the nasal cavity, lungs and lymph nodes. In female rats exposed by inhalation to MDI on days 6-15 of gestation, there was a slight increase in asymmetric sternbrae at the highest dose but no adverse effect was observed on maternal weight gain, number of corpea lutea, implantation sites, pre and post-implantation loss, fetal or placental weight, gross abnormalities or degree of ossification. MDI was tested for mutagenicity in Salmonella typhimurium strains TA98, TA100, TA1535 and TA1537 in the presence or absence of metabolic activation. The chemical was negative for mutagenicity. MDI in the micronucleus assay was negative for mutagenicity. `**QC REVIEWED**`

Evidence for Carcinogenicity:

Evaluation: There is inadequate evidence for the carcinogenicity of 4,4'-methylenediphenyl diisocyanate or polymeric 4,4'-methylenediphenyl diisocyanate in humans. There is limited evidence in experimental animals for the carcinogenicity of a mixture containing monomeric and polymeric 4,4'-methylenediphenyl diisocyanate. Overall evaluation: 4,4'-Methylenediphenyl diisocyanate (industrial preparation) is not classifiable as to its

carcinogenicity in humans (Group 3).[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1056 (1999)] **PEER REVIEWED** WEIGHT OF EVIDENCE CHARACTERIZATION: Under U.S. EPA's 1996 Guidelines for Carcinogenic Risk Assessment, monomeric MDI or polymeric MDI (PMDI) would be classified as not classifiable or a Group D chemical. Under U.S. EPA's 1996 Proposed Guidelines for Carcinogenic Risk Assessment, the carcinogenic potential of MDI/PMDI would be characterized as "cannot be determined, but for which there is suggestive evidence that raises concern for carcinogenic effects" on the following basis. The increased incidence of pulmonary adenomas in male (6/60) and female (2/59) Wistar rats [strain Cpu:WU] and one pulmonary adenocarcinoma in a male rat, all exposed to the highest concentration in a lifetime chronic inhalation study involving PMDI, suggest that PMDI has tumorigenic potential. However, the tumorigenic results, coupled with evidence that methylene diphenyl aniline (MDA) a known animal carcinogen and the principal reaction product of MDI, is found in blood of MDI-exposed rats and nonhydrolyzed urine of PMDI/MDI-exposed humans increases concern about the carcinogenic potential of PMDI/MDI. The available human evidence is inadequate to describe the carcinogenic potential of PMDI/MDI. HUMAN CARCINOGENICITY DATA: Inadequate. ANIMAL CARCINOGENICITY DATA: Limited.[U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS). Summary for Methylene Diphenyl Diisocyanate (monomeric MDI) and polymeric MDI (PMDI) (101-68-8, 9016-87-9). Available from, as of March 15, 2000: http://www.epa.gov/iris/] **PEER REVIEWED**

Human Toxicity Excerpts:

/HUMAN EXPOSURE STUDIES/ Exposure to MDI is irritating to skin, eyes and respiratory passages. For MDI, the relationship between symptoms and exposure levels is still insufficiently known. In one study, nose and throat irritation was observed in about half of 13 employees who had been transferred because of their reactions to isocyanate exposure and in a few of the 20 who had stayed in the same jobs and were still being exposed. Precise exposure levels are not given in this study, but it is reported that the exposure limit for MDI (96 ppb) was reached during some operations and that higher peaks may have occurred.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.70 (2001). Available from, as of March 10, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /HUMAN EXPOSURE STUDIES/ There are a few reported cases of alveolitis caused by exposure to airborne TDI, MDI and HDI. This alveolitis is characterized by restrictive reduction in lung function, interstitial fibrosis, increase of CD8-positive cells in bronchoalveolar lavage fluid (CD4/CD8 < 1.0) and IgG antibodies specific to albumin-bound isocyanate. In a total of 1,780 isocyanate-exposed workers, ... 14 cases of dyspnea and fever associated with exposure to isocyanates /were identified/. These persons had signs of alveolitis on lung x-rays and/or restrictive reduction in lung function and/or reduced diffusion capacity and/or IgG antibodies against albumin-bound TDI, MDI or HDI in serum. Bronchoalveolar lavage and biopsies from the respiratory tract showed inflammatory changes, but no isocyanate-specific IgE antibodies were found in serum. The average exposure time was 6 years (0.5-20 years) but cumulative exposures were neither calculated nor estimated. ...The occurrence of alveolitis /was found/ to be about 1%, whereas /another study/... found a prevalence of 4.7% among workers 75 occupationally exposed to resins containing MDI or MDI prepolymers. In both these studies it was remarked that exposure to MDI was more commonly associated with isocyanate-induced alveolitis than exposure to TDI or HDI.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.74 (2001). Available from, as of March 10, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /HUMAN EXPOSURE STUDIES/ ...12 cases of contact allergy and allergic contact eczema caused by occupational exposure to MDI /were described/. In some cases patients have positive test reactions to several isocyanates, and occasionally to methylene dianiline (MDA) as well - often despite the fact that they had not previously been exposed to the particular substance that induced the reaction. This has been interpreted as evidence of crossreactivity. The patients had been sensitized in jobs such as mold sprayer, car painter, spray painter and medical technician. Several of them had become sensitized because of inadequate protection against skin exposure (work with worn-out gloves or no gloves, for example), although working conditions were otherwise good. In several cases sensitization occurred after a few weeks or months of exposure at work. In some reported cases the patient had MDI or HDI-induced asthma in addition to the contact eczema.[Montelius J ed.; Scientific Basis for

Swedish Occupational Standards XXII p.76 (2001). Available from, as of March 10, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /HUMAN EXPOSURE STUDIES/ Sera of six workers with conclusive evidence for IgE-mediated sensitization to isocyanates were used for evaluation of immunologic cross-reactivities among eight different isocyanate-protein conjugates. In all cases RAST and/or skin-test investigations revealed the presence of IgE antibodies reacting specifically with HSA conjugated with those isocyanates to which workers were exposed as well as with other isocyanates with which they had not been in contact. By the RAST inhibition technique, moderate to strong mutual cross-reactivities between all tested isocyanate-HSA conjugates--even between aromatic and aliphatic ones--could be demonstrated in tests with five sera. The magnitudes of cross-reactivities differed, however, from one patient to another. One serum contained IgE antibodies that were almost completely specific to TDI-HSA; with this serum only weak cross-reactivities with other isocyanate conjugates could be demonstrated. These results indicate the predominance of closely related antigenic determinants in HSA conjugated with different isocyanates. The common antibody-binding regions are obviously recognized to different extents by antibodies of clinically sensitized workers, indicating individual differences in specificities and avidities of antibody populations. Nearly complete lack of IgE binding of ovalbumin-bound TDI in RAST and RAST inhibition indicates carrier-specific antigenicity of isocyanate-protein conjugates. In addition, since unmodified HSA did not bind IgE, antigenic determinants of the conjugates studied should be predominantly formed by the isocyanate-protein bond regions and concurrently by neighboring amino acid residues of the HSA molecule. /Isocyanates/[Baur X; J Allergy Clin Immunol 71 (2): 197-205 (1983)] **PEER REVIEWED** PubMed Abstract /SIGNS AND SYMPTOMS/ Occupational exposure to MDI has produced respiratory effects similar to those reported from TDI exposure. ... An incident /occurred/ in which men who worked 60-120 ft from an MDI foam-spraying operation developed symptoms, including asthmatic breathing, retrosternal soreness, constriction of the chest, cough, retrobulbar pain, depression, headache, nasal discharge, and insomnia. The workers actually spraying the MDI foam wore full protective clothing and air-supplied respirators & were unaffected.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 978] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ ... USED DURING SPRAYING OPERATIONS ... MINUTE DROPLETS, CONTAINING UNREACTED MDI, CAUSE IRRITATION OF RESPIRATORY SYSTEM & SOMETIMES ASTHMATIC BREATHING & RARE CASES OF SENSITIZATION.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 746] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ 4,4-Methylenediphenyl diisocyanate is irritating to the skin, eyes and respiratory tract and induces asthma in humans.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1052 (1999)] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ Strong mucous membrane irritation causes eye, pulmonary, and gastrointestinal tract symptoms. These compounds are potent pulmonary sensitizers which cause bronchospasm, even in patients without prior airway hyperreactivity. Diisocyanate compounds act either as inducers of nonspecific bronchial hyperreactivity or as direct pharmacologic agonists. Isocyanates apparently have the potential to sensitize certain segments of the population. Elevated humoral antibodies (ie, specific IgE antibodies to the p-tolyl determinant but not the diisocyanate conjugate) were detected in sensitized workers, but cell-mediated immunity also may produce hypersensitivity reactions. In the absence of renewed exposure, radioallergosorbent titers may not distinguish sensitive from nonsensitized workers. At high doses, toluene diisocyanate may act directly on bronchial mucosa by interfering with cholinergic and adrenergic mechanisms. /Isocyanates/[Ellenhorn, M.J. and D.G. Barceloux. Medical Toxicology - Diagnosis and Treatment of Human Poisoning. New York, NY: Elsevier Science Publishing Co., Inc. 1988., p. 881] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ Exposure to isocyanates is irritating to the skin, mucous membranes, eyes, and respiratory tract. The most common adverse health outcome associated with isocyanate exposure is asthma due to sensitization; less prevalent are contact dermatitis (both irritant and allergic forms) and hypersensitivity pneumonitis (HP). Contact dermatitis can result in symptoms such as rash, itching, hives, and swelling of the extremities. /Isocyanates/[DHHS; Centers for Disease Control and Prevention -National Institute for Occupational Safety and Health; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 (January 2004). Available from, as of March 20, 2012: http://www.cdc.gov/niosh/docs/2004-116/] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ A worker suspected of having isocyanate-induced asthma/sensitization will exhibit the traditional symptoms of acute

airway obstruction, e.g., coughing, wheezing, shortness of breath, tightness in the chest, and nocturnal awakening. An isocyanate-exposed worker may first develop an asthmatic condition (i.e., become sensitized) after a single (acute) exposure, but sensitization usually takes a few months to several years of exposure. The asthmatic reaction may occur minutes after exposure (immediate), several hours after exposure (late), or a combination of both immediate and late components after exposure (dual). The late asthmatic reaction is the most common, occurring in approximately 40% of isocyanate sensitized workers. After sensitization, any exposure, even to levels below an occupational exposure limit or standard, can produce an asthmatic response that may be life threatening. Experience with isocyanates has shown that monomeric, prepolymeric and polyisocyanate species are capable of producing respiratory sensitization in exposed workers. /Isocyanates/[DHHS; Centers for Disease Control and Prevention -National Institute for Occupational Safety and Health; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 (January 2004). Available from, as of March 20, 2012: http://www.cdc.gov/niosh/docs/2004-116/] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ The initial symptoms associated with isocyanate-induced hypersensitivity pneumonitis (HP) are flu-like, including shortness of breath, nonproductive cough, fever, chills, sweats, malaise, and nausea. After the onset of HP, prolonged and/or repeated exposures may lead to an irreversible decline in pulmonary function and lung compliance and to the development of diffuse interstitial fibrosis. Early diagnosis is difficult since many aspects of HP, i.e., the flu-like symptoms and the changes in pulmonary function, are manifestations common to many other respiratory diseases and conditions. /Isocyanates/[DHHS; Centers for Disease Control and Prevention - National Institute for Occupational Safety and Health; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 (January 2004). Available from, as of March 20, 2012: http://www.cdc.gov/niosh/docs/2004-116/] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ At high doses the isocyanates affect the mucous membranes of the respiratory tract and may lead to fatal pulmonary edema or chronic catarrh. Exposure to low & often even unmeasurable isocyanate concentrations results in sensitization of organisms either by local injury accompanied by the formation of heterogeneous protein to which the organism becomes allergic or by secondary bacterial. /Isocyanates/[Kopecny J, Sevcik M; Chem Prum 30 (7): 372 (1980)] **PEER REVIEWED** /CASE REPORTS/ Group of 24 workers, handling diisocyantes, were investigated by occupational-type bronchial provocation tests for sensitivity to toluene diisocyanate, MDI, and hexamethylene diisocyanate. Eight gave asthmatic reactions to MDI. The possibility of specific sensitivity to diisocyanates may occur.[O'BRIEN IM ET AL; CLIN ALLERGY 9 (1): 1 (1979)] **PEER REVIEWED** PubMed Abstract /CASE REPORTS/ Long-term effect of 4,4'-diphenyl methane diisocyanate on the respiratory system of 318 workers suggests that such workers may develop fibrosis. Long-term exposure tends to restrict pulmonary function and cause decrease in CO single breath transfer factor.[PHAM QT ET AL; ANN OCCUP HYG 21 (2): 121 (1978)] **PEER REVIEWED** PubMed Abstract /CASE REPORTS/ Of 44 workers exposed during production of polyurethane foam for an average of 16 mo, 19 (43.55%) had stress breathlessness but no changes in lung ventilation, and 70% had hyperemia of the conjunctiva. Of 180 workers exposed ... 19% had chronic obstructive lung disease and 21% simple bronchitis. Antibodies to MDI were found in workers exposed to 1.3 ppm/min (13 mg/cu m/min), but not when they were exposed to 0.9 ppm/min (9 mg/cu m/min).[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V19 319 (1978)] **PEER REVIEWED** /CASE REPORTS/ The case of a 34-year-old female nurse is presented. She worked in an accident and emergency department in a district general hospital, with methylene diphenyl diisocyanate (MDI)-containing synthetic plaster casts. She worked with MDI on a daily basis for 4 years. She was out of the department for 1 year and on her return developed cough, wheeze and dyspnea within 5 min of exposure to MDI- containing synthetic casts. A bronchial provocation test was performed and confirmed an early asthmatic response.There was a 39% decrease in the forced expiratory volume in 1 s 15 min after exposure, which required the administration of a bronchodilator on two occasions. The patient has subsequently avoided MDI-containing synthetic plaster casts and has experienced no further respiratory symptoms.This case illustrates that respiratory sensitization can occur as a result of exposure to MDI-containing synthetic casts and highlights the need for vigilance when health care workers are using isocyanate-containing synthetic casts.[Donnelly R et al; Occup Med (Lond) 54 (6): 432-4 (2004)] **PEER REVIEWED** PubMed Abstract /CASE REPORTS/ /Researchers/ assessed the signs and symptoms, pulmonary function changes and residual chemical body burden of school children in the vicinity of an accidental exposure to volatile xylene and methylene diphenyl diisocyanate (MDI). After the exposure episode, children with significant symptoms after MDI exposure (e.g., dizziness, nausea, sore

throat, and breathing difficulties) were sent to nearby emergency medical units for evaluation and admission if necessary. Clinical work-up included pulmonary function tests and measurement of residual MDI in the body by high-performance liquid chromatography analysis of urine. 203 students appeared to develop symptoms associated with contaminant exposure, and 173 affected students were sent to nearby emergency units. In the subsequent surveillance, 22 of 203 affected students (10.8%) revealed a positive history of asthma, which was strongly correlated with the incidence of dyspnea arising from the incident. For children with no previous history of asthma, 60.8% (110 of 181) complained of dyspnea during the episode, and 16.2% required inhaled bronchodilator therapy at the emergency medical units for relief of wheezing symptoms. In a simulation, /researchers/ found the raw material used for tract surfacing, primarily MDI dissolved in xylene, to be present at a concentration (870 ppm w/w) more than 8000-fold the level defined as safe for a working environment. /Researchers/ have detected a direct cause-effect relationship between the accidental spillage of MDI and the appearance of an acute asthma-like syndrome among previously unexposed school children.[Jan RL et al; J Microbiol Immunol Infect 41 (4): 337-41 (2008)] **PEER REVIEWED** PubMed Abstract /CASE REPORTS/ Inhalation of a mixture of MDI (60%), various triisocyanates (30%) and undefined isocyanates (10%) in concentrations of 5 to 20 ppb increased the occurrence of double strand breaks in the leukocytes of a 51-year-old worker occupationally exposed to MDI and MDI oligomers. Analyses were made both before and two hours after an exposure, after the subject had been away from work for 5 days. As a further control, the blood of a healthy unexposed person was also examined.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.78 (2001). Available from, as of March 10, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /EPIDEMIOLOGY STUDIES/ /The aim of this study was/ to assess whether cancer incidence and mortality in chronic obstructive lung diseases were increased in the Swedish polyurethane foam industry cohort, updated with 11 more years of follow up. The mortality and cancer incidence (1959-98) experienced by a cohort of 4175 male and female employees employed for at least one year in the period 1959-87 at one of nine Swedish polyurethane foaming plants were investigated. Comparisons were based on calendar year, sex, and five-year age group specific mortality and incidence rates for Sweden. Workplaces and job tasks were categorically assessed for exposure to toluene diisocyanate (TDI) and methylene diphenyldiisocyanate (MDI) by occupational hygienists. Fewer cancer cases than expected were observed, but the lung cancer incidence was enhanced in women. Women with "apparent exposure" to TDI or MDI did not, however, have a higher lung cancer incidence than those with "no or low exposure". Moreover, a nested case referent study did not find that polyurethane dust exposure had been more prevalent among the female lung cancer cases than among referents. No increased mortality in chronic obstructive lung diseases was observed in the cohort. Results support the findings from two other cohort studies of an increased lung cancer risk among female workers in the polyurethane foam manufacturing industry. Chance or confounding from smoking are not obvious explanations for the coherent findings. However, the study was not able to link isocyanate exposed employment with lung cancer risk.[Mikoczy Z et al; Occup Environ Med 61 (5): 432-7 (2004)] **PEER REVIEWED** PubMed Abstract Full text: PMC1740788 /EPIDEMIOLOGY STUDIES/ The respiratory effects of diphenylmethane diisocyanate (MDI)-based resins and ureaformol- and formophenolic-based resins, used in coal mining, are unknown. This cross-sectional study of 354 miners evaluated respiratory health in miners with MDI-related symptoms (IS) and ureaformol/formophenolic-related symptoms (UFS). The protocol included clinical examination, chest radiograph, questionnaire on respiratory symptoms, smoking habit, job history, resin handling, and spirometry. Resin handling concerned 27.7% of the miners. IS affected 5.6%, and 1.4% also after work. UFS affected 22.6%, and 2.3% also after work. Wheezing affected 35.6%; chronic cough, expectoration, or bronchitis about 10%; dyspnea 5.4%; and asthma 2.8%. The miners with UFS had significantly more frequent chronic cough, expectoration, chronic bronchitis, dyspnea, and wheezing, whereas those with IS at and after work had markedly lower FVC, FEV1, MMEF, FEF50%, and FEF25%. These findings raise the possibility of deleterious effects of exposures to MDI and ureaformol/formophenolic resins on respiratory health and lung function in coal miners during their working life.[Bertrand JP et al; Int J Occup Environ Health 13 (2):181-7 (2007)] **PEER REVIEWED** PubMed Abstract /EPIDEMIOLOGY STUDIES/ To identify effect modification produced by genetic traits found in metabolic enzymes, to investigate how these affect the levels of different biomarkers of sprayed and thermo-degraded polyurethane (PUR) based on 4,4'-diphenylmethane diisocyanate (MDI) and to determine how associated respiratory disorders are affected. Two partly overlapping groups of 141 and 158 factory employees exposed to sprayed or heated MDI-PUR glue were examined in years 0 and 2, respectively, for occurrence of polymorphisms in five genes (N-acetyltransferase NAT2 and the glutathione S-transferases

GSTM1, GSTM3, GSTP1 [codon 105 and 114] and GSTT1) on the basis of the polymerase chain reaction, exposure biomarkers in plasma and urine (P- and U-MDX), by means of gas chromatography-mass spectrometry, specific serum IgG antibodies against MDI (S-IgG-MDI) by means of ELISA, total S-IgE, symptoms in the eyes, nose and lower airways as assessed by questionnaire and interview, and lung function as measured by spirometry. Both the GSTP1 (105) isoleucine/isoleucine and GSTP1 (114) alanine/alanine genotypes showed higher levels of U-MDX than the other genotypes and the GSTP1 (114) genotype modified the P-MDX/U-MDX relationship. GSTP1 (105) isoleucine/isoleucine was found to be associated with lower levels of S-IgG-MDI and fewer eye symptoms, but with an increased risk of symptoms in the airways, as well as with atopy. Presence of the GSTT1 gene resulted in somewhat lower lung function levels than did the null genotype. A slow NAT2 acetylating capacity was associated with lower P- and U-MDX and S-IgG-MDI levels, and better lung function, but a higher risk of eye and airway symptoms.[Littorin M, et al; Int Arch Occup Environ Health 81 (4): 429-41 (2008)] **PEER REVIEWED** PubMed Abstract /EPIDEMIOLOGY STUDIES/ A nested case-control study was carried out in an expanded cohort of 7023 men and women from the same factories. The subjects had worked during 1958-87, but unlike in the cohort study, no minimum period of employment was specified. Each of 119 subjects with a cancer registered during 1959-87 was matched with three controls of the same sex and age (to within six years), who were under follow-up at the time the cancer occurred. Because of missing information, the final analysis was based on 114 cases and 313 referents. Exposures were rated by an occupational hygienist who was unaware of subjects' disease status, and risks were estimated by conditional logistic regression. No association was found between exposure to isocyanates and overall cancer incidence (odds ratio, 0.9; 90% CI, 0.6-1.3). Nor was there any association with rectal cancer. Among subjects with high exposure there was a non-significant increase in prostate cancer (4 cases; odds ratio, 2.7; 95% CI, 0.4-18.1). /Isocyanates/[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 868 (1999)] **PEER REVIEWED** /SURVEILLANCE/ A cross-sectional evaluation was performed of workers in a steel foundry in which methylene diphenyldiisocyanate was used as a component of a binder system used to make cores and molds. Preshift spirometry and clinical evaluations were performed on 26 currently exposed (group I), on six formerly exposed (group II), and on 14 nonexposed workers to 4,4'-diisocyanatodiphenylmethane (group III). Serum samples were assayed for total antibody binding, specific immunoglobulin-E by enzyme linked immunosorbent assay, and specific immunoglobulin-E by the RAST method to 4,4'-diisocyanatodiphenylmethane human serum albumin. Symptoms compatible with occupational asthma were elicited from seven (27%) of 26 group I workers and from three of six group II workers. No symptoms were reported by group III workers. Intrashift change in FEV1 (a mean decrease of 0.049 liters) in group I workers was significantly decreased compared to that in unexposed group III workers (a mean increase of 65 mL; p= 0.043). Specific immunoglobulin- E and total antibody responses to 4,4'-diisocyanatodiphenylmethane-human serum albumin were detected only in workers with current or former exposure to 4,4'-diisocyanatodiphenylmethane. Only one worker was identified with immunoglobulin-E mediated occupational asthma exhibiting a positive prick test and elevated RAST to 4,4'-diisocyanatodiphenylmethane-human serum albumin of 25.5% bound. In this occupational setting, polyclonal immune responses to 4,4'-diisocyanatodiphenylmethane-human serum albumin and clinical sensitization to 4,4'-diisocyanatodiphenylmethane were demonstrated to occur.[Liss GM et al; J Allergy Clin Immunol 82 (1): 55-61 (1988)] **PEER REVIEWED** PubMed Abstract /SURVEILLANCE/ ... The objective of this research was to quantify dermal and inhalation exposure levels in iron foundry workers. Workers involved in mechanized moulding and mechanized production of cores were monitored: 12 core makers, 2 core-sand preparers, and 5 core installers. Personal breathing-zone levels of MDI were measured using impregnated filter sampling. Dermal exposure to MDI was measured using a tape-strip technique. Three or five consecutive tape-strip samples were collected from five exposed skin areas (right and left forefingers, left and right wrists, and forehead). The average personal air concentration was 0.55 ug/cu m, 50-fold lower than the Swedish occupational exposure limit of 30 ug/cu m. The core makers had an average exposure of 0.77 ug/cu m, which was not significantly different from core installers' and core-sand preparers' average exposure of 0.16 ug/cu m (P = 0.059). Three core makers had a 10-fold higher inhalation exposure than the other core makers. The core makers' mean dermal exposure at different skin sites varied from 0.13 to 0.34 ug while the two other groups' exposure ranged from 0.006 to 0.062 ug. No significant difference was observed in the MDI levels between the skin sites in a pairwise comparison, except for left forefinger compared to left and right wrist (P < 0.05). In addition, quantifiable but

decreasing levels of MDI were observed in the consecutive tape strip per site indicating MDI penetration into the skin. This study indicates that exposure to MDI can be quantified on workers' skin even if air levels are close to unquantifiable. Thus, the potential for uncured MDI to deposit on and penetrate into the skin is demonstrated. Therefore, dermal exposure along with inhalation exposure to MDI should be measured in the occupational settings where MDI is present in order to shed light on their roles in the development of occupational isocyanate asthma.[Liljelind I et al; Ann Occup Hyg 54 (1): 31-40 (2010)] **PEER REVIEWED** PubMed Abstract /SURVEILLANCE/ Worker exposure to MDI (methylenediphenyl isocyanate) in the sprayed-on truck bed lining industry was assessed by examining Washington State OSHA inspection files and industrial insurance records. The industry uses MDI to form a protective urethane coating on pick-up truck beds. The lining is applied by a worker using a handheld spray gun with application equipment at temperatures and pressures specified by the urethane supplier. Inspections with MDI sampling were initially identified by searching the agency's laboratory database and were further screened for the targeted process. Data for 13 employers was found and extracted from the inspection records. All were small companies with only 1 to 2 workers exposed to MDI; 10 of the 13 employers had started the bed lining service within the last 4 years. The process was found in truck bed lining specialty shops as well as in other truck-related businesses. Six different urethane products were used with reported MDI monomer concentrations of up to 75 percent along with varying concentrations of MDI pre-polymers and other reactants and solvents. Sampling for MDI by inspectors found 7 worksites with worker exposure in excess of the state and OSHA ceiling limit of 0.200 mg/cu m. Deficiencies in respirator programs and engineering controls for MDI were cited. A review of the industrial insurance records found a total of five MDI-related claims at 4 inspected worksites, two for new-onset asthma. It was concluded that workers in the urethane sprayed-on truck bed lining industry are at an increased risk of developing illnesses associated with isocyanate exposure. Interventions are needed to further assess the hazard as well as motivate and assist franchisers, distributors, and retailers to implement effective engineering controls and respiratory protection programs in this nationally emerging small employer industry.[Lofgren DJ et al; Appl Occup Environ Hyg 18 (10): 772-9 (2003)] **PEER REVIEWED** PubMed Abstract /SURVEILLANCE/ Questionnaires are essential tools for medical screening, but their role in monitoring workers at increased risk of occupational asthma (OA) remains indeterminate. Employees who were at a newly established wood products plant without previous exposure to methylene diphenyl diisocyanate (MDI) completed an initial questionnaire and from one to four follow-up questionnaires during a 2-year period. Onset of symptoms in 132 workers was assessed by exposure groups and modeled using generalized estimating equations.Onset of attacks of dyspnea with wheeze, attacks of dyspnea or cough at rest, and chest tightness were significantly associated with MDI exposure after controlling for age, smoking, and wood dust exposure. Onset of cough on most days was significantly related to smoking and dust. Onset of phlegm production was significantly related to both MDI and dust exposure. Onset of certain symptoms is significantly associated with MDI exposure.[Wang ML, Petsonk EL; Am J Ind Med 46 (3): 226-33 (2004)] **PEER REVIEWED** PubMed Abstract /BIOMONITORING/ The objectives of this study were to determine the levels of biomarkers of exposure to several diisocyanates in the urine and blood of occupationally unexposed workers and to calculate their upper reference limits (URLs). Biomarker levels were determined in urinary and plasma samples obtained from 121 occupationally unexposed workers. URLs were then calculated based on these biomarker levels and the levels in an occupationally exposed group of workers. These URLs may be used for screening for occupational exposure, a worker with a biomarker level above the URL being classified as occupationally exposed. Biomarkers of aromatic diisocyanates, especially biomarkers of 4,4'-methylenediphenyl diisocyanate, were present among occupationally unexposed workers, but the source and nature of the exposure is unknown[Sennbro CJ etal; International Archives of Occupational and Environmental Health 78 (7): 541-546 (2005)] **PEER REVIEWED** /BIOMONITORING/ 4,4'-Methylenediphenyl diisocyanate (MDI) is the most important isocyanate in the manufacture of polyurethanes, dyes, pigments and adhesives. High concentrations of isocyanates are a potent respiratory irritant. Therefore, it is important to develop methods to monitor exposure to such compounds. /Researchers/ monitored biological samples from 40 non-exposed and 45 exposed construction site workers. 4,4'-Methylenedianiline (MDA) and N-acetyl-4,4'-MDA (AcMDA) were determined from untreated urine (U-MDA, U-AcMDA) and MDA was analysed from acid-treated urine (U-MDA-tot). Hemoglobin (Hb) adducts of MDA (Hb-MDA) were determined in all workers. The levels of biomarkers decreased in the following order: U-MDA-tot>U-AcMDA>U-MDA>Hb-MDA. The same order was found for the percentage of samples, which were found positive in exposed workers: 100%, 91%, 91%, 27%. The urine levels U-MDA-tot correlate with U-MDA, U-AcMDA and Hb-MDA with r=0.79, 0.86 and 0.39, respectively (Spearman rank order, $p<0.01$). U-AcMDA correlates with U-

MDA and Hb-MDA with r=0.77 and 0.47, respectively (p<0.01). U-MDA correlates with Hb-MDA (r=0.38, p<0.05). The levels in the controls were significantly lower than in the exposed workers for all compounds (Mann-Whitney test, p<0.01). The median isocyanate-specific IgE-level was higher in the exposed workers, but the difference was statistically not significant. The change of the biomarker levels was compared in a group of workers (n=20), which were analysed prior to isocyanate exposure and after the exposure for approximately 4-7 months. All urine MDA metabolites and the Hb-adduct levels increased significantly (Wilcoxon sign test, p<0.01). Total IgE increased significantly after the exposure with isocyanate activity (p<0.01). With the present work it could be shown that outdoor workers are exposed to a similar extent as workers from a MDI factory. [Sabbioni G et al; Biomarkers 12 (5): 468-83 (2007)] **PEER REVIEWED** PubMed Abstract /BIOMONITORING/ Although methylene diphenyl diisocyanate (MDI) may induce occupational asthma in the workplace, the pathogenic mechanisms are unclear. /In this paper/ by using bronchoalveolar lavage fluid, /it was/ sought to identify proteins that were differentially expressed between subjects with MDI-induced occupational asthma (MDI-OA) and asymptomatic exposed controls (AECs). To find proteins that were differentially expressed between the MDI-OA and AEC groups, 2-dimensional electrophoresis was performed by using bronchoalveolar lavage fluid obtained from subjects after MDI-specific inhalation challenge. The selected protein spots were then identified by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry. The clinical relevance of the differentially expressed spots was compared by ELISA using sera from the MDI-OA/eosinophilic bronchitis, AEC, and unexposed healthy control groups. Receiver operating characteristic curves were then plotted, and the sensitivity and specificity were determined. Twenty-three protein spots were identified that distinguished the subjects with MDI-OA from those in the AEC group. Among them, ferritin expression was downregulated whereas transferrin expression was upregulated in subjects with MDI-OA compared with AEC; these results were validated by ELISA using sera from the MDI-OA/EB and AEC groups. To identify subjects with MDI-OA, the optimal serum cutoff levels were 69.84 ng/mL for ferritin and 2.48 ug/mL for transferrin. When these 2 parameters were combined, the sensitivity was 71.43% and the specificity was 85.71%.Serum ferritin and transferrin levels are associated with the phenotype of MDI-OA.[Hur GY et al; J Allergy Clin Immunol 122 (4): 774-80 (2008)] **PEER REVIEWED** PubMed Abstract /BIOMONITORING/ In a polyurethane production facility where air concentrations of MDI were usually below the detection limit, measurable amounts of 4,4'-MDA (0.035-0.83 pmol/mL) and AcMDA (0.13-7.61 pmol/mL) could be found in urine in 15 of 20 workers after alkaline extraction, and MDA values were 6.5 times higher after acid hydrolysis. MDA was found as hemoglobin adducts in all the examined workers, and one worker also had adducts of AcMDA. Plasma levels of 4,4'-MDA ranged from 0.25 to 5.4 pmol/mL, up to 120 fmol/mg of which was covalently bound to albumin. 2,4-TDA, 2,6-TDA and 4,4'-MDA could be found in hydrolyzed urine from 15 workers at a workplace where TDI- and MDI-based polyurethane was heated. The levels fluctuated widely from day to day. Levels of these metabolites in plasma were much more stable. In four of the monitored workers the levels of MDA declined during an exposure-free period, with biological half times of 2.5- 3.4 days in urine and 10-22 days in plasma. It has long been known that some persons exposed to isocyanates form antibodies specific to conjugates of the isocyanate and serum albumin. These are of doubtful pathogenic relevance, but may be used as biomarkers of exposure (for those persons who develop antibodies). Three percent of workers exposed to spray aerosols of glue based on MDI or HDI had specific IgE antibodies, while 33% had IgG specific to MDI, 32% to TDI and 12% to HDI. After exposure stops, the titer of specific antibodies declines, but it may remain elevated for as long as five years.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.66 (2001). Available from, as of March 8, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /GENOTOXICITY/ Diisocyanates are chemically reactive and induce asthma, but data on genotoxic effects of diisocyanates in humans are limited. The investigation presented here used short term diisocyanate chamber exposure to study DNA strand breaks in lymphocytes of 10 healthy individuals and of 42 workers, with airway symptoms, who had previously been exposed to diisocyanates. The alkaline version of the Comet assay was used to analyze DNA strand breaks in lymphocytes. In addition, blood samples of 10 further control individuals without any exposure to diisocyanates were studied. Substances studied were 4,4'-methylenediphenyldiisocyanate (MDI, n=25), 2,4-toluenediisocynate and 2,6-toluenediisocyanate (TDI, n=5), and 1,6-hexamethylenediisocyanate (HDI, n=12), at concentrations between 5 and 30 ppb for 2 hr. Lymphocytes isolated from the subjects before exposure and 30 min and 19 hr after were used to evaluate DNA damage. No significant changes in DNA strand-break frequencies were measured, as Olive tail moment (OTM), either between groups or before and after diisocyanate exposure. OTM was similar in subjects with an asthmatic reaction (MDI, n=5; TDI, n=1; HDI, n=1)

and in subjects without such a reaction. However, a small and susceptible group (about 10% of the individuals studied) could be identified with higher frequencies of DNA strand breaks in lymphocytes after chamber exposure. The occurrence of DNA damage in this group may be based on indirect mechanisms such as oxidative stress or apoptosis.[Marczynski B et al; Arch Toxicol 79 (6): 355-62 (2005)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ Diisocyanates are highly reactive compounds widely used, for example, in the production of polyurethane foams, elastomers, paints, and adhesives. The high chemical reactivity of these compounds is also reflected in their toxicity: diisocyanates are one of the most important causes of occupational asthma but also other adverse effects, such as irritation and toxic reactions, have been described in exposed subjects. One of the open questions is whether occupational isocyanate exposure is a carcinogenic hazard. The few epidemiological studies available have been based on young cohorts and short follow-up and are not conclusive. Toluene diisocyanate (TDI) has been classified as carcinogenic in animals on the basis of gavage administration studies, but no conclusions are available on inhalation exposure. For 4,4'-methylene diphenyldiisocyanate (MDI) there is suggestive evidence for carcinogenicity in rats. The possible carcinogenic mechanism of TDI and MDI is not clear. Both chemicals have been positive in a number of short-term tests inducing gene mutations and chromosomal damage. The reactive form could be either the diisocyanate itself or may derive from the metabolic activation of the aromatic diamine derivatives formed by hydrolysis. TDI and MDI react with DNA in vivo and in vitro. However, the structure of the adducts has not been identified. Especially from the in vivo experiment it is not known if the adducts are a product from the reaction with the isocyanate or the corresponding amine. In conclusion, both TDI and MDI are highly reactive chemicals that bind to DNA and are probably genotoxic. The alleged animal carcinogenicity of TDI and MDI would suggest that occupational exposure to these compounds is a carcinogenic risk. The few epidemiological studies available have not, however, been able to clarify if TDI and MDI are occupational carcinogens. [Bolognesi C et al; Crit Rev Toxicol 31 (6): 737-72 (2001)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ IRRITANT & ALLERGIC SENSITIZER. SUMMARY TOXICITY STATEMENT; MODERATELY TOXIC. MODERATE= MAY CAUSE REVERSIBLE OR IRREVERSIBLE CHANGES TO EXPOSED TISSUE, NOT PERMANENT INJURY OR DEATH; CAN CAUSE CONSIDERABLE DISCOMFORT.[Sax, N.I. Dangerous Properties of Industrial Materials. 6th ed. New York, NY: Van Nostrand Reinhold, 1984., p. 1236] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ Toxic by inhalation of fumes. Strong irritant.[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 465] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ As a result of the physical characteristic of low but significant vapor pressure, there is a potential for both vapor and particulate exposure in one of the current application of MDI, namely, in foam or film coating of surfaces by spray-gun techniques. Measurements of environmental contamination during the foam application showed levels of total MDI as high as 5 mg/cu m. More than 95% of the high samples were particulates of respirable size range; counts were from 2-8 mppcf. MDI vapor concns at the breathing zone during application did not exceed 0.02 ppm.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 978] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ The ability of diisocyanate antigens to detect specific antibodies in exposed workers and guinea pigs was investigated. Sera were obtained from male English short hair guinea pigs that had been immunized with 4,4'-diisocyanatodiphenylmethane and three workers who had been occupationally exposed to 4,4'-diisocyanatodiphenylmethane. Two workers had symptoms of hypersensitivity pneumonitis and a third symptom of occupational asthma. The serum samples were reacted with antigens prepared by reacting 4,4'-diisocyanatodiphenylmethane with guinea pig serum albumin or human serum albumin and tested for their ability to recognize 4,4'-diisocyanatodiphenylmethane specific antigens utilizing the radioallergosorbent test, the enzyme linked immunosorbent assay, or the Western Blot assay.[Jim R, Karol MH; Chem Res Toxicol 1 (5): 288-93 (1988)] **PEER REVIEWED** PubMed Abstract

Skin, Eye and Respiratory Irritations:

Irritating /to/ eyes, nose, throat.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** A skin and eye irritant. An allergic sensitizer.[Lewis, R.J. Sr. (ed) Sax's Dangerous

Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 2435] **PEER REVIEWED**

Probable Routes of Human Exposure:

... WHEN MDI PREPN ARE SPRAYED OUT OF DOORS OR IN MINE SHAFTS, PERSONS 40 M OR MORE DOWNWIND MAY BE AFFECTED BY UNREACTED ISOCYANATE IN DROPLETS CARRIED BY AIR CURRENT.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1099] **PEER REVIEWED** EARLY INDUSTRIAL EXPERIENCE IN HANDLING MDI /METHYLENEBIS(4-PHENYLISOCYANATE)/ REVEALED NO CASES OF SKIN IRRITATION. MDI ADHERES FIRMLY TO SKIN, HOWEVER, & IRRITATION MAY BE INCR OR PRODUCED BY ATTEMPTS AT REMOVAL.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values, 4th ed., 1980. Cincinnati, Ohio: American Conference of Governmmental Industrial Hygienists, Inc., 1980., p. 274] **PEER REVIEWED** ... THE PHYSICAL CHARACTERISTIC OF LOW BUT SIGNIFICANT VAPOR PRESSURE PRESENTS BOTH A VAPOR & PARTICULATE /(DROPLET)/ EXPOSURE IN ONE OF THE CURRENT APPLICATION MDI NAMELY, IN FOAM- OR FILM-COATING OF SURFACES BY SPRAY-GUN TECHNIQUES. MEASURING ENVIRONMENTAL CONTAMINATION DURING THE FOAM APPLICATION SHOWED LEVELS OF TOTAL MDI AS HIGH AS 5 MG/CU M. MORE THAN 95% OF HIGH SAMPLES WERE PARTICULATES OF RESPIRABLE SIZE RANGE, COUNTS WERE FROM 2 TO 8 MILLION PARTS/CU FT. MDI VAPOR CONCN AT BREATHING ZONE DURING APPLICATION DID NOT EXCEED 0.02 PPM (0.2 MG/CU M).[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 978] **PEER REVIEWED** According to the 2006 TSCA Inventory Update Reporting data, the number of persons reasonably likely to be exposed in the industrial manufacturing, processing, and use of 4,4'-methylenediphenyl diisocyanate is 1000 or greater; the data may be greatly underestimated(1).[(1) US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Feb 21, 2012: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED** NIOSH (NOES Survey 1981-1983) has statistically estimated that 53,321 workers (13,421 of these were female) were potentially exposed to 4,4'-methylenediphenyl diisocyanate in the US(1). Occupational exposure to 4,4'-methylenediphenyl diisocyanate may occur through inhalation and dermal contact with this compound at workplaces where 4,4'-methylenediphenyl diisocyanate is produced or used(SRC). The concentration of 4,4'-methylenediphenyl diisocyanate in a Swedish aluminum foundry ranged from <0.0001 to 0.00018 mg/cu m; more than 75% of the 27 samples were below the detection limit of 0.003 mg/cu m(2). The compound presents high potential exposure in those in electrical machinery production as well as to carpenters, painters, and construction workers(3). Use data indicate that the general population may be exposed to 4,4'-methylenediphenyl diisocyanate via inhalation and dermal contact with consumer products containing this compound(SRC).[(1) NIOSH; NOES. National Occupational Exposure Survey conducted from 1981-1983. Estimated numbers of employees potentially exposed to specific agents by 2-digit standard industrial classification (SIC). Available from, as of Feb 24, 2012: http://www.cdc.gov/noes/ (2) Westberg HB et al; Appl Occup Environ Hyg 16: 66-77 (2001) (3) Brandorff NP et al; Occup Environ Med 52: 454-63 (1995)] **PEER REVIEWED** Emissions of 4,4'-methylenediphenyl diisocyanate into the workplace air from 12 polyurethane coatings during application and drying did not exceed 0.20 mg/cu m (0.02 ppm) in the US and 0.07 mg/cu m (0.007 ppm) in Italy(1). The air concentration of 4,4'-methylenediphenyl diisocyanate was monitored during the spray application of polyurethane foam at indoor and outdoor locations(2); the sprayer and his helpers were exposed to concentrations ranging from 0.001 to 0.129 ppm(2); concentrations at distances greater than 25 ft away were negligible(2).[(1) IARC; IARC Monographs on the Evaluation of Carcinogenic Risks to Humans 19: 315-9 (1979) (2) Bilan RA et al; Am Ind Hyg Assoc J 50: 303-6 (1989)] **PEER REVIEWED**
Emergency Medical Treatment:

Emergency Medical Treatment:

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The following Overview, *** TOLUENE DIISOCYANATE ***, is relevant for this HSDB record chemical.

Life Support:

o This overview assumes that basic life support measures have been instituted.

Clinical Effects:

0.2.1 SUMMARY OF EXPOSURE

0.2.1.1 ACUTE EXPOSURE

A) USES: Toluene diisocyanate (TDI) is one of the isocyanates most employed in the manufacture of polyurethane foams, elastomers, and coatings.

B) TOXICOLOGY: TDI is an irritant to mucous membranes of the eyes, the gastrointestinal and the respiratory tract. It also causes a marked inflammatory reaction on direct skin contact. In some individuals, low level repeated exposure to TDI can cause respiratory sensitization and asthma.

C) EPIDEMIOLOGY: Most exposures are occupational either via inhalation or dermal contact.

D) WITH POISONING/EXPOSURE

1) MILD TO MODERATE TOXICITY: TDI is an irritant to the skin, lungs, conjunctiva and gastrointestinal tract.

2) SEVERE TOXICITY: Laryngitis, chest pain, bronchospasm, sensation of oppression or constriction of the chest, bronchitis, emphysema, pneumonitis and cor pulmonale may result from exposure. Continued exposure to TDI in an asthmatic patient resulted in a fatality. Severe conjunctival irritation and lacrimation may result from exposure to liquid or high vapor concentrations. Glaucoma and iridocyclitis have been reported with a splash exposure.

0.2.3 VITAL SIGNS

0.2.21 CARCINOGENICITY

0.2.21.1 IARC CATEGORY

A) IARC Carcinogenicity Ratings for CAS26471-62-5 (International Agency for Research on Cancer (IARC), 2016; International Agency for Research on Cancer, 2015; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010a; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2008; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2007; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2006; IARC, 2004):

1) IARC Classification

a) Listed as: Toluene diisocyanates

b) Carcinogen Rating: 2B

1) The agent (mixture) is possibly carcinogenic to humans. The exposure circumstance entails exposures

that are possibly carcinogenic to humans. This category is used for agents, mixtures and exposure circumstances for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals. It may also be used when there is inadequate evidence of carcinogenicity in humans but there is sufficient evidence of carcinogenicity in experimental animals. In some instances, an agent, mixture or exposure circumstance for which there is inadequate evidence of carcinogenicity in humans but limited evidence of carcinogenicity in experimental animals together with supporting evidence from other relevant data may be placed in this group.

B) IARC Carcinogenicity Ratings for CAS1321-38-6 (International Agency for Research on Cancer (IARC), 2016; International Agency for Research on Cancer, 2015; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010a; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2008; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2007; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2006; IARC, 2004):

1) Not Listed

0.2.21.2 HUMAN OVERVIEW

A) Toluene diisocyanate is considered a suspected or possible human carcinogen, based on sufficient evidence of carcinogenicity or tumors (tumors of the spleen, subcutaneous, hepatic, ovarian, peritoneum, and mammary gland tissues) in experimental animals.

0.2.22 GENOTOXICITY

A) Sister chromatid exchange values were considerably higher in peripheral blood lymphocytes of 26 workers exposed to TDI in 1 study. There were mixed results in 2 studies of DNA fragmentation patterns after exposure to isocyanates. Micronucleus test values in peripheral blood lymphocytes of workers (n=26) exposed to TDI were almost 3 times greater than in a control group (Marczynski et al, 2005; Bilban, 2004; Marczynski et al, 2003).

Laboratory:

A) Monitor vital signs and mental status, monitor pulmonary exam.

B) Monitor pulse oximetry and/or arterial blood gases, chest radiograph and pulmonary function tests in patients with respiratory signs/symptoms.

Treatment Overview:

0.4.2 ORAL EXPOSURE

A) MANAGEMENT OF MILD TO MODERATE TOXICITY

1) Treatment consists of predominantly symptomatic and supportive care. Monitor patient for respiratory distress. If a cough or breathing difficulty develops, evaluate for respiratory tract irritation, bronchitis and pneumonitis. If bronchospasm develops, administer inhaled (beta 2 adrenergic agonists) and oxygen as needed. Consider systemic corticosteroids in patients with significant bronchospasm. Sensitized individuals should be monitored for severe allergic reaction. These people are at risk for severe asthma and anaphylaxis and should be cautioned to avoid further exposure.

B) MANAGEMENT OF SEVERE TOXICITY

1) In patients who develop severe toxicity, treatment should be primarily focused on airway management. Administer 100% humidified supplemental oxygen, perform endotracheal intubation and provide assisted ventilation as required. Administer inhaled beta 2 adrenergic agonists and systemic steroids.

C) DECONTAMINATION

1) PREHOSPITAL: GI decontamination is not indicated, toxicity is from irritant effects and sensitization, not systemic absorption. Irrigate exposed eyes with water. Remove contaminated clothing and wash exposed skin with soap and water. Administer oxygen to patients with respiratory irritation after inhalation.
2) HOSPITAL: GI decontamination is not indicated, toxicity is from irritant effects and sensitization, not systemic absorption. Irrigate exposed eyes copiously with 0.9% saline. Remove contaminated clothing and wash exposed skin with soap and water. Administer oxygen to patients with respiratory irritation after inhalation.

D) AIRWAY MANAGEMENT

1) Administer 100% humidified supplemental oxygen, perform endotracheal intubation and provide assisted ventilation as required. Administer inhaled beta 2 adrenergic agonists and systemic steroids if bronchospasm develops.

E) ANTIDOTE

1) There is no specific antidote for treatment of TDI exposure.

F) PATIENT DISPOSITION

1) HOME CRITERIA: Patients who are asymptomatic or have minimal irritation after small exposures can be managed at home or the work place.
2) OBSERVATION CRITERIA: Symptomatic patients, patients with known or suspected sensitization, or patients with known large exposures should be referred to a healthcare facility for evaluation and treatment, and observed for 6 hours for signs of toxicity.
3) ADMISSION CRITERIA: Patients with significant symptoms should be admitted for treatment and monitoring. Patients with respiratory failure should be admitted to an ICU setting.
4) CONSULT CRITERIA: Contact a medical toxicologist or poison center for any patient with severe toxicity. Consult an ophthalmologist for patients with severe eye irritation or splash exposure. Patients with an occupational exposure should be referred to an occupational physician and industrial hygienist.

G) PITFALLS

1) Failure to recognize and aggressively treat severe bronchospasm. Patients with inhalation exposure are at risk for sensitization and severe bronchospasm with subsequent exposure. Careful workplace evaluation is required in the event of occupational exposure.

H) DIFFERENTIAL DIAGNOSIS

1) Acute asthma attack, COPD with acute exacerbation, chlorine gas exposure, ammonia gas exposure, other irritant exposure.

0.4.3 INHALATION EXPOSURE

A) INHALATION: Move patient to fresh air. Monitor for respiratory distress. If cough or difficulty breathing develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. Administer oxygen and assist ventilation as required. Treat bronchospasm with an inhaled beta2-adrenergic agonist. Consider systemic corticosteroids in patients with significant

bronchospasm.
B) Randomized, double-blind cross-over studies showed minimal efficacy of bronchodilator therapy. This may be due to the absence of airway hyperresponsiveness in some TDI-induced asthma.

0.4.4 EYE EXPOSURE

A) DECONTAMINATION: Remove contact lenses and irrigate exposed eyes with copious amounts of room temperature 0.9% saline or water for at least 15 minutes. If irritation, pain, swelling, lacrimation, or photophobia persist after 15 minutes of irrigation, the patient should be seen in a healthcare facility.

0.4.5 DERMAL EXPOSURE

A) OVERVIEW

1) DECONTAMINATION: Remove contaminated clothing and jewelry and place them in plastic bags. Wash exposed areas with soap and water for 10 to 15 minutes with gentle sponging to avoid skin breakdown. A physician may need to examine the area if irritation or pain persists (Burgess et al, 1999).

Range of Toxicity:

A) TOXICITY: Available dose-response information concerning humans pertains to inhalational exposure. Concentrations of 2.5 ppm are considered Immediately Dangerous to Life or Health (IDLH). Continued exposure to TDI in an asthmatic patient resulted in a fatality.

B) EXPOSURE LIMITS: Recommended short-term exposure limits for TDI in industry is 0.02 ppm. TDI does not have sufficient warning properties (eg, odor or eye irritancy) at air concentrations below the recommended short term exposure limit.

[Rumack BH POISINDEX(R) Information System Micromedex, Inc., Englewood, CO, 2017; CCIS Volume 172, edition expires May, 2017. Hall AH & Rumack BH (Eds): TOMES(R) Information System Micromedex, Inc., Englewood, CO, 2017; CCIS Volume 172, edition expires May, 2017.] **PEER REVIEWED**

Antidote and Emergency Treatment:

Immediate first aid: Ensure that adequate decontamination has been carried out. If patient is not breathing, start artificial respiration, preferably with a demand-valve resuscitator, bag-valve-mask device, or pocket mask, as trained. Perform CPR as necessary. Immediately flush contaminated eyes with gently flowing water. Do not induce vomiting. If vomiting occurs, lean patient forward or place on left side (head-down position, if possible) to maintain an open airway and prevent aspiration. Keep patient quiet and maintain normal body temperature. Obtain medical attention. /Isocyanates, aliphatic thiocyanates, and related compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 446] **PEER REVIEWED** Basic treatment: Establish a patent airway (oropharyngeal or nasopharyngeal airway, if needed). Suction if necessary. Watch for signs of respiratory insufficiency and assist ventilations if necessary. Administer oxygen by nonrebreather mask at 10 to 15 L/min. Monitor for pulmonary edema and treat if necessary ... . Monitor for shock and treat if necessary ... . Monitor for seizures and treat if necessary ... . For eye contamination, flush eyes immediately with water. Irrigate each eye continuously with 0.9% saline (NS) during transport ... . Do not use emetics. For ingestion, rinse mouth and administer 5 mL/kg up to 200 mL of water for dilution if the patent can swallow, has a strong gag reflex, and does not drool. Administer activated charcoal ... . /Isocyanates, aliphatic thiocyanates, and related compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 446] **PEER REVIEWED** Advanced treatment: Consider orotracheal or nasotracheal intubation for airway control in the patient who is unconscious, has severe pulmonary edema, or is in severe respiratory distress. Positive-pressure ventilation techniques with a bag valve mask device may be beneficial. Consider drug therapy for pulmonary edema ... . Consider administering a beta agonist such as albuterol for severe bronchospasm ... . Monitor cardiac rhythm and treat arrhythmias if necessary ... . Start IV administration of D5W /SRP: "To keep open", minimal flow rate/.

Use 0.9% saline (NS) or lactated Ringer's (LR) if signs of hypovolemia are present. For hypotension with signs of hypovolemia, administer fluid cautiously. Consider vasopressors if patient is hypotensive with a normal fluid volume. Watch for signs of fluid overload ... . Treat seizures with diazepam or lorazepam ... . Use proparacaine hydrochloride to assist eye irrigation ... . /Isocyanates, aliphatic thiocyanates, and related compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 446-7] **PEER REVIEWED** Emergency and supportive measures: After acute high-intensity inhalation exposure, maintain on open airway, give bronchodilators as needed for wheezing, and observe for 8-12 hours for pulmonary edema. Once airway hyperactivity has been documented, further exposure to isocyanate is contraindicated. Involve public health or OSHA agencies to determine whether other workers are at increased risk through improper workplace controls. /Isocyanates/[OLSON, K.R. (Ed). Poisoning and Drug Overdose, Sixth Edition. McGraw-Hill, New York, NY 2012, p. 249] **PEER REVIEWED** Decontamination after high level exposure. Inhalation: Remove the victim from exposure and give supplemental oxygen if available. Skin and eyes: Remove contaminated clothing (liquid or heavy vapor exposure) and wash exposed skin with copious soap and water. Irrigate exposed eyes with saline or tepid water. /Isocyanates/[OLSON, K.R. (Ed). Poisoning and Drug Overdose, Sixth Edition. McGraw-Hill, New York, NY 2012, p. 249] **PEER REVIEWED** The only effective intervention for workers with isocyanate-induced sensitization (asthma) or /hypersensitivity pneumonitis/ (HP) is cessation of all isocyanate exposure. This can be accomplished by removing the worker from the work environment where isocyanate exposure occurs, or by providing the worker with supplied-air respiratory protection and preventing any dermal exposures. /Isocyanates/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 (January 2004). Available from; as of March 10, 2012: http://www.cdc.gov/niosh/docs/2004-116/pdfs/2004-116.pdf] **PEER REVIEWED**
Animal Toxicity Studies:

Toxicity Summary:

IDENTIFICATION AND USE: This chemical exists as a colorless or light yellow fused solid. 4,4'-Methylenediphenyl diisocyanate (MDI) is miscible in water, and soluble in acetone, benzene, kerosene, and nitrobenzene. The product is used to make rigid and semi-rigid polyurethane foams. Pure MDI is distilled from the reaction mixture and is used for reaction injection molding, thermoplastic elastomers, and adhesives. HUMAN EXPOSURE AND TOXICITY: MDI is irritating to skin, eyes, and respiratory passages. Nose and throat irritation has also been observed. A few cases of alveolitis have been reported in workers exposed to MDI vapors. Contact allergy and allergic contact eczema have been reported in workers exposed to MDI. Cases of asthmatic breathing have been observed in workers. Lung fibrosis is also been observed in workers exposed to MDI. Children living in proximity of an accidental MDI release had signs of sore throat, dizziness, nausea and breathing difficulties MDI is an allergic sensitizer. Workers in occupational settings have the potential for inhalation or skin contact with particles of MDI. There is inadequate evidence for the carcinogenicity of MDI in humans. ANIMAL STUDIES: There is limited evidence in experimental animals for the carcinogenicity of MDI. MDI has low oral toxicity in rats. Repeated doses of MDI for 5 days in corn oil produced slight spleen enlargement in rats. In male and female rats exposed to polymeric MDI aerosol there was increased incidences of pulmonary adenomas in high dose males. Accumulation of alveolar macrophages containing polymeric MDI were associated with retractile yellowish material, localized fibrosis and alveolar duct epithelialization and increased alveolar bronchiolization were observed in the lungs of the high dose group. A 2 yr inhalation study using a mixture of MDI and higher weight oligomers showed both male and female rats had treatment related histological changes in the nasal cavity, lungs and lymph nodes. In female rats exposed by inhalation to MDI on days 6-15 of gestation, there was a slight increase in asymmetric sternbrae at the highest dose but no adverse effect was observed on maternal weight gain, number of corpea lutea, implantation sites, pre and post-implantation loss, fetal or placental weight, gross abnormalities or degree of ossification. MDI was tested for mutagenicity in Salmonella typhimurium strains TA98, TA100, TA1535 and TA1537 in the presence or absence of metabolic activation. The chemical was negative for mutagenicity. MDI in the micronucleus assay was negative for mutagenicity. **QC REVIEWED**

Evidence for Carcinogenicity:

Evaluation: There is inadequate evidence for the carcinogenicity of 4,4'-methylenediphenyl diisocyanate or polymeric 4,4'-methylenediphenyl diisocyanate in humans. There is limited evidence in experimental animals for the carcinogenicity of a mixture containing monomeric and polymeric 4,4'-methylenediphenyl diisocyanate. Overall evaluation: 4,4'-Methylenediphenyl diisocyanate (industrial preparation) is not classifiable as to its carcinogenicity in humans (Group 3).[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1056 (1999)] **PEER REVIEWED** WEIGHT OF EVIDENCE CHARACTERIZATION: Under U.S. EPA's 1996 Guidelines for Carcinogenic Risk Assessment, monomeric MDI or polymeric MDI (PMDI) would be classified as not classifiable or a Group D chemical. Under U.S. EPA's 1996 Proposed Guidelines for Carcinogenic Risk Assessment, the carcinogenic potential of MDI/PMDI would be characterized as "cannot be determined, but for which there is suggestive evidence that raises concern for carcinogenic effects" on the following basis. The increased incidence of pulmonary adenomas in male (6/60) and female (2/59) Wistar rats [strain Cpu:WU] and one pulmonary adenocarcinoma in a male rat, all exposed to the highest concentration in a lifetime chronic inhalation study involving PMDI, suggest that PMDI has tumorigenic potential. However, the tumorigenic results, coupled with evidence that methylene diphenyl aniline (MDA) a known animal carcinogen and the principal reaction product of MDI, is found in blood of MDI-exposed rats and nonhydrolyzed urine of PMDI/MDI-exposed humans increases concern about the carcinogenic potential of PMDI/MDI. The available human evidence is inadequate to describe the carcinogenic potential of PMDI/MDI. HUMAN CARCINOGENICITY DATA: Inadequate. ANIMAL CARCINOGENICITY DATA: Limited.[U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS). Summary for Methylene Diphenyl Diisocyanate (monomeric MDI) and polymeric MDI (PMDI) (101-68-8, 9016-87-9). Available from, as of March 15, 2000: http://www.epa.gov/iris/] **PEER REVIEWED**

Non-Human Toxicity Excerpts:

/LABORATORY ANIMALS: Acute Exposure/ Rats were nose-only exposed for 6 hr to polymeric methylenediphenyl-diisocyanate (pMDI). Concentrations varied from 0.12 to 12.7 mg/cu m using a highly respirable aerosol. In regard to the concentration of the monomeric fraction of MDI contained in pMDI, the lowest concentration was in the range of the current workplace limit of MDI which is 0.05 mg/cu m. Biomarkers of exposure were determined in hydrolyzed urine (collection started after cessation of exposure for approximately 18 hr; acid hydrolysis) and hydrolyzed hemoglobin (collection of blood approximately 20 hr after cessation of exposure; alkaline hydrolysis). The determination revealed two-order of magnitudes higher yields of the biomarkers in urine when compared to hemoglobin. The concentration of analytes from the respective biological matrix was highly correlated with the airborne concentration of pMDI whilst their yields exhibited a reciprocal relationship to the airborne concentration of pMDI. A linear relationship could only be demonstrated by using a logarithmic transformation of data. With respect to the amount of 4,4'-methylenediphenyldianiline creatinine (MDA/g creatinine) in hydrolyzed urine of rats at an exposure level similar to the current workplace concentration of MDI, this marker of exposure was approximately 10-times lower in rats than predicted for humans. This suggests that the extrapolation of animal data to man as well as from one exposure regimen to another, without taking into consideration the different deposition/retention patterns of vapors (<or=0.05 mg/cu m) or aerosols of MDI, might be error prone. In summary, taking into account previous and current experimental evidence, these data substantiate further that the formation of MDI-related biomarkers appear to be governed by spontaneously occurring, scavenging reactions at the portal-of-entry. Comparison of MDI with its corresponding amine support that the analytes determined stem from conjugated MDI rather than in vivo hydrolyzed MDI. [Pauluhn J, Leng G; Toxicology 185 (1-2): 35-48 (2003)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... HAS LOW ORAL TOXICITY FOR RATS, SINGLE ORAL DOSES OF 4.7 G/KG FAILED TO KILL. REPEATED DAILY DOSES FOR FIVE DAYS IN CORN OIL, EQUIVALENT TO 4.3 TO 5 G/KG/DAY, PRODUCED ONLY SLIGHT SPLEEN ENLARGEMENT IN TWO OF FIVE RATS.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values, 4th ed., 1980. Cincinnati, Ohio: American Conference of Governmmental Industrial Hygienists, Inc., 1980., p. 274] **PEER REVIEWED** /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ Groups of 60 male and 60 female Wistar rats, six weeks of age, were exposed to target concentrations of 0 (controls), 0.2, 1.0 or 6.0 mg/cu m (analytical value, 0.19, 0.98 or 6.03 mg/cu m) respirable

(particle size, 93.5% < 4.2 um) polymeric 4,4'-methylenediphenyl diisocyanate aerosol (31.0-31.7% (w/w) isocyanate content, 0.06-0.12% hydrolysable chlorine, 0.20-0.37% total chlorine, 0.0001-0.0069% chlorobenzene, 0.003-0.005% phenyl isocyanate, 44.8-50.2% monomeric 4,4'-methylenediphenyl diisocyanate, 0.01% sediment content) for 6 hours per day on five days per week for two years. The exposure concentrations were selected based on results of a 13 week study. Complete histological examination was performed and almost all organs and all grossly observed lesions were examined histologically. Survival at 104 weeks of study was 38/60, 38/60, 42/60 and 36/60 control, low-dose, mid-dose and high-dose males and 41/60, 42/60 48/60 and 50/60 control low-dose, mid-dose and high-dose females. In the high-dose group, pulmonary adenomas were found in 6/60 males ($p < 0.05$ by two-sided Fisher's exact test) and 2/59 females, and pulmonary adenocarcinoma was found in 1/60 males. No lung tumors were found in other groups. Accumulation of alveolar macrophages containing polymeric 4,4'-methylenediphenyl diisocyanate-associated refractile yellowish material, localized fibrosis, alveolar duct epithelialization and increased incidence of calcareous deposits and localized alveolar bronchiolization were observed in the lungs of the high-dose group.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1051 (1999)] **PEER REVIEWED** /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ The object of this study was to compare the relative acute pulmonary irritant potency of respirable aerosols of a variety of non-volatile polyisocyanates. The types of polyisocyanates examined included aliphatic homopolymers and mixed aliphatic-aromatic polyisocyanates consisting of the following monomers: HDI (hexamethylene 1,6-diisocyanate), IPDI (isophorone diisocyanate), MDI (methylene-diphenyl-4,4'-diisocyanate) and TDI (toluene diisocyanate). For reference purposes, the pulmonary irritant polyisocyanate aerosols were compared with monomeric IPDI, a semi-volatile respiratory tract (airway) irritant. In the substances tested, the concentration of free isocyanate moieties ranged from 11% to 38%. The relative potency to elicit pulmonary irritation was assessed by measurements of lung weights and total protein and lactate dehydrogenase (LDH) in the bronchoalveolar lavage fluid (BALF) following a single 6-hr exposure of male rats. The time course of changes was analysed 3 hr and 1, 3 and 7 days after exposure. When exposed to irritant concentrations of aerosol, BALF protein was maximal on post-exposure day 1 and returned to the level of the controls on post-exposure day 7. In contrast, rats exposed to sub-lethal concentrations of monomeric IPDI experienced a time-related increase in BALF protein. Based on this most sensitive endpoint, extrapolated no-observed-effect concentrations (NOECs) were in the range of 2-3 mg /per/ cu m for most polyisocyanates examined. The NOECs from all the substances investigated were in the range 1-50 mg /per/ cu m. Thus, this methodology is adequate to rank the pulmonary irritant potency of polyisocyanate aerosols and to differentiate pulmonary from airway irritants. For pulmonary irritants the estimated acute NOECs were essentially similar to the no-observed-adverse effect concentrations (NOAECs) from long-term, repeated-exposure inhalation studies available for some of the polyisocyanates. A clear dependence of the NOAECs on the content of free isocyanate moieties was not observed. In summary, it is concluded that pulmonary irritation caused by polyisocyanate aerosols can be quantified readily in an acute rat bioassay by analysis of total protein in BALF. Moreover, this experimental evidence suggests that the NOECs of pulmonary irritants based on this endpoint are predictive of the NOAECs observed after subacute/subchronic inhalation exposure, suggesting that acute pulmonary irritation governs the outcome of repeated inhalation studies with such aerosols. However, for isocyanates where airway irritation predominates the pulmonary irritation, long(er)-term inhalation studies appear to be indispensable. The content of free NCO per se appears to be a poor predictor of the pulmonary irritant potency of polyisocyanate aerosols.[Pauluhn J et al; J Appl Toxicol 24 (3): 231-47 (2004)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ Two weeks of exposure to a mixture of MDI polymers with 44.8-50.2% monomer at a concentration of 13.6 mg/cu m resulted in severely retarded growth and some deaths, and 13 weeks of exposure to 12.3 mg/cu m also caused elevated mortality and retarded growth.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.68 (2001). Available from, as of March 8, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Chronic Exposure or Carcinogenicity/ Results from an inhalation study showed that a low level (5-10 adducts/10(9) nucleotides) of arylamine-derived DNA adducts was formed in the olfactory epithelium of female Wistar rats exposed to an average atmospheric concentration of 0.7-2.0 mg/cu m 4,4'-methylenediphenyl diisocyanate for 17 hr per day on five days per week for one year. Adducts were not detected in DNA from lung, liver, bladder, kidney, respiratory epithelium or peripheral blood lymphocytes of exposed animals.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health

Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1054 (1999)] **PEER REVIEWED** /LABORATORY ANIMALS: Chronic Exposure or Carcinogenicity/ Commercially available Poly-MDI was tested in a 2-year inhalation study in rats. The tested material contained 47% aromatic 4,4'-methylenediphenyl diisocyanate (MDI) and 53% higher molecular weight oligomers. Interim sacrifices at one year showed that males and females in the highest dose group (6 mg/cu m) had treatment related histological changes in the nasal cavity, lungs and mediastinal lymph nodes. The incidence and severity of degeneration and basal cell hyperplasia of the olfactory epithelium and Bowman's gland hyperplasia were increased in males at the mid and high doses and in females at the high dose following the two year exposure period. Pulmonary adenomas were found in 6 males and 2 females, and pulmonary adenocarcinoma in one male in the high dose group.[USEPA/OPPT, Design for the Environment; Isocyanates Profile: Automotive Refinishing Shop Project and Philadelphia Project- Toxicology Section: 2 (January 5, 2005). Available from, as of March 1, 2012: http://www.epa.gov/dfe/pubs/auto/profile/] **PEER REVIEWED** /LABORATORY ANIMALS: Chronic Exposure or Carcinogenicity/ In a long-term toxicity and carcinogenicity study with Wistar rats, inhalation of 19, 96 or 576 ppb MDI (a mixture of polymers with 44.8-50.2% MDI monomer), 6 hours/day, 5 days/week for 2 years, resulted in lung adenomas in 10% of the males and 3% of the females in the highest exposure group. One of 60 males in the high-exposure group also had a lung adenocarcinoma. No lung tumors were found in controls. In this study, two years of exposure to 576 ppb MDI was associated with an elevated occurrence of lung tumors, whereas concentrations of 96 ppb or less did not increase the frequency of tumors. [Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.77 (2001). Available from, as of March 10, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Developmental or Reproductive Toxicity/ When female Wistar rats were exposed by inhalation to 4,4-methylenediphenyl diisocyanate (nominal concentration of 1,3 or 9 mg/cu m, 6 hours per day) on days 6 through 15 of gestation, a slight increase of asymmetric sternebrae appeared at the highest dose but no adverse effect was observed on maternal weight gain, number of corpora lutea, implantation sites, pre- and postimplantation loss, fetal or placental weight, gross and visceral anomalies or degree of ossification.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1053 (1999)] **PEER REVIEWED** /LABORATORY ANIMALS: Developmental or Reproductive Toxicity/ MDI is used, amongst other things, as an alternative to formaldehyde in furniture production. This compound, with inhalation as the main route in man, has previously not been studied for its potential prenatal toxic effects. To close this gap in information, gravid Wistar rats, Crl:(WI)BR, were exposed by whole body inhalation to clean air (control), 1, 3, and 9 mg/cu m MDI, respectively, for 6 hours per day from day 6-15 post conceptionem (p.c.). Rats were killed on day 20 p.c. and the following results characterizing prenatal toxic effects were obtained: Treatment caused a dose-dependent decrease in food consumption in all substance-treated groups during exposure, returning to normal values after treatment. The lung weights in the high dose group were significantly increased compared to the sham-treated control animals. Treatment did not influence any other maternal and/or fetal parameters investigated (maternal weight gain, number of Corpora lutea, implantation sites, pre- and postnatal loss, fetal and placental weights, gross and visceral anomalies, degree of ossification) but a slight but significant increase in litters with fetuses displaying asymmetric sternebra(e) was observed after treatment with the highest dose of 9 mg/cu m. Although the relevance of an increase of this minor anomaly in doses that cause effects in dams (reduced food consumption, increased lung weights) is limited and the number observed is still within biological variability, a substance-induced effect in the high dose group cannot be excluded with certainty. Consequently, a no teratogenic effect level of 3 mg/cu m was determined.[Buschmann J; Teratology 50 (5): 40A (1994)] **PEER REVIEWED** /GENOTOXICITY/ 4,4'-Diphenylmethane diisocyanate was evaluated for mutagenicity in the Salmonella/microsome preincubation assay using a standard protocol approved by the National Toxicology Program. Diisocyanate was tested at doses of 0, 10, 33, 100, 333, 1000, 3333, and 10,000 ug/plate in four Salmonella typhimurium strains (TA98, TA100, TA1535, and TA1537) in the presence and absence of Aroclor-induced rat or hamster liver S9. Diisocyanate was negative in these tests and the highest ineffective dose level tested without formation of a precipitate in any Salmonella tester strain was 100 ug/plate. [Zeiger E et al; Environ Mutagen 9: 1-110 (1987)] **PEER REVIEWED** /GENOTOXICITY/ In one study, 4,4'-methylenediphenyl diisocyanate induced mutations in Salmonella typhimurium strain TA100 in the presence of exogenous metabolic activation but not in its absence. It induced a weak mutagenic response in Salmonella typhimurium strain TA98 with exogenous metabolic activation but was not mutagenic in strains

TA1535, TA1537, TA1538 or in Escherichia coli WP2 uvrA.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1054 (1999)] **PEER REVIEWED** /GENOTOXICITY/ Toluene diisocyanate (TDI) and 4,4'-methylenediphenyl diisocyanate (MDI), used in the production of polyurethane foam, are well known for their irritating and sensitizing properties. Contradictory results have been obtained on their genotoxicity. /The study/ investigated the genotoxicity and protein binding of inhaled TDI and MDI in mice by examining micronucleated polychromatic erythrocytes (PCEs) in bone marrow and peripheral blood and TDI- and MDI-derived adducts in hemoglobin. Male C57Bl/6J mice (8 per group) were exposed head-only to TDI vapour (mean concentrations 1.1, 1.5, and 2.4mg/cu m; the mixture of isomers contained, on the average, 63% 2,4-TDI and 37% 2,6-TDI) or MDI aerosol (mean concentrations 10.7, 20.9 and 23.3mg/cu m), during 1hr/day for 5 consecutive days. Bone marrow and peripheral blood were collected 24hr after the last exposure. Inhalation of TDI caused sensory irritation (SI) in the upper respiratory tract, and cumulative effects were observed at the highest exposure level. Inhalation of MDI produced SI and airflow limitation, and influx of inflammatory cells into the lungs. Hemoglobin adducts detected in the exposed mice resulted from direct binding to globin of 2,4- and 2,6-TDI and MDI, and dose-dependent increases were observed especially for 2,4-TDI-derived adducts. Adducts originating from the diamines of TDI (toluene diamine) or MDI (methylene dianiline) were not observed. No significant increase in the frequency of micronucleated PCEs was detected in the bone marrow or peripheral blood of the mice exposed to TDI or MDI. The ratio of PCEs and normochromatic erythrocytes (NCEs) was reduced at the highest concentration of MDI, and a slight reduction of the PCE/NCE ratio, dependent on cumulative inhaled dose, was also seen with TDI. Our results indicate that inhalation of TDI or MDI (1h/day for 5 days), at levels that induce toxic effects and formation of TDI- or MDI-specific adducts in hemoglobin, does not have detectable genotoxic effects in mice, as studied with the micronucleus assay.[Lindberg HK et al; Mutat Res 723(1):1-10 (2011)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ Methylenedi-p-phenyl diisocyanate (MDI) is widely used in the production of polyurethane products. Diisocyanates are reactive compounds, MDI can react under physiological conditions with various functional groups found on biological molecules resulting in conjugate formation or undergo non-enzymatic hydrolysis to form 4,4'-methylenedianiline (MDA). /It was/ previously reported that addition of MDI directly to Chinese hamster lung fibroblasts (V79) cultures did not induce micronuclei (MN), but MDA, and the glutathione and cysteine conjugates of MDI (BisGS-MDI and BisCYS-MDI), induced a concentration-dependent increase in the frequency of MN. The conventional MN assay does not discriminate between MN produced by acentric chromosome fragments from those arising due to whole lagging chromosomes that were not incorporated into daughter nuclei at the time of cell division. The mechanism of MN induction from these potential MDI metabolites/reaction products was explored in the present study using immunofluorescent staining of kinetochore in MN of cytokinesis-blocked V79 cells. This assay discerns the presence of centromere within the MN to distinguish the MN containing centric chromosomes from those containing acentric fragments. Eighty five percent of MDA-induced MN were negative with respect to anti-kinetochore antibody binding (KC(-)). This is consistent with an interaction between MDA and DNA resulting in chromosome breakage. However, BisGS-MDI and BisCYS-MDI induced a higher percentage of MN that were positively stained by the anti-kinetochore antibody (KC(+)). These results suggest that the mechanism of MN formation induced by BisGS-MDI and BisCYS-MDI is mediated through disruption and/or by affecting the function of the mitotic spindle. This mechanism is distinctly different from the mechanism of MN induction by MDA.[Zhong BZ et al; Mutat Res 497 (1-2): 29-37 (2001)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ Four groups of young adult male Brown-Norway rats (strain: BN/RijHsd) were either exposed whole-body (WB) to filtered air (negative control) or to respirable aerosols of monomeric diphenylmethane-4,4'-diisocyanate (MDI) at actual breathing zone concentrations of 9.2 +/- 1.5 and 118 +/- 8.6 mg/cu m. One additional group was exposed to 11,0 +/- 14.4 mg/cu m MDI using a nose-only (NO) mode. Exposure was 1 h/day, one exposure per week on 3 consecutive weeks. MDI aerosols were generated using either a condensation (WB) or a dispersion-condensation (NO) principle with resultant MMADs of 2.4-3.1 um and 1.2 um (GSD approximately l.5), respectively. Humidity ranged from approximately 40% (WB) to approximately 5% (NO). Positive controls received cyclophosphamide and colcemid. Micronuclei in polychromatic erythrocytes (MN-PCE) were counted in bone marrow smears prepared after the final exposure on post-exposure days 1, 2 and 7 and stained with acridine orange or Wright-Giemsa. Both the WB-exposure regimen and the 7-day sampling time point were based upon a previous study in which a significant increase in

MN-PCE was reported to occur. Rats exposed to 118 (WB) and 110 mg/cu m MDI (NO) exhibited signs of respiratory distress, including hypothermia, and increased lung weights when compared to WB-exposed rats. The intensity of changes appeared to be slightly more pronounced in NO-exposed rats. At no time point did this study provide any evidence of an MDI-induced effect on the frequency of MN-PCE. No differences in outcome existed following staining with acridine orange or Wright-Giemsa. There was an absence of any effect on the frequency of mast cells and their frequency was low enough not to interfere with the outcome of study. Positive control groups exhibited significant increases in MN-PCE. In summary, monomeric MDI aerosol did not induce cytogenetic damage in Brown-Norway rats when investigated according to current testing guidelines.[Pauluhn J; Arch Toxicol 75 (4): 234-42 (2001)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ 4,4'-METHYLENEDIPHENYL ISOCYANATE WAS MUTAGENIC IN STRAIN TA100 SALMONELLA TYPHIMURIUM AFTER METABOLIC ACTIVATION WITH S9 MIX.[ANDERSEN M ET AL; SCAND J WORK ENVIRON HEALTH 6 (3): 80 (1980)] **PEER REVIEWED** PubMed Abstract /ALTERNATIVE and IN VITRO TESTS/ The composition of thermal degradation products from two types of polyurethane foams, one based on toluene diisocyanate (TDI) and the other on diphenylmethane diisocyanate (MDI), was analyzed and their toxic lung effects were compared. Isolated perfused lungs of guinea pig were subjected to thermal decomposition products of polyurethane foams from an aerosol generator with compartments for diluting, mixing, and sampling. Thermal degradation of MDI-based polyurethane foams released MDI, phenyl isocyanate, and methyl isocyanate. The emitted particulate fraction was 75% for MDI, whereas that for TDI from TDI-based polyurethane foam was 3%. Thermal degradation products from MDI-based foam caused a pronounced dose-dependent decrease in the measured lung function parameters (conductance and compliance). In contrast, the thermal degradation products from TDI-based foam did not cause any decrease in lung function. Thermal degradation products generated from MDI-based polyurethane foam were more toxic to the lung than those generated from TDI-based polyurethane foam. This difference was probable due to MDI in the particle phase. [Lastbom L et al; Scand J Work Environ Health 29 (2): 152-8 (2003)] **PEER REVIEWED** PubMed Abstract /IMMUNOTOXICITY/ Isocyanates are low-molecular-weight chemicals implicated in allergic asthmatic-type reactions. Identification of chemicals likely to cause asthma is difficult due to the lack of a validated test method. One hypothesis is that differential cytokine induction (Th1 versus Th2 profiles) in the draining lymph node following dermal application can be used to identify asthmagens and distinguish them from contact allergens. In this study, we compared the cytokine mRNA profiles of six chemicals: toluene diisocyanate (TDI), diphenylmethane-4,4'-diisocyanate (MDI), dicyclohexylmethane-4,4'-diisocyanate (HMDI), isophorone diisocyanate (IPDI), p-tolyl(mono)isocyanate (TMI), and meta-tetramethylene xylene diisocyanate (TMXDI). Whereas TDI and MDI are well-known respiratory sensitizers, documentation for HMDI, IPDI, TMI, and TMXDI is limited, but suggests that HMDI and IPDI may have respiratory sensitization potential in humans and TMI and TMXDI do not. Following dermal exposure of BALB/c mice, all six isocyanates induced cytokines characteristic of a Th2 response. Although LLNAs suggested that the doses chosen for the RPA were immunologically equivalent, the isocyanates tested differentiated into two groups, high responders and low responders. However, two of the low responders (TMI and TMXDI) were further tested and induced higher levels of Th2 cytokine message than dinitrochlorobenzene (not an asthmagen).[Plitnick LM et al; Toxicology 207 (3): 487-99 (2005)] **PEER REVIEWED** PubMed Abstract /IMMUNOTOXICITY/ Isocyanate exposure in the workplace has been linked to asthma and allergic rhinitis. Recently, investigators have proposed that Th2 cytokine responses in lymph nodes draining the site of dermal application of chemicals including isocyanates may be used to identify sensitizers that cause asthma-like responses. The purpose of this study was to determine if the cytokine profile induced after dermal sensitization with isocyanates and serum IgE predict immediate (IHS) and methacholine-induced late (LHS) respiratory hypersensitivity responses after intranasal challenge. Dermal application of hexylmethane diisocyanate (HMDI), toluene diisocyanate (TDI), or methylene diisocyanate (MDI) significantly increased interleukin-4 (IL-4), IL-5, and IL-13 secretion in parotid lymph node cells. Isophorone diisocyanate (IPDI) increased IL-4 and IL-13, but not IL-5. Tolyl(mono)isocyanate (TMI), tetramethylene xylene diisocyanate (TMXDI), or the contact sensitizer dinitrochlorobenzene (DNCB), only induced minor increases in some of the Th2 cytokines. HMDI, TDI, MDI, and IPDI elicited greater increases in total serum IgE than DNCB, TMI, and TMXDI. All chemicals except TMXDI caused IHS after intranasal challenge of sensitized female BALB/c mice. Only HMDI-, TMI-, or TMXDI-sensitized and challenged mice had increases in LHS. All chemicals elicited epithelial cytotoxicity indicative of nasal airway irritation. The discordance between dermal cytokine profiles and respiratory responses suggests that dermal responses do not necessarily predict respiratory responses. Serum IgE also was not predictive of the respiratory responses to the

isocyanates, suggesting that other unknown mechanisms may be involved.[Farraj AK et al; Toxicol Sci 100 (1): 99-108 (2007)] **PEER REVIEWED** PubMed Abstract /IMMUNOTOXICITY/ Brown Norway (BN) rats were topically sensitized to polymeric diphenylmethane-diisocyanate (MDI) and challenged with MDI-aerosol approximately every 2 weeks over a time period of 2 months. Half of the sensitized animals were pretreated with capsaicin for partial C-fiber defunctionalization. After the fourth challenge inflammatory and pro-inflammatory factors in bronchoalveolar lavage (BAL) fluid and cells and physiological delayed-onset breathing patterns were analyzed. The latter endpoint was examined in the capsaicin pretreated group before and after each challenge. Findings were compared against naive but repeatedly MDI-challenged BN rats. BAL-neutrophils, -protein, and -LDH as well as lung weights were significantly increased in the MDI-sensitized and challenged rats relative to the naive, challenged control rats. With regard to these endpoints, capsaicin pretreatment did not affect the responsiveness to MDI-aerosol. In contrast, pro-inflammatory cytokines, the Th2 cell cytokine IL-4, and the CC-chemokine MCP-1 were significantly increased in BAL-cells of capsaicin pretreated and MDI-sensitized rats, whilst in the normal MDI-sensitized rats markedly less pronounced changes (if any) occurred. In the former group, IL-4 and MCP-1 were also significantly increased in the lung draining lymph nodes. Time-related increased frequencies of delayed-onset responses were observed in MDI-sensitized rats after subsequent MDI-challenges, however, differences between capsaicin pretreated and normal rats were not found. Despite the remarkable differences between normal and capsaicin pre-treated rats in the concentrations of pro-inflammatory and Th1-/Th2-cell specific cytokines, the inflammatory endpoints in BAL as well as the physiological measurements did not identify appreciable differences amongst these groups. This study included an ancillary study addressing the analysis of the modulating effect of capsaicin pre-treatment of naive Wistar rats exposed for single 6hr to MDI-aerosol. The results indicated more pronounced changes on endpoints in the BAL-fluid of capsaicin-pretreated rats as compared to rats with intact C-fibers. This complex picture appears to suggest that C-fibers may modulate the allergic inflammatory response elicited by MDI-challenge...[Pauluhn J, Vohr HW.; Toxicology 228 (2-3):188-99 (2006)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ 4,4'-Methylenediphenyl diisocyanate (MDI) is the most important of the isocyanates used as intermediates in the chemical industry. Among the main types of damage after exposure to low levels of MDI are lung sensitization and asthma. Albumin adducts of MDI might be involved in the etiology of sensitization reactions. It is, therefore, necessary to have sensitive and specific methods for monitoring the isocyanate exposure of workers. To date, urinary metabolites or protein adducts have been used as biomarkers in workers exposed to MDI. However, with these methods it is not possible to determine whether the biomarkers result from exposure to MDI or to the parent aromatic amine 4,4'-methylenedianiline (MDA). This work presents a procedure for the determination of isocyanate-specific albumin adducts. In a long-term experiment, designed to determine the carcinogenic and toxic effects of MDI, rats were exposed chronically for 3 months, to 0.0 (control), 0.26, 0.70, and 2.06 mg MDI/cu m as aerosols. Albumin was isolated from plasma, digested with Pronase E, and analyzed by LC-MS/MS. MDI formed adducts with lysine: N(6)-[({4-[4-aminobenzyl]phenyl}amino)carbonyl]lysine (MDI-Lys) and N(6)-[({4-[4-(acetylamino)benzyl]phenyl}amino)carbonyl] lysine (AcMDI-Lys). For the quantitation of the adducts in vivo, isotope dilution mass spectrometry was used to measure the adducts in 2 mg of albumin. The adducts found in vivo (MDI-Lys and AcMDI-Lys) and the corresponding isotope labeled compounds (MDI-[(13)C(6) (15)N(2)]Lys and Ac[(2)H(4)]MDI-Lys) were synthesized and used for quantitation. The MDI-Lys levels increased from 0-24.8 pmol/mg albumin, and the AcMDI-Lys levels increased from 0-1.85 pmol/mg albumin. The mean ratio of MDI-Lys/AcMDI-Lys for each dose level was greater than >20. The albumin adducts correlate with other biomarkers measured in the same rats in the past: urinary metabolites and hemoglobin adducts released after mild base hydrolysis. This method will enable one to measure isocyanate-specific albumin adducts in workers. This new biomonitoring procedure will allow for the assessment of suspected exposure sources and may contribute to the identification of individuals who are particularly vulnerable for developing bronchial asthma and other respiratory diseases after exposure to isocyanates. In addition, it will help to improve the production of antigens for the analysis of antibodies in exposed workers.[Kumar A et al; Chem Res Toxicol 22 (12): 1975-83 (2009)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ IN GUINEA PIGS, IT INDUCES SKIN SENSITIVITY SIMILAR TO CONTACT ALLERGY.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V19 319 (1978)] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ The ability of diisocyanate antigens to detect specific antibodies in exposed

workers and guinea pigs was investigated. Sera were obtained from male English short hair guinea pigs that had been immunized with 4,4'-diisocyanatodiphenylmethane and three workers who had been occupationally exposed to 4,4'-diisocyanatodiphenylmethane. Two workers had symptoms of hypersensitivity pneumonitis and a third symptom of occupational asthma. The serum samples were reacted with antigens prepared by reacting 4,4'-diisocyanatodiphenylmethane with guinea pig serum albumin or human serum albumin and tested for their ability to recognize 4,4'-diisocyanatodiphenylmethane specific antigens utilizing the radioallergosorbent test, the enzyme linked immunosorbent assay, or the Western Blot assay. Guinea pig immunoglobulin-G antibodies to 4,4'-diisocyantodiphenylmethane were best detected by an antigen containing 43 moles of 4,4'-diisocyanatodiphenylmethane per mole guinea pig serum albumin. The enzyme linked immunosorbent assay data indicated that a population of antibodies resulted from immunizing guinea pigs with 4,4'-diisocyanatodiphenylmethane. Most of the antibodies showed a specificity for a multihaptenic conjugate; however, a relatively small population of antibodies recognized a less densely substituted 4,4'-diisocyanatodiphenylmethane/human serum albumin conjugate. Human 4,4'-diisocyanatodiphenylmethane specific immunoglobulin-G and immunoglobulin-E antibodies were most effectively recognized by 4,4'-diisocyanatodiphenylmethane/human serum albumin antigens that were monomeric and had a high 4,4'-diisocyanatodiphenylmethane content. It was concluded that human and guinea pig immunoglobulin-G antibodies preferentially react with the monomeric component of 4,4'-diisocyanatodiphenylmethane/human serum albumin and 4,4'-diisocyanatodiphenylmethane/guinea pig serum albumin conjugates. Fractionating moderately or heavily substituted conjugates according to molecular size and using the monomeric fraction would provide a more uniform antigen and increase the sensitivity of detection assays.[Jim R, Karol MH; Chem Res Toxicol 1 (5): 288-93 (1988)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ Two independent bioassays are available which have examined the potential carcinogenicity of monomeric and polymeric methylene diphenyl diisocyanate (MDI) following long-term inhalation exposure in rats. These studies are not directly comparable, however, due to differences in design and conduct of the in-life phase, and differences in nomenclature used for some of the histopathological findings. This paper presents a definitive overview ofthe pulmonary toxicity of MDI developed following a thorough review of both investigations. As part of this process, the test materials and the designs of the studies were compared, and an in-depth review of lung lesions was conducted by an independent reviewing pathologist. This included the re-examination of the original lung slides, supported by an analysis of the exposure regimens, the results of which were used to develop an accurate profile of the doses received by the animals in the two studies. Histopathological findings were then combined with this information to give an overall dose-response curve for both studies as a whole. The range of total inhalation exposures to MDI was calculated as 559, 1972, 2881, 6001, 17,575 and 17,728 mgh/ cu m. Major pulmonary effects included increased lung weights together with bronchiolo-alveolar adenomas and hyperplasia, and interstitial fibrosis which occurred consistently in both studies, indicating a very similar qualitative response of the lungs to polymeric and monomeric MDI. The quantitative response of the lung was clearly dose-related in each study, and when the studies were considered as a whole a reasonable overall dose-response relationship was apparent for major lung lesions. Lung tumours (in low incidences) only occurred at the highest dose level in both studies (17,575 and 17,728 mgh/cu m). For inflammatory and other non-neoplastic pulmonary changes, the lowest dose examined (559 mgh/cu m) was regarded as a no-observed-adverse-effect-level for both polymeric and monomeric MDI. It was concluded that the results of the two studies could be combined to serve as a basis for human risk assessment of MDI.[Feron VJ et al; Arch Toxicol 75 (3): 159-75 (2001)] **PEER REVIEWED** PubMed Abstract

Non-Human Toxicity Values:

LC50 Rat (male) inhalation 369 mg/cu m/4 hr[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 978] **PEER REVIEWED** LC50 Rat (female) inhalation 380 mg/cu m/4 hr[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 978] **PEER REVIEWED**

Ongoing Test Status:

The following link will take the user to the National Toxicology Program (NTP) Test Agent Search Results page, which tabulates all of the "Standard Toxicology & Carcinogenesis Studies", "Developmental Studies", and "Genetic Toxicity Studies" performed with this chemical. Clicking on the "Testing Status" link will take the user to the status (i.e., in review, in progress, in preparation, on test, completed, etc.) and results of all the studies that the NTP has done on this chemical.[Available from: http://ntp-apps.niehs.nih.gov/ntp_tox/index.cfm?fuseaction=ntpsearch.searchresults&searchterm=101-68-8]

TSCA Test Submissions:

Methylenedi-para-phenylene ester of isocyanic acid was examined in Salmonella typhimurium tester strains TA1535, TA1537, TA1538, TA98 and TA100 with and without rat liver homogenate S9 fraction to provide metabolic activation. Using the plate incorporation technique at doses of 0.5, 1.0, 1.5, 2.0 and 2.5 mg/plate, the test article was found to be mutagenic to strains TA98 and TA100 in the presence of activation; the greatest effect (0.27 revertants/uMol) was observed in TA100. In the absence of activation, a mutagenic effect was not observed in any strains. The investigators reported that preliminary cytotoxicity screening had been performed. [Haskell Laboratory; In Vitro Microbial Mutagenicity Studies of Isocyanic Acid, Methylenedi-para-phenylene Ester (1976), EPA Document No. FYI-OTS-0584-0303, Fiche No. OTS0000303-0] **UNREVIEWED**

Metabolism/ Pharmacokinetics:

Metabolism/ Metabolites:

After inhlalation exposure of female Wistar rats to 4,4'-methylene diisocyanate aerosols (0.26, 0.70 and 2.06 mg/cu m chronically for three and 12 months), 4,4'methylenedianiline and N-acetyl-4,4'-methylenedianiline were the major urinary metabolites. Hemoglobin adducts of these metabolites were also detected. The dose-response relationships for hemoglobin adducts and urinary metabolites were non-linear over this dose range. The amounts of 4,4'-methylenedianiline and, to a lesser extent, N-acetyl-4,4'-methylenedianiline found in urine correlated well with the corresponding amount determined as hemoglobin adducts for all dose groups. Similar results were obtained with rats exposed for three and 12 months, indicating that a steady state had been reached by three months. Hemoglobin adducts from rats after a one-week recovery period decreased by approximately 40% for all dosed groups, suggesting that erythrocytes containing modified hemoglobin have a shorter lifespan. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1052 (1999)] **PEER REVIEWED** This work was undertaken to investigate the usefulness of diisocyanate-related protein adducts in blood samples as biomarkers of occupational exposure to toluene diisocyanate (TDI; 2,4- and 2,6-isomers) and 4,4'-methylenediphenyl diisocyanate (MDI). Quantification of adducts as toluene diamines (TDAs) and methylenedianiline (MDA) was performed on perfluoroacylated derivatives by gas chromatography-mass spectrometry (GC-MS/MS) in negative chemical ionisation mode. TDI-derived adducts were found in 77% of plasma and in 59% of globin samples from exposed workers manufacturing flexible polyurethane foam. The plasma levels ranged from 0.003 to 0.58 nmol mL(-1) and those in globin from 0.012 to 0.33 nmol g(-1). The 2,6-isomer amounted to about two-thirds of the sum concentration of TDA isomers. MDI-derived adducts were detected in 3.5% of plasma and in 7% of globin samples from exposed workers manufacturing rigid polyurethane foam. A good correlation was found between the sum of TDA isomers in urine and that in plasma. The relationship between globin adducts and urinary metabolites was ambiguous. Monitoring TDI-derived TDA in plasma thus appears to be an appropriate method for assessing occupational exposure. Contrary to TDI exposure, adducts in plasma or globin were not useful in assessing workers' exposure to MDI. An important outcome of the study was that no amine-related adducts were detected in globin samples from TDI- or MDI-exposed workers, alleviating concerns that TDI or MDI might pose a carcinogenic hazard.[Sakkinen K et al; J Environ Monit 13 (4): 957-65 (2011)] **PEER REVIEWED** PubMed Abstract Methylenedianiline (MDA) could be identified in pooled samples of hydrolyzed plasma and urine from 10 workers exposed to MDI (it is unclear whether thermal breakdown was involved). MDA could be identified in hydrolyzed hemoglobin from 10 of 26 workers exposed to MDI (all but three <0.3 ppb; values for the other three were 1.0, 1.8 and 2.9 ppb). After alkaline extraction there were measurable amounts of acetyl-MDA (AcMDA) and lesser amounts of MDA in urine from 18 of the 26, MDA alone in 4 samples, and neither substance in 4. After acid hydrolysis the MDA

levels were on average about 1/3 higher that the total of AcMDA and MDA in the previous analysis. The levels of hemoglobin adducts had no correlation to metabolites in urine. In a polyurethane production facility where air concentrations of MDI were usually below the detection limit, measurable amounts of 4,4'-MDA (0.035-0.83 pmol/mL) and AcMDA (0.13-7.61 pmol/mL) could be found in urine in 15 of 20 workers after alkaline extraction, and MDA values were 6.5 times higher after acid hydrolysis. MDA was found as hemoglobin adducts in all the examined workers, and one worker also had adducts of AcMDA. Plasma levels of 4,4'-MDA ranged from 0.25 to 5.4 pmol/mL, up to 120 fmol/mg of which was covalently bound to albumin.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.66 (2001). Available from, as of March 7, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED**

Absorption, Distribution & Excretion:

Following topical administration of (14)C 4,4'methylenediphenyl diisocyanate in acetone to female Wistar rats, 20% of the administered dose was eliminated in the feces within 24 hours, while less than 1% appeared in the urine.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V71 1052 (1999)] **PEER REVIEWED** Polyurethanes (PU) are polymers made with diisocyanates such as MDI (4,4'-methylene diphenyl diisocyanate) and TDI (2,4-toluene diisocyanate and 2,6-toluene diisocyanate). Investigations have been undertaken with MDI and TDI to assess dermal uptake and resulting systemic exposure. Absorption, distribution and excretion of MDI was studied in rats using a single dermal administration of (14)C-MDI dissolved in acetone at nominal 165 mg/kg body weight and 15 mg/kg bw (4.0 and 0.4 mg/sq cm) and intradermal injection of (14)C-MDI dissolved in corn oil at nominal 1.4 mg/kg bw. Dermal absorption of (14)C-MDI (at both doses) was low; at or below 1% of the applied dose. Considerable amounts of the applied radioactivity were found at the application site which could not be washed off. By intradermal administration of (14)C-MDI approximately 66% of applied radioactivity remained at the application site with approximately 26% recovered in excreta, cage wash, tissues and carcass. The absorption, distribution and excretion of 2,4-TDI was studied in rats following a single dermal administration of radiolabelled (14)C-2,4-TDI at nominal 350 mg/kg body weight (12 mg/sq cm). Dermal absorption of (14)C-2,4-TDI was at or below 1% of the applied dose. Considerable amounts of the applied radioactivity were found at the application site which could not be washed off. In summary the results show that dermal uptake of MDI and TDI is very low. Due to the chemical reactivity of isocyanates it can be expected that small amounts which might be absorbed will react with tissue constituents directly at the exposed skin area, or will be converted to adducts with biomacromolecules or to biologically inactive oligoureas. Overall it is concluded that, following dermal exposure to MDI and TDI, systemic exposures and resulting toxicity, other than the known sensitization, can be expected to be very low. In addition studies were performed with dermal application of unlabelled 2,4 and 2,6 TDI to check the availability and fate of this chemical on rat skin surface and to assess possible tissue damage. These experiments showed that unchanged test material can be detected on rat skin for up to 8 hr if not washed off. Dermal treatment with 2,4 or 2,6 TDI was associated with irritation with increased severity over a 48 hr period after washing with a decontaminant solution.[Hoffmann HD et al; Toxicol Lett 199 (3): 364-71 (2010)] **PEER REVIEWED** PubMed Abstract

Environmental Fate & Exposure:

Environmental Fate/Exposure Summary:

4,4'-Methylenediphenyl diisocyanate's production and use in polyurethane resins and spandex fibers and in bonding rubber to rayon and nylon may result in its release to the environment through various waste streams. If released to air, a vapor pressure of 5.0X10-6 mm Hg at 25 deg C indicates 4,4'-methylenediphenyl diisocyanate will exist in both the vapor and particulate phases in the atmosphere. Vapor-phase 4,4'-methylenediphenyl diisocyanate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 11 hrs. Particulate-phase 4,4'-methylenediphenyl diisocyanate will be removed from the atmosphere by wet or dry deposition. 4,4'-Methylenediphenyl diisocyanate does not contain chromophores that absorb at wavelengths >290 nm, and therefore is not expected to be susceptible to direct photolysis by sunlight. If released to water or moist soil, 4,4'-methylenediphenyl

diisocyanate is not expected to leach or adsorb to solids due to its rapid hydrolysis. Biodegradation data in soil or water were not available. Since 4,4'-methylenediphenyl diisocyanate reacts with water to form amines and urea, accumulation in the food chain should be low or non-existent. Occupational exposure to 4,4'-methylenediphenyl diisocyanate occurs through inhalation of vapors and aerosols and through dermal contact with this compound and other compounds containing 4,4'-methylenediphenyl diisocyanate. Use data indicate that the general population may be exposed to 4,4'-methylenediphenyl diisocyanate via inhalation and dermal contact with consumer products containing this compound. (SRC) **PEER REVIEWED**

Probable Routes of Human Exposure:

... WHEN MDI PREPN ARE SPRAYED OUT OF DOORS OR IN MINE SHAFTS, PERSONS 40 M OR MORE DOWNWIND MAY BE AFFECTED BY UNREACTED ISOCYANATE IN DROPLETS CARRIED BY AIR CURRENT.[International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971., p. 1099] **PEER REVIEWED** EARLY INDUSTRIAL EXPERIENCE IN HANDLING MDI /METHYLENEBIS(4-PHENYLISOCYANATE)/ REVEALED NO CASES OF SKIN IRRITATION. MDI ADHERES FIRMLY TO SKIN, HOWEVER, & IRRITATION MAY BE INCR OR PRODUCED BY ATTEMPTS AT REMOVAL.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values, 4th ed., 1980. Cincinnati, Ohio: American Conference of Governmmental Industrial Hygienists, Inc., 1980., p. 274] **PEER REVIEWED** ... THE PHYSICAL CHARACTERISTIC OF LOW BUT SIGNIFICANT VAPOR PRESSURE PRESENTS BOTH A VAPOR & PARTICULATE /(DROPLET)/ EXPOSURE IN ONE OF THE CURRENT APPLICATION MDI NAMELY, IN FOAM- OR FILM-COATING OF SURFACES BY SPRAY-GUN TECHNIQUES. MEASURING ENVIRONMENTAL CONTAMINATION DURING THE FOAM APPLICATION SHOWED LEVELS OF TOTAL MDI AS HIGH AS 5 MG/CU M. MORE THAN 95% OF HIGH SAMPLES WERE PARTICULATES OF RESPIRABLE SIZE RANGE, COUNTS WERE FROM 2 TO 8 MILLION PARTS/CU FT. MDI VAPOR CONCN AT BREATHING ZONE DURING APPLICATION DID NOT EXCEED 0.02 PPM (0.2 MG/CU M).[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 978] **PEER REVIEWED** According to the 2006 TSCA Inventory Update Reporting data, the number of persons reasonably likely to be exposed in the industrial manufacturing, processing, and use of 4,4'-methylenediphenyl diisocyanate is 1000 or greater; the data may be greatly underestimated(1).[(1) US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Feb 21, 2012: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED** NIOSH (NOES Survey 1981-1983) has statistically estimated that 53,321 workers (13,421 of these were female) were potentially exposed to 4,4'-methylenediphenyl diisocyanate in the US(1). Occupational exposure to 4,4'-methylenediphenyl diisocyanate may occur through inhalation and dermal contact with this compound at workplaces where 4,4'-methylenediphenyl diisocyanate is produced or used(SRC). The concentration of 4,4'-methylenediphenyl diisocyanate in a Swedish aluminum foundry ranged from <0.0001 to 0.00018 mg/cu m; more than 75% of the 27 samples were below the detection limit of 0.003 mg/cu m(2). The compound presents high potential exposure in those in electrical machinery production as well as to carpenters, painters, and construction workers(3). Use data indicate that the general population may be exposed to 4,4'-methylenediphenyl diisocyanate via inhalation and dermal contact with consumer products containing this compound(SRC).[(1) NIOSH; NOES. National Occupational Exposure Survey conducted from 1981-1983. Estimated numbers of employees potentially exposed to specific agents by 2-digit standard industrial classification (SIC). Available from, as of Feb 24, 2012: http://www.cdc.gov/noes/ (2) Westberg HB et al; Appl Occup Environ Hyg 16: 66-77 (2001) (3) Brandorff NP et al; Occup Environ Med 52: 454-63 (1995)] **PEER REVIEWED** Emissions of 4,4'-methylenediphenyl diisocyanate into the workplace air from 12 polyurethane coatings during application and drying did not exceed 0.20 mg/cu m (0.02 ppm) in the US and 0.07 mg/cu m (0.007 ppm) in Italy(1). The air concentration of 4,4'-methylenediphenyl diisocyanate was monitored during the spray application of polyurethane foam at indoor and outdoor locations(2); the sprayer and his helpers were exposed to concentrations ranging from 0.001 to 0.129 ppm(2); concentrations at distances greater than 25 ft away were negligible(2).[(1) IARC; IARC Monographs on the Evaluation of Carcinogenic Risks to Humans 19: 315-9 (1979) (2) Bilan RA et al; Am Ind Hyg Assoc J 50: 303-6 (1989)] **PEER REVIEWED**

Artificial Pollution Sources:

4,4'-Methylenediphenyl diisocyanate's production and use in the preparation of polyurethane resin and spandex fibers and in bonding rubber to rayon and nylon(1) may result in its release to the environment through various waste streams(SRC).[(1) Lewis RJ Sr; Hawley's Condensed Chemical Dictionary. 15th ed. New York, NY: John Wiley & Sons, Inc., p. 465 (2007)] **PEER REVIEWED**

Environmental Fate:

TERRESTRIAL FATE: When monomeric 4,4'-methylenediphenyl diisocyanate is handled as a liquid (melting point 38 deg C), it will solidify on contact with soil(1). 4,4'-Methylenediphenyl diisocyanate reacts readily with water(1-5). If released to soil, agglomerations of 4,4'-methylenediphenyl diisocyanate react with water to form a hard crust of inert, water-insoluble material comprised of polyureas(1); the polyurea crusts can entrap monomeric 4,4'-methylenediphenyl diisocyanate and prevent further contact with water, thereby increasing the persistence time(1). 4,4'-Methylenediphenyl diisocyanate is not expected to volatilize from dry soil surfaces(SRC) based upon an estimated vapor pressure of 5.0X10-6 mm Hg(6). Biodegradation data in soil were not available(SRC, 2012).[(1) Gilbert DS; J Cellular Plastics 24: 178-92 (1988) (2) Brochhagen FK, Grieveson, BM; Cell Polym 3: 11-7 (1984) (3) Woolrich PF; Amer Ind Hyg Assoc J 43: 89-97 (1982) (4) Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2012). New York, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: 15 Jan 2003. (5) USEPA; Health Hazard Profile on 4,4'-Methylenediphenyl Isocyanate. USEPA Contract No. 68-03-3112 Cincinnati OH: USEPA, ECAO (1984) (6) NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from, as of Feb 24, 2012: http://www.cdc.gov/niosh/npg/] **PEER REVIEWED** AQUATIC FATE: 4,4'-Methylenediphenyl diisocyanate was added to a model marine system and a model river to simulate spill situations(1,2); 4,4'-methylenediphenyl diisocyanate concentrations fell to a maximum of 5% of initial value within one day(1,2). Spills or agglomerations of 4,4'-methylenediphenyl diisocyanate react with water to form a hard crust of inert, water-insoluble material comprised of polyureas(1); the polyurea crusts can entrap monomeric 4,4'-methylenediphenyl diisocyanate and prevent further contact with water, thereby increasing the persistence time(1). Small aquatic releases of 4,4'-methylenediphenyl diisocyanate will hydrolyze rapidly in water with an estimated half-life of a few minutes to a few hours(3-5). Biodegradation data in water were not available(SRC, 2012).[(1) Gilbert DS; J Cellular Plastics 24: 178-92 (1988) (2) Brochhagen FK, Grieveson, BM; Cell Polym 3: 11-7 (1984) (3) Woolrich PF; Amer Ind Hyg Assoc J 43: 89-97 (1982) (4) Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2012). New York, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: 15 Jan 2003. (5) USEPA; Health Hazard Profile on 4,4'-Methylenediphenyl Isocyanate. USEPA Contract No. 68-03-3112 Cincinnati OH: USEPA, ECAO (1984)] **PEER REVIEWED** ATMOSPHERIC FATE: According to a model of gas/particle partitioning of semivolatile organic compounds in the atmosphere(1), 4,4'-methylenediphenyl diisocyanate, which has a vapor pressure of 5.0X10-6 mm Hg at 25 deg C(2), is expected to exist in both the vapor and particulate phases in the ambient atmosphere(SRC). Vapor-phase 4,4'-methylenediphenyl diisocyanate is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals(SRC); the half-life for this reaction in air is estimated to be 11 hours(SRC), calculated from its rate constant of 1.2X10-11 cu cm/molecule-sec at 25 deg C(SRC) determined using a structure estimation method(3). Reaction with atmospheric water vapor(4) may increase the atmospheric degradation rate several fold(SRC). Particulate-phase 4,4'-methylenediphenyl diisocyanate will be removed from the atmosphere by wet and dry deposition(SRC). 4,4'-Methylenediphenyl diisocyanate does not contain chromophores that absorb at wavelengths >290 nm(5), and therefore is not expected to be susceptible to direct photolysis by sunlight(SRC).[(1) Bidleman TF; Environ Sci Technol 22: 361-367 (1988) (2) NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from, as of Feb 24, 2012: http://www.cdc.gov/niosh/npg/ (3) Meylan WM, Howard PH; Chemosphere 26: 2293-99 (1993) (4) Gilbert DS; J Cellular Plastics 24: 178-92 (1988) (5) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Washington, DC: Amer Chem Soc pp. 8-12 (1990)] **PEER REVIEWED**

Environmental Abiotic Degradation:

The rate constant for the vapor-phase reaction of 4,4'-methylenediphenyl diisocyanate with photochemically-produced hydroxyl radicals has been estimated as 1.2X10-11 cu cm/molecule-sec at 25 deg C(SRC) using a structure estimation method(1). This corresponds to an atmospheric half-life of about 11 hours at an atmospheric concentration of 5X10+5 hydroxyl radicals per cu cm(1). 4,4'-Methylenediphenyl diisocyanate does not contain chromophores that absorb at wavelengths >290 nm(2), and therefore is not expected to be susceptible to direct photolysis by sunlight(SRC).[(1) Meylan WM, Howard PH; Chemosphere 26: 2293-99 (1993) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Washington, DC: Amer Chem Soc pp. 8-12 (1990)] **PEER REVIEWED** When monomeric 4,4'-methylenediphenyl diisocyanate comes in contact with water in a spill situation, it reacts with the water to form a hard crust of inert, water-insoluble material comprised mostly of polyureas(1,2). 4,4'-Methylenediphenyl diisocyanate is reported to hydrolyze rapidly in water(3,4); however, a hydrolysis rate constant specific to 4,4'-methylenediphenyl diisocyanate was not available. Based on available data and analogy to other isocyanates, the hydrolysis half-life is on the order of a few minutes to a few hours(5). Reaction with water is complex and usually involves several mechanisms(1); an initial unstable intermediate (acid) is formed that decomposes to the amine with liberation of carbon dioxide, and the amine can react with more 4,4'-methylenediphenyl diisocyanate to form a polyurea(1). Atmospheric chamber studies with the similar compound TDI (toluene diisocyanate) have shown that vapor-phase degradation increased from 15% to about 20% per hour as a result of OH radical attack(6); the 15% per hour rate occurred in the dark (no hydroxyl radical) with a relative humidity of 7-70%(6); therefore, reaction with water vapor in air may be more important than OH radical reaction for 4,4'-methylenediphenyl diisocyanate but this could also be a surface reaction in the chamber(SRC).[(1) Gilbert DS; J Cellular Plastics 24: 178-92 (1988) (2) Brochhagen FK, Grieveson, BM; Cell Polym 3: 11-7 (1984) (3) Woolrich PF; Amer Ind Hyg Assoc J 43: 89-97 (1982) (4) Chadwick DH, Cleveland TH; Kirk-Othmer Encycl Chem Technol 3rd ed. NY, NY: John Wiley and Sons 13: 789-818 (1981) (5) USEPA; Health Hazard Profile on 4,4'-Methylenediphenyl Isocyanate. USEPA Contract No. 68-03-3112 Cincinnati OH: USEPA, ECAO (1984) (6) Gilbert DS; J Cellular Plastics 24: 178-92 (1988)] **PEER REVIEWED** Isocyanates hydrolyze readily in water to yield a carbamic acid, which decarboxylates to produce CO2 and an amine; the latter immediately reacts with more isocyanate to yield a disubstituted urea(1). /Isocyanates/[(1) Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2012). New York, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: 15 Jan 2003] **PEER REVIEWED**

Environmental Bioconcentration:

4,4'-Methylenediphenyl diisocyanate hydrolyzes rapidly in aqueous solution(1-3); therefore, bioconcentration will not be an important environmental fate process(SRC). Exposure of carp to 0.00001% concentrations of 4,4'-methylenediphenyl diisocyanate for an eight week period resulted in no bioaccumulations(4).[(1) Woolrich PF; Amer Ind Hyg Assoc J 43: 89-97 (1982) (2) Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2012). New York, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: 15 Jan 2003. (3) USEPA; Health Hazard Profile on 4,4'-Methylenediphenyl Isocyanate. USEPA Contract No. 68-03-3112 Cincinnati OH: USEPA, ECAO (1984) (4) Brochhagen FK, Grieveson, BM; Cell Polym 3: 11-7 (1984)] **PEER REVIEWED**

Soil Adsorption/Mobility:

4,4'-Methylenediphenyl diisocyanate hydrolyzes rapidly in aqueous solution(1-3); therefore, leaching and adsorption to moist soil and sediment will not be an important environmental fate process(SRC).[(1) Woolrich PF; Amer Ind Hyg Assoc J 43: 89-97 (1982) (2) Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2012). New York, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: 15 Jan 2003. (3) USEPA; Health Hazard Profile on 4,4'-Methylenediphenyl Isocyanate. USEPA Contract No. 68-03-3112 Cincinnati OH: USEPA, ECAO (1984)] **PEER REVIEWED**

Volatilization from Water/Soil:

4,4'-Methylenediphenyl diisocyanate hydrolyzes rapidly in aqueous solution(1-3); therefore, volatilization from water and moist soil will not be an important environmental process(SRC). 4,4'-Methylenediphenyl diisocyanate is not expected to volatilize from dry soil surfaces(SRC) based upon an estimated vapor pressure of 5.0X10-6 mm Hg(4).[(1) Woolrich PF; Amer Ind Hyg Assoc J 43: 89-97 (1982) (2) Six C, Richter F; Ullmann's

Encyclopedia of Industrial Chemistry. 7th ed. (1999-2012). New York, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: 15 Jan 2003. (3) USEPA; Health Hazard Profile on 4,4'-Methylenediphenyl Isocyanate. USEPA Contract No. 68-03-3112 Cincinnati OH: USEPA, ECAO (1984) (4) NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from, as of Feb 24, 2012: http://www.cdc.gov/niosh/npg/] **PEER REVIEWED**

Effluent Concentrations:

4,4'-Methylenediphenyl diisocyanate emission levels of <0.02 to 1.0 mg/kg core material were detected from foundry molds using polyurethane binders(1).[(1) Renman L et al; Am Ind Hyg Assoc J 47: 621-8 (1986)] **PEER REVIEWED**

Other Environmental Concentrations:

4,4'-Methylenediphenyl diisocyanate emission from commercial composite boards cured with polyurethane glue was below the detection limit of 20 parts/trillion. For aluminum and wood substrates cured with glue, the compound was detected at 60 part/trillion in the first 8 hours of sampling but below the detection limit thereafter(1).[(1) Parekh PP, Karoly B; pp 75-79 in Conf. Proceed. - Polyurethanes Expo, Columbus, OH (2001)] **PEER REVIEWED**

Environmental Standards & Regulations:

TSCA Requirements:

Section 8(a) of TSCA requires manufacturers of this chemical substance to report preliminary assessment information concerned with production, exposure, and use to EPA as cited in the preamble in 51 FR 41329. Effective date: 10/29/90; Reporting date: 12/27/90.[40 CFR 712.30 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of February 24, 2012: http://www.ecfr.gov] **PEER REVIEWED** Pursuant to section 8(d) of TSCA, EPA promulgated a model Health and Safety Data Reporting Rule. The section 8(d) model rule requires manufacturers, importers, and processors of listed chemical substances and mixtures to submit to EPA copies and lists of unpublished health and safety studies. Benzene, 1,1'-methylenebis(4-isocyanato)- is included on this list. Effective date: 6/1/87; Sunset date: 6/1/97.[40 CFR 716.120 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of February 24, 2012: http://www.ecfr.gov] **PEER REVIEWED**

CERCLA Reportable Quantities:

Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 5000 lb or 2270 kg. The toll free number of the NRC is (800) 424-8802. The rule for determining when notification is required is stated in 40 CFR 302.4 (section IV. D.3.b).[40 CFR 302.4 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of February 24, 2012: http://www.ecfr.gov] **PEER REVIEWED**

Atmospheric Standards:

This action promulgates standards of performance for equipment leaks of Volatile Organic Compounds (VOC) in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The intended effect of these standards is to require all newly constructed, modified, and reconstructed SOCMI process units to use the best demonstrated system of continuous emission reduction for equipment leaks of VOC, considering costs, non air quality health and environmental impact and energy requirements. Methylene diphenyl diisocyanate is produced, as an intermediate or a final product, by process units covered under this subpart.[40 CFR 60.489 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available

from, as of February 24, 2012: http://www.ecfr.gov] **PEER REVIEWED** Listed as a hazardous air pollutant (HAP) generally known or suspected to cause serious health problems. The Clean Air Act, as amended in 1990, directs EPA to set standards requiring major sources to sharply reduce routine emissions of toxic pollutants. EPA is required to establish and phase in specific performance based standards for all air emission sources that emit one or more of the listed pollutants. Methylenebis(4-phenylisocyanate) is included on this list.[Clean Air Act as amended in 1990, Sect. 112 (b) (1) Public Law 101-549 Nov. 15, 1990] **PEER REVIEWED**
Chemical/Physical Properties:

Molecular Formula:

C15-H10-N2-O2 **PEER REVIEWED**

Molecular Weight:

250.252[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-220] **PEER REVIEWED**

Color/Form:

Light-yellow, fused solid
[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 465] **PEER REVIEWED**
Crystals
[Sax, N.I. Dangerous Properties of Industrial Materials. Vol 1-3 7th ed. New York, NY: Van Nostrand Reinhold, 1989., p. 1481] **PEER REVIEWED**
White to light yellow flakes [Note: A liquid above 99 degrees F]
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**

Odor:

Odorless
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**

Melting Point:

37 deg C[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-220] **PEER REVIEWED**

Octanol/Water Partition Coefficient:

log Kow = 5.22 (est)[US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of Feb 21, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm] **PEER REVIEWED**

Solubilities:

In water, 1.51 mg/L at 25 deg C (est)
[US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of Feb 21, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm] **PEER REVIEWED**

Soluble in acetone, benzene, kerosene, and nitrobenzene
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-220] **PEER REVIEWED**

Vapor Pressure:

5.0X10-6 mm Hg at 25 deg C[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 208] **PEER REVIEWED**

Other Chemical/Physical Properties:

BP: 196 deg C at 5 mm Hg
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-220] **PEER REVIEWED**
Density: 1.197 g/cu cm at 70 deg C
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-220] **PEER REVIEWED**
Index of refraction: 1.5906 at 50 deg C/D
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-220] **PEER REVIEWED**
VAPOR PRESSURE: 0.0075 MM HG @ 94 DEG C /TECHNICAL PRODUCT/
[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V19 315 (1978)] **PEER REVIEWED**
Specific gravity: 1.23 (solid at 25 deg C); 1.19 (Liquid at 50 deg C)
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 208] **PEER REVIEWED**
VAPOR PRESSURE: 0.001 MM HG @ 40 DEG C
[Lewis, R.J. Sax's Dangerous Properties of Industrial Materials. 9th ed. Volumes 1-3. New York, NY: Van Nostrand Reinhold, 1996., p. 2230] **PEER REVIEWED**
Hydrolyzed by water.
[Ashford, R.D. Ashford's Dictionary of Industrial Chemicals. London, England: Wavelength Publications Ltd., 1994., p. 349] **PEER REVIEWED**
Conversion factor: 1 ppm = 10.24 mg/cu m
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 208] **PEER REVIEWED**
Solidification point: 37 deg C
[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 465] **PEER REVIEWED**
Henry's Law constant = 8.95X10-7 atm-cu m/mol at 25 deg C (est)
[US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of Feb 21, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm] **PEER REVIEWED**
Hydroxyl radical reaction rate constant = 1.20X10-11 cu cm/molec-sec at 25 deg C (est)
[Atkinson R; Environ Toxicol Chem 7: 435-62 (1988)] **PEER REVIEWED**

Chemical Safety & Handling:

Odor Threshold:

MDI is reported to be odorless.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.62 (2001). Available from, as of March 5, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED**

Skin, Eye and Respiratory Irritations:

Irritating /to/ eyes, nose, throat.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** A skin and eye irritant. An allergic sensitizer.[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 2435] **PEER REVIEWED**

Fire Potential:

A flammable liquid.[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 2435] **PEER REVIEWED**

Flash Point:

396 DEG F (OPEN CUP)[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values, 4th ed., 1980. Cincinnati, Ohio: American Conference of Governmmental Industrial Hygienists, Inc., 1980., p. 274] **PEER REVIEWED**

Fire Fighting Procedures:

Carbon dioxide or dry chemical.[U.S. Coast Guard, Department of Transportation. CHRIS - Hazardous Chemical Data. Manual Two. Washington, DC: U.S. Government Printing Office, Oct., 1978.] **PEER REVIEWED** If material on fire or involved in fire: Extinguish fire using agent suitable for type of surrounding fire. Material itself does not burn or burns with difficulty. Keep run-off water out of sewers and water sources. /Methylene diphenyl diisocyanate/[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 604] **PEER REVIEWED** Where there is a fire involving isocyanates, carbon dioxide or powder extinguishers must be employed. Firemen must be equipped with self-contained breathing apparatus. /Isocyanates/[International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983., p. 1162] **PEER REVIEWED**

Hazardous Reactivities & Incompatibilities:

Strong alkalis, acids, alcohol [Note: Polymerizes at 450 degrees F].[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**

Hazardous Decomposition:

When heated to decomposition it emits toxic fumes of /nitrogen oxides and sulfur oxides/.[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 2435] **PEER REVIEWED**

Immediately Dangerous to Life or Health:

75 mg/cu m[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**

Protective Equipment & Clothing:

MASK OR RESPIRATOR OF TYPE APPROVED BY USA BUREAU OF MINES (ABOVE 135 DEG C); CLEAN RUBBER GLOVES; CHEMICAL GOGGLES; CLEAN WATERPROOF OR FRESHLY

LAUNDERED PROTECTIVE CLOTHING (COVERALLS, RUBBER BOOTS, CAP, ETC).[U.S. Coast Guard, Department of Transportation. CHRIS - Hazardous Chemical Data. Manual Two. Washington, DC: U.S. Government Printing Office, Oct., 1978.] **PEER REVIEWED** Wear appropriate personal protective clothing to prevent skin contact.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** Wear appropriate eye protection to prevent eye contact.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** Respirator Recommendations: Up to 0.5 mg/cu m:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 10	Any supplied-air respirator. Substance reported to cause eye irritation or damage; may require eye protection.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**
Respirator Recommendations: Up to 1.25 mg/cu m:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 25	Any supplied-air respirator operated in a continuous-flow mode. Substance reported to cause eye irritation or damage; may require eye protection.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**
Respirator Recommendations: Up to 2.5 mg/cu m:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 50	Any self-contained breathing apparatus with a full facepiece.
APF = 50	Any supplied-air respirator with a full facepiece.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**
Respirator Recommendations: Up to 75 mg/cu m:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 2000	Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**
Respirator Recommendations: Emergency or planned entry into unknown concentrations or IDLH conditions:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 10,000	Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.
APF = 10,000	Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH)

Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**
Respirator Recommendations: Escape:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 50	Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister having an N100, R100, or P100 filter. Any appropriate escape-type, self-contained breathing apparatus.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**
Whenever there is potential for exposure to diisocyanates, even concentrations below the NIOSH REL, NIOSH recommends that employees be supplied with supplied-air respiratory protection. (Negative pressure air-purifying respirators are not recommended since diisocyanates have poor odor warning properties.) Also, there should be a respiratory protection program. /Diisocyanates/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.6 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED**
NIOSH investigators recommend that dermal exposures to isocyanate-containing substances be prevented. Employers should provide protective clothing, gloves, and footwear that is impervious to isocyanate--containing compounds. The protective clothing should either be disposed or laundered after each use (e.g., at the end of the work shift). The gloves should be elbow-length and made of an isocyanate-resistant material. /Isocyanate-containing substances/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.6 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED** Face-shields and aprons should be used whenever there is a possibility of a splash or a spill of liquids containing isocyanate-containing materials. /Isocyanate-containing substances/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.6 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED**

Preventive Measures:

SRP: Contaminated protective clothing should be segregated in such a manner so that there is no direct personal contact by personnel who handle, dispose, or clean the clothing. The completeness of the cleaning procedures should be considered before the decontaminated protective clothing is returned for reuse by the workers. Contaminated clothing should not be taken home at the end of shift, but should remain at employee's place of work for cleaning. **PEER REVIEWED** SRP: The scientific literature for the use of contact lenses by industrial workers is inconsistent. The benefits or detrimental effects of wearing contact lenses depend not only upon the substance, but also on factors including the form of the substance, characteristics and duration of the exposure, the uses of other eye protection equipment, and the hygiene of the lenses. However, there may be individual substances whose irritating or corrosive properties are such that the wearing of contact lenses would be harmful to the eye. In those specific cases, contact lenses should not be worn. In any event, the usual eye protection equipment should be worn even when contact lenses are in place. **PEER REVIEWED** The worker should immediately wash the skin when it becomes contaminated.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** Work clothing that becomes wet or significantly contaminated should be removed and replaced.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** Workers whose clothing may have become contaminated should change into uncontaminated clothing before leaving the work premises.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** Personal protection: Keep upwind. Avoid breathing dusts. Wear appropriate chemical protective gloves, boots and goggles. Do not handle broken

packages unless wearing appropriate personal protective equipment. /Methylene diphenyl diisocyanate/[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 604] **PEER REVIEWED** If material not on fire and not involved in fire: Keep material out of water sources and sewers. /Methylene diphenyl diisocyanate/[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 604] **PEER REVIEWED** The open points at the interface between different forms of protective clothing, e.g., the opening that forms between the sleeve of a protective suit and a glove, should be sealed to prevent exposure through the interface. A common and effective method for sealing these interfaces is to use duct tape to join the two different forms of protective clothing. /Isocyanate-containing substances/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.6 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED** NIOSH recommends that employers provide workers with appropriate training on the inhalation and dermal exposure hazards associated with isocyanate-containing materials and on the proper use of personal protective equipment (PPE) associated with protection from these exposures. /Isocyanate-containing substances/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.7 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED** NIOSH recommends that empoloyers conduct industrial hygiene (IH) surveys on all workers potentially exposed to isocyanates. /Isocyanates/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.7 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED** NIOSH recommends both preplacement and periodic medical surveillance programs for all workers potentially exposed to diisocyanates. /Diisocyanates/[DHHS/CDC/NIOSH; A Summary of Health Hazard Evaluations: Issues Related to Occupational Exposure to Isocyanates, 1989 to 2002 p.7 (January 2004). Available from, as of August 13, 2012: http://www.cdc.gov/niosh/docs/2004-116] **PEER REVIEWED**

Storage Conditions:

Isocyanates are transported in railroad tank cars, tank trucks, tanks in ships, containers, and drums. They are stored in steel tanks and processed in steel equipment. For long-term storage stainless steel is recommended. To avoid contamination by atmospheric moisture, a dry air or inert gas blanket is essential. /Isocyanates/[Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2012). NY, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: January 15, 2003] **PEER REVIEWED**

Cleanup Methods:

VENTILATE AREA OF SPILL OR LEAK. FOR SMALL QUANTITIES, ABSORB ON PAPER TOWELS. ... BURN THE PAPER IN SUITABLE LOCATION AWAY FROM COMBUSTIBLE MATERIALS. LARGE QUANTITIES CAN BE COLLECTED & ATOMIZED IN SUITABLE COMBUSTION CHAMBER EQUIPPED WITH APPROPRIATE EFFLUENT GAS CLEANING DEVICE. DISPOSAL METHODS: 1. BY ABSORBING ON VERMICULITE, DRY SAND, EARTH OR A SIMILAR MATERIAL & DISPOSING IN A SECURED SANITARY LANDFILL. 2. BY ATOMIZING IN SUITABLE COMBUSTION CHAMBER EQUIPPED WITH APPROPRIATE EFFLUENT GAS CLEANING DEVICE.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED** Environmental considerations - land spill: Dig a pit, pond, lagoon, holding area to contain liquid or solid material. Cover solids with a plastic sheet to prevent dissolving in rain or fire fighting water. Dike surface flow using soil, sand bags, foamed polyurethane, or foamed concrete. /Methylene diphenyl diisocyanate/[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 604] **PEER REVIEWED** Environmental considerations - water spill: Use natural barriers or oil spill control booms to limit spill travel. Use natural deep water pockets, excavated lagoons, or sand bag barriers to trap material at bottom. Remove trapped material with suction hoses. /Methylene diphenyl diisocyanate/[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 604]

PEER REVIEWED Decontamination of spilled isocyanates and disposal of isocyanate waste are best conducted by using aqueous ammonia (3-8% concentrated ammonia solution in 90-95% water with 0.2-5% liquid detergent) or aqueous sodium carbonate (5-10% sodium carbonate in 90-95% water and 0.2-5% liquid detergent). An alcoholic solution (50% ethanol, isopropyl alcohol, or butanol; 45% water; and 5% concentrated ammonia) may be preferred because of the low miscibility of isocyanates with water. /Isocyanates/[Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2012). NY, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: January 15, 2003] **PEER REVIEWED**

Disposal Methods:

SRP: The most favorable course of action is to use an alternative chemical product with less inherent propensity for occupational harm/injury/toxicity or environmental contamination. Recycle any unused portion of the material for its approved use or return it to the manufacturer or supplier. Ultimate disposal of the chemical must consider: the material's impact on air quality; potential migration in soil or water; effects on animal and plant life; and conformance with environmental and public health regulations. **PEER REVIEWED** SRP: Wastewater from contaminant suppression, cleaning of protective clothing/equipment, or contaminated sites should be contained and evaluated for subject chemical or decomposition product concentrations. Concentrations shall be lower than applicable environmental discharge or disposal criteria. Alternatively, pretreatment and/or discharge to a permitted wastewater treatment facility is acceptable only after review by the governing authority and assurance that "pass through" violations will not occur. Due consideration shall be given to remediation worker exposure (inhalation, dermal and ingestion) as well as fate during treatment, transfer and disposal. If it is not practicable to manage the chemical in this fashion, it must be evaluated in accordance with EPA 40 CFR Part 261, specifically Subpart B, in order to determine the appropriate local, state and federal requirements for disposal. **PEER REVIEWED**

Occupational Exposure Standards:

OSHA Standards:

Permissible Exposure Limit: Table Z-1 Ceiling value: 0.02 ppm (0.2 mg/cu m).[29 CFR 1910.1000 (USDOL); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of February 24, 2012: http://www.ecfr.gov] **PEER REVIEWED**

Threshold Limit Values:

8 hr Time Weighted Avg (TWA): 0.005 ppm[American Conference of Governmental Industrial Hygienists; 2011 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices . Cincinnati, OH 2011, p. 40] **PEER REVIEWED** Excursion Limit Recommendation: Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a work day, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded.[American Conference of Governmental Industrial Hygienists; 2011 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices . Cincinnati, OH 2011, p. 5] **PEER REVIEWED**

NIOSH Recommendations:

Recommended Exposure Limit: 10 Hour Time-Weighted Average: 0.05 mg/cu m (0.005 ppm).[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED** Recommended Exposure Limit: 10 Minute Ceiling Value: 0.2 mg/cu m (0.020 ppm).[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**

Immediately Dangerous to Life or Health:

75 mg/cu m[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Control & Prevention. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from: http://www.cdc.gov/niosh/npg] **PEER REVIEWED**

Other Standards Regulations and Guidelines:

Emergency Response Planning Guidelines (ERPG): ERPG(1) 0.2 mg/cu m (no more than mild, transient effects) for up to 1 hr exposure; ERPG(2) 2 mg/cu m (without serious, adverse effects) for up to 1 hr exposure; ERPG(3) 25 mg/cu m (not life threatening) up to 1 hr exposure.[American Industrial Hygiene Association. The AIHA 2001 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. AIHA Press, Fairfax, VA. 2001., p. 25] **PEER REVIEWED**

Manufacturing/Use Information:

View products that contain this chemical: 4,4'-Methylenediphenyl Diisocyanate

Uses:

Typically, a mixture of MDI and its dimer and trimer is formed (polymeric MDI). This product is used primarily to make rigid and semi-rigid polyurethane foams. Pure MDI is distilled from the reaction mixture and is mainly used for reaction injection-molding, thermoplastic elastomers and adhesives.[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED** Preparation of polyurethane resin and spandex fibers; bonding rubber to rayon and nylon.[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 465] **PEER REVIEWED** MDI is used in two-component polyurethane coating systems which are used for aircraft, tank trucks and truck trailers due to durability and toughness. It is also used to produce polyurethane lacquer coatings applied to certain automobile body components and, to small extent, to patent leather. Other uses ... are in production of thermoplastic polyurethane resins, millable gums and spandex fibers.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. V19 317 (1978)] **PEER REVIEWED** TDI and MDI are used in surface coatings (e.g. for chutes used in mining and agriculture), in the shoe industry for shoe soles, in the automobile industry for shock absorbers, and in a wide variety of other industries. MDI occurs in foundries in binders for casting forms, and in orthopedic surgery in casts for broken bones.[Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.62 (2001). Available from, as of March 5, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED**

Manufacturers:

BASF Corporation, 100 Campus Dr., Florham Park, NJ 07932, (973) 245-6000; Plastics Division, Polyurethanes; Production site: Geismar, LA 70734 /2,4/2,6-Toluene diisocyanate (mixed)/[SRI Consulting. 2011 Directory of Chemical Producers United States. SRI Consulting, Menlo Park, CA 2011, p. 657] **PEER REVIEWED** Bayer MaterialScience LLC., 100 Bayer Rd., Pittsburgh, PA 15205-9741, (800) 662-2927; Production sites: Baytown, TX 77521 /also 2,4/2,6-Toluene diisocyanate (mixed)/[SRI Consulting. 2011 Directory of Chemical Producers United States. SRI Consulting, Menlo Park, CA 2011, p. 657] **PEER REVIEWED** The Dow Chemical Company, 2030 Dow Center, Midland, MI 48674, (989) 636-1000; Production site: Freeport, TX 77541[SRI Consulting. 2011 Directory of Chemical Producers United States. SRI Consulting, Menlo Park, CA 2011, p. 657] **PEER REVIEWED** Huntsman International LLC, 500 Huntsman Way, Salt Lake City, UT 84108, (801) 584-5700, Huntsman Polyurethanes; Production site: Geismar, LA 70734[SRI Consulting. 2011 Directory of Chemical Producers United States. SRI Consulting, Menlo Park, CA 2011, p. 657] **PEER REVIEWED** 4,4'-Methylenediphenyl diisocyanate - Producer and Manufacture Data (2006)

Company	Site	City State Zip	Manufacture	Import

BASF Corporation	BASF Corp - Corporate Headquarters	Florham Park NJ 07932	No	Yes
BASF Corporation	BASF Corp - Geismar	Geismar LA 70734	Yes	No
Bayer MaterialScience	Bayer MaterialScience - Baytown	Baytown TX 77520	Yes	No
Bayer MaterialScience	Bayer MaterialScience - Pittsburgh	Pittsburgh PA 15205	No	Yes
Day International, Inc.	Day International, Inc.	Arden NC 28704	No	Yes
Mitsui & Co. (USA) Inc.	Mitsui & Co - New York	New York NY 10166	No	Yes
Rubicon LLC	Rubicon LLC	Geismar LA 70734	Yes	No
The Dow Chemical Company	Dow Chemical - Headquarters	Midland MI 48674	No	Yes

[US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Feb 21, 2012: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED**

Methods of Manufacturing:

The production of PMDI /polymeric methylenediphenyl diisocyanate/ involves condensation of aniline with formaldehyde in the presence of hydrochloric acid to give oligomeric di- and polyamines that are phosgenated without further need of purification. The percentage distribution of the homologues and isomers of MDA /methylenedianiline/ depends on the ratio of aniline to formaldehyde, the acid concentration, and the reaction conditions. Monomeric MDI is obtained from PMDI by continuous thin-film distillation.[Six C, Richter F; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2012). NY, NY: John Wiley & Sons; Isocyanates, Organic. Online Posting Date: January 15, 2003] **PEER REVIEWED** Pure diphenylmethane 4,4'-diisocyanate formed through a two-step process beginning with the condensation reaction between aniline and formaldehyde, yielding diphenylmethane diamine. A subsequent phosgenation gives the aromatic isocyanate MDI.[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED**

General Manufacturing Information:

The market split is roughly 80 percent polymeric and 20 percent pure MDI.[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED**

Formulations/Preparations:

4,4'-Methylenediphenyl diisocyanate blocked with, for example, phenol is preferred in some applications. [Ashford, R.D. Ashford's Dictionary of Industrial Chemicals. London, England: Wavelength Publications Ltd., 1994., p. 349] **PEER REVIEWED** MDI usually occurs as a mixture of several isomers and oligomers: one common mixture is approximately 30-40% diphenylmethane-4,4'-diisocyanate, 2.5-4.0% diphenylmethane-2,4'-diisocyanate, 0.1-0.2 % diphenylmethane-2,2'- diisocyanate, and the remaining 50-60% oligomers. [Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.62 (2001). Available from, as of March 5, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED**

Consumption Patterns:

28% AS AN INT FOR POLYURETHANE COATINGS; 22% AS AN INT FOR POLYURETHANE ELASTOMERS; 22% AS AN INT FOR POLYURETHANE THERMOPLASTIC RESINS; 19% AS AN INT FOR POLYURETHANE SPANDEX FIBERS; 9% AS AN INT FOR POLYURETHANE MILLABLE GUMS (1974)[SRI] **PEER REVIEWED** Rigid polyurethane foam, 80 percent (construction, 50 percent; refrigeration, 12 percent; packaging, 8 percent; tank and pipe insulation, 3 percent; other foam uses, including transportation, marine flotation and furniture, 7 percent); reaction-injection molding (RIM) applications, 13 percent; cast

elastomers, 2 percent; miscellaneous pure and polymeric MDI uses, including thermoplastic resins and foundry core binders, 5 percent.[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED** Demand: (1997) 1.33 billion pounds; (1998) 1.34 billion pounds; (2002) 1.51 billion pounds.[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED**

U. S. Production:

(1974) 3.63-4.54X10+9 GRAMS (CONSUMPTION)[SRI] **PEER REVIEWED** (1988) 3.65X10+8 lb[United States International Trade Commission. Synthetic Organic Chemicals- United States Production and Sales, 1988. USITC Publication 1989. Washington, DC: United States International Trade Commission, 1989., p. 3-2] **PEER REVIEWED** This is a high volume chemical with production exceeding 1 million pounds annually in the U.S.[Environ Defense; Environmental Defense Scorecard Database. Report for MDI (101-68-8). Available from, as of April 9, 2001: http://www.scorecard.org/] **PEER REVIEWED** Capacity: 1,970 million lbs/yr of polymeric and pure diphenylmethane 4,4'-diisocyanate[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Date of Profile.] **PEER REVIEWED** Benzene, 1,1'-methylenebis(4-isocyanato- is listed as a High Production Volume (HPV) chemical (65FR81686). Chemicals listed as HPV were produced in or imported into the U.S. in >1 million pounds in 1990 and/or 1994. The HPV list is based on the 1990 Inventory Update Rule. (IUR) (40 CFR part 710 subpart B; 51FR21438). [EPA/Office of Pollution Prevention and Toxics; High Production Volume (HPV) Challenge Program. Benzene, 1,1'-methylenebis(4-isocyanato- (101-68-8). Available from, as of February 26, 2012: http://www.epa.gov/hpv/pubs/general/opptsrch.htm] **PEER REVIEWED** Production volumes for non-confidential chemicals reported under the Inventory Update Rule.

Year	Production Range (pounds)
1986	>100 million - 500 million
1990	>50 million - 100 million
1994	>50 million - 100 million
1998	>100 million - 500 million
2002	>100 million - 500 million

[US EPA; Non-confidential Production Volume Information Submitted by Companies for Chemicals Under the 1986-2002 Inventory Update Rule (IUR). Benzene, 1,1'-methylenebis(4-isocyanato- (101-68-8). Available from, as of February 26, 2012: http://www.epa.gov/oppt/iur/tools/data/2002-vol.html] **PEER REVIEWED** Production volume for non-confidential chemicals reported under the 2006 Inventory Update Rule. Chemical: Benzene, 1,1'-methylenebis(4-isocyanato-. Aggregated National Production Volume: 100 to < 500 million pounds.[US EPA; Non-Confidential 2006 Inventory Update Reporting. National Chemical Information. Benzene, 1,1'-methylenebis(4-isocyanato- (101-68-8). Available from, as of February 26, 2012: http://cfpub.epa.gov/iursearch/index.cfm?s=chem&err=t] **PEER REVIEWED**

U. S. Imports:

(1975) 1.00X10+6 grams[SRI] **PEER REVIEWED** Negligible[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED**

U. S. Exports:

(1974) 3.18-3.63X10+10 GRAMS (POLYMERIC FORM)[SRI] **PEER REVIEWED** 5 percent of production[ChemExpo; Chemical Profile Database on Methylene diphenyl diisocyanate (MDI) (101-68-8). Jan 3, 2000.] **PEER REVIEWED**

Laboratory Methods:

Analytic Laboratory Methods:

Method: NIOSH 5521, Issue 2; Procedure: high performance liquid chromatography, electrochemical and ultra violet detection; Analyte: methylene bisphenyl isocyanate (urea derivatives of isocyanate); Matrix: air; Detection Limit: 0.1 ug diisocyanate/sample.[CDC; NIOSH Manual of Analytical Methods, 4th ed. Methylene bisphenyl isocyanate (101-68-8). Available from, as of February 27, 2012: http://www.cdc.gov/niosh/docs/2003-154/] **PEER REVIEWED** Method: NIOSH 5522, Issue 1; Procedure: high performance liquid chromatography, florescence detector/electrochemical detector; Analyte: methylene bisphenyl isocyanate (tryptamine derivatives of isocyanate); Matrix: air; Detection Limit: 0.3 ug/sample.[CDC; NIOSH Manual of Analytical Methods, 4th ed. Methylene bisphenyl isocyanate (101-68-8). Available from, as of February 27, 2012: http://www.cdc.gov/niosh/docs/2003-154/] **PEER REVIEWED** Method: NIOSH 5525, Issue 1; Procedure: high performance liquid chromatography, ultraviolet/fluorecence detection; Analyte: methylene bisphenyl isocyanate (MAP derivatives of isocyanate); Matrix: air; Detection Limit: 0.2 nmole NCO per sample.[CDC; NIOSH Manual of Analytical Methods, 4th ed. Methylene bisphenyl isocyanate (101-68-8). Available from, as of February 27, 2012: http://www.cdc.gov/niosh/docs/2003-154/] **PEER REVIEWED** Method: OSHA 18; Procedure: high pressure liquid chromatography; Analyte: methylene bisphenyl diisocyanate; Matrix: air; Detection Limit: 0.10 ppb.[U.S. Department of Labor/Occupational Safety and Health Administration's Index of Sampling and Analytical Methods. Methylene bisphenyl diisocyanate (101-68-8). Available from, as of February 28, 2012: http://www.osha.gov/dts/sltc/methods/toc.html] **PEER REVIEWED** Method: OSHA 33; Procedure: gas chromatography with thermal energy analysis; Analyte: Methylene bisphenyl diisocyanate (urea derivative); Matrix: air; Detection Limit: 0.15 ug/sample.[U.S. Department of Labor/Occupational Safety and Health Administration's Index of Sampling and Analytical Methods. Methylene bisphenyl diisocyanate (101-68-8). Available from, as of February 28, 2012:] **PEER REVIEWED** Method: OSHA 47; Procedure: high performance liquid chromatography with ultraviolet or fluorescence detector; Analyte: methylene bisphenyl isocyanate; Matrix: air; Detection Limit: 0.8 ug/cu m.[U.S. Department of Labor/Occupational Safety and Health Administration's Index of Sampling and Analytical Methods. Methylene bisphenyl isocyanate (101-68-8). Available from, as of February 28, 2012: http://www.osha.gov/dts/sltc/methods/toc.html] **PEER REVIEWED** HIGH SPEED LIQ CHROMATOGRAPHIC METHOD BASED ON DETERMINATION OF UREAS FORMED FROM REACTION OF ISOCYANATES WITH N-4-NITROBENZYL-N-PROPYLAMINE IS PRESENTED. DETECTION LIMIT FOR METHYLENEBIS(4-PHENYLISOCYANATE) IS 0.005 MG/CU M OR 0.50 PPB. THIS METHOD CANNOT BE USED IN ATMOSPHERES WHICH DECOMPOSE THE NITRO REAGENT BY OXIDN OR REDN.[DUNLAP KL ET AL; ANAL CHEM 48 (3): 497 (1976)] **PEER REVIEWED** METHYLENEBIS(4-PHENYLISOCYANATE) IS DETERMINED IN AIR BY HYDROLYSIS IN HYDROCHLORIC-ACETIC ACID DIAZOTIZATION AND COUPLING, WITH N-1-NAPHTHYLETHYLENEDIAMINE, & DETERMINED SPECTROPHOTOMETRICALLY AT 555 NM. THE RANGE USED IS 1.5-15 UG (0.007-0.073 PPM IN A 20 LITER SAMPLE).[DIMITRIADES B; HEALTH LAB SCI 12 (3): 283 (1975)] **PEER REVIEWED** ISOCYANATES WERE DETERMINED IN AIR BY HIGH-PERFORMANCE LIQ CHROMATOGRAPHY USING 1-(2-METHOXYPHENYL)PIPERAZINE AS THE ELECTROGENIC REAGENT.[WARWICK CJ ET AL; ANALYST (LONDON) 106 (1263): 676 (1981)] **PEER REVIEWED** UREA DERIVATIVES OF COMMON ISOCYANATES WERE FORMED WITH N-4-NITROBENZYL-N-PROPYLAMINE & CHROMATOGRAPHED BY REVERSED-PHASE LIQ CHROMATOGRAPHY. DETECTION LIMIT FOR 4,4-DIPHENYLMETHANE WAS BELOW 1 PPB FOR A 20 LITER AIR SAMPLE.[GRAHAM JD; J CHROMATOGR SCI 18 (8): 384 (1980)] **PEER REVIEWED** A METHOD IS DESCRIBED FOR ANALYSIS OF AIRBORNE METHYLENEBIS(4-PHENYLISOCYANATE) USING GLC. IT IS COLLECTED IN ACIDIC ABSORBING SOLN WHERE IT UNDERGOES HYDROLYSIS, CONVERTED TO THE FREE DIAMINE WITH CAUSTIC, & EXTRACTED INTO TOLUENE. DERIV ANALYZED BY GLC USING ELECTRON CAPTURE DETECTOR.[BISHOP RW ET AL; AM IND ASSOC J 44 (3): 151 (1983)] **PEER REVIEWED** HIGH-PERFORMANCE LIQUID CHROMATOGRAPHIC METHOD, COLORIMETRIC METHOD & CONTINUOUS TAPE MONITORING METHOD WERE UTILIZED TO DETERMINE THE CONCENTRATIONS OF DIPHENYLMETHANE DIISOCYANATE IN AIR.[ROSENBERG C, PFAFFLI P; AM IND HYG ASSOC J 43 (3): 160 (1982)] **PEER REVIEWED**

Sampling Procedures:

SAMPLING & ANALYTICAL METHODS FOR 4,4'-BIS(CARBONYLAMINO)DIPHENYLMETHANE IN AIR WERE DEVELOPED. THE SAMPLER CONTAINED A GLASS FIBER FILTER IMPREGNATED WITH A REAGENT.[TUCKER SP, ARNOLD JE; ANAL CHEM 54 (7): 1137 (1982)] **PEER REVIEWED** UNDER NORMAL SPRAYING OPERATIONS, MDI IS PRESENT IN AIR AS AN AEROSOL & NOT AS A GAS. CALIBRATION OF CONTINUOUS READING MONITORS (MODEL 7000 & MCM 4000) FOR MEASUREMENT OF MDI IS DESCRIBED.[DHARMARAJAN V ET AL; J AM IND HYG ASSOC 39 (9): 737 (1978)] **PEER REVIEWED**

Special References:

Special Reports:

WOOLRICH PF; TOXICOLOGY, INDUSTRIAL HYGIENE AND MEDICAL CONTROL OF TDI, MDI AND PMPPI; AM IND HYG ASSOC J 43 (2): 89 (1982). A REVIEW OF THE TOXICOLOGY, INDUSTRIAL HYGIENE, & MEDICAL CONTROL OF MDI IS PRESENTED.Canadian Centre for Occupational Health and Safety; Methylene Bisphenyl isocyanate and Polymethylene Polyphenyl Isocyanate p.1-20 (1987). The hazards of methylene-bisphenyl-isocyanate and polymethylene-polyphenyl-isocyanate are discussed.National Occupational Health and Safety Commission (Worksafe Australia); Isocyanates p.1-16 (1990). Safety guide to the identification and safe use of isocyanates in the workplace.Banks DE et al; Isocyanate-Induced Respiratory Disease; Annals of Allergy 57 (6): 389-96 (1986). Clinical features of isocyanate induced asthma, adverse respiratory effects associated with methylene-diphenyl-diisocyanate exposure, adverse respiratory effects due to exposure to other isocyanate compounds, pathophysiology of isocyanate asthma, and challenge testing and the diagnosis of isocyanate asthma are discussed.U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS) for Methylene diphenyl diisocyanate (monomeric MDI) and polymeric MDI (PMDI) (101-68-8; 9016-87-9) Toxicological Review in Adobe PDF.[Available from, as of February, 1998: http://www.epa.gov/iris/]

Synonyms and Identifiers:

Synonyms:

BENZENE, 1,1'-METHYLENEBIS(4-ISOCYANATO-**PEER REVIEWED** BIS(PARA-ISOCYANATOPHENYL)METHANE**PEER REVIEWED** BIS(4-ISOCYANATOPHENYL)METHANE**PEER REVIEWED** CARADATE 30**PEER REVIEWED** DESMODUR 44**PEER REVIEWED** DIFENIL-METAN-DIISOCIANATO (ITALIAN)**PEER REVIEWED** DIFENYLMETHAAN-DISSOCYANAAT (DUTCH)**PEER REVIEWED** 4-4'-DIISOCYANATE DE DIPHENYLMETHANE (FRENCH)**PEER REVIEWED** 4,4'-DIISOCYANATODIPHENYLMETHANE**PEER REVIEWED** DI-(4-ISOCYANATOPHENYL)METHANE**PEER REVIEWED** DIPHENYLMETHAN-4,4'-DIISOCYANAT (GERMAN)**PEER REVIEWED** PARA,PARA'-DIPHENYLMETHANE DIISOCYANATE**PEER REVIEWED** DIPHENYLMETHANE 4,4'-DIISOCYANATE**PEER REVIEWED** Diphenylmethyl diisocyanate**PEER REVIEWED** HYLENE M50**PEER REVIEWED** ISOCYANIC ACID, METHYLENEDI-P-PHENYLENE ESTER**PEER REVIEWED** ISONATE 125M**PEER REVIEWED** ISONATE 125 MF**PEER REVIEWED** MDI**PEER REVIEWED** METHYLENEBIS(4-ISOCYANATOBENZENE)**PEER REVIEWED** METHYLENEBIS(PARA-PHENYLENE ISOCYANATE)**PEER REVIEWED** METHYLENEBIS(4-PHENYLENE ISOCYANATE)**PEER REVIEWED** METHYLENE BISPHENYL ISOCYANATE**PEER REVIEWED** METHYLENEBIS(PARA-PHENYL ISOCYANATE)**PEER REVIEWED** PARA,PARA'-**METHYLENEBIS(PHENYL ISOCYANATE)**PEER REVIEWED** METHYLENEBIS(4-PHENYL ISOCYANATE)**PEER REVIEWED** 4,4'-**METHYLENEBIS(PHENYL ISOCYANATE)**PEER REVIEWED** Methylenebis(4-phenylisocyanate)**PEER REVIEWED** METHYLENEDI-PARA-PHENYLENE DIISOCYANATE**PEER REVIEWED** 4,4'-METHYLENEDI-P-PHENYLENE DIISOCYANATE**PEER REVIEWED** METHYLENEDI-PARA-PHENYLENE ISOCYANATE**PEER REVIEWED** 4,4'-METHYLENEDIPHENYLENE ISOCYANATE**PEER REVIEWED** NACCONATE 300**PEER REVIEWED** NCI-C50668**PEER REVIEWED**

Formulations/Preparations:

4,4'-Methylenediphenyl diisocyanate blocked with, for example, phenol is preferred in some applications. [Ashford, R.D. Ashford's Dictionary of Industrial Chemicals. London, England: Wavelength Publications Ltd., 1994., p. 349] **PEER REVIEWED** MDI usually occurs as a mixture of several isomers and oligomers: one common mixture is approximately 30-40% diphenylmethane-4,4'-diisocyanate, 2.5-4.0% diphenylmethane-2,4'-diisocyanate, 0.1-0.2 % diphenylmethane-2,2'- diisocyanate, and the remaining 50-60% oligomers. [Montelius J ed.; Scientific Basis for Swedish Occupational Standards XXII p.62 (2001). Available from, as of March 5, 2012: http://www.inchem.org/documents/kemi/kemi/ah2001_20.pdf] **PEER REVIEWED**

Administrative Information:

Hazardous Substances Databank Number:

2630

Last Review Date:

Reviewed by SRP on 5/17/2012

Last Revision Date:

20121012

Update History:

Field Update on 2013-06-17, 1 fields added/edited/deleted
Complete Update on 2012-10-12, 49 fields added/edited/deleted
Field Update on 2010-04-27, 1 fields added/edited/deleted
Field Update on 2009-04-16, 2 fields added/edited/deleted
Field Update on 2008-08-15, 25 fields added/edited/deleted
Complete Update on 04/19/2002, 53 fields added/edited/deleted.
Field Update on 01/14/2002, 1 field added/edited/deleted.
Field Update on 08/08/2001, 1 field added/edited/deleted.
Complete Update on 02/09/2001, 2 fields added/edited/deleted.
Complete Update on 03/30/2000, 1 field added/edited/deleted.
Complete Update on 02/02/2000, 1 field added/edited/deleted.
Complete Update on 09/21/1999, 1 field added/edited/deleted.
Complete Update on 08/24/1999, 8 fields added/edited/deleted.
Complete Update on 05/11/1999, 1 field added/edited/deleted.
Complete Update on 03/29/1999, 1 field added/edited/deleted.
Complete Update on 01/27/1999, 1 field added/edited/deleted.
Complete Update on 11/12/1998, 1 field added/edited/deleted.
Complete Update on 08/25/1998, 1 field added/edited/deleted.
Complete Update on 08/10/1998, 9 fields added/edited/deleted.
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Complete Update on 10/10/1990, 1 field added/edited/deleted.
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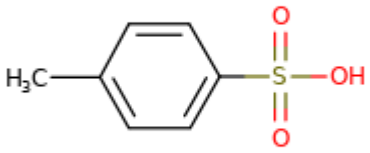
Complete Update on 11/21/1989, 8 fields added/edited/deleted.
Field Update on 07/06/1988, 1 fields added/edited/deleted.
Complete Update on 10/03/1986
Created 19830401 by DS

P-TOLUENESULFONIC ACID

CASRN: 104-15-4
UNII: QGV5ZG5741
Reviewed by SRP on 5/11/1995



FULL RECORD DISPLAY
Displays all fields in the record.
For other data, click on the Table of Contents

Human Health Effects:

Human Toxicity Excerpts:

/IT IS/ HIGHLY IRRITATING TO SKIN, MUCOUS MEMBRANES.[The Merck Index. 9th ed. Rahway, New Jersey: Merck & Co., Inc., 1976., p. 1226] **PEER REVIEWED** MODERATELY TOXIC; SKIN IRRITANT. [Hawley, G.G. The Condensed Chemical Dictionary. 9th ed. New York: Van Nostrand Reinhold Co., 1977., p. 869] **PEER REVIEWED** Contact with eyes or skin causes severe irritation. Ingestion causes irritation of mouth and stomach.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED** Irritating to skin, eyes and mucous membranes. Highly toxic if swallowed.[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED**

Skin, Eye and Respiratory Irritations:

Irritating to skin and eyes.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

Probable Routes of Human Exposure:

Humans are most likely primarily exposed to **p-toluenesulfonic acid** by dermal contact or inhalation in occupational settings. Consumption through contaminated drinking water may be possible. (SRC) **PEER REVIEWED** 56664 workers are potentially exposed to **p-toluenesulfonic acid** based on statistical estimates derived from the NIOSH survey conducted between 1972-74 in the USA(1). 16526 workers are potentially exposed to p-toluenesulfonic acid based on statistical estimates derived from the NIOSH survey conducted between 1981-83 in the USA(2).[(1) NIOSH: National Occupational Hazard Survey (1974) (2) NIOSH; National Occupational Exposure Survey (1983)] **PEER REVIEWED**

Emergency Medical Treatment:

Emergency Medical Treatment:

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The following Overview, *** ACIDS ***, is relevant for this HSDB record chemical.

Life Support:

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o   This overview assumes that basic life support measures
      have been instituted.
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Clinical Effects:

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0.2.1 SUMMARY OF EXPOSURE
   0.2.1.1 ACUTE EXPOSURE
     A)  USES: Household uses include toilet, metal and drain
         cleaners, rust remover, in batteries, and as a primer
         for artificial nails. Used in clandestine
         methamphetamine labs (ie, hydrochloric and sulfuric
         acid). Industrial uses include: metal refining,
         plumbing, bleaching, engraving, plating, photography,
         disinfection, munitions, fertilizer manufacture, metal
         cleaning, and rust removal.
     B)  TOXICOLOGY: Acids cause coagulation necrosis. Hydrogen
         ions desiccate epithelial cells, causing edema,
         erythema, tissue sloughing and necrosis, with formation
         of ulcers and eschars.
     C)  EPIDEMIOLOGY: Inadvertent ingestions occur with
         moderate frequency in children, and are less common
         than alkaline exposures. Serious exposures are rare in
         the developed world (generally only seen with
         deliberate ingestions), largely because only low
         concentration acids are available in the home. Serious
         effects are more common in developing countries.
     D)  WITH POISONING/EXPOSURE
      1)  MILD TO MODERATE ORAL TOXICITY: Patients with mild
          ingestions may only develop irritation or Grade I
          (superficial hyperemia and edema) burns of the
          oropharynx, esophagus or stomach; acute or chronic
          complications are unlikely. Patients with moderate
          toxicity may develop Grade II burns (superficial
          blisters, erosions and ulcerations) are at risk for
          subsequent stricture formation, particularly gastric
          outlet and esophageal. Some patients (particularly
          young children) may develop upper airway edema.
      2)  SEVERE ORAL TOXICITY: May develop deep burns and
          necrosis of the gastrointestinal mucosa. Complications
          often include perforation (esophageal, gastric, rarely
          duodenal), fistula formation (tracheoesophageal,
          aortoesophageal), and gastrointestinal bleeding. Upper
          airway edema is common and often life threatening.
          Hypotension, tachycardia, tachypnea and, rarely, fever
          may develop. Other rare complications include
          metabolic acidosis, hemolysis, renal failure,
          disseminated intravascular coagulation, elevated liver
          enzymes, and cardiovascular collapse. Stricture
          formation (primarily gastric outlet and esophageal,
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less often oral) is likely to develop long term. Esophageal carcinoma is another long term complication. Severe toxicity is generally limited to deliberate ingestions in adults in the US, because acidic products available in the home are generally of low concentration.

a) PREDICTIVE: The grade of mucosal injury at endoscopy is the strongest predictive factor for the occurrence of systemic and GI complications and mortality. Initial signs and symptoms may not reliably predict the extent of GI burns.

3) INHALATION EXPOSURE: Mild exposure may cause dyspnea, pleuritic chest pain, cough and bronchospasm. Severe inhalation may cause upper airway edema and burns, hypoxia, stridor, pneumonitis, tracheobronchitis, and rarely acute lung injury or persistent pulmonary function abnormalities. Pulmonary dysfunction similar to asthma has been reported.

4) OCULAR EXPOSURE: Ocular exposure can produce severe conjunctival irritation and chemosis, corneal epithelial defects, limbal ischemia, permanent vision loss and in severe cases perforation.

5) DERMAL EXPOSURE: A minor exposure can cause irritation and partial thickness burns. More prolonged or a high concentration exposure can cause full thickness burns. Complications may include cellulitis, sepsis, contractures, osteomyelitis, and systemic toxicity.

0.2.3 VITAL SIGNS

0.2.20 REPRODUCTIVE HAZARDS

A) Single doses of dibromoacetic acid has resulted in reductions of sperm and serum testosterone in experimental animals. Repeated or single oral administration of monobromoacetic acid did not produce effects on male rat reproductive organs or sperm.

Laboratory:

A) Obtain a complete blood count and electrolytes in all patients with significant burns after acid ingestion.

B) In patients with signs and symptoms suggesting severe burns, perforation, or bleeding (or adults with deliberate, high volume or high concentration ingestions), obtain renal function tests, liver enzymes, serial CBC, INR, PT, PTT, fibrinogen, fibrin degradation products, type and crossmatch for blood, and monitor urine output and urinalysis. Serum lactate and base deficit may also be useful in these patients.

C) Monitor pulse oximetry or arterial blood gases in patients with signs and symptoms suggestive of upper airway edema or burns.

D) Obtain an upright chest x-ray in patients with signs and symptoms suggesting severe burns, perforation, or bleeding (or adults with deliberate, high volume or high concentration ingestions) to evaluate for pneumomediastinum or free air under the diaphragm. The absence of these findings DOES NOT rule out the possibility of necrosis or perforation of the esophagus or stomach. Obtain a chest radiograph in patients with pulmonary signs or symptoms.

E) Several weeks after ingestion, barium contrast radiographs of the upper GI tract are useful in patients who sustained grade 2 or 3 burns, to evaluate for strictures.

Treatment Overview:

0.4.2 ORAL EXPOSURE

A) MANAGEMENT OF MILD TO MODERATE ORAL TOXICITY

1) Within the first 12 hours of exposure, if burns are absent or grade I severity, patient may be discharged when able to tolerate liquids and soft foods by mouth. If mild grade II burns, admit for intravenous fluids, slowly advance diet as tolerated. Perform barium swallow or repeat endoscopy several weeks after ingestion (sooner if difficulty swallowing) to evaluate for stricture formation.

B) MANAGEMENT OF SEVERE ORAL TOXICITY

1) Resuscitate with 0.9% saline; blood products may be necessary. Early airway management in patients with upper airway edema or respiratory distress. Early (within 12 hours) gastrointestinal endoscopy to evaluate for burns. Early bronchoscopy in patients with respiratory distress or upper airway edema. Early surgical consultation for patients with severe grade II or grade III burns, large deliberate ingestions, or signs, symptoms or laboratory findings concerning for tissue necrosis or perforation.

C) DECONTAMINATION

1) INGESTION: In patients without vomiting or respiratory distress who are able to swallow, dilute with 4-8 ounces milk/water if possible shortly after ingestion; then NPO until after endoscopy. Neutralization, gastric lavage, and activated charcoal are all contraindicated. OCULAR: Copious irrigation until pH neutral. DERMAL: Remove contaminated clothes, brush off particulate corrosives, follow with copious irrigation. INHALATION: Humidified oxygen.

D) AIRWAY MANAGEMENT

1) Aggressive airway management in patients with deliberate ingestions or any indication of upper airway injury. Severe edema may make intubation difficult; be prepared for surgical airway management (cricothyroidotomy) in patients with severe upper airway edema.

E) ENDOSCOPY

1) Should be performed as soon as possible (preferably within 12 hours, not more than 24 hours) in any patient with acid ingestion. The grade of mucosal injury at endoscopy is the strongest predictive factor for the occurrence of systemic and GI complications and mortality. The absence of visible oral burns does NOT reliably exclude the presence of esophageal or gastric burns.

F) BRONCHOSPASM

1) Treat with oxygen, inhaled beta agonists and consider systemic corticosteroids.

G) CORTICOSTEROIDS

1) The use of corticosteroids to prevent stricture formation is controversial. Corticosteroids should not be used in patients with grade I or grade III injury, as there is no evidence that it is effective. Evidence for grade II burns is conflicting, and the risk of perforation and infection is increased with steroid use, so routine use is not recommended.

H) STRICTURE

1) A barium swallow or repeat endoscopy should be performed several weeks after ingestion in any patient with grade II or III burns or with difficulty swallowing to evaluate for stricture formation. Recurrent dilation may be required. Some authors advocate early stent placement in these patients to prevent stricture formation.

I) SURGICAL MANAGEMENT
1) Immediate surgical consultation should be obtained on any patient with grade III or severe grade II burns on endoscopy, significant abdominal pain, metabolic acidosis, hypotension, coagulopathy, or a history of large ingestion. Early laparotomy can identify tissue necrosis and impending or unrecognized perforation, early resection and repair in these patients is associated with improved outcome.

J) EYE INJURY
1) Copious irrigation until pH neutral; perform slit lamp exam. Ophthalmology consult. Antibiotics and mydriatics may be indicated.

K) PATIENT DISPOSITION
1) OBSERVATION CRITERIA: Patients with an acid ingestion should be sent to a health care facility for evaluation. Patients with an endoscopic evaluation that demonstrates no burns or only minor grade I burns and who can tolerate oral intake can be discharged to home.
2) ADMISSION CRITERIA: Symptomatic patients, and those with endoscopically demonstrated grade II or higher burns should be admitted. Patients with respiratory distress, grade III burns, or extensive grade II burns, acidosis, hemodynamic instability, gastrointestinal bleeding, or large ingestions should be admitted to an intensive care setting.

L) PITFALLS
1) The absence of oral burns does NOT reliably exclude the possibility of significant esophageal burns.
2) Patients may have severe tissue necrosis and impending perforation requiring early surgical intervention without having severe hypotension, rigid abdomen, or radiographic evidence of intraperitoneal air.
3) Patients with any evidence of upper airway involvement require early airway management before airway edema progresses.
4) The extent of eye injury (degree of corneal opacification and perilimbal whitening) may not be apparent for 48 to 72 hours after the burn. All patients with acidic eye injury should be evaluated by an ophthalmologist.

M) DIFFERENTIAL DIAGNOSIS
1) Alkaline corrosive ingestion, gastrointestinal hemorrhage, or perforated viscus.

0.4.3 INHALATION EXPOSURE

A) INHALATION: Move patient to fresh air. Monitor for respiratory distress. If cough or difficulty breathing develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. Administer oxygen and assist ventilation as required. Treat bronchospasm with an inhaled beta2-adrenergic agonist. Consider systemic corticosteroids in patients with significant bronchospasm.

B) INHALATION: Administer oxygen. If respiratory symptoms develop obtain chest x-ray, monitor pulse oximetry and/or blood gases. Treat bronchospasm with inhaled beta2-adrenergic agonists. If acute lung injury develops, consider PEEP. Evaluate for esophageal, dermal and eye burns as indicated.

0.4.4 EYE EXPOSURE

A) DECONTAMINATION: Remove contact lenses and irrigate exposed eyes with copious amounts of room temperature 0.9% saline or water for at least 15 minutes. If irritation, pain, swelling, lacrimation, or photophobia persist after 15 minutes of irrigation, the patient

should be seen in a healthcare facility.
B) CAUSTIC EYE DECONTAMINATION: Immediately irrigate each affected eye with copious amounts of water or sterile 0.9% saline for about 30 minutes. Irrigating volumes up to 20 L or more have been used to neutralize the pH. After this initial period of irrigation, the corneal pH may be checked with litmus paper and a brief external eye exam performed. Continue direct copious irrigation with sterile 0.9% saline until the conjunctival fornices are free of particulate matter and returned to pH neutrality (pH 7.4). Once irrigation is complete, a full eye exam should be performed with careful attention to the possibility of perforation.
C) EYE ASSESSMENT: The extent of eye injury (degree of corneal opacification and perilimbal whitening) may not be apparent for 48 to 72 hours after the burn.

0.4.5 DERMAL EXPOSURE
A) OVERVIEW
1) DECONTAMINATION: Remove contaminated clothing and jewelry and irrigate exposed areas with copious amounts of water. A physician may need to examine the area if irritation or pain persists.

Range of Toxicity:

A) TOXICITY: Serious burns are less likely if the pH >3. Injury is usually greater with either a large ingestion (usually deliberate), or a high concentration acid (usually not a household product). With highly concentrated liquids (eg, 20N), severe burns may occur in up to 100% of all patients.
B) In a case series of unintentional caustic ingestions (mixed liquid and solid, acids and bases) among children, the incidence of significant esophageal or gastric burns was 5% to 35%. However, adults with deliberate acid ingestions are more likely to develop significant esophageal and/or gastric burns (40% to 95%).

[Rumack BH POISINDEX(R) Information System Micromedex, Inc., Englewood, CO, 2017; CCIS Volume 172, edition expires May, 2017. Hall AH & Rumack BH (Eds): TOMES(R) Information System Micromedex, Inc., Englewood, CO, 2017; CCIS Volume 172, edition expires May, 2017.] **PEER REVIEWED**

Antidote and Emergency Treatment:

Remove contaminated clothing and shoes. Flush affected area with plenty of water. If in eyes, hold eyelids open and flush with plenty of water. If swallowed and victim is conscious, have victim drink water or milk.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

Animal Toxicity Studies:

Non-Human Toxicity Excerpts:

Animal experiments show moderate systemic toxicity and high irritation[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED**

Non-Human Toxicity Values:

LD50 MICE INTRAVENOUS 160 MG/KG[HIRANO M; 864-T(P-TOLUENESULFONATE); GAN TO KAGAKU RYOHO 6(1) 183 (1979)] **PEER REVIEWED** LD50 RATS INTRAVENOUS 70 MG/KG[HIRANO M; 864-T(P-TOLUENESULFONATE); GAN TO KAGAKU RYOHO 6(19 183 (1979)] **PEER REVIEWED** LD50 Rat oral 400

mg/kg[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

Metabolism/ Pharmacokinetics:

Metabolism/ Metabolites:

YIELDS 3-METHYLCATECHOL IN PSEUDOMONAS: FOCHT, DD & WILLIAMS, FD, CAN J MICROBIOL, 16, 309 (1970); YIELDS 4-METHYLCATECHOL IN PSEUDOMONAS: CAIN, RB & FARR, DR, BIOCHEM J. 106, 859 (1968). /FROM TABLE/[Goodwin, B.L. Handbook of Intermediary Metabolism of Aromatic Compounds. New York: Wiley, 1976., p. T-17] **PEER REVIEWED**

Absorption, Distribution & Excretion:

PROBABLY EXCRETED AS **P-TOLUENESULFONIC ACID**. /FROM TABLE/[Patty, F. (ed.). Industrial Hygiene and Toxicology: Volume II: Toxicology. 2nd ed. New York: Interscience Publishers, 1963., p. 1841] **PEER REVIEWED** FOLLOWING ORAL OR IP ADMIN, P-TOLUENESULFONATE WAS EVENLY DISTRIBUTED IN TISSUES, EXCEPT IN BRAIN & FAT TISSUES.[HIRAMO M; GAN TO KAGAKU RYOHO 6 (1): 183 (1979)] **PEER REVIEWED**

Pharmacology:

Therapeutic Uses:

EXPTL USE: IT WAS EFFECTIVE AGAINST CHRONIC MYELOGENOUS LEUKEMIA IN HUMANS AND HAD LITTLE TOXIC EFFECTS ON BONE MARROW.[HIRANO M; 864-T(P-TOLUENESULFONATE); GAN TO KAGAKU RYOHO 6 (1): 183 (1979)] **PEER REVIEWED**

Environmental Fate & Exposure:

Environmental Fate/Exposure Summary:

p-Toluenesulfonic acid may enter the environment in wastewater from its production or use in organic synthesis. It will remain in aquatic environments where it may biodegrade. Biodegradation may proceed very slowly if acclimated microorganisms are absent from the bodies of water. p-Toluenesulfonic acid will not bioconcentrate into aquatic organisms. Humans are most likely primarily exposed to p-toluenesulfonic acid by dermal contact or inhalation in occupational settings. Exposure from consumption of contaminated drinking water may be possible. (SRC) **PEER REVIEWED**

Probable Routes of Human Exposure:

Humans are most likely primarily exposed to **p-toluenesulfonic acid** by dermal contact or inhalation in occupational settings. Consumption through contaminated drinking water may be possible. (SRC) **PEER REVIEWED** 56664 workers are potentially exposed to **p-toluenesulfonic acid** based on statistical estimates derived from the NIOSH survey conducted between 1972-74 in the USA(1). 16526 workers are potentially exposed to p-toluenesulfonic acid based on statistical estimates derived from the NIOSH survey conducted between 1981-83 in the USA(2).[(1) NIOSH: National Occupational Hazard Survey (1974) (2) NIOSH; National Occupational Exposure Survey (1983)] **PEER REVIEWED**

Natural Pollution Sources:

None. (SRC) **PEER REVIEWED**

Artificial Pollution Sources:

Wastewater from production(1). Wastewater from its use in organic synthesis or as a catalyst(1).[(1) Research Triangle Institute; Industrial Process Profile for Environmental Use, Chapt 6 The Industrial Organic Chemicals Industry (1977)] **PEER REVIEWED**

Environmental Fate:

TERRESTRIAL FATE: **p-Toluenesulfonic acid** is a strong acid (pKa = -1.34(1)) and is completely dissociated and highly soluble (about 620 g/L(2)) in water. It would be expected to leach fairly rapidly. Its biodegradation in soil is unknown(SRC).[(1) Serjeant EP, Dempsey B; IUPAC Chemical Data Series No 23 NY, NY: Pergamon Press (1979) (2) Budavari D et al; The Merck Index 11th ed Rahway, NJ: Merck & Co Inc pp 1501-2 (1989)] **PEER REVIEWED** AQUATIC FATE: Once released into the aquatic compartment, **p- toluenesulfonic acid** will not be transported into the sediment or volatilize to the atmosphere. Based on the results of biodegradation screening studies(1-8), it may slowly biodegrade if acclimated microbial populations are present. p- Toluenesulfonic acid would not be expected to bioconcentrate in aquatic organisms(SRC).[(1) Pitter P; Water Res 10: 231-5 (1976) (2) Huddleston RL, Setzkom EA; Soap Chem Specialties 4: 63-4 (1965) (3) Hammerton C; J Appl Chem 5: 517-24 (1955) (4) Alexander M, Lustigman BK; J Agric Food Chem 14: 410-3 (1966) (5) Leidner H et al; Xenobiotica 10: 47-56 (1980) (6) Malaney GW, McKinney RE; Water Sewage Works 113: 302-9 (1966) (7) Focht DD, Williams FD; Can J Microbiol 16: 309-16 (1970) (8) Bird A, Cain RB; Biochem J 140: 121-34 (1974)] **PEER REVIEWED** ATMOSPHERIC FATE: Based on its estimated vapor pressure, 2.7X10-6 mm Hg at 25 deg C(2), **p-toluenesulfonic acid** should exist in the atmosphere both as an aerosol and as a vapor(4). Vapor-phase p- toluenesulfonic acid will react with photochemically-produced hydroxyl radicals resulting in an estimated half-life of 11.8 days (3,SRC). p-Toluenesulfonic acid is highly soluble in water, 620,000 mg/L(1), and therefore should be scavenged by rain(SRC).[(1) Budavari S; The Merck Index 11th ed Rahway, NJ: Merck & Co Inc pp 1501-2 (1989) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods, NY: McGraw-Hill Chapt 14 (1982) (3) Meylan WM, Howard PH; Chemosphere 26: 2293-9 (1993) (4) Bidleman TF; Environ Sci Technol 22: 361-7 (1988)] **PEER REVIEWED**

Environmental Biodegradation:

Experimental results are conflicting on the biodegradability of **p-toluenesulfonic acid**. Results range from 100% degradation in a few days with acclimated activated sludge to no degradation in 37-64 days(1-6). There are special species that are capable of degrading this compound and its degradation depends on the existance and cultivation of these species in the environment(7,8).[(1) Pitter P; Water Res 10: 231-5 (1976) (2) Huddleston RL, Setzkom EA; Soap Chem Specialties 4: 63-4 (1965) (3) Hammerton C; J Appl Chem 5: 517-24 (1955) (4) Alexander M, Lustigman BK; J Agric Food Chem 14: 410-3 (1966) (5) Leidner H et al; Xenobiotica 10: 47-56 (1980) (6) Malaney GW, McKinney RE; Water Sewage Works 113: 302-9 (1966) (7) Focht DD, Williams FD; Can J Microbiol 16: 309-16 (1970) (8) Bird A, Cain RB; Biochem J 140: 121-34 (1974)] **PEER REVIEWED**

Environmental Abiotic Degradation:

p-Toluenesulfonic acid will not directly photolyze since it does not absorb light above 290 nm. It is a strong acid (pKa = -1.34(5)) and will be completely dissociated in the environmental pH range. It will not react with water under environmental conditions(1). p-Toluenesulfonic acid has a very low estimated vapor pressure (2.7X10-6 mm Hg at 25 degC(3)) and therefore in the atmosphere, it will exist largely as an aerosol(3). Vapor-phase p-toluenesulfonic acid reacts with photochemically-produced hydroxyl radicals in the atmosphere with an estimated rate constant of 1.36X10-12 cu cm/molecule-s(2). Assuming a hydroxyl radical concn of 5X10+5 radicals/cu cm, the half-life of p-toluenesulfonic acid in the atmosphere would be 11.8 days(SRC). The vapor phase reaction of p-toluenesulfonic acid with sunlight produced hydroxyl radicals in a typical ambient atmosphere has been estimated to be about 2 days(2).[(1) Morita H; Soil Sci 131: 30-3 (1981) (2) Meylan WM, Howard PH; Chemosphere 26: 2293-9 (1993) (3) Bidleman TF; Environ Sci Technol 22: 361-7 (1988) (4) Lyman WJ et al (eds); Handbook of Chemical Property Estimation Methods, NY: McGraw-Hill Chapt 14 (1982) (5) Serjeant EP, Dempsey B; IUPAC Chemical Data Series No 23 NY, NY: Pergamon Press (1979)] **PEER REVIEWED**

Environmental Bioconcentration:

Using an estimated log Kow of -0.62(1), one would estimate a BCF of 0.2 for **p- toluenesulfonic acid** using a recommended regression equation(2). This would indicate that p-toluenesulfonic acid would not bioconcentrate in aquatic organisms(SRC).[(1) Meylan WM, Howard PH; J Pharm Sci 84: 83-92 (1995) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods, NY: McGraw-Hill Chapt 5, Eqn 5-2 (1982)] **PEER REVIEWED**

Soil Adsorption/Mobility:

The log Koc for **p- toluenesulfonic acid** estimated from molecular structure is 19(1). According to a suggested classification scheme(2), this estimated Koc suggests that p-toluenesulfonic acid is highly mobile in soil and would readily leach(SRC).[(1) Meylan WM et al; Environ Sci Technol 26: 1560-7 (1992) (2) Swann RL et al; Res Rev 85: 17-28 (1983)] **PEER REVIEWED**

Volatilization from Water/Soil:

The Henry's Law constant for **p-toluenesulfonic acid** estimated from molecular structure is 2.78X10-9 atm-cu-m/mol(1). Chemicals with such low Henry's Law constants are nonvolatile from water(2).[(1) Meylan WM, Howard PH; Environ Toxicol Chem 10: 1283-93 (1991) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods, NY: McGraw-Hill Chapt 15 (1982)] **PEER REVIEWED**

Environmental Water Concentrations:

DRINKING WATER: **p-Toluenesulfonic acid** has been qualitatively detected in British drinking waters from lowland river water and groundwater(1).[(1) Crathorne B et al; Environ Sci Technol 18: 797-802 (1984)] **PEER REVIEWED**

Chemical/Physical Properties:

Molecular Formula:

C7-H8-O3-S **PEER REVIEWED**

Molecular Weight:

172.20[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**

Color/Form:

MONOCLINIC LEAFLETS OR PRISMS
[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**

Boiling Point:

140 DEG C @ 20 MM HG[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**

Melting Point:

106-107 DEG C /ANHYDROUS/[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**

Dissociation Constants:

-1.34[Serjeant EP, Dempsey B; IUPAC Chemical Data Series No 23 NY, NY: Pergamon Press, p. 334 (1979)] **PEER REVIEWED**

Solubilities:

ABOUT 67 G/100 ML WATER; SOL IN ALCOHOL, ETHER
[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**
VERY SOL IN WATER /SODIUM SALT/
[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**

Spectral Properties:

IR: 4398 (Coblentz Society Spectral Collection)
[Weast, R.C. and M.J. Astle. CRC Handbook of Data on Organic Compounds. Volumes I and II. Boca Raton, FL: CRC Press Inc. 1985., p. V2 375] **PEER REVIEWED**
UV: 6540 (Sadtler Research Laboratories Spectral Collection)
[Weast, R.C. and M.J. Astle. CRC Handbook of Data on Organic Compounds. Volumes I and II. Boca Raton, FL: CRC Press Inc. 1985., p. V2 375] **PEER REVIEWED**
MASS: 133 (Aldermaston, Eight Peak Index of Mass Spectra, UK)
[Weast, R.C. and M.J. Astle. CRC Handbook of Data on Organic Compounds. Volumes I and II. Boca Raton, FL: CRC Press Inc. 1985., p. V2 375] **PEER REVIEWED**
MAX ABSORPTION (WATER): 222 NM (LOG E= 4.0); 261 NM (LOG E= 2.5); 2 NM (LOG E= 2.2)
[Weast, R.C. (ed.). Handbook of Chemistry and Physics. 60th ed. Boca Raton, Florida: CRC Press Inc., 1979., p. C-529] **PEER REVIEWED**
SADTLER REFERENCE NUMBER: 19785 (IR, PRISM); 6540 (UV) /HYDRATE/
[Weast, R.C. (ed.). Handbook of Chemistry and Physics. 60th ed. Boca Raton, Florida: CRC Press Inc., 1979., p. C-529] **PEER REVIEWED**

Other Chemical/Physical Properties:

HYGROSCOPIC
[Weast, R.C. (ed.). Handbook of Chemistry and Physics. 60th ed. Boca Raton, Florida: CRC Press Inc., 1979., p. C-529] **PEER REVIEWED**
REPORTED AS CRYSTALLIZING WITH ONE WATER OR FOUR WATER MOLECULES
[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**
MELTING POINT: 38 DEG C /METASTABLE FORM/
[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED**
Boiling point = 38 deg C
[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA3 520] **PEER REVIEWED**
Melting point = 106 deg C /monohydrate/; 93 deg C /trihydrate/
[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA3 520] **PEER REVIEWED**

Chemical Safety & Handling:

Skin, Eye and Respiratory Irritations:

Irritating to skin and eyes.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED**

Fire Potential:

Ignites after considerable preheating.[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED**

NFPA Hazard Classification:

Health: 3. 3= Materials that, on short exposure, could cause serious temporary or residual injury, including those requiring protection from all bodily contact. Fire fighters may enter the area only if they are protected from all contact with the material. Full protective clothing, incl self-contained breathing apparatus, coat, pants, gloves, boots and bands around legs, arms and waist should be provided. No skin surface should be exposed.[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-87] **QC REVIEWED** Flammability: 1. 1= Materials that must be preheated before ignition will occur, such as class IIIB combustible liquids and solids and semi-solids whose flash point exceeds 200 deg F (93.4 deg C), as well as most ordinary combustible materials. Water may cause frothing if it sinks below the surface of the burning liquid and turns to steam. However, a water fog that is gently applied to the surface of the liquid will cause a frothing which will extinguish the fire.[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-87] **QC REVIEWED** Reactivity: 1. 1= Includes materials that are normally stable, but may become unstable at elevated temperatures and pressures and materials that will react with water with some release of energy, but not violently. Fires involving these materials should be approached with caution.[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-87] **QC REVIEWED**

Flash Point:

363 DEG F (184 DEG C) (CLOSED CUP)[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-87] **QC REVIEWED**

Hazardous Reactivities & Incompatibilities:

Reacts with water.[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED** A strong acid which can react with common metals.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED** Sulfonates. When heated to decomp, or in contact with acid or acid fumes, they emit highly toxic fumes of sulfur dioxide. Acetic Acid, Acetic Anhydride, Water. Explosions can occur when using an analytical method involving sequential addition if acetic acid, aqueous **p-toluenesulfonic acid** and acetic anhydride to serum.[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED**

Other Hazardous Reaction:

Irritating gases may be produced when heated.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981.] **PEER REVIEWED** Caution is advised ... to prevent explosions when using an analytical method involving sequential addition of

acetic acid, aqueous **4-toluenesulfonic acid** and acetic anhydride to serum ... . /4-Toluenesulfonic acid; water/[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 452] **PEER REVIEWED** Accidental slow addition of water to a mixture of the anhydride and acetic acid ... led to a violent large scale explosion. This was simulated closely in the laboratory, again in the absence of mineral acid catalyst ... . If unmoderated, the rate of acid-catalysed hydrolysis of (water insoluble) acetic anhydride can accelerate to explosive boiling ... . /Acetic anhydride; Water/[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 452] **PEER REVIEWED**

Stability/Shelf Life:

Normally stable; unstable at high temperature and pressure.[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED**

Disposal Methods:

SRP: At the time of review, criteria for land treatment or burial (sanitary landfill) disposal practices are subject to significant revision. Prior to implementing land disposal of waste residue (including waste sludge), consult with environmental regulatory agencies for guidance on acceptable disposal practices. **PEER REVIEWED** Spillage disposal: /SRP: For laboratory quantities:/ Wear eye protection, laboratory coat and nitrile rubber gloves. Scoop into a pail of cold water. Neutralize with sodium carbonate and wash into the drain with at least 50 times its volume of water.[Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 439] **PEER REVIEWED**

Manufacturing/Use Information:

Uses:

/USED AS REAGENT IN/ KIRSTEN MODIFICATION OF KLEBER METHOD (FOR LEMON OIL). [Association of Official Analytical Chemists. Official Methods of Analysis. 10th ed. and supplements. Washington, DC: Association of Official Analytical Chemists, 1965. New editions through 13th ed. plus supplements, 1982., p. 13/317 19.088] **PEER REVIEWED** Manufacture of 4-formylbenzenesulfonic acid, p-sulfobenzoic acid, 2-chlorotoluene-4-sulfonic acid, and 4-(chloromethyl)phenylmethanesulfonic acid[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA3 520] **PEER REVIEWED** Effect solubility of disperse dyes, initiator for catalytic polymerization of caprolactam, catalyst for dimerization of alpha- methylstyrene.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. V22 48-9] **PEER REVIEWED** Manufacture of dyes and oral antidiabetic drugs; conversion to sodium and ammonium salts for manufacture of hydrotropes.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. V22 60] **PEER REVIEWED** Catalyst in coatings, paint, polymer, and textile industries. Stabilizer for monomers and polymers, pharmaceutical intermediate, cleaning agents, plating additive.[Kuney, J.H., J.M. Mullican (eds.). Chemcyclopedia. Washington, DC: American Chemical Society, 1994., p. 115] **PEER REVIEWED**

Manufacturers:

Ruetgers-Nease Chemical Co, Inc, Hq, 201 Struble Rd, State College, PA 16801, (814) 238-2424; Production sites: 10740 Paddy's Run Rd, Harrison, OH 45061; State College, PA 16801 /o-, **p-toluenesulfonic acid**/[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975] **PEER REVIEWED** Albright & Wilson Americas, Hqr, P.O. Box 26229, Richmond, VA 23260, (804) 550-4300; Production site: Charleston, SC 29400[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975] **PEER REVIEWED** BIT Manufacturing, Inc. State Highway 68, Copperhill, TN 37317 (615) 496-3331[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975]

PEER REVIEWED DynaChem, Inc., Maple Grove Road, P.O. Box 19, Georgetown, IL 61846, (217) 662-2136[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975] **PEER REVIEWED** Ferro Corporation, Hqr, 1000 Lakeside Avenue. Cleveland, OH 44114- 1183, (216) 641-8580; Production site: Chemicals Group, Grant Chemical Division, Baton Rouge, LA 70821[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975] **PEER REVIEWED** PMC, Inc., Hqr, 12243 Branford Street, P.O. Box 1367, Sun Valley, CA 91352, (818) 896-1101; Specialties Group Division, Production site: Chicago, IL 60628[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975] **PEER REVIEWED** Sloss Industries Corporation, 3500 35th Ave. N., P.O. Box 3527, Birmingham, AL 35202, (205) 808-7915[SRI. 1994 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International, 1994., p. 975] **PEER REVIEWED**

Methods of Manufacturing:

PREPARED BY SULFONATION OF TOLUENE WITH 96-100% SULFURIC ACID; WHEN CARRIED OUT AT 75 DEG C COMPOSITION OF REACTION PRODUCT IS 75% PARA-, 19% ORTHO- AND 6% META-**TOLUENESULFONIC ACID**.[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED** CONVENIENT LAB PREPN. SEPARATION OF TOLUENE FROM PETROLEUM FRACTIONS CAN BE ACCOMPLISHED BY SULFONATION WITH SULFURIC ACID @ 60 DEG C.[Budavari, S. (ed.). The Merck Index - Encyclopedia of Chemicals, Drugs and Biologicals. Rahway, NJ: Merck and Co., Inc., 1989., p. 1501-2] **PEER REVIEWED** BY ACTION OF CHLOROSULFONIC ACID ON TOLUENE AT A LOW TEMPERATURE.[Hawley, G.G. The Condensed Chemical Dictionary. 9th ed. New York: Van Nostrand Reinhold Co., 1977., p. 869] **PEER REVIEWED**

General Manufacturing Information:

Purification is possible by crystallization from 66% sulfuric acid or via the barium salt.[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA3 520] **PEER REVIEWED**

Formulations/Preparations:

GRADES: ANHYDROUS; MONOHYDRATE; 40% AQUEOUS SOLUTION[Hawley, G.G. The Condensed Chemical Dictionary. 9th ed. New York: Van Nostrand Reinhold Co., 1977., p. 869] **PEER REVIEWED** Anhydrous grade, monohydrate gradem solution forms, dark brown semicrystaline to crystalline solid.[Kuney, J.H., J.M. Mullican (eds.). Chemcyclopedia. Washington, DC: American Chemical Society, 1994., p. 114] **PEER REVIEWED**

U. S. Production:

(1972) PROBABLY GREATER THAN 1.36X10+6 GRAMS[SRI] **PEER REVIEWED** (1975) PROBABLY GREATER THAN 6.81X10+6 GRAMS[SRI] **PEER REVIEWED**

U. S. Imports:

(1975) 2.20X10+7 GRAMS (PRINCPL CUSTMS DISTS)[SRI] **PEER REVIEWED**
Synonyms and Identifiers:

Synonyms:

BENZENESULFONIC ACID, 4-METHYL-**PEER REVIEWED** KYSELINA P-TOLUENESULFONOVA (CZECH)**PEER REVIEWED** **P-METHYLBENZENESULFONIC ACID****PEER REVIEWED** **4-**

METHYLBENZENESULFONIC ACIDPEER REVIEWED** **P-METHYLPHENYLSULFONIC ACID**PEER REVIEWED** P-TOLUENE SULFONATE**PEER REVIEWED** **TOLUENESULFONIC ACID**PEER REVIEWED** **4-TOLUENESULFONIC ACID**PEER REVIEWED** **P-TOLUENESULPHONIC ACID**PEER REVIEWED** **P-TOLYLSULFONIC ACID**PEER REVIEWED** **TOSIC ACID**PEER REVIEWED**

Associated Chemicals:

p-Toluenesulfonic acid hydrate;6192-52-5

Formulations/Preparations:

GRADES: ANHYDROUS; MONOHYDRATE; 40% AQUEOUS SOLUTION[Hawley, G.G. The Condensed Chemical Dictionary. 9th ed. New York: Van Nostrand Reinhold Co., 1977., p. 869] **PEER REVIEWED**
Anhydrous grade, monohydrate gradem solution forms, dark brown semicrystaline to crystalline solid.[Kuney, J.H., J.M. Mullican (eds.). Chemcyclopedia. Washington, DC: American Chemical Society, 1994., p. 114] **PEER REVIEWED**
Administrative Information:

Hazardous Substances Databank Number:

2026

Last Review Date:

Reviewed by SRP on 5/11/1995

Last Revision Date:

20030214

Update History:

Complete Update on 02/14/2003, 1 field added/edited/deleted.
Complete Update on 01/18/2002, 2 fields added/edited/deleted.
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Complete Update on 11/06/2000, 1 field added/edited/deleted.
Complete Update on 09/12/2000, 1 field added/edited/deleted.
Complete Update on 06/12/2000, 1 field added/edited/deleted.
Complete Update on 03/28/2000, 1 field added/edited/deleted.
Complete Update on 09/21/1999, 1 field added/edited/deleted.
Complete Update on 08/26/1999, 1 field added/edited/deleted.
Complete Update on 10/29/1998, 1 field added/edited/deleted.
Complete Update on 06/02/1998, 1 field added/edited/deleted.
Complete Update on 10/26/1997, 1 field added/edited/deleted.
Complete Update on 03/17/1997, 1 field added/edited/deleted.
Complete Update on 10/15/1996, 1 field added/edited/deleted.
Complete Update on 01/23/1996, 1 field added/edited/deleted.
Complete Update on 09/05/1995, 47 fields added/edited/deleted.
Field Update on 04/20/1995, 1 field added/edited/deleted.
Field Update on 04/20/1995, 1 field added/edited/deleted.

Field Update on 12/28/1994, 1 field added/edited/deleted.
Complete Update on 03/25/1994, 1 field added/edited/deleted.
Field update on 12/23/1992, 1 field added/edited/deleted.
Complete Update on 11/02/1990, 10 fields added/edited/deleted.
Complete Update on 06/04/1985

SODIUM HYDROXIDE

CASRN: 1310-73-2
UNII: 55X04QC32I
Reviewed by SRP on 1/19/2012

FULL RECORD DISPLAY
Displays all fields in the record.
For other data, click on the Table of Contents

Human Health Effects:

Human Toxicity Excerpts:

/HUMAN EXPOSURE STUDIES/ ... Esophageal motor function in 21 children (7.5 +/- 2.9 years) with caustic strictures /was assessed/. /All patients had ingested **sodium hydroxide**./ Esophageal manometry was performed using a water-infusion system interfaced with a polygraph and displayed on a computer screen. The data were compared with those obtained from 9 healthy children. Radionuclide transit was determined by studying deglutition of a single bolus of (99m)Tc-pertechnetate in 10 mL of water. Non-peristaltic low-amplitude and long-duration waves were the most common findings detected in patients with strictures longer than 20% of esophageal length (N = 11). Compared with the control group, these patients presented lower mean amplitude and longer mean duration of waves (24.4 +/- 11.2 vs 97.9 +/- 23.7 mmHg, P < 0.05, and 6.7 +/- 2.4 vs 1.6 +/- 0.1 s, P < 0.05, respectively). Six patients presented low-amplitude waves just below the constricted site. Ten children presented delayed esophageal transit. There was an association between dysphagia and abnormalities on manometry (P = 0.02) and between symptoms and scintigraphy data (P = 0.01). Dysphagia in caustic strictures is due to esophageal motility abnormalities, which are closely related to the scarred segment.[Da-Costa-Pinto EA et al; Braz J Med Biol Res. 37 (11): 1623-30 (2004)] **PEER REVIEWED** PubMed Abstract /HUMAN EXPOSURE STUDIES/ ... The irritant effects and barrier disruption properties of ... **sodium hydroxide** (NaOH), particularly in combination with an anionic detergent, sodium lauryl sulphate (SLS) /were quantified/. In a tandem repeated irritation test, the irritants were applied for 30 min twice daily for 4 days to the skin of the mid-back of 19 healthy volunteers of both sexes. ... Used bioengineering techniques for measurement of transepidermal water loss (TEWL) and skin colour reflectance, as well as visual scoring. ... NaOH induced a strong reaction when applied occlusively and nonocclusively as well as in combination with SLS, with an early onset of the inflammatory signs, leading to discontinuation of the application on the third day in most of the test fields. Notably, the irritant effect of NaOH was not as marked when applied sequentially with SLS.[Fluhr JW et al; Br J Dermatol. 151 (5): 1039-48 (2004)] **PEER REVIEWED** PubMed Abstract /HUMAN EXPOSURE STUDIES/ A human skin irritation test with 0.5 % NaOH was performed using exposure periods of 15, 30 and 60 min. The treatment sites were assessed 24, 48 and 72 hr after patch removal. The results showed that after a maximum exposure of 60 min, 61 % of the volunteers (20 of 33) showed a positive skin irritation reaction. [Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.14 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /HUMAN EXPOSURE STUDIES/ A NaOH concentration of 0.5 % was tested within an interlaboratory evaluation of a human patch test for the identification of skin irritation hazard /after 1 hr exposure/. A 25 mm Plain Hill Top Chamber containing a Webril pad was used and the treatment sites were assessed for irritation using a four-point scale at 24, 48 and 72 hr after initiation of exposure. NaOH 0.5 % was irritating for 55 % of the volunteers.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-

2) p.14 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /HUMAN EXPOSURE STUDIES/ Four different patch systems, Finn chamber, Hill Top patch, Van der Bend chamber and Webril patch, were used to determine the skin irritation response of 1 % NaOH. Webril and Hill top patches generated the greatest levels of response. Eleven of 14 and 5 of 14 volunteers showed a positive skin reaction after 30 minutes for Webril and Hill top patches, respectively. With Finn and Van der Bend chambers 5 of 14 and 7 of 14 volunteers showed a positive reaction after 4 hr, respectively, which shows that the reactivity was reduced with these systems.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.14 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ Caustic dusts are irritating to the upper respiratory system. ... prolonged exposure to high concentrations may cause discomfort and ulceration of nasal passages. /caustic dusts/[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 1417] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ SYMPTOMATOLOGY: INGESTION OF LYE CAUSES SWALLOWING TO BECOME PAINFUL & DIFFICULT ALMOST IMMEDIATELY. BURNING PAIN EXTENDS DOWN ESOPHAGUS TO STOMACH. CONTAMINATED AREAS OF LIPS, CHIN, TONGUE, & PHARYNX BECOME EDEMATOUS & COVERED WITH EXUDATE. PROFUSE SALIVATION. BECAUSE OF PHARYNGEAL AND ESOPHAGEAL EDEMA, IT MAY BECOME IMPOSSIBLE AFTER A FEW HOURS TO SWALLOW EVEN SALIVA. MUCOUS MEMBRANES ARE AT FIRST WHITE BUT LATER BROWN, EDEMATOUS, GELATINOUS, AND NECROTIC. VOMITUS IS THICK AND SLIMY DUE TO MUCUS; LATER IT MAY CONTAIN BLOOD AND SHREDS OF MUCOUS MEMBRANE. PULSE ... RAPID & FEEBLE; RESPIRATIONS ... FAST & SHALLOW; SKIN IS COLD & CLAMMY; COLLAPSE ENSUES. DEATH DUE TO SHOCK, ASPHYXIA FROM GLOTTIC EDEMA OR INTERCURRENT INFECTION (PNEUMONIA) COMMONLY OCCURS ON 2ND OR ... 3RD DAY. ASPIRATION PNEUMONITIS ... DESCRIBED. CONVALESCENCE MAY BE INTERRUPTED DURING FIRST WEEK BY ESOPHAGEAL PERFORATION OR PERHAPS EVEN GASTRIC PERFORATION. MEDIASTINITIS MAY PRESENT AS SEVERE SUBSTERNAL PAIN WITH FEVER. IF COMPLICATIONS DO NOT APPEAR, LIQUID AND SOFT FOOD CAN BE SWALLOWED WITH COMPARATIVE EASE WITHIN 5 TO 7 DAYS. WITHIN 5 TO 7 DAYS. ... IN MOST CASES THIS ABSENCE OF DISTRESS MARKS LATENT PERIOD AND THAT ESOPHAGEAL STRICTURES WILL DEVELOP WITHIN WEEKS OR MONTHS UNLESS EFFECTIVE TREATMENT IS INSTITUTED. /LYE/[Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984., p. II-66] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ Skin contact; Levels of toxic effect: (1) There is not necessarily an immediate sensation of irritation or pain. (2) Primary irritant dermatitis. (3) Multiple small burns with temporary loss of hair. (4) Deterioration of keratin material. (5) Intracellular edema. (6) Severe burns, corrosion of tissue, and deep ulcerations.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.81 (1981)] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ Contact with the eyes causes disintegration and sloughing of conjunctival and corneal epithelium, corneal opacification, marked edema, and ulceration; After 7 to 13 days either gradual recovery begins, or there is progression of ulceration and corneal opacification. Complications of severe eye burns are symblepharon (adhesion of the lid to the eyeball) with overgrowth of the cornea by a vascularized membrane, progressive or recurrent corneal ulceration, and permanent corneal opacification.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981., p. 2] **PEER REVIEWED** /SIGNS AND SYMPTOMS/ On the skin, solutions of about 25 to 50% cause the sensation of irritation within about 3 minutes; With solutions of 4% /NaOH/ this does not occur until after several hours. If not removed from the skin, severe burns with deep ulceration will occur; Exposure to the dust or mist may cause multiple small burns, with temporary loss of hair.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981., p. 2] **PEER REVIEWED** /CASE REPORTS/ ... /The study/ present the case of an elderly woman with dementia who developed severe alkaline tongue burn and edema after unintentional short contact with solid **sodium hydroxide** drain cleaner. ... [Yanturali S et al; Vet Hum Toxicol. 46 (6): 319-21 (2004)] **PEER REVIEWED** PubMed Abstract /CASE REPORTS/ A 31 year man had **sodium hydroxide** blown into his amblyopic left eye after an explosion caused by placing solid **sodium hydroxide** into a plugged drain. He washed the eye immediately in a shower and

arrived at hospital within 5 minutes. On examination the cornea was opaque and the lower two thirds of the conjunctiva were ischemic. Topical irrigation was repeated and he was transferred to the operating room where intraocular irrigation was commenced. About 100-120 mL of Ringer's solution was used in this procedure over 90 minutes. At this time the cornea was slightly clearer. Methylprednisolone was given by retobulbar and subconjunctival injection. Continuous slow topical irrigation was continued for a further 24 hours. On the first post-operative day visual acuity was present to light, intraocular pressure was high and a cataract was present. Topical antibiotics, systemic and topical corticosteroids and carbonic anhydrase inhibitors were given. Two weeks after the injury aspiration-irrigation of the cataract was undertaken with an improvement in visual acuity. Acetylcysteine drops were used and a soft contact lens was put in place. He was discharged three weeks after the injury but returned three days later with severe pain, hypopyon and hyphema. The cornea ulcerated and perforated 27 days after the injury. The perforation was repaired with a corneoscleral free hand graft. Despite the presence of light perception the eye was enucleated at the patient's request 70 days after the injury.[IPCS; UK Poisons Information Document: Sodium Hydroxide (1310-73-2). Available from, as of October 5, 2011: http://www.inchem.org/documents/ukpids/ukpids/ukpid26.htm] **PEER REVIEWED** /CASE REPORTS/ A 20 year old patient presented 2 hours after accidentally spraying herself in the face with an oven cleaner containing 4% **sodium hydroxide**. She had removed the excess liquid but did not irrigate the area. She did not experience any pain until nearly 2 hours later. On examination she was in moderate distress with no ocular involvement. The right side of her face was erythematous and blistering in a serpiginous pattern extending from the infraorbital rim to the body and angle of her mandible. The area of the right cheek had a bronze discoloration. The body surface area involved was about 2%. The area was irrigated for 60 minutes. Despite this the burn continued to show signs of third degree burn involvement. She was transferred to a burns unit and underwent surgical debridement and skin graft. Follow up six weeks later revealed good healing and no complications. [IPCS; UK Poisons Information Document: Sodium Hydroxide (1310-73-2). Available from, as of October 5, 2011: http://www.inchem.org/documents/ukpids/ukpids/ukpid26.htm] **PEER REVIEWED** /CASE REPORTS/ A 14 year old boy took a **sodium hydroxide** solution (30%) in to his mouth. He immediately spat it out. He drank some milk and water and vomited. On arrival about 30 minutes later he had retrosternal pain and had difficulty swallowing. He was given antibiotics and steroids. Esophagoscopy was performed two days later and revealed mucosal lesions in the upper esophagus. He began to improve and was able to take mashed food orally. He then began to develop difficulty in swallowing and a X-ray on day 23 revealed a stricture at the level of the carina of trachea. On the 38th day esophagoscopy with dilatation of the stricture was performed. About 2 hr later he suffered immediate retrosternal pain. An X-ray showed perforation of the stricture. This was sewn up via a left side thoracotomy. Serious inflammatory changes were observed with mediastinal emphysema and a purulent pleuritis. A nasogastric tube and three drains were left in place. On the 44th day after ingestion profuse bleeding was observed through the nasogastric tube and drains were noted. He became shocked and the decision was made to operate. He suffered a cardiac arrest while general anaesthetic was being given. A right side thoracotomy showed a 4-5 mm rupture of the descending part of the aorta with bleeding into the left pleura. After cardiac massage, blood transfusion and repair of the rupture he stabilized. Part of the esophagus was removed due to inflammation. On day 52 another hemorrhage occurred. He was operated on again and the hemorrhage was seen to arise from the aortic rupture. The aorta wall was fragile and could not be repaired. The patient died on the operating table. A purulent mediastinitis, bilateral purulent pleuritis, lung atalectasis and pericarditis were observed at postmortem.[IPCS; UK Poisons Information Document: Sodium Hydroxide (1310-73-2). Available from, as of October 5, 2011: http://www.inchem.org/documents/ukpids/ukpids/ukpid26.htm] **PEER REVIEWED** /CASE REPORTS/ A 16 month old female refused to drink and began drooling after ingesting the residue of a **sodium hydroxide** solution which the mother had been using for cleaning. She vomited several times with the vomitus containing a small amount of blood. The pharynx was red and there was slight bleeding of the upper gums. The chest was initially clear but 90 minutes after admission inspiratory and expiratory wheezes were present and a chest X-ray suggested aspiration pneumonia. At 15 hours post-ingestion laryngoscopy and esophagoscopy were performed. The false cords and epiglottis were found to be red and edematous. The cricopharyngeus was ulcerated and bleeding. The esophageal mucosa was bleeding and circumferential second and third degree burns were present. The child required intubation and ventilation and was started on methylprednisolone and ampicillin. Ventilatory support was necessary for three weeks. Subsequent laryngoscopy revealed laryngeal edema and burns which resulted in laryngeal stenosis. An esophagoscopy at five weeks post-ingestion revealed esophageal narrowing. A barium swallow showed multiple esophageal strictures and hypoperistalsis of the proximal segment of the

esophagus. The child required nine esophageal dilatations, and was eventually able to take oral feedings. She was discharged one year after the ingestion.[IPCS; UK Poisons Information Document: Sodium Hydroxide (1310-73-2). Available from, as of October 5, 2011: http://www.inchem.org/documents/ukpids/ukpids/ukpid26.htm] **PEER REVIEWED** /CASE REPORTS/ A 42-year-old female swallowed approximately 30 mL of 16 % NaOH in a suicide attempt. This resulted in a 9 cm stricture of the esophagus which was treated by gastric antral patch esophagoplasty.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.13 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /CASE REPORTS/ ... 9 cases of liquid NaOH ingestion which resulted in esophageal and gastric injury. One person who ingested 10 g NaOH in water suffered transmural necrosis of the esophagus and stomach and died 3 days after admission to the hospital.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.13 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /CASE REPORTS/ A fatal burn due to dermal NaOH exposure of a worker at an aluminum plant has been reported. He was found lying in a shallow pool of concentrated NaOH, which had been heated to approximately 95 deg C.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.13 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /CASE REPORTS/ ... The inhalation of aerosols of 5 % NaOH by a 25-year-old women resulted in irreversible obstructive lung injury after working for one day in a poorly ventilated room. ...[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.13 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /CASE REPORTS/ A 28-year old member of an oil-well drilling crew sustained extensive splash burns of the left eye from NaOH and received emergency care from a general physician prior to being hospitalized. At the hospital, initial examination showed vision limited to light perception, corneal clouding to such an extent that iris markings were not discernable, necrosis of most of the bulbar conjunctiva, some sloughing in the nasal area of the cornea, blanched and necrotic cul-de-sac, and some involvement of the lids and adjacent skin. The treatment of the patient at the hospital consisted of daily debridement of necrotic areas, local atropine, antibiotics, steroids, systematic ACTH, vitamins, antacids, and proteolytic enzymes. The treatment produced some improvement with time so that usual, late sequelae such as vascular invasion and symblepharon did not occur, and the cornea cleared sufficiently within 7 weeks that vision returned to near normal.[Horowitz ID; Am J Ophthalmol 61: 340-341 (1966) as cited in NIOSH; Criteria Document: Sodium Hydroxide p.29 (1975) DHEW Pub. NIOSH 76-105] **PEER REVIEWED** /SURVEILLANCE/ 200 patients with suspected caustic ingestation were examined. No steroids were administered to the patients involved. Lesions in the esophagus were found in 93 patients. Thirty-two patients with deep circular burns had nasogastric tubes inserted immediately. Of these patients, 2 developed esophageal strictures, but subsequent dilatation was successful. No stricture formation was observed in the group of patients with noncircular lesions. This low percentage of stricture formation is due to the use of nasogastric tubes. Since neither the presence nor the severity of esophageal burns is predictable, an endoscopy should be performed in all suspected cases. In the absence of severe pharyngeal lesions, the use of a flexible fiberoptic endoscope is preferable because it also allows examination of the stomach and proximal part of the duodenum. [Wijburg FA et al; Ann Otol Rhinol Laryngol 94 (4 Part 1): 337-41 (1985)] **PEER REVIEWED** PubMed Abstract /ALTERNATIVE and IN VITRO TESTS/ Predicting the toxic potential of compounds to the ocular surface has depended on the Draize test for the past half century. Alternatives to Draize testing have recently been sought for a number of reasons. Stress gene expression has emerged as a means of quantifying cellular reaction and, thus, the toxic potential of the compound in question. This study examines the expression of the major stress response gene heme oxygenase-1 (HO-1) in a human corneal epithelial cell line (HCE-T) following challenges with a number of known ocular irritants. HCE-T was used to investigate the effect of ocular irritants on cell viability and HO-1 expression. Irritants tested included hydrogen peroxide, isopropyl alcohol, **sodium hydroxide** and trichloroacetic acid. HCE-T cells were grown to 80% confluency and treated with the listed irritants at a concentration range of 10-100 uM. Cell viability and northern blot analysis were performed following a 24 and 48 hr incubation period. HCE-T cells expressed HO-1 mRNA and HO activity similar to other human cell lines. Northern blot analysis demonstrated that levels of HO-1 mRNA transcripts increased regularly after exposure to the irritants in a concentration-dependent manner. Studies on the effect of various inhibitors and inducers of HO-1 on cell viability showed that inhibition of HO-1 potentiates the cytotoxic effect of ocular irritants. In contrast, pre-induction of HO-1 in HCE-T decreases the effect of various irritants on cell

viability. These results are consistent with the idea that HO-1 mRNA levels may be used as an indicator of toxicity resulting from ocular irritants and that HCE-T cells respond to stress in a fashion similar to other human cell lines. This strategy for testing may be important in the development of an alternative to Draize testing. The results of this study also suggest that HO-1 may constitute a part of the protective defense mechanism against chemical injury.[Braunstein SG et al; Curr Eye Res. 19 (2): 115-22 (1999)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ IN BIOPSY SPECIMENS FROM THE FOREARM VOLAR SURFACE **SODIUM HYDROXIDE** PRODUCED INTRACELLULAR EDEMA & INCREASED NUMBERS OF LAMELLAR GRANULES ON THE OUTER SURFACE OF THE UPPERMOST GRANULAR CELL LAYER.[NAGAO S ET AL; ACTA DERMATO-VENEREOL 52 (1): 11-23 (1972)] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ Cases of squamous cell carcinoma of the esophagus have occurred with latent periods of 12 to 42 years after ingestion; These cancers may have been sequelae of tissue destruction and possibly scar formation rather than from a direct carcinogenic action of **sodium hydroxide** itself.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981., p. 2] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ There is a latent period between contact of NaOH with the skin and the sensation of irritation.[NIOSH; Criteria Document: Sodium Hydroxide p.62 (1975) DHEW Pub. NIOSH 76-105] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ "Button" batteries, which contain concentrated solutions of sodium or potassium hydroxide, represent a serious risk for leakage, corrosion, and perforation when lodged in the esophagus.[Klaassen, C.D., M.O. Amdur, Doull J. (eds.). Casarett and Doull's Toxicology. The Basic Science of Poisons. 5th ed. New York, NY: McGraw-Hill, 1995., p. 976] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ Malfunctioning automobile air-bag inflation systems may release **sodium hydroxide** powder, a byproduct in the chemical conversion of sodium azide to nitrogen gas that inflates the auto air bags. Chemical surface burns will require symptomatic treatment.[Ellenhorn, M.J., S. Schonwald, G. Ordog, J. Wasserberger. Ellenhorn's Medical Toxicology: Diagnosis and Treatment of Human Poisoning. 2nd ed. Baltimore, MD: Williams and Wilkins, 1997., p. 1094] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ Seventy-five percent of all caustic injury to the esophagus in chidren under 5 years results from **sodium hydroxide**. Eighty-three percent of these victims are under 3 yr, and 62% are males. Gastric acid is not sufficiently strong or present in sufficient quantity to neutralize even small quantities of strong alkali.[Gossel, T.A., J.D. Bricker. Principles of Clinical Toxicology. 3rd ed. New York, NY: Raven Press, Ltd., 1994., p. 222] **PEER REVIEWED**

Skin, Eye and Respiratory Irritations:

Liquid or solid **sodium hydroxide** is a severe skin irritant. It causes second and third degree burns on short contact and is very injurious to the eyes.[U.S. Coast Guard, Department of Transportation. CHRIS - Hazardous Chemical Data. Volume II. Washington, D.C.: U.S. Government Printing Office, 1984-5.] **PEER REVIEWED** HAZARD WARNING: The irritating nature of the aerosol on the mucous membranes is presumed to be adequate warning to maintain air concn at tolerable levels.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.74 (Date)] **PEER REVIEWED** Irritating to skin, eyes, and respiratory system.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

Medical Surveillance:

The skin, eyes, and respiratory tract should receive special attention in any placement or periodic examination. NIOSH recommends that workers subject to **sodium hydroxide** exposure have comprehensive preplacement medical examinations. Medical examinations shall be made available promptly to all workers with signs or symptoms of skin, eye, or upper respiratory tract irritation resulting from exposure to sodium hydoxide.[Sittig M; Handbook of Toxic and Hazardous Chemicals p.606 (1981)] **PEER REVIEWED**

Probable Routes of Human Exposure:

According to the 2006 TSCA Inventory Update Reporting data, the number of persons reasonably likely to be exposed in the industrial manufacturing, processing, and use of **sodium hydroxide** is 1000 or greater; the data

may be greatly underestimated(1).[(1) US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Sept 9, 2011: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED** NIOSH (NOES Survey 1981-1983) has statistically estimated that 2,819,743 workers (995,960 of these were female) were potentially exposed to **sodium hydroxide** in the US(1). NIOSH (NOES Survey 1981-1983) has statistically estimated that 370,582 workers (137,156 of these were female) were potentially exposed to liquid **sodium hydroxide** in the US(1). The NOES Survey does not include farm workers. Occupational exposure to **sodium hydroxide** may occur through dermal contact with this compound at workplaces where **sodium hydroxide** is produced or used(SRC).[(1) NIOSH; NOES. National Occupational Exposure Survey conducted from 1981-1983. Estimated numbers of employees potentially exposed to specific agents by 2-digit standard industrial classification (SIC). Available from, as of Oct 11, 2011: http://www.cdc.gov/noes/] **PEER REVIEWED** Inhalation of dust or mist, ingestion, and skin or eye contact.[Sittig M; Handbook of Toxic and Hazardous Chemicals p.606 (1981)] **PEER REVIEWED**

Emergency Medical Treatment:

Emergency Medical Treatment:

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The following Overview, *** CORROSIVES-ALKALINE ***, is relevant for this HSDB record chemical.

Life Support:

o This overview assumes that basic life support measures have been instituted.

Clinical Effects:

```
0.2.1 SUMMARY OF EXPOSURE
   0.2.1.1 ACUTE EXPOSURE
     A)  USES: Used as drain openers, household cleaners (oven,
         bathroom), hair relaxers, dishwasher soap, and in
         automobile air bags. In industry used as cleaners, in
         cement, and as chemical precursors.
     B)  TOXICOLOGY: Alkaline corrosives cause liquefaction
         necrosis. They saponify the fats in the cell membrane,
         destroying the cell and allowing deep penetration into
         mucosal tissue. In gastrointestinal tissue an initial
         inflammatory phase may be followed by tissue necrosis
         (sometimes resulting in perforation), then granulation
         and finally stricture formation.
     C)  EPIDEMIOLOGY: Exposure is common. Serious effects are
         rare in the developed world (generally only seen in
         adults with deliberate ingestion), largely because
         mostly low concentration corrosives are present in
         products available in the home. Serious effects are
         more common in developing countries.
     D)  WITH POISONING/EXPOSURE
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1) MILD TO MODERATE ORAL TOXICITY: Patients with mild ingestions may only develop irritation or grade I (superficial hyperemia and edema) burns of the oropharynx, esophagus or stomach; acute or chronic complications are unlikely. Patients with moderate toxicity may develop grade II burns (superficial blisters, erosions and ulcerations) are at risk for subsequent stricture formation, particularly esophageal. Some patients (particularly young children) may develop upper airway edema.
   a) Alkaline corrosive ingestion may produce burns to the oropharynx, upper airway, esophagus and occasionally stomach. Spontaneous vomiting may occur. The absence of visible oral burns does NOT reliably exclude the presence of esophageal burns. The presence of stridor, vomiting, drooling, and abdominal pain are associated with serious esophageal injury in most cases.
   b) PREDICTIVE: The grade of mucosal injury at endoscopy is the strongest predictive factor for the occurrence of systemic and GI complications and mortality.
2) SEVERE ORAL TOXICITY: May develop deep burns and necrosis of the gastrointestinal mucosa. Complications often include perforation (esophageal, gastric, rarely duodenal), fistula formation (tracheoesophageal, aortoesophageal), and gastrointestinal bleeding. Hypotension, tachycardia, tachypnea and, rarely, fever may develop. Stricture formation (esophageal, less often oral or gastric) is likely to develop long term. Esophageal carcinoma is another long term complication. Upper airway edema is common and often life threatening. Severe toxicity is generally limited to deliberate ingestions in adults in the US, because alkaline products available in the home are generally of low concentration.
3) INHALATION EXPOSURE: Mild exposure may cause cough and bronchospasm. Severe inhalation may cause upper airway edema and burns, stridor, and rarely acute lung injury.
4) OCULAR EXPOSURE: Ocular exposure can produce severe conjunctival irritation and chemosis, corneal epithelial defects, limbal ischemia, permanent visual loss and in severe cases perforation.
5) DERMAL EXPOSURE: Mild exposure causes irritation and partial thickness burns. Metabolic acidosis may develop in patients with severe burns or shock. Prolonged exposure or high concentration products can cause full thickness burns.

0.2.3 VITAL SIGNS

Laboratory:

A) Obtain a complete blood count in symptomatic patients following an alkaline corrosive ingestion.
B) In patients with signs and symptoms suggesting severe burns, perforation, or bleeding (or adults with deliberate, high volume or high concentration ingestions), obtain renal function tests, serum electrolytes, INR, PTT, type and crossmatch for blood, and monitor urine output. Serum lactate and base deficit may also be useful in these patients.
C) Monitor pulse oximetry or arterial blood gases in patients with signs and symptoms suggestive of upper airway edema or burns.
D) Obtain an upright chest x-ray in patients with signs and symptoms suggesting severe burns, perforation, or

bleeding (or adults with deliberate, high volume or high concentration ingestions) to evaluate for pneumomediastinum or free air under the diaphragm. The absence of these findings DOES NOT rule out the possibility of necrosis or perforation of the esophagus or stomach. Obtain a chest radiograph in patients with pulmonary signs or symptoms.

E) Several weeks after ingestion, barium contrast radiographs of the upper GI tract are useful in patients who sustained grade II or III burns, to evaluate for strictures.

Treatment Overview:

0.4.2 ORAL EXPOSURE

A) MANAGEMENT OF MILD TO MODERATE ORAL TOXICITY

1) Perform early (within 12 hours) endoscopy in patients with stridor, drooling, vomiting, significant oral burns, difficulty swallowing or abdominal pain, and in all patients with deliberate ingestion. If burns are absent or grade I severity, patient may be discharged when able to tolerate liquids and soft foods by mouth. If mild grade II burns, admit for intravenous fluids, slowly advance diet as tolerated. Perform barium swallow or repeat endoscopy several weeks after ingestion (sooner if difficulty swallowing) to evaluate for stricture formation.

B) SEVERE ORAL TOXICITY

1) Resuscitate with 0.9% saline; blood products may be necessary. Early airway management in patients with upper airway edema or respiratory distress. Early (within 12 hours) gastrointestinal endoscopy to evaluate for burns. Early bronchoscopy in patients with respiratory distress or upper airway edema. Early surgical consultation for patients with severe grade II or grade III burns, large deliberate ingestions, or signs, symptoms or laboratory findings concerning for tissue necrosis or perforation.

C) DILUTION

1) Dilute with 4 to 8 ounces of water may be useful if it can be performed shortly after ingestion in patients who are able to swallow, with no vomiting or respiratory distress; then the patient should be NPO until assessed for the need for endoscopy. Neutralization, activated charcoal, and gastric lavage are all contraindicated.

D) AIRWAY MANAGEMENT

1) Aggressive airway management in patients with deliberate ingestions or any indication of upper airway injury.

E) ENDOSCOPY

1) Should be performed as soon as possible (preferably within 12 hours, not more than 24 hours) in any patient with deliberate ingestion, adults with any signs or symptoms attributable to inadvertent ingestion, and in children with stridor, vomiting, or drooling after inadvertent ingestion. Endoscopy should also be considered in children with dysphagia or refusal to swallow, significant oral burns, or abdominal pain after unintentional ingestion. Children and adults who are asymptomatic after inadvertent ingestion do not require endoscopy. The grade of mucosal injury at endoscopy is the strongest predictive factor for the occurrence of systemic and GI complications and mortality. The absence of visible oral burns does NOT reliably exclude the presence of esophageal burns.

F) CORTICOSTEROIDS

1) The use of corticosteroids to prevent stricture formation is controversial. Corticosteroids should not be used in patients with grade I or grade III injury, as there is no evidence that it is effective. Evidence for grade II burns is conflicting, and the risk of perforation and infection is increased with steroid use.

G) STRICTURE

1) A barium swallow or repeat endoscopy should be performed several weeks after ingestion in any patient with grade II or III burns or with difficulty swallowing to evaluate for stricture formation. Recurrent dilation may be required. Some authors advocate early stent placement in these patients to prevent stricture formation.

H) SURGICAL MANAGEMENT

1) Immediate surgical consultation should be obtained on any patient with grade III or severe grade II burns on endoscopy, significant abdominal pain, metabolic acidosis, hypotension, coagulopathy, or a history of large ingestion. Early laparotomy can identify tissue necrosis and impending or unrecognized perforation, early resection and repair in these patients is associated with improved outcome.

I) PATIENT DISPOSITION

1) OBSERVATION CRITERIA: Patients with alkaline corrosive ingestion should be sent to a health care facility for evaluation. Patients who remain asymptomatic over 4 to 6 hours of observation, and those with endoscopic evaluation that demonstrates no burns or only minor grade I burns and who can tolerate oral intake can be discharged home.

2) ADMISSION CRITERIA: Symptomatic patients, and those with endoscopically demonstrated grade II or higher burns should be admitted. Patients with respiratory distress, grade III burns, acidosis, hemodynamic instability, gastrointestinal bleeding, or large ingestions should be admitted to an intensive care setting.

J) PITFALLS

1) The absence of oral burns does NOT reliably exclude the possibility of significant esophageal burns.

2) Patients may have severe tissue necrosis and impending perforation requiring early surgical intervention without having severe hypotension, rigid abdomen, or radiographic evidence of intraperitoneal air.

3) Patients with any evidence of upper airway involvement require early airway management before airway edema progresses.

4) The extent of eye injury (degree of corneal opacification and perilimbal whitening) may not be apparent for 48 to 72 hours after the burn. All patients with corrosive eye injury should be evaluated by an ophthalmologist.

K) DIFFERENTIAL DIAGNOSIS

1) Acid ingestion, gastrointestinal hemorrhage, or perforated viscus.

0.4.3 INHALATION EXPOSURE

A) DECONTAMINATION

1) Administer oxygen as necessary. Monitor for respiratory distress.

B) AIRWAY MANAGEMENT

1) Manage airway aggressively in patients with significant respiratory distress, stridor or any evidence of upper

airway edema. Monitor for hypoxia or respiratory distress.

C) BRONCHOSPASM

1) Treat with oxygen, inhaled beta agonists and consider systemic corticosteroids.

0.4.4 EYE EXPOSURE

A) DECONTAMINATION

1) Exposed eyes should be irrigated with copious amounts of 0.9% saline for at least 30 minutes, until pH is neutral and the cul de sacs are free of particulate material.

2) An eye examination should always be performed, including slit lamp examination. Ophthalmologic consultation should be obtained. Antibiotics and mydriatics may be indicated.

0.4.5 DERMAL EXPOSURE

A) OVERVIEW

1) DECONTAMINATION

a) Remove contaminated clothes and any particulate matter adherent to skin. Irrigate exposed skin with copious amounts of water for at least 15 minutes or longer, depending on concentration, amount and duration of exposure to the chemical. A physician may need to examine the area if irritation or pain persist.

Range of Toxicity:

A) LIQUID CORROSIVES - With highly concentrated liquids (30% **sodium hydroxide**) esophageal burns may occur in up to 100% of patients, even after accidental ingestion.

B) Serious burns are less likely if the pH is less than 11.5. Injury is greater with large exposures and high concentrations.

C) More recent series of caustic ingestions (mixed liquid and solid) in children report incidences of significant esophageal burns from 5% to 35%. Adults with deliberate ingestions are more likely to develop significant esophageal burns (30% to 80%).

D) LOW PHOSPHATE DETERGENTS and electric dishwasher soaps may result in oral and esophageal burns.

[Rumack BH POISINDEX(R) Information System Micromedex, Inc., Englewood, CO, 2017; CCIS Volume 172, edition expires May, 2017. Hall AH & Rumack BH (Eds): TOMES(R) Information System Micromedex, Inc., Englewood, CO, 2017; CCIS Volume 172, edition expires May, 2017.] **PEER REVIEWED**

Antidote and Emergency Treatment:

/EXPERIMENTAL/ An experimental study was conducted to investigate the effects of erythropoietin on the acute phase of esophageal burn damage induced by **sodium hydroxide**. A standard esophageal alkaline burn was produced by the application of 10% **sodium hydroxide** to the distal esophagus in an in vivo rat model. Fifty-six female rats were allocated into three groups: Group BC (baseline control, n = 8) rats were uninjured and untreated, Group PC (positive control, n = 24) rats were injured but untreated and Group EPO (erythropoietin-treated, n = 24) rats were injured and given subcutaneous erythropoietin (1,000 IU/kg per day), 15 min, 24, and 48 hr after administration of the NaOH solution. Six animals from Group PC and six from Group EPO were killed at 4, 24, 48, and 72 hr after application of NaOH to the esophagus. All of animals in Group BC were killed 4 hr after exposure to 0.9% NaCl. Oxidative damage was assessed by measuring levels of malondialdehyde (MDA) and nitric oxide (NO), and activities of superoxide dismutase (SOD) and catalase (CAT) in homogenized samples of esophageal tissue. Histologic damage to esophageal tissue was scored by a single pathologist blind to groups. MDA levels in the BC and EPO groups were significantly lower than those in the PC group ($p < 0.05$). CAT and SOD activities, and NO levels in the BC and EPO groups were significantly higher than in the PC group ($p < 0.05$). Esophageal tissue damage measured at 4, 24, 48, and 72 hr after NaOH application was significantly less in the EPO group than in the PC group ($p < 0.05$). When administered early after an esophageal burn induced by 10% **sodium hydroxide** in this rat model, erythropoietin significantly

attenuated oxidative damage, as measured by biochemical markers and histologic scoring.[Bakan V et al; Pediatr Surg Int. 26 (2): 195-201 (2010)] **PEER REVIEWED** PubMed Abstract /EXPERIMENTAL/ ... Esophageal burns were induced in male rats by the administration of 10% **sodium hydroxide**. Lipid peroxidation (LPO) products were then measured at the following times: 0, 1, 6, 24, 48 and 72 hr after treatment. Tissue hydroxyproline (HP) concentrations in the injured area were assessed at 14 days after the administration of **sodium hydroxide**. The groups received either systemic melatonin or normal saline. There were two, non-ischemic, sham control groups treated with or without melatonin. LPO products, malondialdehyde (MDA) and 4-hydroxyalkenal (4-HDA), increased immediately after the administration of **sodium hydroxide**; this indicates the participation of free radicals in the development of damage. Melatonin diminished the oxidative response and the amount of HP in the late phase of the lesion. Melatonin reduced oxidative damage in the early phase of the esophageal burns induced by **sodium hydroxide**.[Larios-Arceo F et al; J Pineal Res. 45 (2): 219-23 (2008)] **PEER REVIEWED** PubMed Abstract When **caustic soda** comes into contact with the skin it does not usually cause immediate pain, but it does start to cause immediate damage. It fails to coagulate protein which would serve to prevent further penetration. Thus, upon contact with eyes, washing with water must be started within 10 seconds and continued for at least 15 minutes to prevent permanent injury. Following contact with skin, washing with water must be started immediately to prevent corrosive chemical burns.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 1:861] **PEER REVIEWED** /SRP: Experimental/ Alkali-burned corneas were treated with 2% ascorbic acid. Topical applications and subconjunctival injections were given for 32 days. Treatment with ascorbic acid significantly decreased the incidence of corneal ulcerations and perforations compared to the control group that received the vehicle. These results confirm previous studies and strongly suggest that ascorbic acid presents a potential for use in the alkali-burned human eye.[Pertoutsos G and Pouliguen Y; Ophthalmic Res 16 (4): 185-89 (1984)] **PEER REVIEWED** PubMed Abstract /SRP: Experimental/ ... The effect of cimetidine administered intraperitoneally in doses of 2.5, 10, and 50 mg/kg, on: (1) The gastric acid secretory responses in 1 and 4 hr pylorous-ligated rats, and (2) the rat gastric mucosal lesions induced by intragastric administration of ... 0.2 M NaOH ... is discussed. It was found that ... all doses of cimetidine significantly prevented the gastric lesion development induced by different necrotizing agents ... (0.2 M NaOH). The cytoprotecting dose of cimetidine was of 2.5 mg/kg. The duration of cimetidine-induced cytoprotection was 1 hr long before the administration of the necrotizing agent. These results suggest a real cimetidine-induced gastric cytoprotection.[Mor'on F et al; Arch Int Pharmacodyn Ther 265 (2): 309-19 (1983)] **PEER REVIEWED** PubMed Abstract /SRP: Experimental/ An experimental study on morniflumate, the beta-morpholinoethyl ester of niflumic acid, was undertaken in the rat to test its gastroprotective and "cytoprotective" properties and to assess its effects on gastric secretion and on the prostaglandin contents in the stomach wall. Morniflumate induced intense anad usually dose-dependent inhibition of the ... gastric necrotic lesions caused by ... NaOH 0.2 mol/l. ... Morniflumate also exerted marked inhibition of gastric acid secretion both in normal and in pylorus-ligated rats. The compound raised the concn of "cytoprotective" prostaglandins in the glandular portion of the stomach but did not reverse the synthesis-block effect of the ulcerogenic nonsteroidal anti-inflammatory drugs whose gastric effects it inhibited.[Schiantarelli P et al; Arzneimittelforsch 34 (8): 885-90 (1984)] **PEER REVIEWED** PubMed Abstract /SRP: Experimental/ The gastric damaging effects of necrotizing concn of **sodium hydroxide** were strongly reduced by paracetamol. ... Paracetamol might be protective by stimulating the biosynthesis of prostaglandins in the stomach wall.[Van Kolfschoten AA et al; Toxicol Appl Pharmacol 69 (1): 37-42 (1983] **PEER REVIEWED** PROTECTION AGAINST DAMAGE FROM LOCALLY APPLIED **SODIUM HYDROXIDE** HAS BEEN SHOWN TO BE POSSIBLE UNDER EXPTL CONDITIONS IN RABBIT CORNEAS BY INJECTION OF ANIMAL'S SERUM INTO CORNEA TO INCR ITS LOCAL BUFFERING CAPACITY.[Grant, W. M. Toxicology of the Eye. 2nd ed. Springfield, Illinois: Charles C. Thomas, 1974., p. 931] **PEER REVIEWED** Immediate first aid: Remove patient from contact with the material. Ensure that adequate decontamination has been carried out. If patient is not breathing, start artificial respiration, preferably with a demand valve resuscitator, bag-valve-mask device, or pocket mask, as trained. Perform CPR if necessary. Immediately flush contaminated eyes with gently flowing water. Do not induce vomiting. If vomiting occurs, lean patient forward or place on the left side (head-down position, if possible) to maintain an open airway and prevent aspiration. Keep patient quiet and maintain normal body temperature. Obtain medical attention. /Inorganic Bases/Alkaline Corrosives and Related Compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 191] **PEER REVIEWED** Basic treatment: Establish a patent airway

(oropharyngeal or nasopharyngeal airway, if needed). Suction if necessary. Watch for signs of respiratory insufficiency and assist ventilations if necessary. Administer oxygen by nonrebreather mask at 6 to 12 L/min. Monitor for pulmonary edema and treat if necessary ... . Monitor for shock and treat if necessary ... . For eye contamination, flush eyes immediately with water. Irrigate each eye continuously with 0.9% saline (NS) during transport ... . Do not use emetics. For ingestion, rinse mouth and administer 5 ml/kg up to 200 ml of water for dilution if the patent can swallow, has a strong gag reflex, and does not drool ... . Do not attempt to neutralize. Cover skin burns with dry sterile dressings after decontamination ... . /Inorganic Bases/Alkaline Corrosives and Related Compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 191-2] **PEER REVIEWED** Advanced treatment: Consider orotracheal or nasotracheal intubation for airway control in the patient who is unconscious, has severe pulmonary edema, or is in severe respiratory distress. Early intubation, at the first signs of upper airway obstruction, may be necessary. Positive-pressure ventilation techniques with a bag valve mask device may be beneficial. Consider drug therapy for pulmonary edema ... . Monitor cardiac rhythm and treat arrhythmias as necessary ... . Start IV administration of D5W /SRP: "To keep open", minimal flow rate/. Use 0.9% saline (NS) or lactated Ringer's (LR) if signs of hypovolemia are present. For hypotension with signs of hypovolemia, administer fluid cautiously. Consider vasopressors if patient is hypotensive with a normal fluid volume. Watch for signs of fluid overload ... . Use proparacaine hydrochloride to assist eye irrigation ... . /Inorganic Bases/Alkaline Corrosives and Related Compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 192] **PEER REVIEWED**

Animal Toxicity Studies:

Non-Human Toxicity Excerpts:

/LABORATORY ANIMALS: Acute Exposure/ ... Enucleated bovine and porcine (n = 59 each) eyes were used for exposure to sodium, ammonium, and calcium hydroxide, respectively, /in three different concentrations 11 M, 6 M, or 0.25 M and were splashed onto the eye using a syringe. Approximately 5 mL each alkali solution was splashed onto the fully exposed cornea, ensuring that the entire cornea was covered. Each assigned to a predesignated time interval (30 sec, 60 sec, 12 min, 30 min, 8 hr, and 24 hr) for exposure and were immediately washed in water./ Eyes were subjected to fluorescein staining, 5-bromo-2'-deoxy-uridine (BrdU) labeling. Excised cornea was subjected to protein extraction, spectrophotometric determination of protein amount, dynamic light scattering and SDS-PAGE profiling, mass spectrometric protein identification, and iTRAQ-labeled quantification. Select identified proteins were subjected to Western blot and immunohistochemical analyses. Alkali exposure resulted in lower protein extractability from corneal tissue. Elevated aggregate formation was found with strong alkali exposure (sodium hydroxide>ammonium, calcium hydroxide), even with a short duration of exposure compared with controls. The protein yield after exposure varied as a function of post exposure time. Protein profiles changed because of alkali exposure. Concentration and strength of the alkali affected the profile change significantly. Mass spectrometry identified 15 proteins from different bands with relative quantification. Plexin D1 was identified for the first time in the cornea at a protein level that was further confirmed by Western blot and immunohistochemical analyses. Exposure to alkaline chemicals results in predictable and reproducible changes in corneal protein profile. Stronger alkali, longer durations, or both, of exposure resulted in lower yields and significant protein profile changes compared with controls.[Parikh T et al; Invest Ophthalmol Vis Sci. 52 (3): 1819-31 (2011)] **PEER REVIEWED** PubMed Abstract Full text: PMC3101685 /LABORATORY ANIMALS: Acute Exposure/ Keratin material in the skin underwent rapid decomposition in **sodium hydroxide** above pH 9.2. Aliquots of washed human hair and fingernails were mixed with various amounts of sodium solution and the extent of keratin breakdown was measured by estimating the cystine produced. The cystine portion of the keratin complex of human hair or nails was readily cleaved by **sodium hydroxide** in the S-S bond. After 20 hr of contact with 0.1N or 0.25N **sodium hydroxide**, 61.4% and 97.6%, respectively, of the nail keratin were decomposed. Thus, a high degree of destruction of tissue even by a dilute **sodium hydroxide** solution can occur from prolonged contact.[NIOSH; Criteria Document: Sodium Hydroxide p.30 (1975) DHEW Pub. NIOSH 76-105] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ The objective of this study was/ to investigate immediate changes in water-soluble metabolites of ocular tissue in alkali-burned eyes by using high-resolution 1H-NMR spectroscopy. Adult New Zealand rabbit eyes were burned with 1 M NaOH for 1 min. Normal eyes were used as control. Samples from aqueous humor

and perchloric acid extracts of the cornea and lens were analyzed on a NMR spectrometer operating at 500 MHz for protons. Metabolites were quantified by comparing peak area with an added internal standard, TSP (3'-trimethylsilylpropinate-2,2,3,3-d4). Alkali burn of corneal surface causes immediate changes in concentration of many water-soluble metabolites in the anterior segment. Even as far away as the lens a significant increase in lactate was found. Cornea showed a significant increase in glucose and a significant decrease in hypo-taurine concentration. Most changes were observed in aqueous humor, with significant increases in succinate, creatine, scyllo- and myo-inositol and a significant decrease in citrate concentration. Furthermore, a small decrease in ascorbate concentration in aqueous humor was observed.[Risa O et al; Graefes Arch Clin Exp Ophthalmol. 240 (1): 49-55 (2002)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... To study morphological and functional alterations of the esophagus in rabbits submitted to esophageal infusion of **caustic soda** (NaOH). The 88 rabbits studied were divided into 4 groups: G1 (n=22) were submitted to esophageal infusion with distilled water. G2, G3, and G4 were submitted to esophageal infusion of 2%, 4% and 6% NaOH respectively. Morphological alterations were studied in 12 animals from each group and manometric alterations in the remaining 10. An analysis was made of lower esophageal sphincter (LES) pressure, number and amplitude of contractions in the distal third of the esophagus. These studies were performed before (moment M1) and at 30 min, 6 hr, and 24 hr after (moments M2, M3, and M4, respectively) esophageal infusion. Morphological evaluation: G1 - no alterations; G2 - edema, hyperemia, and ecdysis; G3 - enlarged calibre of esophagus, ulcers, ecdysis of mucosa; G4 - lesions similar to G3, but more intense, areas of extensive hemorrhage at M3 and M4. Functional evaluation: LES was higher at M2; the number of distal third lower esophageal contractions in G3, and G4 was lower; and the contraction amplitude was lower in G4. ... Esophageal infusion with NaOH caused lesions in the esophageal wall, with gravity proportional to solution concentration. Infusion caused LES spasm at M2, and reduced both contraction number and amplitude in the distal third of the esophagus.[Henry MA et al; Acta Cir Bras. 23 (1): 16-21 (2008)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... An experimental study on rats was designed to evaluate systemic effects of household bleaches that contain 4% sodium hypochlorite and less than 0.05% **sodium hydroxide** on lungs, livers, kidneys and intestines after 2, 4, 6, 12, 24 and 48 hr of administration via intragastric route. Prominent congestion and some interstitial mononuclear cellular infiltration were observed in the lungs, the livers and the kidneys of the rats after administration of household bleaches. Additionally, the lungs showed expansion of the alveolar spaces. While erosive changes were present in the stomachs, the intestines were normal. These histopathological changes were especially prominent at early periods of systemic administration. In the second part of the study, to assess whether these findings would hold for intravenous administration of household bleaches, another group of rats were given intravenous administration of household bleach and after 4 hr of intravenous administration of household bleach, the same histopathological changes above were observed in the lungs, kidneys and livers. ...[Andiran F et al; Drug Chem Toxicol. 22 (3): 545-53 (1999)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ To investigate the optimal concentration of **sodium hydroxide** (NaOH) on esophageal stricture formation in rats to establish an animal model of benign esophageal stricture (BES). Corrosive esophageal burn was produced by internal application of different concentrations of NaOH to the distal esophagus in rats. As many as 66 male rats were randomly divided into eight groups: Group A (control, n = 6), Group B (sham-operated group, n = 6), Group C (5% NaOH, n = 8), Group D (10% NaOH, n = 8), Group E (20% NaOH, n = 8), Group F (30% NaOH, n = 10), Group G (40% NaOH, n = 14), and Group H (50% NaOH, n = 6). Surviving rats were killed at 28 days. The survival rate, body weight gain, symptoms, and histopathological changes were assessed. The mortality rate was high in Groups G and H (73 and 67%). The prevalence of symptoms of BES was 43% in Groups D and E, 50% in Group F, 75% in Group G, and 100% in Group H. Statistically significant stricture formation of the esophagus was observed in Groups F and G. The degree of tissue damage was significantly higher in Groups E, F, and G. ... [Okata Y et al; Pediatr Surg Int. 27 (1): 73-80 (2011)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... Ten microliters of ... 2 or 8% **sodium hydroxide** (NaOH) were directly applied to the cornea of the right eye of each test rabbit. Untreated left eyes served as the controls. Eyes and eyelids were macroscopically examined for signs of irritation beginning 3 hours after dosing and periodically until recovery or day 35. Eyes and eyelids from animals in each group were collected for microscopic examination after 3 hours and on days 1, 3, and 35. The macroscopic and microscopic changes were consistent with ... mild (2% NaOH ...), and severe (8% NaOH) irritancy. ... As with surfactants, as the extent of initial injury increased, the intensity and duration of the subsequent responses increased. ... The initial extent of injury associated with ocular irritation may be used to predict the subsequent responses and final outcome. ...

[Maurer JK, Parker RD; Toxicol Pathol. 28 (5): 679-87 (2000)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... Esophageal burns were induced in male rats by the administration of 10% **sodium hydroxide**. Lipid peroxidation (LPO) products were then measured at the following times: 0, 1, 6, 24, 48 and 72 hr after treatment. Tissue hydroxyproline (HP) concentrations in the injured area were assessed at 14 days after the administration of **sodium hydroxide**. The groups received either systemic melatonin or normal saline. There were two, non-ischemic, sham control groups treated with or without melatonin. LPO products, malondialdehyde (MDA) and 4-hydroxyalkenal (4-HDA), increased immediately after the administration of **sodium hydroxide**; this indicates the participation of free radicals in the development of damage. Melatonin diminished the oxidative response and the amount of HP in the late phase of the lesion. Melatonin reduced oxidative damage in the early phase of the esophageal burns induced by **sodium hydroxide**. [Larios-Arceo F et al; J Pineal Res. 45 (2): 219-23 (2008)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... This study examined the roles of vascular dysfunction and inflammation to the esophageal injury response to different caustic substances in mice. The esophageal responses to **sodium hydroxide** (10%, 5%, and 2.5%) ... were evaluated by intravital videomicroscopy and histopathology. Intravital microscopy was used to monitor changes in the diameter of arterioles and venules, the adhesion and movement of leukocytes in venules, and the time of cessation of arteriolar blood flow in mouse esophagus. The esophageal mucosa was exposed to caustic substances for 0 to 60 minutes before evaluation. The higher concentrations of **sodium hydroxide** ... elicited rapid stasis in both arterioles and venules, which was accompanied by arteriolar constriction and thrombosis. An accumulation of adherent leukocytes in venules was not observed with any agent. Histopathological evaluation revealed marked cellular and interstitial edema in the mucosa with alkali. ... Ischemia and thrombosis are dominant processes, whereas inflammation is less important in the pathogenesis of acute corrosive injury to the esophageal mucosa.[Osman M et al; J Pediatr Surg. 43 (9): 1672-8 (2008)] **PEER REVIEWED** PubMed Abstract Full text: PMC2583796 /LABORATORY ANIMALS: Acute Exposure/ An in vivo test was conducted with Yorkshire weanling pigs using applications of 2N (8 %), 4N (16 %) and 6N (24%) NaOH on the lower abdominal region. Gross blisters developed within 15 minutes of application and 8 and 16 % NaOH produced severe necrosis in all epidermal layers. A concentration of 24 % produced numerous and severe blisters with necrosis extending deeper into the subcutaneous tissue. Also an in vitro test was performed with isolated perfused skin flaps of Yorkshire weanling pigs using NaOH concentrations of 4N (16 %) and 6N (24%). At both concentrations NaOH showed severe necrosis of all epidermal cell layers and dermis. At times this lesion extended deep into the subcutaneous layers.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.13 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ Ocular blood flow was determined using radioactive S 85 microspheres after an alkali NaOH burn to the eye /of adult albino rabbits/. With 20 uL NaOH, blood flow was significantly increased in the iris, ciliary processes, and choroid from 2 through 4 hr. This correlated well with the sustained increase in intraocular pressure (IOP) seen after a 20 uL burn. A 50 uL burn increased blood flow 1 hr, but it returned toward normal levels beyond 2 hr. ... There appeared to be a meaningful correlation between IOP changes and altered blood flow following ocular alkali burns. The blood flow changes paralleled those occurring after the topical application of prostaglandins and supported the concept that ocular blood flow dynamics are mediated by prostaglandins.[Green K et al; Arch Ophthalmol (Chicago) 103 (4): 569-71 (1985)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ Species differences have been observed in degrees of damage and of recovery after contamination of the eye with **sodium hydroxide**. In comparisons made /in separate studies/ they eyes of monkeys react a little less, and recover a little better, than the eyes of rabbits. It is believed that human eyes are more like monkey eyes.[Grant, W.M. Toxicology of the Eye. 3rd ed. Springfield, IL: Charles C. Thomas Publisher, 1986., p. 834] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ ... ADMIN **CAUSTIC SODA** IN A BARIUM MEAL TO DOGS AND FOLLOWED THE GASTROINTESTINAL PROGRESS OF THIS FLUID MASS BY FLUOROSCOPY. IT FOLLOWED THE MAGENSTRASSE TO THE ANTRUM, WHERE IT INDUCED PYLOROSPASM, TRAPPING THE CORROSIVE AT THAT SITE. AUTOPSY CONFIRMED THAT THIS WAS THE LOCUS OF THE GREATEST NECROTIC DAMAGE. SUBSEQUENT INVESTIGATIONS HAVE CONFIRMED THAT LYE ADMIN TO ERECT DOG PRODUCES HEMORRHAGIC GASTRITIS ...[Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984., p. III-246] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ WITHIN THE FIRST MIN AFTER TOPICAL APPLICATION OF **SODIUM HYDROXIDE** TO GUINEA PIGS, BLOCKADE OF RESP ENZYMES IN

DERMAL CELLS AND SWELLING OF DERMAL COLLAGENIC FIBERS OCCURRED.[PANCHENKO KI; VESTN DERMATOL VENEROL (2): 28-32 (1977)] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ RATS ADMIN 0.2 mL OF 0.1 N **SODIUM HYDROXIDE** DEMONSTRATED IMMEDIATE NECROSIS OF DERMAL TISSUE. MARKED REDUCTIONS IN GLYCOGEN AND TOTAL LIPID WERE OBSERVED.[SANYAL S ET AL; INDIAN J MED RES 63 (11): 1609-19 (1975)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ The hair of adult mice was clipped and a circular area 2 cm in diameter was painted by applicator with 50 % NaOH. Afterwards the area was irrigated with water at various intervals. The mortality of mice was 20, 40, 80 and 71 % when they were irrigated 30 min, 1 hr, 2 hr or not at all after the application. The animals were observed daily for up to 7 days after the treatment. All animals developed rapidly progressive burns. No mortality or burns were observed when the mice were irrigated immediately after the application.[Organization for Economic Cooperation and Development; Screening Information Data Set for Sodium Hydroxide, (1310-73-2) p.12 (March 2002). Available from, as of October 4, 2011: http://www.inchem.org/pages/sids.html] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ 0.05 mL of 0.123N (0.5%), 0.5N (2.0%), and 2.0N (8.0%) **sodium hydroxide** were applied into the eyes of 3 anesthetized albino rabbits. The intraocular pressure increased 5, 18, and 37 mm Hg, respectively, within 2.5 min.[Chiang TS et al; Invest Ophthamol 10: 270-273 (1971) as cited in NIOSH; Criteria Document: Sodium Hydroxide p.43 (1975) DHEW Pub. NIOSH 76-105] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ Damage to the gastric fundic mucosa was produced in rats by intragastric administration of 1 mL 0.2 M NaOH, ... a control group received 1 mL saline solution. The animals were killed 1 hr later, and the number and severity of ulcers (lesions) noted. The gastric fundic mucosa were excised and frozen, and assayed enzymatically for adenosine triphosphate (ATP), adenosine diphosphate (ADP), adenosine monophosphate (AMP) and lactate, while the tissue level of cyclic adenosine monophosphate (cAMP) was estimated by radioimmunoassay. It was found that: (1) The number and severity of gastric lesions (ulcers) increased significantly in all groups treated by the necrotizing agent; (2) The extent of ATP breakdown into ADP increased significantly, while the ATP transformation into cAMP by adenylate cyclase, and of cAMP into AMP by phosphodiesterase, decreased. ... It was concluded that: (1) The mucosal damage develops as a consequence of a very active metabolic adaption of the rat gastric fundic mucosa, notably the significantly increased ATP transformation into ADP, which is not the consequence of hypoxaemia; (2) The feed-back mechanism system between the membrane-bound ATP-dependent energy systems is broken as the mucosal damage develops, the main changes being significantly decreased ATP transformation into cAMP, and significant alterations by neural, hormonal, and pharmacological influences in the membrane-bound ATP-dependent energy systems.[Mor'on F et al; Int J Tissue React 5(4): 357-362 (1983)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Acute Exposure/ ... a 10s exposure of rabbit esophagus to 7N (22.5%) **sodium hydroxide** produces necrosis in all layers of the tissue.[Gossel, T.A., J.D. Bricker. Principles of Clinical Toxicology. 3rd ed. New York, NY: Raven Press, Ltd., 1994., p. 224] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ A 5% aqueous solution of **sodium hydroxide** produced severe necrosis when applied to the skin of rabbits for 4 hr. Rats were exposed to an aerosol of 40% aqueous **sodium hydroxide** whose particles were less than 1 um in diameter. ... After 3 weeks two 2 of the 10 rats died. ... Examination showed mostly normal lung tissue with foci of enlarged alveolar septa, emphysema, bronchial ulceration, and enlarged lymph adenoidal tissues.[Clayton, G.D., F.E. Clayton (eds.) Patty's Industrial Hygiene and Toxicology. Volumes 2A, 2B, 2C, 2D, 2E, 2F: Toxicology. 4th ed. New York, NY: John Wiley & Sons Inc., 1993-1994., p. 772] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ Oral intubation of /**sodium hydroxide** in/ a 4% solution in rabbits caused mucosal and submucosal necrosis within 10 seconds, a 12% solution eroded into the muscle, and a 28% solution caused perforation. Similar results are seen in cats. A 5% aqueous solution of **sodium hydroxide** applied to the skin of rabbits for 4 hr produced severe necrosis; however, a 1% solution (pH 13.4) failed to cause gastric, esophageal, or other damage. Instillation of a 1% solution into the conjunctival sac failed to cause ocular or conjunctival injury in rabbits, provided the eye was promptly irrigated with copious amounts of water.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 1416] **PEER REVIEWED** /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ 27 white rats died within a month, mostly from bronchopneumonia, after twice weekly exposures to an aerosol of unknown airborne concn generated from an aqueous 40% NaOH solution. When exposed to an aerosol generated from aqueous 20% NaOH solution, the septa were emphymatously (sic) dilated and cracked, the bronchi were dilated and their epithelial cover was thin and frequently desquamated, and a light roundcell infiltration of the submucus membrane tissue occurred. Other rats were exposed to aerosols generated from 10%

and 5% solutions of NaOH. In the group exposed to aerosols from 10% NaOH, little change occurred. In the group exposed to aerosols from 5% NaOH, rats had dilation of the bronchi and a slight degeneration of the mucus membrane and thickened strata of the lymphadenoid tissue surrounding the bronchi.[NIOSH; Criteria Document: Sodium Hydroxide p.46 (1975) DHEW Pub. NIOSH 76-105] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ ... /Changes in Aldehyde dehydrogenase 3A1 (ALDH3A1) expression after corneal alkaline burns to the mouse cornea were detected using/ ... RTQ-PCR to monitor the transcriptional change of ALDH3A1. ... Used zymography to test enzyme activity changes of ALDH3A1 in the alkali burn cornea; And SDS-PAGE and mass spectrometry technology were used to verify protein content changes and to identify ALDH3A1 protein. ... Alkali burn of the corneal surface caused a rapid decrease of ALDH3A1 in the corneal at both the RNA and protein levels, which leads to the loss of the protective component of the corneal surface and makes it vulnerable to further damage. The ALDH3A1 level in the cornea gradually recovered during the healing process. Use of an anti-oxidation reagent as a treatment ingredient for alkali burn of the corneal surface could compensate for the decrease of anti-oxidation protection potential caused by ALDH3A1 loss. /alkaline burn/[Feng Y et al; Mol Vis. 10: 845-50 (2004)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ A micropolarographic system was used as a quantitative means of monitoring the healing course of corneal epithelium following a 10 second exposure to 0.20 N **sodium hydroxide** solution. ... The healing course following those exposures consisted of two well defined phases: an initial period of hypoflux lasting some 48 hr before rising back up to the pre-lesion baseline, followed then by a period of hyperflux lasting about 7 days before decreasing once again down to the pre-lesion baseline.[Mauger TF, Hill RM; Acta Ophthalmol (Copenh) 63 (3): 264-7 (1985)] **PEER REVIEWED** PubMed Abstract /OTHER TOXICITY INFORMATION/ INGESTION OF ANY CAUSTIC AGENT ... /CAUSES/ CORROSION OF MUCOUS MEMBRANES OF UPPER PART OF DIGESTIVE TRACT. VOMITING, COLIC, & PURGATION MAY FOLLOW, WITH PROSTRATION & DEATH FROM ACUTE SHOCK. ... CORROSION OF MOUTH. /CAUSTIC AGENTS/[Clarke, M. L., D. G. Harvey and D. J. Humphreys. Veterinary Toxicology. 2nd ed. London: Bailliere Tindall, 1981., p. 25] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ The efficacy of various disinfectants was tested against cultures from rabbit feces containing coccidian parasites (Eimeria intestinalis, E. magna, E. media, E. perforans, and E. stidae). At concn of 0.5-5%, ... NaOH ... suppressed oocyte development, but /was/ not lethal. ... The most effective treatment (96-98% efficient) was achieved using a mixture of 2% CCl4, 2% NaOH, 5% ammonia water, and 5% NaCl.[Abramova VF, Karare MV; Profil Parazit Bolezn Zhivotn 30-3 (1985)] **PEER REVIEWED** /OTHER TOXICITY INFORMATION/ Rats that inhaled unmeasured concentrations of **sodium hydroxide** aerosols for 30 min/day suffered pulmonary damage after 2.5 mos.[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 1416] **PEER REVIEWED**

Ecotoxicity Excerpts:

/AQUATIC SPECIES/ Concentration 20-100 mg/L in water kills some species of aquatic wildlife due to increase in pH.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.1 (1981)] **PEER REVIEWED** /AQUATIC SPECIES/ Chronic exposure of guppies to **sodium hydroxide** (> or =25 mg/L) decreased their survival rate and weight gain, and caused either late or premature sexual maturity resulting in decreased fertility.[Rustamova SA; Gidrobiol ZH 13 (3): 96-9 (1977)] **PEER REVIEWED**

Non-Human Toxicity Values:

LD50 Rabbit dermal 1,350 mg/kg[National Research Council; Prudent Practices in the Laboratory. Handling and Management of Chemical Hazards. the National Academies Press, Washington, D.C. 2011, p. CD] **PEER REVIEWED** LD50 Rat oral 140-340 mg/kg[National Research Council; Prudent Practices in the Laboratory. Handling and Management of Chemical Hazards. the National Academies Press, Washington, D.C. 2011, p. CD] **PEER REVIEWED** LD50 Mouse ip 40 mg/kg[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 3254] **PEER REVIEWED**

Ecotoxicity Values:

EC50; Species: Ceriodaphnia dubia (Water Flea) age <24 hr neonate; Conditions: freshwater, static, 23 deg C; Concentration: 40380 ug/L for 48 hr (95% confidence interval: 34590-47130 ug/L); Effect: intoxication, immobilization /100% purity/[Warne MSJ, Schifko AD; Ecotoxicol Environ Saf 44 (2): 196-206 (1999) as cited in the ECOTOX database. Available from, as of November 15, 2011: http://cfpub.epa.gov/ecotox/] **PEER REVIEWED** LC50; Species: Carassius auratus (Goldfish); Conditions: freshwater, static; Concentration: 160000 ug/L for 24 hr[Jensen RA; A Simplified Bioassay Using Finfish for Estimating Potential Spill Damage, In: Proc Control of Hazardous Material Spills: 104-108 (1978) as cited in the ECOTOX database. Available from, as of November 15, 2011: http://cfpub.epa.gov/ecotox/] **PEER REVIEWED** LC100; Species: Cyprinus carpio; Concentration: 180 ppm for 24 hr at 25 deg C /Conditions of bioassay not specified in source examined/[Nishiuchi Y; Suisan Zoshoku 23: 132 (1975)] **PEER REVIEWED** LC50; Species: Poecilia reticulata (Guppy) age 3-4 week young organisms; Conditions: saltwater, renewal, 24 deg C, pH >9.8-<10.0, salinity 2.8%, dissolved oxygen > or =70% saturated; Concentration: 209000 ug/L for 24 hr (95% confidence interval: 153000-286000 ug/L) /98.6% purity/[Adema DMM; Aquatic Toxicity of Compounds that may be Carried by Ships (Marpol 1973 Annex II). A Progress Report for 1985, Tech Rep No R85/217: 40 (1985) as cited in the ECOTOX database. Available from, as of November 15, 2011: http://cfpub.epa.gov/ecotox/quick_query.htm] **PEER REVIEWED** LC50; Species: Poecilia reticulata (Guppy) age 3-4 week young organisms; Conditions: saltwater, renewal, 24 deg C, pH >9.8-<10.0, salinity 2.8%, dissolved oxygen > or =70% saturated; Concentration: 196000 ug/L for 48 hr (95% confidence interval: 144000-267000 ug/L) /98.6% purity/[Adema DMM; Aquatic Toxicity of Compounds that may be Carried by Ships (Marpol 1973 Annex II). A Progress Report for 1985, Tech Rep No R85/217: 40 (1985) as cited in the ECOTOX database. Available from, as of November 15, 2011: http://cfpub.epa.gov/ecotox/quick_query.htm] **PEER REVIEWED** LC50; Species: Poecilia reticulata (Guppy) age 3-4 week young organisms; Conditions: saltwater, renewal, 24 deg C, pH >9.8-<10.0, salinity 2.8%, dissolved oxygen > or =70% saturated; Concentration: 196000 ug/L for 96 hr (95% confidence interval: 144000-267000 ug/L) /98.6% purity/[Adema DMM; Aquatic Toxicity of Compounds that may be Carried by Ships (Marpol 1973 Annex II). A Progress Report for 1985, Tech Rep No R85/217: 40 (1985) as cited in the ECOTOX database. Available from, as of November 15, 2011: http://cfpub.epa.gov/ecotox/quick_query.htm] **PEER REVIEWED**

Metabolism/ Pharmacokinetics:

Absorption, Distribution & Excretion:

ALKALIS PENETRATE SKIN SLOWLY.[Dreisbach, R. H. Handbook of Poisoning. 9th ed. Los Altos, California: Lange Medical Publications, 1977., p. 202] **PEER REVIEWED** Ammonium hydroxide penetrates fastest, followed by **sodium hydroxide**, potassium hydroxide, and finally calcium hydroxide. [Sullivan, J.B. Jr., G.R. Krieger (eds.). Hazardous Materials Toxicology-Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins, 1992., p. 433] **PEER REVIEWED**

Interactions:

An experimental study was conducted to investigate the effects of erythropoietin on the acute phase of esophageal burn damage induced by **sodium hydroxide**. A standard esophageal alkaline burn was produced by the application of 10% **sodium hydroxide** to the distal esophagus in an in vivo rat model. Fifty-six female rats were allocated into three groups: Group BC (baseline control, n = 8) rats were uninjured and untreated, Group PC (positive control, n = 24) rats were injured but untreated and Group EPO (erythropoietin-treated, n = 24) rats were injured and given subcutaneous erythropoietin (1,000 IU/kg per day), 15 min, 24, and 48 hr after administration of the NaOH solution. Six animals from Group PC and six from Group EPO were killed at 4, 24, 48, and 72 hr after application of NaOH to the esophagus. All of animals in Group BC were killed 4 hr after exposure to 0.9% NaCl. Oxidative damage was assessed by measuring levels of malondialdehyde (MDA) and nitric oxide (NO), and activities of superoxide dismutase (SOD) and catalase (CAT) in homogenized samples of esophageal tissue. Histologic damage to esophageal tissue was scored by a single pathologist blind to groups. MDA levels in the BC and EPO groups were significantly lower than those in the PC group ($p < 0.05$). CAT and SOD activities, and NO levels in the BC and EPO groups were significantly higher than in the PC group ($p < 0.05$). Esophageal tissue damage measured at 4, 24, 48, and 72 hr after NaOH application was significantly less in the EPO group than in the PC group ($p < 0.05$). When administered early after an esophageal burn induced by

10% **sodium hydroxide** in this rat model, erythropoietin significantly attenuated oxidative damage, as measured by biochemical markers and histologic scoring.[Bakan V et al; Pediatr Surg Int. 26 (2): 195-201 (2010)] **PEER REVIEWED** PubMed Abstract SRP4: Interacts with acid salts to form bases. **PEER REVIEWED** ... Esophageal burns were induced in male rats by the administration of 10% **sodium hydroxide**. Lipid peroxidation (LPO) products were then measured at the following times: 0, 1, 6, 24, 48 and 72 hr after treatment. Tissue hydroxyproline (HP) concentrations in the injured area were assessed at 14 days after the administration of **sodium hydroxide**. The groups received either systemic melatonin or normal saline. There were two, non-ischemic, sham control groups treated with or without melatonin. LPO products, malondialdehyde (MDA) and 4-hydroxyalkenal (4-HDA), increased immediately after the administration of **sodium hydroxide**; this indicates the participation of free radicals in the development of damage. Melatonin diminished the oxidative response and the amount of HP in the late phase of the lesion. Melatonin reduced oxidative damage in the early phase of the esophageal burns induced by **sodium hydroxide**.[Larios-Arceo F et al; J Pineal Res. 45 (2): 219-23 (2008)] **PEER REVIEWED** PubMed Abstract /SRP: Experimental/ The gastric damaging effects of necrotizing concn of **sodium hydroxide** were strongly reduced by paracetamol. ... Paracetamol might be protective by stimulating the biosynthesis of prostaglandins in the stomach wall.[Van Kolfschoten AA et al; Toxicol Appl Pharmacol 69 (1): 37-42 (1983)] **PEER REVIEWED** PROTECTION AGAINST DAMAGE FROM LOCALLY APPLIED **SODIUM HYDROXIDE** HAS BEEN SHOWN TO BE POSSIBLE UNDER EXPTL CONDITIONS IN RABBIT CORNEAS BY INJECTION OF ANIMAL'S SERUM INTO CORNEA TO INCR ITS LOCAL BUFFERING CAPACITY.[Grant, W. M. Toxicology of the Eye. 2nd ed. Springfield, Illinois: Charles C. Thomas, 1974., p. 931] **PEER REVIEWED** Immediate first aid: Remove patient from contact with the material. Ensure that adequate decontamination has been carried out. If patient is not breathing, start artificial respiration, preferably with a demand valve resuscitator, bag-valve-mask device, or pocket mask, as trained. Perform CPR if necessary. Immediately flush contaminated eyes with gently flowing water. Do not induce vomiting. If vomiting occurs, lean patient forward or place on the left side (head-down position, if possible) to maintain an open airway and prevent aspiration. Keep patient quiet and maintain normal body temperature. Obtain medical attention. /Inorganic Bases/Alkaline Corrosives and Related Compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 191] **PEER REVIEWED** Pharmacology:

Therapeutic Uses:

Caustics[National Library of Medicine's Medical Subject Headings online file (MeSH, 2011)] **PEER REVIEWED** Vet: Caustic, dehorning of calves.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED** VET: A 2% solution of **soda lye** (contains 94% **sodium hydroxide**) in hot water is used as a disinfectant against many common pathogens, such as those causing fowl cholera and pullorum disease.[Kahn, C.M. (Ed.); The Merck Veterinary Manual 9th ed. Merck & Co. Whitehouse Station, NJ. 2005, p. 2153] **PEER REVIEWED**

Interactions:

An experimental study was conducted to investigate the effects of erythropoietin on the acute phase of esophageal burn damage induced by **sodium hydroxide**. A standard esophageal alkaline burn was produced by the application of 10% **sodium hydroxide** to the distal esophagus in an in vivo rat model. Fifty-six female rats were allocated into three groups: Group BC (baseline control, n = 8) rats were uninjured and untreated, Group PC (positive control, n = 24) rats were injured but untreated and Group EPO (erythropoietin-treated, n = 24) rats were injured and given subcutaneous erythropoietin (1,000 IU/kg per day), 15 min, 24, and 48 hr after administration of the NaOH solution. Six animals from Group PC and six from Group EPO were killed at 4, 24, 48, and 72 hr after application of NaOH to the esophagus. All of animals in Group BC were killed 4 hr after exposure to 0.9% NaCl. Oxidative damage was assessed by measuring levels of malondialdehyde (MDA) and nitric oxide (NO), and activities of superoxide dismutase (SOD) and catalase (CAT) in homogenized samples of esophageal tissue. Histologic damage to esophageal tissue was scored by a single pathologist blind to groups. MDA levels in the BC and EPO groups were significantly lower than those in the PC group ($p < 0.05$). CAT and

SOD activities, and NO levels in the BC and EPO groups were significantly higher than in the PC group ($p < 0.05$). Esophageal tissue damage measured at 4, 24, 48, and 72 hr after NaOH application was significantly less in the EPO group than in the PC group ($p < 0.05$). When administered early after an esophageal burn induced by 10% **sodium hydroxide** in this rat model, erythropoietin significantly attenuated oxidative damage, as measured by biochemical markers and histologic scoring.[Bakan V et al; Pediatr Surg Int. 26 (2): 195-201 (2010)] **PEER REVIEWED** PubMed Abstract SRP4: Interacts with acid salts to form bases. **PEER REVIEWED** ... Esophageal burns were induced in male rats by the administration of 10% **sodium hydroxide**. Lipid peroxidation (LPO) products were then measured at the following times: 0, 1, 6, 24, 48 and 72 hr after treatment. Tissue hydroxyproline (HP) concentrations in the injured area were assessed at 14 days after the administration of **sodium hydroxide**. The groups received either systemic melatonin or normal saline. There were two, non-ischemic, sham control groups treated with or without melatonin. LPO products, malondialdehyde (MDA) and 4-hydroxyalkenal (4-HDA), increased immediately after the administration of **sodium hydroxide**; this indicates the participation of free radicals in the development of damage. Melatonin diminished the oxidative response and the amount of HP in the late phase of the lesion. Melatonin reduced oxidative damage in the early phase of the esophageal burns induced by **sodium hydroxide**.[Larios-Arceo F et al; J Pineal Res. 45 (2): 219-23 (2008)] **PEER REVIEWED** PubMed Abstract /SRP: Experimental/ The gastric damaging effects of necrotizing concn of **sodium hydroxide** were strongly reduced by paracetamol. ... Paracetamol might be protective by stimulating the biosynthesis of prostaglandins in the stomach wall.[Van Kolfschoten AA et al; Toxicol Appl Pharmacol 69 (1): 37-42 (1983)] **PEER REVIEWED** PROTECTION AGAINST DAMAGE FROM LOCALLY APPLIED **SODIUM HYDROXIDE** HAS BEEN SHOWN TO BE POSSIBLE UNDER EXPTL CONDITIONS IN RABBIT CORNEAS BY INJECTION OF ANIMAL'S SERUM INTO CORNEA TO INCR ITS LOCAL BUFFERING CAPACITY.[Grant, W. M. Toxicology of the Eye. 2nd ed. Springfield, Illinois: Charles C. Thomas, 1974., p. 931] **PEER REVIEWED** Immediate first aid: Remove patient from contact with the material. Ensure that adequate decontamination has been carried out. If patient is not breathing, start artificial respiration, preferably with a demand valve resuscitator, bag-valve-mask device, or pocket mask, as trained. Perform CPR if necessary. Immediately flush contaminated eyes with gently flowing water. Do not induce vomiting. If vomiting occurs, lean patient forward or place on the left side (head-down position, if possible) to maintain an open airway and prevent aspiration. Keep patient quiet and maintain normal body temperature. Obtain medical attention. /Inorganic Bases/Alkaline Corrosives and Related Compounds/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 191] **PEER REVIEWED** Environmental Fate & Exposure:

Probable Routes of Human Exposure:

According to the 2006 TSCA Inventory Update Reporting data, the number of persons reasonably likely to be exposed in the industrial manufacturing, processing, and use of **sodium hydroxide** is 1000 or greater; the data may be greatly underestimated(1).[(1) US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Sept 9, 2011: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED** NIOSH (NOES Survey 1981-1983) has statistically estimated that 2,819,743 workers (995,960 of these were female) were potentially exposed to **sodium hydroxide** in the US(1). NIOSH (NOES Survey 1981-1983) has statistically estimated that 370,582 workers (137,156 of these were female) were potentially exposed to liquid **sodium hydroxide** in the US(1). The NOES Survey does not include farm workers. Occupational exposure to **sodium hydroxide** may occur through dermal contact with this compound at workplaces where **sodium hydroxide** is produced or used(SRC).[(1) NIOSH; NOES. National Occupational Exposure Survey conducted from 1981-1983. Estimated numbers of employees potentially exposed to specific agents by 2-digit standard industrial classification (SIC). Available from, as of Oct 11, 2011: http://www.cdc.gov/noes/] **PEER REVIEWED** Inhalation of dust or mist, ingestion, and skin or eye contact.[Sittig M; Handbook of Toxic and Hazardous Chemicals p.606 (1981)] **PEER REVIEWED**

Environmental Fate:

AQUATIC FATE: In the case of a solid, anhydrous **sodium hydroxide** spill on soil, ground water pollution will occur if precipitation occurs prior to clean up. Precipitation will dissolve some of the solid (with much heat given off) and create an aqueous solution of **sodium hydroxide**, which then would be able to infiltrate the soil. However, prediction of the concentration and properties of the solution produced would be difficult. [Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.24 (1981)] **PEER REVIEWED**

Environmental Biodegradation:

BOD: none[U.S. Coast Guard, Department of Transportation. CHRIS - Hazardous Chemical Data. Volume II. Washington, D.C.: U.S. Government Printing Office, 1984-5.] **PEER REVIEWED**

Environmental Water Concentrations:

GROUNDWATER: **Sodium hydroxide** was identified as a chemical of concern in wells associated with the Pavilion Area Groundwater Plume in Pavilion Wyoming in Fremont County. Land use in the area is agricultural with some properties used for natural gas production. Sampling was conducted from March 2 through 6, 2009 and May 14, and 15, 2009(1).[(1) US EPA; Expanded Site Investigation - Field Sampling Plan, Pavillion Area Groundwater Investigation. Pavilion, Fremont County, Wyoming. USEPA Contract No. EP-W-05-050. TDD No., 0901-01. January 6, 2010. START 3. Superfund Technical Assessment and Response Team 3-Region 8.Available from, as of Oct 11, 2011: http://www.epa.gov/region8/superfund/wy/pavillion/Pavillion_GWInvestigationFSP.pdf] **PEER REVIEWED**

Effluent Concentrations:

Estimated emissions of **sodium hydroxide** as one of the typical pollutants released from the synthetic organic chemical manufacturing industry (production/processing) may range from (unit process, product): alkylation, ethylbenzene, 1.9 to 21.5; condensation, polyethylene terephthalate, 0.065 to 23.1; dehydrogenation, isoprene, 0.5 to 19; dehydrohalogenation, vinylidene chloride, 45.5 to 605.5; polymerization, polyethylene terephthalate, 0.1 to 23.1 (all in g/kg produced)(1). The compound was spilled at an estimated 3,500 gallons into the Newark Bay on October 1991 from the Gist Brocades facility(2). **Sodium hydroxide** was involved in 2.6% of 6,928 chemical accidents in the US over a 5 year period up to 1985 at a reportable quantity of 2200 kg(3).[(1) Carpenter CE et al; Toxic Subst J 10: 323-71 (1990) (2) Gunster DG et al; Ecotoxicol Environ Saf 25: 202-13 (1993) (3) Meharg AA; Rev Environ Contam Toxicol 138: 21-48 (1994)] **PEER REVIEWED**

Environmental Standards & Regulations:

FIFRA Requirements:

Residues of **sodium hydroxide** are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops or to raw agricultural commodities after harvest. Use: neutralizer. Limit: none.[40 CFR 180.910 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED** Residues of **sodium hydroxide** are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to animals. Use: neutralizer. Limit: none.[40 CFR 180.930 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED** The Agency has completed its review of all available information, and has determined that the data are sufficient to support reregistration of products containing **sodium hydroxide**. ... The Agency therefore finds that products containing **sodium hydroxide** as an active ingredient are eligible for reregistration. ... Although the Agency has found that certain products containing **sodium hydroxide** are eligible for registration, it should be understood that the Agency may take appropriate regulatory action, and/or require the submission of additional data to support the registration of products containing **sodium hydroxide**, if new information comes to the Agency's attention or if the data requirements for reregistration (or the guidelines for

generating such data) change.[USEPA/Office of Pesticide Programs; Reregistration Eligibility Decision Document - Sodium Hydroxide p.9 (September 1992). Available from, as of October 10, 2011: http://www.epa.gov/pesticides/reregistration/status.htm] **PEER REVIEWED** As the federal pesticide law FIFRA directs, EPA is conducting a comprehensive review of older pesticides to consider their health and environmental effects and make decisions about their continued use. Under this pesticide reregistration program, EPA examines newer health and safety data for pesticide active ingredients initially registered before November 1, 1984, and determines whether the use of the pesticide does not pose unreasonable risk in accordance to newer saftey standards, such as those described in the Food Quality Protection Act of 1996. Pesticides for which EPA had not issued Registration Standards prior to the effective date of FIFRA '88 were divided into three lists based upon their potential for human exposure and other factors, with List B containing pesticides of greater concern than those on List C, and with List C containing pesticides of greater concern than those on List D. **Sodium hydroxide** is found on List D. Case No: 4065; Pesticide type: fungicide, herbicide, antimicrobial; Case Status: RED Approved 09/92; OPP has made a decision that some/all uses of the pesticide are eligible for reregistration, as reflected in a Reregistration Eligibility Decision (RED) document .; Active ingredient (AI): **sodium hydroxide**; Data Call-in (DCI) Date(s): 09/30/92; AI Status: OPP has completed a Reregistration Eligibility Decision (RED) document for the case/AI.[United States Environmental Protection Agency/ Prevention, Pesticides and Toxic Substances; Status of Pesticides in Registration, Reregistration, and Special Review. (1998) EPA 738-R-98-002, p. 326] **PEER REVIEWED**

CERCLA Reportable Quantities:

Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1000 lb or 454 kg. The toll free number of the NRC is (800) 424-8802. The rule for determining when notification is required is stated in 40 CFR 302.4 (section IV.D.3.b).[40 CFR 302.4 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED**

Clean Water Act Requirements:

Sodium hydroxide is designated as a hazardous substance under section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. These regulations apply to discharges of this substance. This designation includes any isomers and hydrates, as well as any solutions and mixtures containing this substance.[40 CFR 116.4 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED**

FDA Requirements:

Substance added directly to human food affirmed as generally recognized as safe (GRAS).[21 CFR 184.1763 (USFDA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED** **Sodium hydroxide** used as a general purpose food additive in animal drugs, feeds, and related products is generally recognized as safe when used in accordance with good manufacturing or feeding practice.[21 CFR 582.1763 (USFDA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED**

Allowable Tolerances:

Residues of **sodium hydroxide** are exempted from the requirement of a tolerance when used in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops or to raw agricultural commodities after harvest. Use: neutralizer. Limit: none.[40 CFR 180.910 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED** Residues of **sodium hydroxide** are exempted from the requirement of a tolerance when used in accordance with good agricultural

practice as inert (or occasionally active) ingredients in pesticide formulations applied to animals. Use: neutralizer. Limit: none.[40 CFR 180.930 (USEPA); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED**

Chemical/Physical Properties:

Molecular Formula:

H-Na-O[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**

Molecular Weight:

40.00[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**

Color/Form:

White, orthogonal crystals
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 4-90] **PEER REVIEWED**

Colorless to white ... solid (flakes, beads, granular form).
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from, as of Oct 7, 2011: http://www.cdc.gov/niosh/npg/] **PEER REVIEWED**

Brittle, white, translucent crystalline solid
[Eggeman T; Kirk-Othmer Encyclopedia of Chemical Technology. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: 15 April 2011] **PEER REVIEWED**

Odor:

... Odorless ...
[NIOSH. NIOSH Pocket Guide to Chemical Hazards. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2010-168 (2010). Available from, as of Oct 7, 2011: http://www.cdc.gov/niosh/npg/] **PEER REVIEWED**

Taste:

Detection - the minimum physical intensity detection by a subject where he or she is not required to identify the stimulus but just detect the existence of the stimulus - in water: 8.00X10-3 mol/L.
[ASTM; Compilation of Odor and Taste Threshold Values Data p.150 (1978)] **PEER REVIEWED**

Boiling Point:

1388 deg C[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 4-90] **PEER REVIEWED**

Melting Point:

323 deg C[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 4-90] **PEER REVIEWED**

Corrosivity:

Very corrosive (caustic) to ... aluminum metal in presence of moisture[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**

Density/Specific Gravity:

2.13 g/cu cm 25 deg C[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 4-90] **PEER REVIEWED**

Dissociation Constants:

SRP4: Completely dissociated **PEER REVIEWED**

Heat of Combustion:

SRP4: Non-combustible **PEER REVIEWED**

Heat of Vaporization:

175 kJ/mol at 1388 deg C[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 6-130] **PEER REVIEWED**

pH:

pH of a 0.05% wt/wt solution about 12; 0.5% solution about 13; 5% solution about 14[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**

Solubilities:

1 g dissolves in 7.2 mL absolute alcohol, 4.2 mL methanol; also soluble in glycerol
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**
1 g dissolves in 0.9 mL water, 0.3 mL boiling water
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**

Spectral Properties:

Refractive index at 589.4 nm: 1.433 at 320 deg C; 1.421 at 420 deg C
[Eggeman T; Kirk-Othmer Encyclopedia of Chemical Technology. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: 15 April 2011] **PEER REVIEWED**

Surface Tension:

At 18 deg C: 74.35 dynes/cm (2.72 wt%), 75.85 dynes/cm (5.66 wt%), 83.05 dynes/cm (16.66 wt%), 96.05 dynes/cm (30.56 wt%), 101.05 dynes/cm (35.90 wt%)[Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87., p. F-31] **PEER REVIEWED**

Vapor Pressure:

1.82X10-21 mm Hg at 25 deg C /extrapolated/[Ohe S; Computer Aided Data Book of Vapor Pressure. Tokyo, Japan: Data Book Publ. Co. (1976)] **PEER REVIEWED**

Viscosity:

4.0 cP at 350 deg C[General Electric Co; Material Safety Data Sheet MSDS #3 (1984)] **PEER REVIEWED**

Other Chemical/Physical Properties:

5% solution (wt/wt): density: 1.056, FP: -4 deg C, BP: 102 deg C. 10% solution (wt/wt): density: 1.111, FP: -10 deg C, BP: 105 deg C. 20% solution (wt/wt): density: 1.222, FP: -26 deg C, BP: 110 deg C. 30% solution (wt/wt): density: 1.333, FP: 1 deg C, CP: 115 deg C. 40% solution (wt/wt): density: 1.434, FP: 15 deg C, BP: 125 deg C. 50% solution (wt/wt): density: 1.530, FP: 12 deg C, BP: 140 deg C
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**
VP: 1 Pa at 513 deg C; 10 Pa at 605 deg C; 100 Pa at 722 deg C; 1kPa at 874 deg C; 10 kPa at 1080 deg C; 100 kPa at 1377 deg C
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 6-90] **PEER REVIEWED**
Rapidly absorbs carbon dioxide and water from air
[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED**
Deliquescent
[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 1146] **PEER REVIEWED**
Heat of Formation: -425.8 kK/mol at 298.15 K (crystal); -191.0 kJ/mol at 298.15 K (gas)
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 5-13] **PEER REVIEWED**
Heat of Transition, alpha to beta, J/g = 103.3. Heat of formation from the elements: Alpha form, kJ/mol = 422.46; Beta form, kJ/mol = 426.60. Transition temperature, 299.6 deg C.
[Eggeman T; Kirk-Othmer Encyclopedia of Chemical Technology. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: 15 April 2011] **PEER REVIEWED**
70-73 % solution: MP 62 deg C; Density = 2.0 at 15.5 deg C
[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.1 (1981)] **PEER REVIEWED**
Caustic soda reacts with all the mineral acids to form the corresponding salts. It also reacts with weak-acid gases, such as hydrogen sulfide, sulfur dioxide, and carbon dioxide. **Caustic soda** reacts with amphoteric metals (Al, Zn, Sn) and their oxides to form complex anions such as AlO2(-), ZnO2(-2), SNO2(-2), and H2 (or H2O with oxides). All organic acids also react with **sodium hydroxide** to form soluble salts. Another common reaction of **caustic soda** is dehydrochlorination.
[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V1: 1008] **PEER REVIEWED**
Heat capacity (constant pressure): 59.5 J/mol-K (crystal); 48.0 j/mol-K (gas)
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 5-13] **PEER REVIEWED**
Heat of Fusion: 6.60 kJ/mol at 25 deg C
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 6-149] **PEER REVIEWED**
Heat of Solution: -44.51 kJ/mol @ 323 deg C
[Lide, D.R. (ed.). CRC Handbook of Chemistry and Physics. 76th ed. Boca Raton, FL: CRC Press Inc., 1995-1996., p. 5-100] **PEER REVIEWED**

Chemical Safety & Handling:

DOT Emergency Guidelines:

/GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Fire or Explosion: Non-combustible, substance itself does not burn but may decompose upon heating to produce corrosive and/or toxic fumes. Some are oxidizers and may ignite combustibles (wood, paper, oil, clothing, etc.). Contact with metals may evolve flammable hydrogen gas. Containers may explode when heated. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Health: TOXIC; inhalation, ingestion, or skin contact with material may cause severe injury or death. Contact with molten substance may cause severe burns to skin and eyes. Avoid any skin contact. Effects of contact or inhalation may be delayed. Fire may produce irritating, corrosive and/or toxic gases. Runoff from fire control or dilution water may be corrosive and/or toxic and cause pollution. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Public Safety: CALL Emergency Response Telephone Number ... As an immediate precautionary measure, isolate spill or leak area in all directions for at least 50 meters (150 feet) for liquids and at least 25 meters (75 feet) for solids. Keep unauthorized personnel away. Stay upwind. Keep out of low areas. Ventilate enclosed areas. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Protective Clothing: Wear positive pressure self-contained breathing apparatus (SCBA). Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection. Structural firefighters' protective clothing provides limited protection in fire situations ONLY; it is not effective in spill situations where direct contact with the substance is possible. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Evacuation: ... Fire: If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Fire: Small fires: Dry chemical, CO2 or water spray. Large fires: Dry chemical, CO2, alcohol-resistant foam or water spray. Move containers from fire area if you can do it without risk. Dike fire control water for later disposal; do not scatter the material. Fire involving tanks or car/trailer loads: Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Do not get water inside containers. Cool containers with flooding quantities of water until well after fire is out. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank. ALWAYS stay away from tanks engulfed in fire. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ Spill or Leak: ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area). Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Stop leak if you can do it without risk. Prevent entry into waterways, sewers, basements or confined areas. Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers. DO NOT GET WATER INSIDE CONTAINERS. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium**

hydroxide solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED** /GUIDE 154: SUBSTANCES - TOXIC AND/OR CORROSIVE (NON-COMBUSTIBLE)/ First Aid: Move victim to fresh air. Call 911 or emergency medical service. Give artificial respiration if victim is not breathing. Do not use mouth-to-mouth method if victim ingested or inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Administer oxygen if breathing is difficult. Remove and isolate contaminated clothing and shoes. In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes. For minor skin contact, avoid spreading material on unaffected skin. Keep victim warm and quiet. Effects of exposure (inhalation, ingestion or skin contact) to substance may be delayed. Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves. /**Sodium hydroxide**, bead; **Sodium hydroxide**, dry; **Sodium hydroxide**, flake; **Sodium hydroxide**, granular; **Sodium hydroxide**, solid; **Sodium hydroxide** solution/[U.S. Department of Transportation. 2008 Emergency Response Guidebook. Washington, D.C. 2008] **PEER REVIEWED**

Skin, Eye and Respiratory Irritations:

Liquid or solid **sodium hydroxide** is a severe skin irritant. It causes second and third degree burns on short contact and is very injurious to the eyes.[U.S. Coast Guard, Department of Transportation. CHRIS - Hazardous Chemical Data. Volume II. Washington, D.C.: U.S. Government Printing Office, 1984-5.] **PEER REVIEWED** HAZARD WARNING: The irritating nature of the aerosol on the mucous membranes is presumed to be adequate warning to maintain air concn at tolerable levels.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.74 (Date)] **PEER REVIEWED** Irritating to skin, eyes, and respiratory system.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

Fire Potential:

Not combustible.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

NFPA Hazard Classification:

Health: 3. 3= Materials that, on short exposure, could cause serious temporary or residual injury, including those requiring protection from all bodily contact. Fire fighters may enter the area only if they are protected from all contact with the material. Full protective clothing, including self-contained breathing apparatus, coat, pants, gloves, boots, and bands around legs, arms, and waist, should be provided. No skin surface should be exposed. [National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED** Flammability: 0. 0= This degree includes any material that will not burn under typical fire conditions.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED** Instability: 1. 1= This degree includes materials that are normally stable, but that may become unstable at elevated temperatures and pressures. Fires involving these materials should be approached with caution.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

Fire Fighting Procedures:

Extinguish fire using agent suitable for surrounding fire. Use water spray to keep fire-exposed containers cool. [National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED** If material on fire or involved in fire: Extinguish fire using agent suitable for type of surrounding fire. (Material itself does not burn or burns with difficulty.) Use "alcohol" foam, dry chemical or carbon dioxide. Keep run-off water out of sewers and water sources.[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 823] **PEER REVIEWED**

Hazardous Reactivities & Incompatibilities:

GENERATES CONSIDERABLE HEAT WHEN ... SOLN IS MIXED WITH ACID.[The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983., p. 1236] **PEER REVIEWED** CRUDE HYDROQUINONE WAS PUMPED INTO **SODIUM HYDROXIDE** STORAGE TANK BY MISTAKE. THE HYDROQUINONE LIQUOR AT 85 DEG C DECOMP RAPIDLY IN THE PRESENCE OF THE **SODIUM HYDROXIDE** RESULTING IN OVERFLOW OF TANK & EVOLUTION OF CONSIDERABLE AMOUNT OF HEAT.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-180] **PEER REVIEWED** Much heat is evolved when the solid material is dissolved in water. Therefore, cold water and caution must be used for this process.[International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983., p. 116] **PEER REVIEWED** Caustic solutions generate heat when further diluted with water. With concentrations of 40% or greater, the heat generated can raise the temperature above the boiling point, resulting in sporadic, dangerous eruptions of the solution.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 1:848] **PEER REVIEWED** With aluminum, arsenic trioxide, sodium, and arsenate: An aluminum ladder was used (instead of the usual wooden one) to gain access to a tank containing the alkaline arsenical mixture. Hydrogen produced by alkaline reaction on the ladder generated arsine, which poisoned the three workers involved.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 22] **PEER REVIEWED** With bromine: A bucket containing 25% **sodium hydroxide** solution was used to catch and neutralize bromine dripping from a leak. Lack of stirring allowed a layer of unreacted bromine to form below the alkali. Many hours later, a violent eruption occurred when the layers were disturbed during disposal operations. Continuous stirring is essential to prevent stratification of slowly reacting, mutually insoluble, liquids.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 102] **PEER REVIEWED** With octanol and diborane: Addition of **sodium hydroxide** solution during work-up of a reaction mixture of oxime and diborane in tetrahydrofuran is very exothermic, a mild explosion being noted on one occasion.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 71] **PEER REVIEWED** /**Sodium hydroxide**/ with 4-methyl-2-nitrophenol, sodium carbonate, and methanol: Failure to agitate a large-scale mixture of the reagents caused an eruption due to exothermic action when mixing occurred.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 710] **PEER REVIEWED** With zinc: Accidental contamination of a metal scoop with flake **sodium hydroxide**, prior to its use with zinc dust, caused ignition of the latter. A stiff paste prepared from zinc dust and 10% **sodium hydroxide** solution attains a temperature above 100 deg C after exposure to air for 15 min.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 1472] **PEER REVIEWED** With zinc and 4-methyl-2-nitrophenol: In preparation of 2,2-dimethoxyazoxybenzene, solvent ethanol was distilled out of the mixture of o-nitroanisole, zinc and **sodium hydroxide**, before reaction was complete. The exothermic reaction continued unmoderated, and finally exploded.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 710] **PEER REVIEWED** With 2,2,2-trichloroethanol: Accidental contact of 50% **sodium hydroxide** solution with residual trichloroethanol in a pump caused an explosion. This was confirmed in laboratory experiments. Chlorohydroxyacetylene, the isomeric chloroketene or chlorooxirene, may have been formed by elimination of hydrogen chloride.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 248] **PEER REVIEWED** Water; acids; flammable liquids; organic halogens; metals such as aluminum, tin, & zinc; nitromethane [Note: Corrosive to metals].[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 284] **PEER REVIEWED** Reacts to form explosive products with ammonia + silver nitrate (forms silver nitride); N,N'-bis(trinitroethyl)urea (in storage) ...[Lewis, R.J. Sax's Dangerous Properties of Industrial Materials. 9th ed. Volumes 1-3. New York, NY: Van Nostrand Reinhold, 1996., p. 2970] **PEER REVIEWED** Under the proper conditions of temperature, pressure, and state of division, it can ignite or react violently with ... acetaldehyde, ... allyl alcohol, allyl chloride, ... benzene-1,4-diol, chlorine trifluoride, ... 1,2-dichloroethylene, ... nitroethane, nitromethane, nitroparaffins, nitropropane, ... cinnamaldehyde, ... 2,2-dichloro-3,3-dimethylbutane, ... Reacts with formaldehyde hydroxide to yield formic acid and hydrogen.[Lewis, R.J. Sax's Dangerous Properties of Industrial Materials. 9th ed. Volumes 1-3. New York, NY: Van Nostrand Reinhold, 1996., p. 2970] **PEER REVIEWED** **Sodium hydroxide** in contact

with water may generate enough heat to ignite adjacent combustible materials.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-181] **PEER REVIEWED** Mixing **sodium hydroxide** and acrolein in a closed container caused the temperature and pressure to increase.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-180] **PEER REVIEWED** Phosphorus boiled with alkaline hydroxides yields mixed phosphines which may ignite spontaneously in air.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-146] **PEER REVIEWED** Mixing **sodium hydroxide** and acetic anhydride in a closed container caused the temperature and pressure to increase.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-179] **PEER REVIEWED** An extremely violent polymerization reaction of acrolein results from contact with alkaline material such as **sodium hydroxide**.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-179] **PEER REVIEWED** The presence of residue of weak **sodium hydroxide** solution in a pressure vessel caused maleic anhydride to decompose in runaway explosive reaction.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-180] **PEER REVIEWED** When heated, trichloroethylene and **sodium hydroxide** form explosive mixtures of dichloroacetylene.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-181] **PEER REVIEWED** As benzene extract of allyl benzenesulfonate prepared from allyl alcohol and benzene sulfonyl chloride in presence of aqueous **sodium hydroxide** under vacuum distillation two fractions came off, then the temperature rose to 135 deg C, when the, residue darkened and exploded.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-12] **PEER REVIEWED** Using /**sodium hydroxide**/... to dry impure tetrahydrofuran, which can contain peroxides, is hazardous. Serious explosions can occur.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 491-195] **PEER REVIEWED** 700 KG OF 4-CHLORO-2-METHYLPHENOL, LEFT IN CONTACT WITH CONCN **SODIUM HYDROXIDE** SOLN FOR 3 DAYS, DECOMPOSED, REACHING RED HEAT AND EVOLVING FUMES WHICH IGNITED EXPLOSIVELY. PRESENCE OF TRACES OF **SODIUM HYDROXIDE** PROBABLY CAUSED FORMATION OF ACETYLENIC SODIUM SALT OF 3-METHYL-2-PENTEN-4-YN-1-OL WHICH EXPLODED IN METAL STILL.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 704] **PEER REVIEWED** HEATING MIXT OF NITROBENZENE, FLAKE **SODIUM HYDROXIDE** AND A LITTLE WATER IN AUTOCLAVE LED TO EXPLOSION. VIOLENT EXPLOSION OCCURRED DURING ALKALINE HYDROLYSIS OF TETRACHLOROBENZENE IN ETHYLENE GLYCOL @ ATMOSPHERIC PRESSURE, WHICH WAS REGARDED AS SAFE PROCESS.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 604] **PEER REVIEWED** DURING DESTRUCTION OF CHEMICAL WARFARE AMMUNITION, PIERCED SHELLS CONTAINING CHLOROPICRIN REACTED VIOLENTLY WITH ALCOHOLIC **SODIUM HYDROXIDE**. ACCIDENTAL CONTACT OF 50% **SODIUM HYDROXIDE** SOLN WITH RESIDUAL TRICHLOROETHANOL IN PUMP CAUSED AN EXPLOSION.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 248] **PEER REVIEWED** CHLOROFORM-METHANOL MIXTURE WAS PUT INTO DRUM CONTAMINATED WITH **SODIUM HYDROXIDE**. VIGOROUS REACTION COMMENCED, AND DRUM EXPLODED. ADDN OF **SODIUM HYDROXIDE** SOLN DURING WORK-UP OF REACTION MIXTURE OF OXIME & DIBORANE IN TETRAHYDROFURAN IS VERY EXOTHERMIC, A MILD EXPLOSION BEING NOTED ON ONE OCCASION.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 133] **PEER REVIEWED** DRY MIXTURES OF SODIUM TETRAHYDROBORATE WITH **SODIUM HYDROXIDE** CONTAINING 15-40% OF TETRAHYDROBORATE LIBERATE HYDROGEN EXPLOSIVELY AT 230-270 DEG C. EXPLOSIVE REACTIONS OCCUR WHEN ZIRCONIUM IS COMBINED WITH ALKALI METAL HYDROXIDES.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 64] **PEER REVIEWED** INTERACTION OF CYANOGEN AZIDE WITH 10% ALKALI FORMS SODIUM 5-AZIDOTETRAZOLIDE, WHICH EXPLODES VIOLENTLY IF ISOLATED.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 188] **PEER REVIEWED** In **sodium hydroxide's** reaction with amphoteric metals, hydrogen gas is generated which may form an explosive mixture.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 1:849] **PEER

REVIEWED** With 1,2,4,5-tetrachlorobenzene: Several serious incidents have been reported about the commercial preparation of 2,4,5-trichlorophenol by alkaline hydrolysis of methanolic alkali at 125 deg C, reaction went out of control. In one incident the temperature reached 400 deg C after hydrolysis in ethylene glycol solution, the residue from vacuum stripping exploded, probably owing to overheating. In 1968, a violent explosion occurred during hydrolysis in ethylene glycol at atmosphere pressure, which had been regarded as a safe process. [Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 562] **PEER REVIEWED** RAGS SOAKED IN **SODIUM HYDROXIDE** & CINNAMALDEHYDE OVERHEATED AND IGNITED WHEN THEY CAME INTO CONTACT IN WASTE BIN. ACCIDENTAL CONTAMINATION OF METAL SCOOP WITH FLAKE **SODIUM HYDROXIDE** CAUSED IGNITION OF ZINC.[Bretherick, L. Handbook of Reactive Chemical Hazards. 4th ed. Boston, MA: Butterworth-Heinemann Ltd., 1990, p. 780] **PEER REVIEWED**

Hazardous Decomposition:

When heated to decomposition it emits toxic fumes of /sodium oxide/.[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 3254] **PEER REVIEWED**

Hazardous Polymerization:

SRP4: Not polymerized **PEER REVIEWED**

Other Hazardous Reaction:

Corrosion is a problem at temperatures above 60 degrees C, therefore, the use of steel for caustic-handling is not recommended at elevated temperatures. Stress cracking may also occur when **caustic soda** solution concentrations exceed 20% at temperatures in excess of 60 degrees C.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 1:859] **PEER REVIEWED**

Immediately Dangerous to Life or Health:

10 mg/cu m[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED**

Protective Equipment & Clothing:

Hazards from spills and leaks should be minimized by an adequate supply of water for washing-down. ... Adequate ventilation should be provided in areas where **caustic ... soda** mist or dust is present. ... For the protection of the eyes, safety goggles should be worn, as well as face shields, if complete face protection is necessary. Eyewash fountains and safety showers must be available at any location where eye and/or skin contact can occur. Protection against mist or dust of this compound can be provided by filter or dust-type respiratory protective equipment. ... Safety shoes ... are recommended.[International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983., p. 116] **PEER REVIEWED** Respirator selection: 100 mg/cu m: a) High-efficiency particulate respirator with a full facepiece, b) Supplied air respirator with a full facepiece, helmet, or hood. , c) Self-contained breathing apparatus with a full facepiece. 200 mg/cu m: a) Powered air-purifying respirator with a high-efficiency filter with a full facepiece, or b) Type C SA with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous- flow mode. . Escape: a) Dust and mist respirator, except single-use respirators with full facepiece, or b) Self-contained breathing apparatus with a full facepiece.[NIOSH; Pocket Guide to Chemical Hazards p.167 (1981) DHEW (NIOSH) Pub No. 78-210] **PEER REVIEWED** **Sodium hydroxide**: Chemical protective clothing composed of natural rubber, neoprene, nitrile, or styrene/butadiene (SBR)-coated fabric is highly recommended, having break

through times greater than one hour. Butyl rubber, neoprene and SBR, polyethylene, chlorinated polyurethane, or polyvinyl alcohol may be used but data suggests break through times of approximately an hour or more. [ACGIH; Guidelines Select of Chem Protect Clothing Volume #1 Field Guide p.67 (1983)] **PEER REVIEWED** **Sodium hydroxide**, 30-70%: Chemical protective clothing composed of natural rubber, neoprene, nitrile, or polyvinyl chloride (PVC) is highly recommended, having break through times greater than one hour. Butyl rubber, nitrile/PVC, polyethylene, chlorinated polyethylene, or styrene/butadiene coated approximately an hour or more. Some data for polyvinyl alcohol (usually from immersion tests) suggest break through times greater than one hour are not likely.[ACGIH; Guidelines Select of Chem Protect Clothing Volume #1 Field Guide p.67 (1983)] **PEER REVIEWED** Wear appropriate personal protective clothing to prevent skin contact. [NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Wear appropriate eye protection to prevent eye contact.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Eyewash fountains should be provided in areas where there is any possibility that workers could be exposed to the substance; this is irrespective of the recommendation involving the wearing of eye protection.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Facilities for quickly drenching the body should be provided within the immediate work area for emergency use where there is a possibility of exposure. [Note: It is intended that these facilities provide a sufficient quantity or flow of water to quickly remove the substance from any body areas likely to be exposed. The actual determination of what constitutes an adequate quick drench facility depends on the specific circumstances. In certain instances, a deluge shower should be readily available, whereas in others, the availability of water from a sink or hose could be considered adequate.] [NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Respirator Recommendations: Up to 10 mg/cu m:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 25	Any supplied-air respirator operated in a continuous-flow mode. Substance causes eye irritation or damage; eye protection needed.
APF = 50	Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter.
APF = 25	Any powered, air-purifying respirator with a high-efficiency particulate filter. Substance causes eye irritation or damage; eye protection needed.
APF = 50	Any self-contained breathing apparatus with a full facepiece.
APF = 50	Any supplied-air respirator with a full facepiece.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Respirator Recommendations: Emergency or planned entry into unknown concentrations or IDLH conditions:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 10,000	Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.
APF = 10,000	Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety &

Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Respirator Recommendations: Escape:

Assigned Protection Factor (APF)	Respirator Recommendations
APF = 50	Any air-purifying, full-facepiece respirator with an N100, R100, or P100 filter. Any appropriate escape-type, self-contained breathing apparatus.

[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Emergency response personal protective equipment: wear special protective clothing and positive pressure self-contained breathing apparatus. Butyl rubber, natural rubber, Neoprene, nitrile rubber, polyethylene, polyvinyl chloride, Teflon, Viton, or Saranex barrier recommended.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

Preventive Measures:

SRP: The scientific literature for the use of contact lenses by industrial workers is inconsistent. The benefits or detrimental effects of wearing contact lenses depend not only upon the substance, but also on factors including the form of the substance, characteristics and duration of the exposure, the uses of other eye protection equipment, and the hygiene of the lenses. However, there may be individual substances whose irritating or corrosive properties are such that the wearing of contact lenses would be harmful to the eye. In those specific cases, contact lenses should not be worn. In any event, the usual eye protection equipment should be worn even when contact lenses are in place. **PEER REVIEWED** Nickel is the preferred metal for handling **caustic soda** at all concentrations and temperatures. However, the high cost and limited availability of nickel precludes its use for most applications. Mild steel is adequate for almost all caustic-handling applications. Plastics and plastic-lined steel are now available as construction materials. Fiberglass reinforced plastic tanks of Derakane vinyl ester resin are suitable for many applications. Polypropane is commonly used for lining pipe for protection against mechanical damage.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 1:858] **PEER REVIEWED** Any dilutions of caustic from concentrations greater than 25% should be done cautiously.[Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 1:849] **PEER REVIEWED** Personnel protection: Keep upwind. Avoid breathing vapors. ... Avoid bodily contact with the material.[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 823] **PEER REVIEWED** If material not on fire and not involved in fire: Keep material out of water sources and sewers. Build dikes to contain flow as necessary. Attempt to stop leak if without undue personnel hazard. [Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 823] **PEER REVIEWED** The worker should immediately wash the skin when it becomes contaminated.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Work clothing that becomes wet or significantly contaminated should be removed and replaced.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Workers whose clothing may have become contaminated should change into uncontaminated clothing before leaving the work premises.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED** Local ventilation should be provided to reduce exposure levels to acceptable levels. [Clayton, G.D., F.E. Clayton (eds.) Patty's Industrial Hygiene and Toxicology. Volumes 2A, 2B, 2C, 2D, 2E, 2F: Toxicology. 4th ed. New York, NY: John Wiley & Sons Inc., 1993-1994., p. 773] **PEER REVIEWED** SRP: Local exhaust ventilation should be applied wherever there is an incidence of point source emissions or dispersion of regulated contaminants in the work area. Ventilation control of the contaminant as close to its point of generation is both the most economical and safest method to minimize personnel exposure to

airborne contaminants. Ensure that the local ventilation moves the contaminant away from the worker. **PEER REVIEWED** SRP: Contaminated protective clothing should be segregated in such a manner so that there is no direct personal contact by personnel who handle, dispose, or clean the clothing. The completeness of the cleaning procedures should be considered before the decontaminated protective clothing is returned for reuse by the workers. Contaminated clothing should not be taken home at the end of shift, but should remain at employee's place of work for cleaning. **PEER REVIEWED**

Stability/Shelf Life:

CONTAINERS OF LYE MUST BE TIGHTLY CLOSED TO PREVENT CONVERSION TO SODIUM CARBONATE BY CARBON DIOXIDE OF AIR.[Jones, L.M., et al. Veterinary Pharmacology & Therapeutics. 4th ed. Ames: Iowa State University Press, 1977., p. 867] **PEER REVIEWED**

Shipment Methods and Regulations:

No person may /transport,/ offer or accept a hazardous material for transportation in commerce unless that person is registered in conformance ... and the hazardous material is properly classed, described, packaged, marked, labeled, and in condition for shipment as required or authorized by ... /the hazardous materials regulations (49 CFR 171-177)./[49 CFR 171.2; U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of November 22, 2011: http://www.ecfr.gov] **PEER REVIEWED** The International Air Transport Association (IATA) Dangerous Goods Regulations are published by the IATA Dangerous Goods Board pursuant to IATA Resolutions 618 and 619 and constitute a manual of industry carrier regulations to be followed by all IATA Member airlines when transporting hazardous materials.[International Air Transport Association. Dangerous Goods Regulations. 47th Edition. Montreal, Quebec Canada. 2006., p. 255] **PEER REVIEWED** The International Maritime Dangerous Goods Code lays down basic principles for transporting hazardous chemicals. Detailed recommendations for individual substances and a number of recommendations for good practice are included in the classes dealing with such substances. A general index of technical names has also been compiled. This index should always be consulted when attempting to locate the appropriate procedures to be used when shipping any substance or article. [International Maritime Organization. International Maritime Dangerous Goods Code. London, UK. 2004., p. 89] **PEER REVIEWED**

Storage Conditions:

CONTAINERS SHOULD BE STORED IN ROOMS WITH TRAPPED FLOOR DRAINS TOWARDS WHICH FLOORS SHOULD BE SLANTED. WHERE FLOOR DRAINS ARE NOT PROVIDED, CURBS OR DRAINED GUTTER, COVERED WITH ... GRILL, SHOULD BE CONSTRUCTED @ DOOR OPENINGS. [International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983., p. 116] **PEER REVIEWED** Volumetric **sodium hydroxide** soln used in laboratory must be protected from air to avoid formation of carbonate.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED** Store in a cool, dry, well-ventilated location. Separate from organic and oxidizing materials, acids, metal powders. Immediately remove and properly dispose of any spilled material.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

Cleanup Methods:

On/in soil (solid): Construct barriers to convert or divert to impervious surface. Promptly shovel into steel containers.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.2 (1981)] **PEER REVIEWED** Soil, Liquid: Absorb small amounts of spill with sand, vermiculite or other inert absorbant material; Shovel into steel containers. May also remove material with vacuum equipment.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.2 (1981)] **PEER REVIEWED** Environment considerations - Land spill:: Dig a pit, pond, lagoon, or holding area to contain liquid or solid material. Dike

surface flow using soil, sand bags, foamed polyurethane, or foamed concrete. Absorb bulk liquid with fly ash of cement powder.[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 823] **PEER REVIEWED** Environmental considerations - Water spill: Use natural barriers or oil spill control booms to limit spill travel. Neutralize with dilute acid.[Association of American Railroads; Bureau of Explosives. Emergency Handling of Hazardous Materials in Surface Transportation. Association of American Railroads, Pueblo, CO. 2005, p. 823] **PEER REVIEWED** Perlite and Cellosive WP3H (hydroxyethyl cellulose) have been tested and recommended for vapor suppression and/or containment of 50% **sodium hydroxide** solutions.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.91 (1981)] **PEER REVIEWED** Keep water away from release. Stop or control the leak, if this can be done without undue risk. Prompt cleanup and removal are necessary. Shovel into suitable dry container. Control runoff and isolate discharged material for proper disposal.[National Fire Protection Association; Fire Protection Guide to Hazardous Materials. 14TH Edition, Quincy, MA 2010, p. 49-136] **PEER REVIEWED**

Disposal Methods:

SRP: The most favorable course of action is to use an alternative chemical product with less inherent propensity for occupational harm/injury/toxicity or environmental contamination. Recycle any unused portion of the material for its approved use or return it to the manufacturer or supplier. Ultimate disposal of the chemical must consider: the material's impact on air quality; potential migration in soil or water; effects on animal and plant life; and conformance with environmental and public health regulations. **PEER REVIEWED** Following neutralization either at the spill site or at a waste management facility, the resultant sludge can be disposed of in a secure landfill.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.92 (1981)] **PEER REVIEWED** SRP: Wastewater from contaminant suppression, cleaning of protective clothing/equipment, or contaminated sites should be contained and evaluated for subject chemical or decomposition product concentrations. Concentrations shall be lower than applicable environmental discharge or disposal criteria. Alternatively, pretreatment and/or discharge to a permitted wastewater treatment facility is acceptable only after review by the governing authority and assurance that "pass through" violations will not occur. Due consideration shall be given to remediation worker exposure (inhalation, dermal and ingestion) as well as fate during treatment, transfer and disposal. If it is not practicable to manage the chemical in this fashion, it must be evaluated in accordance with EPA 40 CFR Part 261, specifically Subpart B, in order to determine the appropriate local, state and federal requirements for disposal. **PEER REVIEWED** Put into large vessel containing water. Neutralize with HCL /hydrochloric acid/. Discharge into the sewer with sufficient water. Recommendable methods: Neutralization & discharge to sewer. Peer review: Dilute greatly (< pH 9) before discharge. (Peer-review conclusions of an IRPTC expert consultation (May 1985))[United Nations. Treatment and Disposal Methods for Waste Chemicals (IRPTC File). Data Profile Series No. 5. Geneva, Switzerland: United Nations Environmental Programme, Dec. 1985., p. 280] **PEER REVIEWED**
Occupational Exposure Standards:

OSHA Standards:

Permissible Exposure Limit: Table Z-1 8-hr Time Weighted Avg: 2 mg/cu m.[29 CFR 1910.1000 (USDOL); U.S. National Archives and Records Administration's Electronic Code of Federal Regulations. Available from, as of October 9, 2011: http://www.ecfr.gov] **PEER REVIEWED** Vacated 1989 OSHA PEL Ceiling limit 2 mg/cu m is still enforced in some states.[NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 97-140. Washington, D.C. U.S. Government Printing Office, 1997., p. 371] **PEER REVIEWED**

Threshold Limit Values:

Ceiling Limit: 2 mg/cu m.[American Conference of Governmental Industrial Hygienists; 2011 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices . Cincinnati, OH 2011, p. 53] **PEER REVIEWED**

NIOSH Recommendations:

Recommended Exposure Limit: 15 Minute Ceiling Value: 2 mg/cu m.[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED**

Immediately Dangerous to Life or Health:

10 mg/cu m[NIOSH. NIOSH Pocket Guide to Chemical Hazards & Other Databases CD-ROM. Department of Health & Human Services, Centers for Disease Prevention & Control. National Institute for Occupational Safety & Health. DHHS (NIOSH) Publication No. 2005-151 (2005)] **PEER REVIEWED**

Other Standards Regulations and Guidelines:

Australia: 2 mg/cu m, peak limitation (1990); Federal Republic of Germany: 2 mg/cu m, short-term level 4 mg/cu m, 5 min, 8 times per shift (1990); Sweden: 2 mg/cu m ceiling (1990); United Kingdom: 10 min STEL 2 mg/cu m (1991)[American Conference of Governmental Industrial Hygienists, Inc. Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I, II, III. Cincinnati, OH: ACGIH, 1991., p. 1417] **PEER REVIEWED** Emergency Response Planning Guidlines (ERPGs) for **sodium hydroxide**:

ERPG	Maximum Airborne Concentration
The ERPG-1: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.	0.5 mg/cu m
The ERPG-2: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.	5 mg/cum
The ERPG-3: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.	50 mg/cu m

[American Industrial Hygiene Association. 2010 Emergency Response Planning Guidelines (ERPG) Workplace Environmental Exposure Level (WEEL). American Industrial Hygiene Association Guideline Foundation. Fairfax, VA 2010., p. 26] **PEER REVIEWED**

Manufacturing/Use Information:

View products that contain this chemical: SODIUM HYDROXIDE

Uses:

Both oil base and water base fracturing fluids are being used in the fracturing industry. Water base, which includes alcohol-water mixtures and low strength acids, make up the majority of treating fluids. The common chemicals added to these fluids are polymers for viscosity development, crosslinkers for viscosity enhancement, pH control chemicals, gel breakers for polymer degradation following the treatment, surfactants, clay stabilizers, alcohol, bactericides, fluid loss additives and friction reducer. /Hydraulic fracturing/[Halliburton; Hydraulic Fracturing. Document ID: EPA-HQ-ORD-2010-0674-1634 p.32. Available from, as of October 27, 2011: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-ORD-2010-0674-1634] **PEER REVIEWED** Hydraulic fracturing uses a specially blended liquid which is pumped into a well under extreme pressure causing cracks in rock formations underground. These cracks in the rock then allow oil and natural gas to flow, increasing resource production. ... Chemical Name: **Sodium hydroxide**; Chemical Purpose: Adjusts the pH of fluid to

maintain the effectiveness of other components, such as crosslinkers; Product Function: pH Adjusting agent. [FracFocus; Chemical Disclosure Registry, Hydraulic Fracturing, How it Works; What Chemicals are Used. Available from, as of October 28, 2011: http://fracfocus.org/chemical-use/what-chemicals-are-used] **PEER REVIEWED** For **sodium hydroxide** (USEPA/OPP Pesticide Code: 075603) ACTIVE products with label matches. /SRP: Registered for use in the U.S. but approved pesticide uses may change periodically and so federal, state and local authorities must be consulted for currently approved uses./[National Pesticide Information Retrieval System's USEPA/OPP Chemical Ingredients Database on Sodium Hydroxide (1310-73-2). Available from, as of October 10, 2011: http://npirspublic.ceris.purdue.edu/ppis/] **PEER REVIEWED** In inorganic chemistry, **sodium hydroxide** is used in the manufacture of sodium salts, for alkaline ore digestion, and for pH regulation.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** The organic chemical industry uses **sodium hydroxide** for saponification reactions, production of nucleophilic anionic intermediates, etherification and esterification, basic catalysis, and the production of free organic bases. **Sodium hydroxide** solution is used for scrubbingwaste gases and neutralizing wastewater.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** In the paper industry ... **sodium hydroxide** solution is used for cooking wood (removal of lignin).[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** The textile industry uses **sodium hydroxide** solution to manufacture viscose and viscose staple fibers. The **sodium hydroxide** solution used must contain only traces of chloride ions (rayon quality). The surface of cotton can be improved by treatment with **sodium hydroxide** solution (mercerization).[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** ... Used for sodium phosphate production in the detergent industry. Soaps are manufactured by the saponification of fats and oils with **sodium hydroxide** solution, and detergents are produced from organic sulfonic acids and **sodium hydroxide**.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** In the aluminum industry, **sodium hydroxide** is used mainly for the treatment of bauxite.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** Waterworks use dilute **sodium hydroxide** solution to regenerate ion exchangers for water purification and wastewater treatment.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** In the food industry, **sodium hydroxide** is used for degreasing, cleaning, and for peeling potatoes.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). NY, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** Vegetable oil refining; regenerating ion exchange resins; organic fusions; peeling of fruits and vegetables in food industry; etching and electroplating[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 1146] **PEER REVIEWED** NaOH solutions are used to neutralize acids and make sodium salts, e.g., in petroleum refining to remove sulfuric and organic acids; to treat cellulose in making viscose rayon and cellophane; in reclaiming rubber to dissolve out the fabric; in making plastics to dissolve casein. NaOH solutions hydrolyze fats and form soaps; they precipitate alkaloids (bases) and most metals (as hydroxides) from water solutions of their salts. Pharmaceutic aid (alkalizer). [Thomson/Micromedex. Drug Information for the Health Care Professional. Volume 1, Greenwood Village, CO. 2007., p. 1485] **PEER REVIEWED** Gelling agent[US EPA; Expanded Site Investigation - Field Sampling Plan, Pavillion Area Groundwater Investigation. Pavillion, Fremont County, Wyoming. USEPA Contract No. EP-W-05-050. TDD No., 0901-01. January 6, 2010. START 3. Superfund Technical Assessment and Response Team 3-Region 8. Available from, as of Oct 11, 2011: http://www.epa.gov/region8/superfund/wy/pavillion/Pavillion_GWInvestigationFSP.pdf] **PEER REVIEWED** It is used in the manufacture of rayon, mercerized cotton, soap, paper, aluminum, petroleum, chemicals, and dye-stuffs. It is also used for metal cleaning, electrolytic extraction of zinc, tin plating, oxide coating, laundering, and bleaching.[Zenz, C., O.B. Dickerson, E.P. Horvath. Occupational Medicine. 3rd ed. St. Louis, MO., 1994, p. 674] **PEER REVIEWED** MEDICATION: VET (See also: Therapeutic Uses) **PEER REVIEWED**

Manufacturers:

American Azide Corp., 3770 Howard Hughes Parkway, Suite 300, Las Vegas, NV 89109, (702) 735-2200; Production site: 10622 West 6400 North, P.O. Box 629, Cedar City, UT 84721[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Bayer MaterialScience LLC, 100 Bayer Rd., Pittsburgh, PA 15205-9741, (800) 662-2927; Production site: 8500 West Bay Rd., Baytown, TX 77521[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Bleachtech LLC, 8895 Ryan Rd., Seville, OH 44273, (330) 769-5300; Production site: Seville, OH 44273[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** The Dow Chemical USA, 2030 Dow Center, Midland, MI 48642, (989) 636-1000; Production sites: 2301 N. Brazosport Blvd., Freeport, TX 77541; 21255 Highway 1, Plaquemine, LA 70764[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Equa-Chlor LLC, 3541 Industrial Way, Longview, WA 98632, (360) 636-2123; Production site: 3541 Industrial Way, Longview, WA 98632[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** ERCO Worldwide (USA) Inc., 101 Highway 73 South, Nekoosa, WI 54457, (715) 887-4000; Production site: State Highway 73 South, P.O. Box 161, Port Edwards, WI 54469[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** FMC Corporation, 1735 Market St., Philadelphia, PA 19103, (215) 299-6000; Industrial Chemicals Group, Alkali Chemicals Division; Production site: Highway 374, P.O. Box 872, Green River, WY 82935[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Formosa Plastics Corp USA, 9 Peach Tree Rd., Livingston, NJ 07039, (973) 922-2090; Production sites: P.O. Box 271, Gulf States Rd., Baton Rouge, LA 70821; P.O. Box 700, 201 Formosa Dr., Point Comfort, TX 77978[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Georgia Gulf Corp., 115 Perimeter Center Place, Suite 460, Atlanta, GA 30346, (770) 395-4500; Production site: 26100 Louisiana Hwy. 405, P.O. Box 629, Plaquemine, LA 70765[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Kuehne Chemical Corp., 86 N. Hackensack Ave., South Kearny, NJ 07032, (973) 589-0700; Production site: 1645 River Rd., P.O. Box 294, Delaware City, DE 19706[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Occidental Chemical Corp., Occidental Tower, 5005 LBJ Freeway, Dallas, TX 75244, (972) 404-3800; Chloro-Vinyls Group; Production sites: Convent, LA 70723; Corpus Christi, TX 78400; Geismar, LA 70734; Hahnville, LA 70057; La Porte, TX 77571; Niagara Falls, NY 14303; Wichita, KS 67215[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Olin Corporation, 190 Carondelet Plaza, Suite 1530, Clayton, MO 63105-3443, (314) 480-1400; Olin Chlor Alkali Products Div., Production sites: Augusta, GA 30906-2139; Charleston, TN 37310-0248; Henderson, NV 89015; McIntosh, AL 36553-0028; Niagara Falls, NY 14302-0748; St. Gabriel, LA 70776[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** PPG Industries, Inc., One PPG Place, Pittsburgh, PA 15272, (412) 434-3131; Chemicals Group; Production sites: Lake Charles, LA 70601; Natrium, WV 26155[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** SABIC Innovative Plastics, 1 Plastics Avenue, Pittsfield, MA 01201, (413) 448-7110; Production site: Burkville, AL 36752; Mount Vernon, IN 47620[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Shintech Inc., 3 Greenway Plaza, Suite 1150, Houston, TX 77046, (713) 965-0713; Production site: 26270 Highway 405, Plaquemine, LA 70764, (225) 685-1021[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Trinity Manufacturing, INC., 11 E.V. Hogan Dr., P.O. Box 1519, Hamlet, NC 28345, (910) 582-5650; Production site: Hamlet, NC 28345[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** Westlake Vinyls, Inc., Westlake Center, 2801 Post Oak Blvd., Houston, TX 77056, (713) 960-9111; Production site: 230 Johson Riley Rd., P.O. Box 1027, Calvert City, KY 42029[SRI Consulting, 2010 Directory of Chemical Producers. Menlo Park, CA. 2010, p. 857] **PEER REVIEWED** **Sodium Hydroxide** - Producer and Manufacture Data (2006)

Company	Site	City State Zip	Manufacture	Import
ATI Wah Chang	ATI Wah Chang	Albany OR 97321	No	Yes
Alcan International Network U.S.A. Inc.	Alcan International Network U.S.A. Inc.	Stamford CT 06902	No	Yes
Alcoa Inc.	Alcoa Corporate Center	Pittsburgh PA 15212	No	Yes

Barrick Gold Corporation	Barrick Gold Corp - Bald Mountain Mine	Ely NV 89301	No	Yes
Barrick Gold Corporation	Barrick Goldstrike Mines Inc.	Carlin NV 89822	No	Yes
Barrick Turquoise Ridge Inc.	Turquoise Ridge Joint Venture	Golconda NV 89414	No	Yes
Basic Chemicals Company, LLC	Basic Chemicals Co - Geismar	Geismar LA 70734	Yes	No
Basic Chemicals Company, LLC	Basic Chemicals Co - Wichita Plant	Wichita KS 67215	Yes	No
Bayer MaterialScience	Bayer MaterialScience - Pittsburgh	Pittsburgh PA 15205	No	Yes
Bayer MaterialScience	Bayer MaterialScience - Baytown	Baytown TX 77520	Yes	No
CITGO Asphalt Refining Company	CITGO Asphalt Refining - Savannah Refinery	Savannah GA 31408	No	Yes
Canexus U.S., Inc.	Canexus - Houston	Houston TX 77067	No	Yes
Delta Chemical Corporation	Delta Chemical Corp - Baltimore	Baltimore MD 21226	No	Yes
Domtar, Inc.	Domtar Maine Corp.	Baileyville ME 04694	No	Yes
EMD Chemicals, Inc.	EMD Chemicals - Cincinnati	Cincinnati OH 45212	No	Yes
Equa-Chlor Marketing, LLC	Equa-Chlor, LLC	Longview WA 98632	No	Yes
Erco Worldwide, a division of Superior Plus LP.	Erco Worldwide - Nekoosa	Nekoosa WI 54457	Yes	No
Erco Worldwide, a division of Superior Plus LP.	Erco Worldwide - Saskatoon	Saskatoon CN S7K 3R3 Canada	No	Yes
FMC Corporation	FMC Corp - Westvaco Plant	Green River WY 82935	Yes	No
FMC Wyoming Corporation	FMC Wyoming Corp - Westvaco Plant	Green River WY 82935	Yes	No
FMC Wyoming Corporation	FMC Wyoming Corp - Granger Plant	Granger WY 82934	Yes	No
Fairbanks Gold Mining Inc.	Fairbanks Gold Mining - Fort Knox Mine	Fairbanks AK 99712	No	Yes
Finch Pruyn & Co., Inc.	Finch Pruyn & Co., Inc.	Glens Falls NY 12801	No	Yes
Ford Motor Company	Ford Motor Co - Sterling Plant	Sterling Heights MI 48310	No	Yes
Formosa Plastics Corporation	Formosa Plastics Corp - Livingston Headquarters	Livingston NJ 07039	No	Yes
Formosa Plastics Corporation	Formosa Plastics Corp - Texas	Point Comfort TX 77978	Yes	No
GE Plastics Mt.Vernon, Inc.	GE Plastics Mt.Vernon, Inc.	Mt. Vernon IN 47620-9367	Yes	No
General Chemical	General Chem Perform Prods -	Midlothian TX	Yes	No

Performance Products, LLC	Reheis Interm - Midlothian	76065		
General Electric Company	GE Plastics	Burkville AL 36752-4007	Yes	No
Georgia Gulf Chemicals and Vinyls, LLC	Georgia Gulf Chemicals and Vinyls - Plaquemine Plant	Plaquemine LA 70765-0629	Yes	No
Golden Sunlight Mines, Inc.	Golden Sunlight Mine	Whitehall MT 59759	No	Yes
Ineos Chlor Americas, Inc	Ineos Chlor Americas, Inc	Wilmington DE 19810	No	Yes
JCI Jones Chemcials, Inc.	JCI Jones Chemicals - Headquarters	Sarasota FL 34236		
JohnsonDiversey, Inc	JohnsonDiversey, Inc	Sturtevant WI 53177-0902	No	Yes
K.G. International, Inc.	K.G. International, Inc.	Miami FL 33166	No	Yes
Kinross Gold USA Inc.	Kinross Gold - Round Mountain Gold Corporation	Round Mountain NV 89045	No	Yes
Konica Minolta Graphic Imaging U.S.A., Inc.	Konica Minolta Graphic imaging U.S.A., Inc.	Glen Cove NY 11542	No	Yes
Lonza, Inc.	Lonza - Williamsport	Williamsport PA 17701	Yes	No
Los Angeles Chemical Company	Los Angeles Chemical Co. Huntington Beach, CA	Huntington Beach CA 92649	No	Yes
Merichem Chemicals & Refinery Services, LLC	Merichem Chemicals & Refinery Services - Houston	Houston TX 77023-5013	No	Yes
Mitsubishi International Corporation	Mitsubishi International Corp - Houston	Houston TX 77010-2009	No	Yes
Occidental Chemical Corporation	Occidental Chemical Corp - Taft Plant	Hahnville LA 70057-2608	Yes	No
Occidental Chemical Corporation	Occidental Chemical Corp - Niagara Falls	Niagara Falls NY 14302	Yes	No
Occidental Chemical Corporation	Occidental Chemical Corp - Ingleside	Gregory TX 78359	Yes	No
Occidental Chemical Corporation	Occidental Chemical Corp - Delaware City	New Castle DE 19720	Yes	No
Occidental Chemical Corporation	Occidental Chemical Corp - Convent	Convent LA 70723	Yes	No
Oxy Vinyls, LP	Oxy Vinyls - Battleground Plant	La Porte TX 77571	Yes	No

[US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Sept 9, 2011: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED**

Sodium Hydroxide - Producer and Manufacture (2006)

Company	Site	City State Zip	Manufacture	Import
PPG Industries, Inc.	PPG Industries - Lake Charles	Lake Charles LA 70602	Yes	No
PPG Industries, Inc.	PPG Industries - New Martinsville	New Martinsville WV 26155	Yes	No
Pioneer Americas LLC	Pioneer Americas - CN CargoFlo	Warren MI 48089	No	Yes

Pioneer Americas LLC	Pioneer Americas - CSXT Transflo	Albany NY 12205	No	Yes
Pioneer Americas LLC	Pioneer Americas - CSXT Transflo	Buffalo NY 14206	No	Yes
Pioneer Americas LLC	Pioneer Americas - CSXT Transflo	Elizabeth NJ 07201	No	Yes
Pioneer Americas LLC	Pioneer Americas - Henderson	Henderson NV 89015	Yes	No
Pioneer Americas LLC	Pioneer Americas - Kinder Morgan	Richmond CA 94804	No	Yes
Pioneer Americas LLC	Pioneer Americas - Kinder Morgan Liquids Terminal	Argo IL 60501	No	Yes
Pioneer Americas LLC	Pioneer Americas - Safe Handling	Auburn ME 04211	No	Yes
Pioneer Americas LLC	Pioneer Americas - Seeler Industries	Joliet IL 60435	No	Yes
Pioneer Americas LLC	Pioneer Americas - St. Gabriel	St. Gabriel LA 70776	Yes	No
Pioneer Americas LLC	Pioneer Americas - Tacoma Terminal	Tacoma WA 98421	No	Yes
Placid Refining Company, L.L.C.	Placid Refining Co - Port Allen Refinery	Port Allen LA 70767	Yes	No
Port Townsend Paper Corporation	Port Townsend Paper Mill	Port Townsend WA 98368	Yes	Yes
Quadra Chemicals, Inc.	Quadra Chemicals, Inc. - Portland, OR	Portland OR 97210	No	Yes
Reckitt Benckiser Inc	Reckitt Benckiser - Parsippany	Parsippany NJ 07054	No	Yes
Rhodia Inc	Rhodia Inc - Cranbury	Cranbury NJ 08512	No	Yes
SDW Holdings Corporation	S.D. Warren Co. (Sappi Fine Paper North America) - Skowhegan	Skowhegan ME 04976	No	Yes
Solvay Chemicals, Inc.	Solvay Chemicals - Corporate Office	Houston TX 77098	No	Yes
Syngenta Crop Protection, Inc.	Syngenta Crop Protection - Pasadena	Pasadena TX 77507	Yes	No
TR International, Incorporated	TR International Inc - Seattle	Seattle WA 98101	No	Yes
Tembec USA LLC	Tembec USA - St Francisville Operations St.	Francisville LA 70775	Yes	No
Tesoro Refining and Marketing Company	Tesoro Refining & Marketing Co - Anacortes	Anacortes WA 98221	Yes	No
Texas Molecular LP	TM Chemicals, LP	Deer Park TX 77536	Yes	No
The Dow Chemical Company	Dow Chemical - Headquarters	Midland MI 48674	No	Yes
The Dow Chemical Company	Dow Chemical - Plaquemine	Plaquemine LA 70764	Yes	No
Ulrich Chemical, Inc.	Ulrich Chemical, Inc - Indianapolis	Indianapolis IN 46226	Yes	No

Ulrich Chemical, Inc.	Ulrich Chemical, Inc - Louisville	Louisville KY 40216	Yes	No
Ulrich Chemical, Inc.	Ulrich Chemical, Inc - Fort Wayne	Fort Wayne IN 46803	Yes	No
Ulrich Chemical, Inc.	Ulrich Chemical, Inc - Evansville	Evansville IN 47711	Yes	No
Ulrich Chemical, Inc.	Ulrich Chemical, Inc - Terre-Haute	Terre-Haute IN 47802	Yes	No
United Refining Company	United Refining Company - Vulcan Asphalt Facility	Cordova AL 35550	No	Yes
United Refining Company	United Refining Company - Warren	Warren PA 16365	No	Yes
Univar USA Inc.	Univar USA Inc - Redmond	Redmond WA 98052	No	Yes
Vulcan Materials Company	Vulcan Materials Co - Geismar Plant	Geismar LA 70734	Yes	No
Vulcan Materials Company	Vulcan Materials Co - Port Edwards Plant	Port Edwards WI 54469	Yes	No
Vulcan Materials Company	Vulcan Materials Co - Wichita Plant	Wichita KS 67215	Yes	No
Westlake Chemical Corporation	Westlake Vinyls, Inc.	Calvert City KY 42029	Yes	No

[US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of Sept 8, 2011: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED**

Methods of Manufacturing:

By reacting calcium hydroxide with sodium carbonate; from sodium chloride by electrolysis; from sodium metal and water vapor at low temperature.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED** **Sodium hydroxide** is produced industrially mainly by the electrolysis of sodium chloride. This yields **sodium hydroxide** solution, chlorine, and hydrogen in the mass ratios 1:0.88:0.025.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** Solid **sodium hydroxide** (**caustic soda**) is obtained by evaporating **sodium hydroxide** solution until the water content is < 0.5 - 1.5 wt%. The most efficient utilization of energy is achieved with multistage equipment.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** Causticization of sodium carbonate: A hot, ca. 12% solution of sodium carbonate is mixed with quicklime (CaO). The calcium carbonate that precipitates out is removed and the ca. 12% solution of **sodium hydroxide** is evaporated in several stages. [Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA24: 349 (1993)] **PEER REVIEWED** Ferrite Recovery process (mainly used in small paper pulp plants): Waste liquor containing sodium salt and organic substances is evaporated, and the residue mixed with Fe2O3 and calcined. The sodium ferrite formed is decomposed by water to give **sodium hydroxide** and Fe2O3.[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA24: 347 (1993)] **PEER REVIEWED** Solid **sodium hydroxide** (**Caustic soda**) is obtained by evaporating **sodium hydroxide** solution until the water content is <0.5-1.5 wt %.[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA24: 349 (1993)] **PEER REVIEWED**

General Manufacturing Information:

All U.S. production, except for that in Granger and Green River, WY, is by brine electrolysis.[SRI. 1997 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International 1997., p. 892] **PEER REVIEWED** Chlorine and **sodium hydroxide** are usually coproduced /by brine electrolysis/ in a ratio of 1 ton of chlorine to 1.1 tons of **sodium hydroxide**.[SRI. 1998 Directory of Chemical Producers - United States of America. SRI International, Menlo Park, CA. 1998., p. 892] **PEER REVIEWED** **Caustic soda** (NaOH) and chlorine are coproducts and consequently **caustic soda** production has been limited by chlorine demand. Increased demand for **caustic soda** over that of chlorine will be presumably addressed by a switch to soda ash (sodium carbonate) where possible.[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V1: 939 (1991)] **PEER REVIEWED** Produced commercially in two forms: a 50 wt % solution (the most common form) and in the solid (**caustic soda**) as prills, flakes, or cast shapes.[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA24: 347 (1993)] **PEER REVIEWED** The relative energy requirements for the production of **sodium hydroxide** by the three electrolytic processes are Amalgam:Diaphragm:Membrane at 92:100:75 %.[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA24: 348 (1993)] **PEER REVIEWED** In 1990, **sodium hydroxide** production among the three most widely used processes was: United States (Amalgam 18%, Diaphram 76%, Membrane 6%); Canada (Amalgam 15%, Diaphram 81%, Membrane 4%); Western Europe (Amalgam 65%, Diaphram 29%, Membrane 6%); Japan (Amalgam 0%, Diaphram 20%, Membrane 80%).[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA24: 347 (1993)] **PEER REVIEWED** The diaphram cell process (Griesheim cell, 1985, mercury cell (amalgam) process (Castner-Kellner cell 1892) and membrane cell process (1970) represent a different method of keeping the chlorine produced at the anode separate from the **caustic soda** and hydrogen produced, directly or indirectly, at the cathode. In the mercury cell process, sodium amalgam is produced at the cathode and reacted in water in a separate reactor, the decomposer. In the diaphragm cell process, the anode and cathode areas are separated by a permeable asbestos-based diaphragm. In the membrane cell process, the anode and cathode are separated by a cation-permeable ion-exchange membrane.[Gerhartz, W. (exec ed.). Ullmann's Encyclopedia of Industrial Chemistry. 5th ed.Vol A1: Deerfield Beach, FL: VCH Publishers, 1985 to Present., p. VA6: 406 (1986)] **PEER REVIEWED** A survey of household materials involved in serious poisonings in children aged under 5 yr was conducted to identify substances that would best be packaged with safety closures. The substances identified as causing the most serious side effects and for which safety closures may be indicated included ... **sodium hydroxide** (**caustic soda**).[Craft AW et al; Br Med J 288(Mar 3): 682 (1984)] **PEER REVIEWED**

Formulations/Preparations:

Solid **sodium hydroxide** is supplied in the form of flakes, prills, cast blocks, and less commonly as tablets, briquettes, or granules.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** Grades: commercial; ground; flake; beads; Food Chemical Codex grade; granulated (60% and 76% Na2O); rayon (low in iron, copper, and manganese); purified by alcohol (sticks, lumps, and drops); reagent; highest purity: CP, USP.[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 1146] **PEER REVIEWED** When kept in tight containers, the usual grades contain 97-98% **sodium hydroxide**.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED** Anhydrous (Rayon Grade) 99.0% minimum; Rayon Grade: 50% liquid; Regular Grade: 50% liquid, 47.7-51% purity.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.1 (1981)] **PEER REVIEWED** Drano crystals contain 54.2% **sodium hydroxide**; Clinitest tablets contain 232.5 mg **sodium hydroxide** /From table/[Gossel, T.A., J.D. Bricker. Principles of Clinical Toxicology. 3rd ed. New York, NY: Raven Press, Ltd., 1994., p. 224] **PEER REVIEWED** Mr. Clean Multi-Surfaces Antibacterial (The Procter & Gamble Co.), **Sodium hydroxide** 0.34%.[Purdue University; National Pesticide Information Retrieval System, Sodium hydroxide (1310-73-2), PC Code: 75603. Available from, as of October 14, 2011 http://npirspublic.ceris.purdue.edu/ppis/] **PEER

REVIEWED** Ultra Mr. Clean (The Procter & Gamble Co.), **Sodium hydroxide** 0.46%.[Purdue University; National Pesticide Information Retrieval System, Sodium hydroxide (1310-73-2), PC Code: 75603. Available from, as of October 14, 2011 http://npirspublic.ceris.purdue.edu/ppis/] **PEER REVIEWED** PH 12.6 (Western Pacific Pulp & Paper), **Sodium hydroxide** 0.18%.[Purdue University; National Pesticide Information Retrieval System, Sodium hydroxide (1310-73-2), PC Code: 75603. Available from, as of October 14, 2011 http://npirspublic.ceris.purdue.edu/ppis/] **PEER REVIEWED**

Impurities:

Major impurities which are normally tested for are sodium chloride, sodium carbonate, sodium sulfate, sodium chlorate, iron, and nickel.[Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Volumes 1: New York, NY. John Wiley and Sons, 1991-Present., p. V1: 1012 (1991)] **PEER REVIEWED**

Consumption Patterns:

51% IS CONSUMED IN CHEMICAL PROCESSING AND METAL PROCESSING OTHER THAN ALUMINUM; 6% FOR ALUMINUM PROCESSING; 18% IS USED IN PAPER AND PULP MANUFACTURE; 13% IS USED IN THE PETROLEUM, TEXTILE, SOAP, AND FOOD INDUSTRIES; 4% IS USED IN RAYON AND CELLOPHANE PRODUCTION; 8% IS USED IN OTHER APPLICATIONS (1974).[SRI] **PEER REVIEWED** CHEMICAL PROFILE: **Caustic soda**. Organic Chemicals, 30%; Inorganic Chemicals, 20%; Pulp & Paper, 20%; Exports, 10%; Soaps and Detergents, 5%; Petroleum, 5%; Textiles, 4%; Alumina, 3%; Other, 3% (1986).[CHEMICAL PROFILE: Caustic Soda, 1986] **PEER REVIEWED** CHEMICAL PROFILE: **Caustic soda**. Pulp and paper, 22%; organic chemicals, 20%; inorganic chemicals, 11%; soaps and detergents, 7%; petroleum, 7%; water treatment, 7%; textiles, 5%; alumina, 4%; other, 9%; exports, 8%. [Kavaler AR; Chemical Marketing Reporter 235 (25): 50 (1989)] **PEER REVIEWED** Direct application, 55% (pulp & paper, 24%; soaps and detergents, 10%; alumina, 6%; petroleum, 7%; textiles, 5%; water treatment, 5%; miscellaneous, 43%); organic chemicals 36% (propylene oxide, 23%; polycarbonates, 5%; ethyleneamines, 3%; epoxy resins, 3%; miscellaneous, 66%); inorganic chemicals, 9% (sodium/calcium hypochlorite, 24%; sulfur-containing compounds, 14%; sodium cyanide, 10%; miscellaneous 52%)[Kavaler AR; Chemical Marketing Reporter, June 1, 1998, p. 37 Chemical Profile: Caustic Soda] **PEER REVIEWED**

U. S. Production:

(1972) 9.27X10+12 GRAMS[SRI] **PEER REVIEWED** (1975) 8.7X10+12 GRAMS[SRI] **PEER REVIEWED** (1985) 9.24X10+12 g[Chem Eng News 64(16): 13(1986)] **PEER REVIEWED** (1990) 24.06 billion lb[Chem & Engineering News 70 (15): 17 (4/13/92)] **PEER REVIEWED** (1991) 23.43 billion lb[Chem & Engineering News 71 (15): 11 (4/12/93)] **PEER REVIEWED** (1992) 24.50 billion lb[Chem & Engineering News 72 (15): 13 (4/11/94)] **PEER REVIEWED** (1993) 25.71 billion lb[Chem & Engineering News 72 (15): 13 (4/11/94)] **PEER REVIEWED** CHEMICAL PROFILE: **Caustic soda**. Demand: 1988: 12.3 million tons (33,700 tons per day); 1989: 12.5 million tons (34,250 tons per day); 1993 /projected/: 13.4 million tons (36,700 tons per day). (Includes exports, but not imports, which totaled 858,000 tons last year.)[Kavaler AR; Chemical Marketing Reporter 235 (25): 50 (1989)] **PEER REVIEWED** Annual production capacity estimate as of 4/1/97: 14.3 million short tons.[SRI. 1997 Directory of Chemical Producers -United States of America. Menlo Park, CA: SRI International 1997., p. 891-2] **PEER REVIEWED** Demand: (1996) 13.9 million tons; (1997) 14.2 million tons (figures are for liquid material and include amounts dried, Includes exports, which amounted to 2 million short tons in 1996, but not imports, which were 540,000 tons).[Kavaler AR; Chemical Marketing Reporter, June 1, 1998, p. 37, Chemical Profile: Caustic Soda] **PEER REVIEWED** Production volumes for non-confidential chemicals reported under the Inventory Update Rule.

Year	Production Range (pounds)
1986	>100 million - 500 million
1990	>1 million - 10 million
1994	>1 million - 10 million

1998	>100 million - 500 million
2002	>100 million - 500 million

[US EPA; Non-confidential Production Volume Information Submitted by Companies for Chemicals Under the 1986-2002 Inventory Update Rule (IUR). Sodium hydroxide (1310-73-2). Available from, as of October 11, 2011: http://www.epa.gov/oppt/iur/tools/data/2002-vol.html] **PEER REVIEWED** Production volume for non-confidential chemicals reported under the 2006 Inventory Update Rule. Chemical: **Sodium hydroxide**. Aggregated National Production Volume: 1 billion pounds and greater.[US EPA; Non-Confidential 2006 Inventory Update Reporting. National Chemical Information. Sodium hydroxide (1310-73-2). Available from, as of October 11, 2011: http://cfpub.epa.gov/iursearch/index.cfm?s=chem&err=t] **PEER REVIEWED**

U. S. Imports:

(1972) 9.53X10+10 GRAMS[SRI] **PEER REVIEWED** (1975) 9.8X10+10 GRAMS[SRI] **PEER REVIEWED** (1984) 4.78X10+11 g[BUREAU OF THE CENSUS. U.S. IMPORTS FOR CONSUMPTION AND GENERAL IMPORTS 1984 p.1-351] **PEER REVIEWED** 1996: 540,000 tons[Kavaler AR; Chemical Marketing Reporter, June 1, 1998, p. 37, Chemical Profile: Caustic Soda] **PEER REVIEWED**

U. S. Exports:

(1972) 1.1X10+12 GRAMS[SRI] **PEER REVIEWED** (1975) 1.00X10+12 GRAMS[SRI] **PEER REVIEWED** (1984) 1.14X10+12 g[BUREAU OF THE CENSUS. U.S. EXPORTS, SCHEDULE E, 1984 p.2-92] **PEER REVIEWED** 1996: 2 million tons.[Kavaler AR; Chemical Marketing Reporter, June 1, 1998, p. 37, Chemical Profile: Caustic Soda] **PEER REVIEWED**

Laboratory Methods:

Analytic Laboratory Methods:

Method: NIOSH 7401, Issue 2; Procedure: acid-base titration; Analyte: hydroxide (alkalinity); Matrix: air; Detection Limit: 0.03 mg/sample (as NaOH).[CDC; NIOSH Manual of Analytical Methods, 4th ed. Alkaline Dusts (1310-73-2). Available from, as of October 12, 2011: http://www.cdc.gov/niosh/docs/2003-154/] **PEER REVIEWED**

Sampling Procedures:

ANALYTE: **SODIUM HYDROXIDE**; MATRIX: AIR; PROCEDURE: FILTER COLLECTION, EXTRACTION WITH AQUEOUS ACID.[U.S. Department of Health, Education Welfare, Public Health Service. Center for Disease Control, National Institute for Occupational Safety Health. NIOSH Manual of Analytical Methods. 2nd ed. Volumes 1-7. Washington, DC: U.S. Government Printing Office, 1977-present., p. V4 S381-1] **PEER REVIEWED** Workplace monitoring: Sampling and analysis may be performed by collection of **sodium hydroxide** in a glass bubble containing hydrochloric acid, followed by subsequent titration.[Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981., p. 2] **PEER REVIEWED** Detector tubes certified by NIOSH under 42 CFR part 84 or other direct-reading devices calibrated to measure **sodium hydroxide** may be used. [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981., p. 2] **PEER REVIEWED**

Special References:

Special Reports:

Environment Canada; Tech Info for Problem Spills: **Sodium Hydroxide** (Draft) (1981)NIOSH; Criteria Document: **Sodium Hydroxide** (1975) DHEW Pub. NIOSH 76-105

History and Incidents:

This article reports a chemical burn incident that occurred on August 7th, 2005, when a Matsa typhoon hit Shanghai, China. This is the largest chemical burn incident reported in the literature for 20 years in China, involving 118 alkali burn patients who were rescued by the Burn Department of Shanghai Changhai Hospital independently.The scene of the incident was investigated, and the clinical, emergency and hospitalized data of the patients were summarized.The main injurious chemical was a water solution of **sodium hydroxide** and ammonium chloride. The 118 victims were mostly young men with 5%TBSA deep thickness burn of both lower extremities, including 31 patients who had additional light coughing. Of 58 patients who were finally hospitalized, 42 patients received surgical treatment. Most of these patients recovered within 1 month. There were no deaths. ...[Ma B et al; Burns. 33 (5): 565-71 (2007)] **PEER REVIEWED** PubMed Abstract Over a six-month period, the New Jersey Poison Information System received 61 calls related to exposures to alkaline corrosives. Seven of these calls related to a new oven-cleaner product, oven-cleaner pads. These pads are sealed in a protective plastic wrap and contain lye in excess of 5%. ... Five of the callers sustained injuries from their exposure, and three of these sustained burns, one in the oral cavity and one in the eye. None suffered permanent sequelae, but the potential for such is considerable. The method of application, concn of base, and prolonged exposure to a widely covered area may make this product particularly hazardous. /Alkaline corrosives/[Vilogi J et al; Am J Emerg Med 3 (5): 412-4 (1985)] **PEER REVIEWED** PubMed Abstract

Synonyms and Identifiers:

Synonyms:

CAUSTIC SODA**PEER REVIEWED** **Caustic Soda**, Bead (DOT)**PEER REVIEWED** **Caustic Soda**, Dry (DOT)**PEER REVIEWED** **Caustic Soda**, Flake (DOT)**PEER REVIEWED** **Caustic Soda**, Granular (DOT)**PEER REVIEWED** **Caustic Soda**, Solid (DOT)**PEER REVIEWED** HYDROXYDE DE SODIUM (FRENCH)**PEER REVIEWED** **NATRIUMHYDROXID (GERMAN)****PEER REVIEWED** **NATRIUMHYDROXYDE (DUTCH)****PEER REVIEWED** Soda, caustic**PEER REVIEWED** Soda, hydrate**PEER REVIEWED** **SODA LYE****PEER REVIEWED** **Sodium Hydrate****PEER REVIEWED** **Sodium Hydroxide**, Bead (DOT)**PEER REVIEWED** **Sodium(hydroxide** de) (French)**PEER REVIEWED** **Sodium Hydroxide**, Dry (DOT)**PEER REVIEWED** **Sodium Hydroxide**, Flake (DOT)**PEER REVIEWED** **Sodium Hydroxide**, Granular (DOT)**PEER REVIEWED** **Sodium Hydroxide**, Solid (DOT)**PEER REVIEWED** USEPA/OPP Pesticide Code: 075603**PEER REVIEWED**

Formulations/Preparations:

Solid **sodium hydroxide** is supplied in the form of flakes, prills, cast blocks, and less commonly as tablets, briquettes, or granules.[Kurt C, Bittner J; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2011). New York, NY: John Wiley & Sons; Sodium Hydroxide. Online Posting Date: July 15, 2006] **PEER REVIEWED** Grades: commercial; ground; flake; beads; Food Chemical Codex grade; granulated (60% and 76% Na2O); rayon (low in iron, copper, and manganese); purified by alcohol (sticks, lumps, and drops); reagent; highest purity: CP, USP.[Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 1146] **PEER REVIEWED** When kept in tight containers, the usual grades contain 97-98% **sodium hydroxide**.[O'Neil, M.J. (ed.). The Merck Index - An Encyclopedia of Chemicals, Drugs, and Biologicals. Whitehouse Station, NJ: Merck and Co., Inc., 2006., p. 1485] **PEER REVIEWED** Anhydrous (Rayon Grade) 99.0% minimum; Rayon Grade: 50% liquid; Regular Grade: 50% liquid, 47.7-51% purity.[Environment Canada; Tech Info for Problem Spills: Sodium Hydroxide (Draft) p.1 (1981)] **PEER REVIEWED** Drano crystals contain 54.2% **sodium hydroxide**; Clinitest tablets contain 232.5 mg **sodium hydroxide** /From table/[Gossel, T.A., J.D. Bricker. Principles of Clinical Toxicology. 3rd ed. New York, NY: Raven Press, Ltd., 1994., p. 224] **PEER REVIEWED** Mr. Clean Multi-Surfaces Antibacterial (The Procter & Gamble Co.), **Sodium hydroxide** 0.34%.[Purdue University; National Pesticide Information Retrieval System, Sodium hydroxide (1310-73-2), PC Code: 75603. Available from, as of October 14, 2011 http://npirspublic.ceris.purdue.edu/ppis/] **PEER REVIEWED** Ultra Mr. Clean (The Procter & Gamble Co.), **Sodium hydroxide** 0.46%.[Purdue University; National Pesticide Information Retrieval System, Sodium hydroxide (1310-73-2), PC Code: 75603.

Available from, as of October 14, 2011 http://npirspublic.ceris.purdue.edu/ppis/] **PEER REVIEWED** PH 12.6 (Western Pacific Pulp & Paper), **Sodium hydroxide** 0.18%.[Purdue University; National Pesticide Information Retrieval System, Sodium hydroxide (1310-73-2), PC Code: 75603. Available from, as of October 14, 2011 http://npirspublic.ceris.purdue.edu/ppis/] **PEER REVIEWED**

Shipping Name/ Number DOT/UN/NA/IMO:

IMO 8.0; **Sodium hydroxide** solid; **Sodium hydroxide** solutionUN 1823; **Sodium hydroxide**, solidUN 1824; **Sodium hydroxide** solution

Standard Transportation Number:

49 352 35; Dry49 352 40; Liquid49 352 43; 52% Solution

EPA Hazardous Waste Number:

D002; A waste containing **sodium hydroxide** may (or may not) be characterized a hazardous waste following testing for corrosivity characteristics as prescribed by the Resource Conservation and Recovery Act (RCRA) regulations.

Administrative Information:

Hazardous Substances Databank Number:

229

Last Review Date:

Reviewed by SRP on 1/19/2012

Last Revision Date:

20120426

Update History:

Complete Update on 2012-04-26, 2 fields added/edited/deleted
Complete Update on 2012-04-20, 62 fields added/edited/deleted
Field Update on 2008-09-02, 2 fields added/edited/deleted
Field Update on 2008-08-15, 25 fields added/edited/deleted
Field Update on 2007-06-07, 1 fields added/edited/deleted
Field Update on 2006-04-18, 2 fields added/edited/deleted
Field Update on 2006-04-17, 2 fields added/edited/deleted
Complete Update on 2005-06-24, 1 fields added/edited/deleted
Field Update on 2005-01-29, 2 fields added/edited/deleted
Complete Update on 10/16/2002, 3 fields added/edited/deleted.
Field Update on 02/13/2002, 1 field added/edited/deleted.
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Complete Update on 02/08/2000, 1 field added/edited/deleted.
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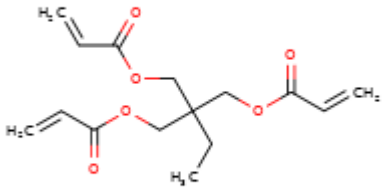
Complete Update on 08/08/1989, 5 fields added/edited/deleted.
Complete Update on 03/09/1987
Created 19830315 by GCF

Trimethylolpropane triacrylate

CASRN: 15625-89-5
UNII: 4B67KGL96S
Reviewed by SRP on 9/13/2012



FULL RECORD DISPLAY
Displays all fields in the record.
For other data, click on the Table of Contents

Human Health Effects:

Human Toxicity Excerpts:

/HUMAN EXPOSURE STUDIES/ Skin sensitivity and photo patch testing of 0.2% **trimethylolpropane triacrylate** in petrolatum was performed on 47 employees of a citrus juice bottling plant who were exposed to ultraviolet-cured printing inks. All 47 workers had positive reactions to one or both tests. Because few workers showed skin sensitization to **trimethylolpropane triacrylate**, the past skin reactions were considered to be irritant, not allergic, reactions to the inks and their components.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**
/HUMAN EXPOSURE STUDIES/ Four workers in a plastic floor manufacturing facility developed hand and face dermatitis a year after the introduction of a varnish with an aziridine-based hardener containing 3% to 5% **trimethylolpropane triacrylate**. The workers had positive reactions to skin patch tests with **trimethylolpropane triacrylate** in acetone at 0.0001% (1/4), 0.03% (3/4), and 0.1% (4/4), with the most severe reactions occurring in the worker who reacted to the 0.0001% formulation.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**
/HUMAN EXPOSURE STUDIES/ Seven of 10 workers exposed to ultraviolet-curable printing inks at a plastic food container manufacturing plant developed contact dermatitis; one person had a positive reaction for sensitization to 0.1% **trimethylolpropane triacrylate** in petrolatum.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**
/HUMAN EXPOSURE STUDIES/ /Investigators/ reported the development of allergic dermatitis in six people who worked with ultraviolet-curable inks containing **trimethylolpropane triacrylate** for 3 to 32 weeks. All six had positive reactions to skin patch tests with 0.1% or 0.5% **trimethylolpropane triacrylate** in acetone.
[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**
/HUMAN EXPOSURE STUDIES/ After **trimethylolpropane triacrylate** and pentaerythritol triacrylate were introduced as components of radiation drying ink in an ink formulating facility, five of 26 workers developed eczematous dermatitis. Four of the five affected workers had positive reactions to patch tests using 0.2% **trimethylolpropane triacrylate** in a varnish formulation or in solution in petrolatum; the fifth worker developed irritant dermatitis to undiluted polyfunctional acrylates.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**
/CASE REPORTS/ A 28-year-old man developed conjunctivitis starting 1 month after using UV-cured paint. He had a positive patch test result with 0.001% **trimethylolpropane triacrylate**. A 51-year-old woman monitoring a laminating machine that used photosensitive resist containing 0.08% **trimethylolpropane triacrylate** in a

small room developed conjunctivitis. She had a positive patch test against 0.1% **trimethylolpropane triacrylate**. A 62-year-old woman who worked in a small, confined space while using a thermal printer developed asthma. All of these individuals became asymptomatic when exposure to the compounds containing **trimethylolpropane triacrylate** ceased.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

Probable Routes of Human Exposure:

According to the 2006 TSCA Inventory Update Reporting data, the number of persons reasonably likely to be exposed in the industrial manufacturing, processing, and use of **trimethylolpropane triacrylate** is 1000 or greater; the data may be greatly underestimated(1).[(1) US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of July 12, 2012: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED** NIOSH (NOES Survey 1981-1983) has statistically estimated that 5,274 workers (809 of these were female) were potentially exposed to **trimethylolpropane triacrylate** in the US(1). Occupational exposure to **trimethylolpropane triacrylate** may occur through inhalation and dermal contact with this compound at workplaces where **trimethylolpropane triacrylate** is produced or used(SRC). Workers involved in the manufacturing, processing, product handling, and application of **trimethylolpropane triacrylate** are at risk of exposure(2). A potential exists for widespread exposure of consumers through the use of **trimethylolpropane triacrylate** in products such as latex paints and furniture and floor polishes(2).[(1) NIOSH; NOES. National Occupational Exposure Survey conducted from 1981-1983. Estimated numbers of employees potentially exposed to specific agents by 2-digit standard industrial classification (SIC). Available from, as of July 12, 2012: http://www.cdc.gov/noes/ (2) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012; Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**
Emergency Medical Treatment:

Antidote and Emergency Treatment:

/SRP:/ Immediate first aid: Ensure that adequate decontamination has been carried out. If patient is not breathing, start artificial respiration, preferably with a demand valve resuscitator, bag-valve-mask device, or pocket mask, as trained. Perform CPR if necessary. Immediately flush contaminated eyes with gently flowing water. Do not induce vomiting. If vomiting occurs, lean patient forward or place on the left side (head-down position, if possible) to maintain an open airway and prevent aspiration. Keep patient quiet and maintain normal body temperature. Obtain medical attention. /Poisons A and B/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 160] **PEER REVIEWED** /SRP:/ Basic treatment: Establish a patent airway (oropharyngeal or nasopharyngeal airway, if needed). Suction if necessary. Watch for signs of respiratory insufficiency and assist ventilations if needed. Administer oxygen by nonrebreather mask at 10 to 15 L/min. Monitor for pulmonary edema and treat if necessary ... . Monitor for shock and treat if necessary ... . Anticipate seizures and treat if necessary ... . For eye contamination, flush eyes immediately with water. Irrigate each eye continuously with 0.9% saline (NS) during transport ... . Do not use emetics. For ingestion, rinse mouth and administer 5 mL/kg up to 200 mL of water for dilution if the patient can swallow, has a strong gag reflex, and does not drool ... . Cover skin burns with dry sterile dressings after decontamination ... . /Poisons A and B/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 160] **PEER REVIEWED** /SRP:/ Advanced treatment: Consider orotracheal or nasotracheal intubation for airway control in the patient who is unconscious, has severe pulmonary edema, or is in severe respiratory distress. Positive-pressure ventilation techniques with a bag valve mask device may be beneficial. Consider drug therapy for pulmonary edema ... . Consider administering a beta agonist such as albuterol for severe bronchospasm ... . Monitor cardiac rhythm and treat arrhythmias as necessary ... . Start IV administration of D5W /SRP: "To keep open", minimal flow rate/. Use 0.9% saline (NS) or lactated Ringer's if signs of hypovolemia are present. For hypotension with signs of hypovolemia, administer fluid cautiously. Watch for signs of fluid overload ... . Treat seizures with diazepam or lorazepam ... . Use proparacaine

hydrochloride to assist eye irrigation ... . /Poisons A and B/[Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 160-1] **PEER REVIEWED**

Animal Toxicity Studies:

Non-Human Toxicity Excerpts:

/LABORATORY ANIMALS: Acute Exposure/ Eye irritation was scored 9 on a 10-grade scale 24 hours after application of **trimethylolpropane triacrylate**. By a Draize test, instillation of **trimethylolpropane triacrylate** into rabbit eyes induced irritation and reversible corneal opacity for 7 days.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

/LABORATORY ANIMALS: Acute Exposure/ The NTP conducted a contact hypersensitivity study in conjunction with a subchronic study of technical grade **trimethylolpropane triacrylate**. It was not shown to be a skin sensitizer in female BALB/c mice. Although there was a significant trend toward increased responses at doses of 0.05%, 0.1%, and 0.25% in the murine local lymph node assay (LLNA), no individual dose was significantly different from the vehicle control and the highest response did not reach the threefold stimulation index suggested for a positive in the LLNA. **Trimethylolpropane triacrylate** was negative in a mouse ear swelling test. In the same study, **trimethylolpropane triacrylate** was positive in the murine irritancy assay at concentrations of 0.05%, 0.25%, and 0.5% when applied directly to the skin.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

/LABORATORY ANIMALS: Acute Exposure/ /Investigators/ immunized outbred male and female Hartley guinea pigs (number not specified) with subcutaneous injection into the footpad and the nape of the neck with 0.1 mL of an emulsion containing **trimethylolpropane triacrylate** in ethanol:saline (1:4) in FCA. The total **trimethylolpropane triacrylate** dose was 11.5 umol. Skin tests of 0.02 mL of 0.25% or 0.5% **trimethylolpropane triacrylate** in acetone:olive oil (4:1) were then applied to the shaved flank of the guinea pig, and reactions were recorded at 24, 48, 72, and 96 hours. Skin reactions were graded on a scale of 0 (no reaction) to 3 (severe reaction). On day 7, the reactions for both concentrations were mild at 24 hours and moderate at 48 hours; the 24- and 48-hour reactions on day 14 were moderate.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

/LABORATORY ANIMALS: Acute Exposure/ In a maximization test of acrylates and methacrylate esters, outbred female SSc:AL guinea pigs were induced with three 2 x 50 uL intradermal injections, including one of FCA in sterile water and one each of a test compound (methyl methacrylate, ethyleneglycol dimethacrylate, triethyleneglycol dimethacrylate, or trimethylolpropane trimethylacrylate) in soybean oil and in a mixture of emulsified FCA and water. On day 7, approximately 250 mg of 10% sodium lauryl sulfate in petrolatum was applied to the neck and left uncovered for 24 hours. On day 8, the test compound or petrolatum (400 uL) was applied to a filter paper patch that was applied to the flank and left in place for 48 hours. On day 21, the guinea pigs were challenged with up to six patches containing 25 uL of the sensitizing compound: 2-hydroxy-methacrylate, 1,6-hexane diolodiacrylate, pentaerythritol triacrylate, or **trimethylolpropane triacrylate**. Sensitization determinations were made at 48 and 72 hours. The treatment was repeated on the opposite flank of each animal after 35 days. Positive skin sensitization reactions occurred in 14 of 19 guinea pigs induced with trimethylolpropane trimethylacrylate and challenged with 2% **trimethylolpropane triacrylate**; animals induced with the other test chemicals did not have cross reactions with **trimethylolpropane triacrylate**.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

/LABORATORY ANIMALS: Acute Exposure/ In a maximization test to determine skin sensitivity and cross-sensitivity reactions, groups of 15 female albino Dunkin/Hartley guinea pigs were sensitized topically with 25% solutions of commercial-grade pentaerythritol tri- or tetraacrylate in petrolatum and then challenged with two applications on the flank, 1 week apart, of 0.015 g pentaerythritol tri- or tetraacrylate (commercial grade and purified) or **trimethylolpropane triacrylate** in petrolatum. A booster of the sensitizing chemical was administered intradermally on the neck 48 hours after the first challenge. Of the 10 animals that became sensitized to commercial-grade pentaerythritol triacrylate, seven also reacted to **trimethylolpropane triacrylate**. Only one guinea pig became sensitized to commercial grade pentaerythritol tetraacrylate; this

animal also reacted to **trimethylolpropane triacrylate**. These results indicated that pentaerythritol triacrylate was the more potent sensitizer and that guinea pigs sensitized to pentaerythritol triacrylate may cross-react to **trimethylolpropane triacrylate**.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ Groups of 10 female albino Hartley/Dalkin guinea pigs were induced and then challenged with **trimethylolpropane triacrylate**. Three intradermal injections were administered to each shoulder: 0.1 mL of a 0.5% or 10% solution of **trimethylolpropane triacrylate** in propylene glycol; 0.05 mL Freund's Complete Adjuvant (FCA) and 0.05 mL of a 0.5% or 10% solution of **trimethylolpropane triacrylate** in propylene glycol; and 0.1 mL FCA. After 1 week, 0.5% or 10% **trimethylolpropane triacrylate** in petrolatum was applied to the animals' shaved shoulders, which were then wrapped for 48 hours. The animals were challenged 2 weeks after the topical exposure with skin patches of nonirritant concentrations of **trimethylolpropane triacrylate** for 24 hours. Four guinea pigs that were administered 0.5% **trimethylolpropane triacrylate** and 10 of 20 guinea pigs administered the 10% solution became sensitized; the intradermal sensitivity concentration for 50% of the animals was determined to be 5.4%. [DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Acute Exposure/ **Trimethylolpropane triacrylate** was administered undiluted or in acetone or mineral oil to the interscapular region of male C3H/HeJ mice. All five mice administered 50 mg undiluted **trimethylolpropane triacrylate** died 1 day after treatment; clinical findings included lethargy, inactivity, and salivation shortly after application.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ B6C3F1 mice were administered up to 12 mg/kg **trimethylolpropane triacrylate** in acetone topically, 5 days per week for 14 weeks. All mice survived to the end of the study without an effect on body weight. In males and females administered 12 mg/kg **trimethylolpropane triacrylate**, irritation at the site of application was observed. Nonneoplastic skin lesions including epidermal hyperplasia, hyperkeratosis, necrosis, and chronic inflammation were observed at the site of application in males and females.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ F344/N rats were treated topically with up to 12 mg/kg **trimethylolpropane triacrylate** in acetone 5 days per week for 14 weeks. All rats survived to the end of the study with no effect on body weight. Irritation at the site of application was observed in half of males and all females receiving 12 mg/kg **trimethylolpropane triacrylate**. At the site of application, nonneoplastic skin lesions including epidermal hyperplasia and chronic inflammation were observed in males and females. [DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ A group of three mice administered 50 mg of a 10% solution in acetone twice per week for 2 weeks developed epilated, crusty, severely burned skin. Very slight crusting of the skin was observed in mice treated with 50 mg of a 5% solution in mineral oil twice per week for 5 weeks.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Chronic Exposure or Carcinogenicity/ ... Trimethylolpropanetriacrylate (**TMPTA**) and pentaerythritol triacrylate (PETA) are industrially important representatives of multifunctional acrylates. The current studies characterized the toxicity of 3-month topical administration of technical grade **TMPTA** and PETA in F344/N rats and B6C3F1 mice, and evaluated the carcinogenic potential of **TMPTA** and PETA in hemizygous Tg.AC (v-Ha-ras) transgenic mice. Administration of 0.75, 1.5, 3, 6, and 12 mg/kg **TMPTA** and PETA for 3 months resulted in hyperplastic, degenerative, and necrotic lesions, accompanied by chronic inflammation of the skin, with severities generally increasing with dose. Lesions were slightly more severe in rats, when compared with mice, and illustrate the irritant potential of **TMPTA** and PETA. A similar dosage regimen was used for the 6-month study with Tg.AC mice. Topical application of **TMPTA** and PETA to Tg.AC mice showed dose-dependent increases in squamous cell papillomas at the site of application, with decreases in the latency of their appearance in mice receiving 3 mg/kg or greater. Papillomas, the reporter phenotype in Tg.AC mice, were accompanied by a few squamous cell carcinomas, along with hyperplastic and inflammatory lesions. Although chronic inflammation might have

contributed to the development of the skin lesions, the dose-related nature of the induction of the skin papillomas in Tg.AC mice by **TMPTA** and PETA may reflect a potential for carcinogenicity.[Doi AM et al; Toxicol Pathol 33 (6): 631-40 (2005)] **PEER REVIEWED** PubMed Abstract /LABORATORY ANIMALS: Chronic Exposure or Carcinogenicity/ Under the conditions of these 2-year dermal studies, there was some evidence of carcinogenic activity of **trimethylolpropane triacrylate** in male F344/N rats based on increased incidences of malignant mesothelioma. There was no evidence of carcinogenic activity of **trimethylolpropane triacrylate** in female F344/N rats administered 0.3, 1.0, or 3.0 mg/kg. There was no evidence of carcinogenic activity of **trimethylolpropane triacrylate** in male B6C3F1/N mice administered 0.3, 1.0, or 3.0 mg/kg. There was some evidence of carcinogenic activity of **trimethylolpropane triacrylate** in female B6C3F1/N mice based on increased incidences of uncommon malignant hepatic neoplasms (hepatoblastoma and hepatocholangiocarcinoma) and stromal polyp or stromal sarcoma of the uterus.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /LABORATORY ANIMALS: Chronic Exposure or Carcinogenicity/ No neoplasms occurred in 50 male C3H/HeJ mice dermally administered 100 mg/kg of a solution of 5% **trimethylolpropane triacrylate** in mineral oil to the interscapular region twice per week for up to 80 weeks. Ten percent of the group was examined histologically. Slight epilation of the skin was noted at the site of application; in addition, acanthosis of the epidermis occurred in 46 mice and fibrosis of the dermis in 38 mice. No lesions were noted in control mice. [DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /GENOTOXICITY/ ... Tests with the **trimethylolpropane triacrylate** cross-linked polymer ... showed no induction of unscheduled DNA synthesis in rat primary hepatocyte cultures and no increase in the incidence of chromosomal aberrations in bone marrow of male or female rats administered the **trimethylolpropane triacrylate** cross-linked polymer as slurries by oral gavage in amounts up to 16 mL/kg. The **trimethylolpropane triacrylate** monomer was positive in tests for chromosomal aberration induction in CHO cells and in mouse lymphoma L5178Y tk+/- cells, producing dose-related increases in aberrations in both systems over dose ranges that reached 0.7 ug/mL.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /GENOTOXICITY/ **Trimethylolpropane triacrylate** monomer, at doses of 0.6, 0.65, and 0.7 ug/mL, was tested in mouse lymphoma L5178Y tk+/- cells, in the absence of exogenous metabolic activation, for induction of forward mutations at the tk locus, and induction of chromosomal aberrations and micronuclei. Significant dose-related increases were observed for all three endpoints; mutant tk colonies were almost exclusively small in size, indicative of the induction of large deletions or other chromosomal alterations rather than point mutations. [DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /GENOTOXICITY/ No increase in the frequency of micronucleated normochromatic erythrocytes (NCEs) was observed in peripheral blood samples from male or female mice administered dermal applications of 0.75 to 12 mg **trimethylolpropane triacrylate**/kg body weight for 3 or 6 months. In the 3-month study, ratios of micronucleated polychromatic erythrocytes (PCEs) to NCEs in peripheral blood were unaltered by chemical treatment, indicating an absence of induced bone marrow toxicity. However, in the 6-month study, increases in the percentage of PCEs were noted in 12 mg/kg male and female mice, indicating a stimulation of erythropoiesis and the presence of increased numbers of immature erythrocytes in circulating blood.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /GENOTOXICITY/ Nine acrylate/methacrylate esters were tested for the induction of mutations, aberrations and micronuclei in cultured L5178Y mouse lymphoma cells without exogenous activation. With the exception of 2-ethylhexyl acrylate, and dicyclopentenyloxyethyl methacrylate which produced equivocal mutagenic responses, the other seven compounds (2-hydroxyethyl acrylate, dicyclopentenyloxyethyl acrylate, tetraethylene glycol diacrylate, tetraethylene glycol dimethacrylate, **trimethylolpropane triacrylate**, trimethylolpropane trimethacrylate, and pentaerythritol triacrylate) produced positive mutagenic responses with different potencies. For the mutagenic acrylates/methacrylates, primarily small-colony, trifluorothymidine (TFT)-resistant mutants were induced, suggesting a clastogenic mechanism that was supported by increased aberrations and micronucleus frequencies (except for trimethylolpropane trimethacrylate which was positive for aberration but not micronucleus induction). Generally, it was found that multifunctional compounds (esters with greater than 1 functional vinyl group) required lower concentrations than monofunctional compounds to induce maximal

cytotoxic, mutagenic, and clastogenic responses. ...[Dearfield KL et al; Mutagenesis 4 (5): 381-93 (1989)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ ... In the present study, /investigators/ have compared the standard monolayer assay with a suspension adapted CHO assay that uses cell numbers comparable to that of the L5178Y mouse lymphoma assay. Nine compounds, ethyl methanesulfonate (EMS), methyl methanesulfonate (MMS), 2-methoxy-6-chloro-9-[3-(ethyl-2-chloroethyl)-aminopropylamino]-acridine 2HCl (ICR 170), methyl acrylate, ethyl acrylate, tetraethylene glycol diacrylate, **trimethylolpropane triacrylate**, 2-ethylhexyl acrylate and dicyclopentenyloxyethyl methacrylate were evaluated in the monolayer and suspension assays. Both assays gave the same overall qualitative results for the test compounds. There were some quantitative differences in the mutant frequency for the three compounds found to be mutagenic (EMS, MMS and ICR 170). The acrylates (many of which appear to exert their genotoxic effect through a clastogenic mechanism) were negative in both test systems. ...[Moore MM et al; Mutagenesis 6 (1): 77-85 (1991)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ Three cross-linked polyacrylate polymers containing either methylenebis-acrylamide (MBA), **trimethylolpropane triacrylate** (**TMPTA**), or triallylamine (TAA) cross-linkers were tested for genotoxicity with the Salmonella mammalian microsome assay, the L5178Y mouse lymphoma TK +/- assay, the unscheduled DNA synthesis assay in primary cultures of rat hepatocytes, and the in vivo bone marrow cytogenetic assay. The results indicate that none of the three polymers was genotoxic in these assays.[Thompson ED et al; Environ Mol Mutagen 18 (3): 184-99 (1991)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ ... Four multifunctional acrylates and acrylic acid were tested for mutagenicity in the Salmonella typhimurium and mouse lymphoma L5178Y TK+/-assays. In the Salmonella assay, two of the compounds (**trimethylolpropane triacrylate** and trimethylolpropanetrimethacrylate) showed weakly positive results with a single tester strain (TA1535) in the presence of hamster liver S9; the other three compounds were negative. All five compounds were negative in the Salmonella assay without S9 activation. In the mouse lymphoma assay, two of the compounds (acrylic acid and ethylene glycol diacrylate) were positive in both the presence and the absence of S9, one compound was positive only in the presence of S9 (ethylene glycol dimethacrylate), and one compound was positive only in the absence of S9 (**trimethylolpropane triacrylate**). [Cameron TP et al; Environ Mol Mutagen 17 (4): 264-71 (1991)] **PEER REVIEWED** PubMed Abstract /GENOTOXICITY/ **Trimethylolpropane triacrylate** monomer (79% pure) demonstrated weak mutagenic activity in Salmonella typhimurium strain TA1535 when testing occurred in the presence of hamster liver S9 activation enzymes; negative results were obtained with other strains, with and without induced rat or hamster liver S9 enzymes. Tests conducted with the cross-linked polymer (molecular weights that ranged up to 1,000,000), using concentrations up to 6,666 ug/plate, showed no mutagenic activity in any of several strains of S. typhimurium, with or without exogenous metabolic activation derived from induced rat liver.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** /IMMUNOTOXICITY/ The immunogenicities of two acrylate chemicals, **trimethylolpropane triacrylate** (**TMPTA**) and methyl acrylate (MeAc), and one related vinyl compound, 4-vinyl pyridine (4VP), were investigated by determining the in vivo induction of IgG antibodies in guinea pigs. The injection of the chemicals emulsified in Freund's complete adjuvant resulted in the induction of serum antibody responses against MeAc and 4VP but not **TMPTA**. However, antibody with anti-**TMPTA** activity was produced following immunization of guinea pigs with **TMPTA** conjugated to protein, which allowed comparisons to be made of the immunogenic structural features of the compounds.[Bull JE et al; Int Arch Allergy Appl Immunol 83 (3): 310-4 (1987)] **PEER REVIEWED** PubMed Abstract

National Toxicology Program Studies:

Groups of 65 male and 65 female mice received dermal applications of 0, 0.3, 1.0, or 3.0 mg **trimethylolpropane triacrylate**/kg body weight in acetone, 5 days per week for 105 to 106 weeks (core study). At 2 weeks, 13 weeks, and 12 months, five animals per sex per dose group were randomly selected for histological examination of skin tissue. Survival and mean body weights of all dosed groups were similar to those of the vehicle control groups. Liver neoplasms in female mice included hepatoblastoma in the 0.3 and 3.0 mg/kg groups and hepatocholangiocarcinoma in the 1.0 and 3.0 mg/kg groups. Based on the rarity of these neoplasms in female mice, and their absence in the concurrent vehicle controls, hepatoblastoma and hepatocholangiocarcinoma were considered to be treatment-related lesions. The incidences of uterine stromal polyp and stromal polyp or stromal sarcoma (combined) in female mice occurred with positive trends, and the

incidences were significantly increased in the 3.0 mg/kg group. Compared to the vehicle control incidences, the incidences of epidermal hyperplasia, melanocyte hyperplasia, and chronic inflammation at the site of application were significantly increased in core study males and females administered 3.0 mg/kg; incidences of epidermal hyperplasia in 1.0 mg/kg females and chronic inflammation in 1.0 mg/kg males were also significantly increased. At the interim evaluations, increased incidences of epidermal hyperplasia and inflammation or chronic active inflammation were observed at the site of application in males and females.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** Groups of 65 male and 65 female rats received dermal applications of 0, 0.3, 1.0, or 3.0 mg **trimethylolpropane triacrylate**/kg of body weight in acetone, 5 days per week for 104 to 105 weeks (core study). At 2 weeks, 13 weeks, and 12 months, five animals per sex per dose group were randomly selected for histological examination of skin tissue. Survival and mean body weights of all dosed groups were similar to those of the vehicle control groups. In male rats, there was a positive trend in the incidences of malignant mesothelioma; the incidence in 3.0 mg/kg males was significantly greater than the vehicle control incidence. Nonneoplastic skin lesions at the site of application in core study rats included epidermal hyperplasia and hyperkeratosis. The incidences of these lesions in male rats administered 1.0 or 3.0 mg/kg were significantly increased. In females at the site of application, incidences of epidermal hyperplasia were significantly increased at 1.0 and 3.0 mg/kg and incidences of hyperkeratosis were significantly increased in all dosed groups. At the interim evaluations, increased incidences of epidermal hyperplasia, sebaceous gland hyperplasia, and or hyperkeratosis were observed at the site of application in males and females.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** **Trimethylolpropane triacrylate** (1,500 to 10,000 ug per plate) did not induce gene mutations in S. typhimurium strains TA98 or TA100 or in E. coli strain WP2 uvrA/pKM101, with or without exogenous metabolic activation.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

Non-Human Toxicity Values:

LD50 Rabbit skin 5170 mg/kg[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 3591] **PEER REVIEWED** LD50 Rat oral 5190 mg/kg[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 3591] **PEER REVIEWED**

Ongoing Test Status:

The following link will take the user to the National Toxicology Program (NTP) Test Agent Search Results page, which tabulates all of the "Standard Toxicology & Carcinogenesis Studies", "Developmental Studies", and "Genetic Toxicity Studies" performed with this chemical. Clicking on the "Testing Status" link will take the user to the status (i.e., in review, in progress, in preparation, on test, completed, etc.) and results of all the studies that the NTP has done on this chemical.[Available from, as of June 21, 2012: http://ntp-apps.niehs.nih.gov/ntp_tox/index.cfm?fuseaction=ntpsearch.searchresults&searchterm=15625-89-5] Metabolism/ Pharmacokinetics:

Absorption, Distribution & Excretion:

In male B6C3F1 mice, 75% of the dose was absorbed 72 hours after a single application of 1.2 mg/kg. The percent dose remaining at the dose site was higher in mice (31%) than in rats (9%). Approximately 42% of the applied dose was recovered in urine, feces, and exhaled carbon dioxide 72 hours after application, an amount similar to that excreted by rats (45%) following dermal application of 1.7 mg/kg. The radioactivity associated with tissues at 72 hours was less than 1%. The nonapplication site skin had an elevated tissue:blood ratio. [DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** Metabolism and disposition of (14)C-**trimethylolpropane triacrylate** was investigated in male F344/N rats and

B6C3F1 mice following single intravenous administration and dermal application (protected from oral grooming). In male rats, the percent dose absorbed was 55.7%, 32.7%, or 18.7% at 72 hours following dermal application of 1.7, 15.2, or 130 mg/kg. In mass terms, approximately five times more **trimethylolpropane triacrylate** was absorbed as the dose concentration increased by one order of magnitude. About 9% of the dose was recovered from the dose site regardless of the applied dose. About 45%, 19%, or 5% of the applied dose was recovered in the excreta 72 hours after dermal application of 1.7, 15.2, or 130 mg/kg, respectively. The radioactivity associated with tissues at 72 hours was less than 1%. The kidney had elevated tissue:blood ratios at each dose. Following intravenous administration of 9.4 mg/kg (14)C-**trimethylolpropane triacrylate** in male rats, a total of 77.4% of the applied dose was excreted in urine, feces, and exhaled carbon dioxide 72 hours after administration. Among the tissues collected, the highest radiolabeled concentration was associated with blood. [DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED** After a single 124 mg/kg dermal application of (14)C-**trimethylolpropane triacrylate** in male rats followed by tape stripping the application site at 72 hours, most of the radioactivity associated with the dose site was **trimethylolpropane triacrylate** thereby confirming that the test article was stable on the skin.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

Environmental Fate & Exposure:

Environmental Fate/Exposure Summary:

Trimethylolpropane triacrylate's production and use as a multifunctional monomer, cross-linking agent, reactive diluent, and chemical intermediate and use in producing inks, coatings, varnishes, paints and resins may result in its release to the environment through various waste streams. If released to air, an estimated vapor pressure of 5.9X10-4 mm Hg at 25 deg C indicates **trimethylolpropane triacrylate** will exist solely as a vapor phase in the atmosphere. Vapor-phase **trimethylolpropane triacrylate** will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 11 hours. Vapor-phase **trimethylolpropane triacrylate** will also be degraded in the atmosphere by reaction with ozone; the half-life for this reaction in air is estimated to be 2 days. **Trimethylolpropane triacrylate** is reported to be light sensitive and may undergo spontaneous polymerization when exposed to direct sunlight; therefore, direct photolysis may be important in aer. If released to soil, **trimethylolpropane triacrylate** is expected to have moderate to low mobility based upon an estimated Koc values of 207 and 1510. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 6X10-10 atm-cu m/mole. **Trimethylolpropane triacrylate's** estimated vapor pressure suggests that volatilize from dry soil surfaces will not be important fate process; however, **trimethylolpropane triacrylate** is a liquid with a noticeable acrylic odor suggesting some volatilization may occur. A 19% of theoretical BOD using the Japanese MITI test suggests that some biodegradation may occur in soil and water; in the 4-week biodegradation test, 87% of initial **trimethylolpropane triacrylate** was degraded yielding the di- and monoacrylate esters plus trimethylolpropane. If released into water, **trimethylolpropane triacrylate** is expected to have some adsorption to suspended solids and sediment based upon the estimated Koc values. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. An estimated BCF of 30 suggests the potential for bioconcentration in aquatic organisms is low which is consistent with test results using carp. Base-catalyzed hydrolysis in water is relatively slow with estimated half-lives of 9 years and 331 days at pH 7 and pH 8, respectively. Photodegradation may occur in water exposed to sunlight. Occupational exposure to **trimethylolpropane triacrylate** may occur through inhalation and dermal contact with this compound at workplaces where **trimethylolpropane triacrylate** is produced or used. Workers involved in the manufacturing, processing, product handling, and application of **trimethylolpropane triacrylate** are at risk of exposure. A potential exists for widespread exposure of consumers through the use of **trimethylolpropane triacrylate** in products such as latex paints and furniture and floor polishes. (SRC) **PEER REVIEWED**

Probable Routes of Human Exposure:

According to the 2006 TSCA Inventory Update Reporting data, the number of persons reasonably likely to be exposed in the industrial manufacturing, processing, and use of **trimethylolpropane triacrylate** is 1000 or greater; the data may be greatly underestimated(1).[(1) US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of July 12, 2012: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED** NIOSH (NOES Survey 1981-1983) has statistically estimated that 5,274 workers (809 of these were female) were potentially exposed to **trimethylolpropane triacrylate** in the US(1). Occupational exposure to **trimethylolpropane triacrylate** may occur through inhalation and dermal contact with this compound at workplaces where **trimethylolpropane triacrylate** is produced or used(SRC). Workers involved in the manufacturing, processing, product handling, and application of **trimethylolpropane triacrylate** are at risk of exposure(2). A potential exists for widespread exposure of consumers through the use of **trimethylolpropane triacrylate** in products such as latex paints and furniture and floor polishes(2).[(1) NIOSH; NOES. National Occupational Exposure Survey conducted from 1981-1983. Estimated numbers of employees potentially exposed to specific agents by 2-digit standard industrial classification (SIC). Available from, as of July 12, 2012: http://www.cdc.gov/noes/ (2) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012; Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Artificial Pollution Sources:

Trimethylolpropane triacrylate's production and use as a multifunctional monomer, cross-linking agent, reactive diluent, and chemical intermediate and use in producing inks, coatings, varnishes, paints and resins(1) may result in its release to the environment through various waste streams(SRC).[(1) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Environmental Fate:

TERRESTRIAL FATE: Based on a classification scheme(1), an estimated Koc value of 1510(SRC), determined from a structure estimation method(2), indicates that **trimethylolpropane triacrylate** is expected to have low mobility in soil(SRC). Volatilization of **trimethylolpropane triacrylate** from moist soil surfaces is not expected to be an important fate process(SRC) given an estimated Henry's Law constant of 6X10-10 atm-cu m/mole(SRC), using a fragment constant estimation method(2). **Trimethylolpropane triacrylate's** estimated vapor pressure of 5.9X10-4 mm Hg at 25 deg C(SRC), determined from a fragment constant method(2), suggests that volatilization from dry soil surfaces will not be important fate process(SRC); however, **trimethylolpropane triacrylate** is a liquid with a noticeable acrylic odor(3) suggesting some volatilization may occur(SRC). A 19% of theoretical BOD using activated sludge in the Japanese MITI test(4) suggests that some biodegradation may occur in soil(SRC); in the 4-week biodegradation test, 87% of initial **trimethylolpropane triacrylate** was degraded yielding the di- and monoacrylate esters plus trimethylolpropane(4).[(1) Swann RL et al; Res Rev 85: 17-28 (1983) (2) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm (3) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/ (4) NITE; Chemical Risk Information Platform (CHRIP). Biodegradation and Bioconcentration. Tokyo, Japan: Natl Inst Tech Eval. Available from, as of July 12, 2012: http://www.safe.nite.go.jp/english/db.html] **PEER REVIEWED** AQUATIC FATE: Based on a classification scheme(1), an estimated Koc value of 1510(SRC), determined from a structure estimation method(2), indicates that **trimethylolpropane triacrylate** is expected to adsorb to suspended solids and sediment(SRC). Volatilization from water surfaces is not expected(3) based upon an estimated Henry's Law constant of 6X10-10 atm-cu m/mole(SRC), developed using a fragment constant estimation method(2). According to a classification scheme(4), an estimated BCF of 30(SRC), from a log Kow of 2.75(5) and a regression-derived equation(2), suggests the potential for bioconcentration in aquatic organisms is low. Bioconcentration tests using 6 or 8 week exposures found low bioconcentration(6). A base-catalyzed second-order hydrolysis rate constant of 0.0242 L/mole-sec at 25 deg C(SRC) was estimated using a structure

estimation method(7); this corresponds to half-lives of 9 years and 331 days at pH values of 7 and 8, respectively(SRC). A 19% of theoretical BOD using activated sludge in the Japanese MITI test(6) suggests that some biodegradation may occur in soil(SRC); in the 4-week biodegradation test, 87% of initial **trimethylolpropane triacrylate** was degraded yielding the di- and monoacrylate esters plus trimethylolpropane(6).[(1) Swann RL et al; Res Rev 85: 17-28 (1983) (2) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm (3) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Washington, DC: Amer Chem Soc pp. 15-1 to 15-29 (1990) (4) Franke C et al; Chemosphere 29: 1501-14 (1994) (5) Edelbach DJ, Lodge KB; Phys Chem Chem Phys 2: 1763-1771 (2000) (6) NITE; Chemical Risk Information Platform (CHRIP). Biodegradation and Bioconcentration. Tokyo, Japan: Natl Inst Tech Eval. Available from, as of July 12, 2012: http://www.safe.nite.go.jp/english/db.html (7) Mill T et al; Environmental Fate and Exposure Studies Development of a PC-SAR for Hydrolysis: Esters, Alkyl Halides and Epoxides. EPA Contract No. 68-02-4254. Menlo Park, CA: SRI International (1987)] **PEER REVIEWED** ATMOSPHERIC FATE: According to a model of gas/particle partitioning of semivolatile organic compounds in the atmosphere(1), **trimethylolpropane triacrylate**, which has an estimated vapor pressure of 5.9X10-4 mm Hg at 25 deg C(SRC), determined from a fragment constant method(2), is expected to exist solely as a vapor in the ambient atmosphere. Vapor-phase **trimethylolpropane triacrylate** is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals(SRC); the half-life for this reaction in air is estimated to be 11 hours(SRC), calculated from its rate constant of 3.4X10-11 cu cm/molecule-sec at 25 deg C(SRC) that was derived using a structure estimation method(2). Vapor-phase **trimethylolpropane triacrylate** is also degraded in the atmosphere by reaction with ozone(SRC); the half-life for this reaction in air is estimated to be 2 days(SRC), calculated from its rate constant of 5.25X10-18 cu cm/molecule-sec at 25 deg C(SRC) that was derived using a structure estimation method(2). **Trimethylolpropane triacrylate** is reported to be light sensitive when exposed to direct sunlight(3); therefore, direct photolysis may have some importance in the environment(SRC).[(1) Bidleman TF; Environ Sci Technol 22: 361-367 (1988) (2) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm (3) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Environmental Biodegradation:

AEROBIC: **Trimethylolpropane triacrylate**, present at 100 mg/L, reached 19% of its theoretical BOD in 4 weeks using an activated sludge inoculum at 30 mg/L in the Japanese MITI test(1); however, total degradation of **trimethylolpropane triacrylate** was 87% over the 4-week period with the formation of the diacrylate and monoacrylate esters plus trimethylolpropane(1).[(1) NITE; Chemical Risk Information Platform (CHRIP). Biodegradation and Bioconcentration. Tokyo, Japan: Natl Inst Tech Eval. Available from, as of July 12, 2012: http://www.safe.nite.go.jp/english/db.html] **PEER REVIEWED**

Environmental Abiotic Degradation:

The rate constant for the vapor-phase reaction of **trimethylolpropane triacrylate** with photochemically-produced hydroxyl radicals has been estimated as 3.4X10-11 cu cm/molecule-sec at 25 deg C(SRC) using a structure estimation method(1). This corresponds to an atmospheric half-life of about 11 hours at an atmospheric concentration of 5X10+5 hydroxyl radicals per cu cm(1). The rate constant for the vapor-phase reaction of **trimethylolpropane triacrylate** with ozone has been estimated as 5.25X10-18 cu cm/molecule-sec at 25 deg C(SRC) that was derived using a structure estimation method(1) which corresponds to an atmospheric half-life of about 2 days at an atmospheric concentration of 7X10+11 ozone molecules per cu cm(1). A base-catalyzed second-order hydrolysis rate constant of 0.0242 L/mole-sec at 25 deg C(SRC) was estimated using a structure estimation method(2); this corresponds to half-lives of 9 years and 331 days at pH values of 7 and 8, respectively(SRC). **Trimethylolpropane triacrylate** is reported to be light sensitive and may undergo spontaneous polymerization when exposed to direct sunlight(3); therefore, photodegradation may have some importance in the environment(SRC).[(1) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm

(2) Mill T et al; Environmental Fate and Exposure Studies Development of a PC-SAR for Hydrolysis: Esters, Alkyl Halides and Epoxides. EPA Contract No. 68-02-4254. Menlo Park, CA: SRI International (1987) (3) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Environmental Bioconcentration:

An estimated BCF of 30 was calculated in fish for **trimethylolpropane triacrylate**(SRC), using a log Kow of 2.75(1) and a regression-derived equation(2). According to a classification scheme(3), this BCF suggests the potential for bioconcentration in aquatic organisms is low(SRC). Based on exposure periods of 6 or 8 weeks in flow-through tests, the bioconcentration potential of **trimethylolpropane triacrylate** in carp has been classified as low (actual BCF values not reported)(4).[(1) Edelbach DJ, Lodge KB; Phys Chem Chem Phys 2: 1763-1771 (2000) (2) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm (3) Franke C et al; Chemosphere 29: 1501-14 (1994) (4) NITE; Chemical Risk Information Platform (CHRIP). Biodegradation and Bioconcentration. Tokyo, Japan: Natl Inst Tech Eval. Available from, as of July 12, 2012: http://www.safe.nite.go.jp/english/db.html] **PEER REVIEWED**

Soil Adsorption/Mobility:

Using a structure estimation method based on molecular connectivity indices(1), the Koc of **trimethylolpropane triacrylate** can be estimated to be 1510(SRC). According to a classification scheme(2), this estimated Koc value suggests that **trimethylolpropane triacrylate** is expected to have low mobility in soil.[(1) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm (2) Swann RL et al; Res Rev 85: 17-28 (1983)] **PEER REVIEWED**

Volatilization from Water/Soil:

The Henry's Law constant for **trimethylolpropane triacrylate** is estimated as 6X10-10 atm-cu m/mole(SRC) using a fragment constant estimation method(1). This Henry's Law constant indicates that **trimethylolpropane triacrylate** is expected to be essentially nonvolatile from water surfaces(2). **Trimethylolpropane triacrylate's** Henry's Law constant indicates that volatilization from moist soil surfaces is not expected to occur(SRC). **Trimethylolpropane triacrylate's** estimated vapor pressure of 5.9X10-4 mm Hg at 25 deg C(SRC), determined from a fragment constant method(1), suggests that volatilize from dry soil surfaces will not be important fate process(SRC); however, **trimethylolpropane triacrylate** is a liquid with a noticeable acrylic odor(3) suggesting some volatilization may occur(SRC).[(1) US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Washington, DC: Amer Chem Soc pp. 15-1 to 15-29 (1990) (3) NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Chemical/Physical Properties:

Molecular Formula:

C15-H20-O6[National Library of Medicine, SIS; ChemIDplus Lite Record for Trimethylolpropane triacrylate (15625-89-5). Available from, as of June 26, 2012: http://chem.sis.nlm.nih.gov/chemidplus/chemidlite.jsp] **PEER REVIEWED**

Molecular Weight:

296.316[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-512] **PEER REVIEWED**

Color/Form:

Viscous, colorless to tan liquid
[NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Odor:

Acrylic or pungent odor
[NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Density/Specific Gravity:

1.11 g/cu cm at 20 deg C[NITE; Chemical Risk Information Platform (CHRIP). Biodegradation and Bioconcentration. Tokyo, Japan: Natl Inst Tech Eval. Available from, as of July 12, 2012: http://www.safe.nite.go.jp/english/db.html] **PEER REVIEWED**

Octanol/Water Partition Coefficient:

log Kow = 2.75[Edelbach DJ, Lodge KB; Phys Chem Chem Phys 2(8): 1763-1771 (2000)] **PEER REVIEWED**

Solubilities:

Insoluble in water
[NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Spectral Properties:

Index of refraction = 1.4735 at 20 deg C
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-512] **PEER REVIEWED**

Vapor Pressure:

5.9X10-4 mm Hg at 25 deg C (est)[US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm] **PEER REVIEWED**

Other Chemical/Physical Properties:

BP: >200 deg C at 1 mm Hg
[Haynes, W.M. (ed.) CRC Handbook of Chemistry and Physics. 91st ed. Boca Raton, FL: CRC Press Inc., 2010-2011, p. 3-512] **PEER REVIEWED**

Hygroscopic, light sensitive, and incompatible with strong oxidizing agents, acids, and bases; may undergo spontaneous polymerization when exposed to direct sunlight and heat
[NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**
Henry's Law constant = 6X10-10 atm-cu m/mol at 25 deg C (est)
[US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm] **PEER REVIEWED**
Hydroxyl radical reaction rate constant = 3.4X10-11 cu cm/molecule-sec at 25 deg C (est)
[US EPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011. Available from, as of July 12, 2012: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm] **PEER REVIEWED**

Chemical Safety & Handling:

Hazardous Decomposition:

When heated to decomposition it emits acrid smoke and irritating fumes.[Lewis, R.J. Sr. (ed) Sax's Dangerous Properties of Industrial Materials. 11th Edition. Wiley-Interscience, Wiley & Sons, Inc. Hoboken, NJ. 2004., p. 3591] **PEER REVIEWED**

Disposal Methods:

SRP: The most favorable course of action is to use an alternative chemical product with less inherent propensity for occupational harm/injury/toxicity or environmental contamination. Recycle any unused portion of the material for its approved use or return it to the manufacturer or supplier. Ultimate disposal of the chemical must consider: the material's impact on air quality; potential migration in soil or water; effects on animal and plant life; and conformance with environmental and public health regulations. **PEER REVIEWED**
Occupational Exposure Standards:

Other Standards Regulations and Guidelines:

Workplace Environmental Exposure Level (WEEL): 8-hr Time-weighted Average (TWA) 1 mg/cu m, skin.[2011 Emergency Response Planning Guidelines (ERPG) & Workplace Exposure Level (WEEL). American Industrial Hygiene Association, Fairfax, VA 2011, p. 47] **PEER REVIEWED**
Manufacturing/Use Information:

Uses:

Used in the production of ultraviolet-curable inks, electron beam irradiation-curable coatings, and polymers and resins; as a component of photopolymer and flexographic printing plates and photoresists; and as an ingredient in acrylic glues and anaerobic sealants. Also used in paper and wood impregnates, wire and cable extrusion, polymer-impregnated concrete, and polymer concrete structural composites.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/?objectid=BD8DA5DC-123F-7908-7B1846717AF01C32] **PEER REVIEWED** **Trimethylolpropane triacrylate** is a multifunctional monomer with a wide range of industrial applications as a cross-linking agent, reactive diluent, and chemical intermediate. It is used in the production of ultraviolet-curable inks, electron beam irradiation-curable coatings, thermal paper, plastic hardener, optical fibers, UV-cured acrylate varnishes in the furniture industry, and polymers and resins; as a component of photopolymer and flexographic printing plates and photoresists; and as an ingredient in acrylic glues, adhesives, and anaerobic sealants. It is incorporated in colloidal dispersions for industrial baked coatings, waterborne and solvent based alkyds, and vinyl/acrylic nonwoven binders. Additionally, **trimethylolpropane triacrylate** is used in paper and wood impregnates, wire and cable extrusion, polymer-impregnated concrete, polymer concrete structural composites, and production of superabsorbent polymers for baby diapers.[NTP; NTP Technical Report on the Toxicology and Carcinogenesis Studies of Trimethylolpropane Triacrylate (Technical Grade) (CAS NO. 15625-89-5), NTP TR 576, NIH

Publication No. 12-5918, Feb 2012. Available from, as of July 12, 2012: http://ntp.niehs.nih.gov/] **PEER REVIEWED**

Manufacturers:

Sartomer USA, LLC, Oaklands Corporate Center, 502 Thomas Jones Way, Exton, PA 19341, (610) 363-4100; Production site: 610 S. Bolmar St, West Chester, PA 19382[SRI Consulting. 2011 Directory of Chemical Producers United States. SRI Consulting, Menlo Park, CA 2011, p. 907] **PEER REVIEWED**

Trimethylolpropane triacrylate - Producer and Manufacture Data (2006)

Company	Site	City State Zip	Manufacture	Import
Akzo Nobel Coatings Inc.	Akzo Nobel Coatings - Clinton	High Point NC 27261	No	Yes
BASF Corporation	BASF Corp - Corporate Headquarters	Florham Park NJ 07932	No	Yes
Cognis Corporation	Cognis Corp - Cincinnati	Cincinnati OH 45232-1446		
Congoleum Corporation	Congoleum Corporation	Mercerville NJ 08619	No	Yes
Cytec Industries Inc.	Cytec Surface Specialties Inc. - Celanese Pampa Plant	Pampa TX 79065		
Cytec Industries Inc.	Cytec Surface Specialties Inc. - North Augusta Plant	North Augusta SC 29842		
Cytec Industries Inc.	Cytec Surface Specialties Inc. - Smyrna	Smyrna GA 30080		
DynaChem Inc.	DynaChem Inc.	Georgetown IL 61846	Yes	No
FRP Services & Co. (America) Inc.	FRP Services & Co. (America) Inc.	White Plains NY 10606	No	Yes
Hexion Specialty Chemicals, Inc.	Hexion Specialty Chems - Smith Street (Corporate)	Houston TX 77002	No	Yes
Rahn USA Corp.	Rahn USA Corp - Aurora	Aurora IL 60504	No	Yes
Sartomer Company, Inc.	Sartomer Co - West Chester Plant	West Chester PA 19382		
Sartomer Company, Inc.	Sartomer Co - Chatham, VA Plant	Chatham VA 24531		
Summit Chemical Inc.	Summit Chemical Inc.	Torrance CA 90501	No	Yes
WeylChem Corporation	WeylChem Corporation	Augusta GA 30906	Yes	No

[US EPA; Inventory Update Reporting (IUR). Non-confidential 2006 IUR Records by Chemical, including Manufacturing, Processing and Use Information. Washington, DC: U.S. Environmental Protection Agency. Available from, as of July 12, 2012: http://cfpub.epa.gov/iursearch/index.cfm] **PEER REVIEWED**

Methods of Manufacturing:

Trimethylolpropane triacrylate is manufactured by esterification of trimethylolpropane; acrylic acid is a known impurity in the technical-grade compound.[DHHS/NTP; Testing Status for Trimethylolpropane triacrylate. Available from, as of June 20, 2012: http://ntp.niehs.nih.gov/NTP/About_NTP/TRPanel/2012/February/DraftTR576.pdf] **PEER REVIEWED**

General Manufacturing Information:

Ethylenimine and propylenimine react with trifunctional acrylates, such as 2-ethyl-2-(hydroxymethyl)-1,3-propanediol triacrylate ... to produce trifunctional aziridines.[Steuerle U, Feuerhake R; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2012). NY, NY: John Wiley & Sons; Aziridines. Online Posting Date: December 15, 2006] **PEER REVIEWED**

Impurities:

Trimethylolpropane triacrylate is manufactured by esterification of trimethylolpropane; acrylic acid is a known impurity in the technical-grade compound.[IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work). Available at: http://monographs.iarc.fr/ENG/Classification/index.php p. 285 (1991)] **PEER REVIEWED**

U. S. Production:

2-Propenoic acid, 2-ethyl-2-[[(1-oxo-2-propenyl)oxy]methyl]-1,3-propanediyl ester is listed as a High Production Volume (HPV) chemical (65FR81686). Chemicals listed as HPV were produced in or imported into the U.S. in >1 million pounds in 1990 and/or 1994. The HPV list is based on the 1990 Inventory Update Rule. (IUR) (40 CFR part 710 subpart B; 51FR21438).[EPA/Office of Pollution Prevention and Toxics; High Production Volume (HPV) Challenge Program. 2-Propenoic acid, 2-ethyl-2-[[(1-oxo-2-propenyl)oxy]methyl]-1,3-propanediyl ester (15625-89-5). Available from, as of June 20, 2012: http://www.epa.gov/hpv/pubs/general/opptsrch.htm] **PEER REVIEWED** Production volumes for non-confidential chemicals reported under the Inventory Update Rule.

Year	Production Range (pounds)
1986	>10 million - 50 million
1990	>1 million - 10 million
1994	>10 million - 50 million
1998	>10 million - 50 million
2002	>10 million - 50 million

[US EPA; Non-confidential Production Volume Information Submitted by Companies for Chemicals Under the 1986-2002 Inventory Update Rule (IUR). 2-Propenoic acid, 2-ethyl-2-[[(1-oxo-2-propenyl)oxy]methyl]-1,3-propanediyl ester (15625-89-5). Available from, as of June 12, 2012: http://www.epa.gov/oppt/iur/tools/data/2002-vol.html] **PEER REVIEWED** Production volume for non-confidential chemicals reported under the 2006 Inventory Update Rule. Chemical: 2-Propenoic acid, 1,1'-[2-ethyl-2-[[(1-oxo-2-propen-1-yl)oxy]methyl]-1,3-propanediyl] ester. Aggregated National Production Volume: 10 to < 50 million lbs.[US EPA; Non-Confidential 2006 Inventory Update Reporting. National Chemical Information. 2-Propenoic acid, 1,1'-[2-ethyl-2-[[(1-oxo-2-propen-1-yl)oxy]methyl]-1,3-propanediyl] ester (15625-89-5). Available from, as of June 20, 2012: http://cfpub.epa.gov/iursearch/index.cfm?s=chem&err=t] **PEER REVIEWED**

Synonyms and Identifiers:

Synonyms:

Acrylic acid, 1,1,1-(trihydroxymethyl)propane triester**PEER REVIEWED** 1,3-Propanediol, 2-ethyl-2-(hydroxymethyl)-, triacrylate**PEER REVIEWED** 2-Ethyl-2-(hydroxymethyl)-1,3-propanediol triacrylate**PEER REVIEWED**

Administrative Information:

Hazardous Substances Databank Number:

8054

Last Review Date:

Reviewed by SRP on 9/13/2012

Last Revision Date:

20130409

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