California Environmental Protection Agency
DEPARTMENT OF TOXIC SUBSTANCES CONTROL

PRIORITY PRODUCT PROFILE

CHILDREN'S FOAM-PADDED SLEEPING PRODUCTS CONTAINING TDCPP

MARCH 2014

Department of Toxic Substances Control

SAFER CONSUMER PRODUCTS

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

The mission of DTSC is to protect California's people and environment from harmful effects of toxic substances through the restoration of contaminated resources, enforcement, regulation and pollution prevention.

INTRODUCTION

Under the Department of Toxic Substances Control's (DTSC) Safer Consumer Products regulations, DTSC must publish a proposed initial Priority Products list by March 28, 2014. This draft list imposes no new regulatory requirements on product manufacturers until DTSC finalizes it by adopting regulations. This profile provides DTSCs rationale for proposing this Priority Product. To the extent practical, it follows the organization of the regulations. The section titled "Hazard Traits of the Chemical of Concern" identifies the authoritative lists[1] of chemicals on which tris(1,3-dichloro-2-propyl) phosphate (TDCPP) appears and provides additional information on the chemical's hazard traits. The "Exposures" section identifies the chemical types specified in the regulations[2] into which TDCPP falls.

Priority Product Identification

The Department of Toxic Substances Control has identified as a Priority Product children's foam-padded sleeping products with polyurethane foam that contain tris(1,3-dichloro-2-propyl) phosphate (TDCPP).

Problem Identified

TDCPP is a high production volume chemical that is commonly used as an additive flame retardant. TDCPP is found at percentage levels in flexible polyurethane foam and is a replacement for the flame retardant pentabromodiphenyl ether (pentaBDE), which was banned in California in 2006 (California Health and Safety Code section 108922) (OEHHA 2011). "Additive" flame retardants are not chemically bound to polyurethane foam and have been demonstrated to escape into indoor (and ultimately, outdoor) environments. TDCPP is a carcinogen and is associated with additional non-cancer health effects. Exposure to TDCPP in the polyurethane foam contained in consumer products may occur through dermal absorption, inhalation, or ingestion (including via hand-to-mouth exposure from contaminated dust that gets onto a child's hands).

TDCPP is known to the State of California to cause cancer. Evidence of carcinogenicity includes increased incidence of liver and kidney tumors in male and female rats and testicular tumors in male rats. TDCPP is metabolized in the body to several compounds that are also considered carcinogens. TDCPP is associated with other health effects including kidney, liver, and testicular abnormalities. Research has shown evidence of developmental toxicity, reproductive toxicity, and neurotoxicity related to TDCPP exposure.

In biomonitoring studies, TDCPP has been found in human fat, breast milk, and seminal fluid (Hudec et al. 1981; LeBel and Williams 1983; LeBel and Williams 1986; LeBel et al. 1989; Sundkvist et al. 2010). With the phase-out of pentabromodiphenyl ether (pentaBDE) as a fire retardant nationwide, and its ban in California, use of TDCPP has grown significantly, especially in flexible polyurethane foam. TDCPP is now one of the most commonly used flame retardants found in baby products with polyurethane foam (Stapleton et al. 2011). Due to

[1] Identified in subsection (a)(1) of section 69502.2 of title 22 of the California Code of Regulations.
[2] Identified in subsection (a)(2) of section 69502.2 of title 22 of the California Code of Regulations.

its ease of release from foam products, TDCPP has been detected in dust in homes, offices, automobiles, and daycare centers worldwide.

The U.S. Environmental Protection Agency (U.S. EPA) estimates that children ages 1-5 ingest on average approximately 100-200 mg dust/day; this is significantly more than adults, who on average ingest approximately 20-50 mg dust/day (U.S. EPA 2002). The Consumer Product Safety Commission (CPSC) calculated that TDCPP exposures to consumers for non-cancer health effects are above the ADI (acceptable daily intake) of 0.005 mg/kg/day. CPSC estimated that TDCPP in furniture foam alone exposes adults to twice the ADI, and exposes children to five times the ADI (Babich 2006). Further, CPSC estimated a cancer risk for a lifetime of exposure to TDCPP-treated foam-filled furniture to be 300 per million; a substance may be considered hazardous if the lifetime individual cancer risk exceeds one per million. (Babich 2006).

Priority Product Description

This Priority Product includes the following sleeping products containing polyurethane foam and tris(1,3-dichloro-2-propyl) phosphate (TDCPP):

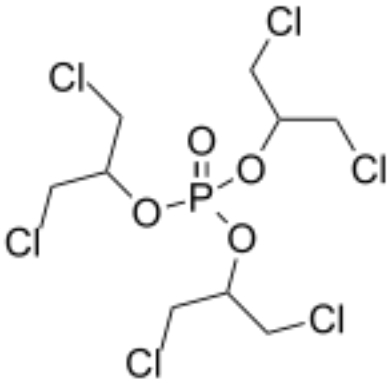
- Nap mats with polyurethane foam
- Juvenile product pads in soft-sided portable cribs
- Infant travel bed foam
- Portable infant sleeper foam
- Playard foam
- Play pen foam
- Bassinet foam
- Nap cots with foam pads
- Car bed foam pads
- Foam sleep positioners

RATIONALE FOR PRIORITY PRODUCT SELECTION

Evaluation of Adverse Impacts and Exposures

(See California Code of Regulations, title 22, section 69503.2(b)(1) and section 69503.3)

1. Chemical of Concern: TDCCP.



- Chemical Abstract Service (CAS) Registry Number: 13674-87-8
- Structure
- Molecular Formula: $OP(OCH(CH_2Cl)_2)_3$
- IUPAC and common names:
  Tris(1,3-dichloro-2-propyl) phosphate
  Tris(1,3-dichloro-2-propanyl) phosphate
  Tris (1,3-dichloroisopropyl) phosphate
  Tris(1,3-dichloropropan-2-yl) phosphate
  Tris(2-chloro-1-(chloromethyl)ethyl) phosphate
  Tris(1-chloromethyl-2-chloroethyl) phosphate
  Tris(1,3-dichloroisopropyl) phosphate
  Tris(2,2′-dichloroisopropyl) phosphate
  Tris(beta, beta'-dichloroisopropyl) phosphate
  Chloroalkyl phosphate
  Phosphoric acid tris(1,3-dichloro-2-propyl) ester
  1,3-dichloro-2-propanol phosphate (3:1)
  Chlorinated Tris
  TDCPP
  TDCP
  TCCP (NRC 2000, ChemSpider 2013).

- Trade names:
  Fyrol FR2
  Fyrol FR-2
  PF 38
  PF 38/3
  Firemaster T33P
  CRP
  Apex Flame Proof Emulsion 197 or 212
  Emulsion 212
  Antiblaze 195
  Amgard
  Amgard TDCP
  Tolgard TDCP
  Tolgard TDCP MK1
  Foforan Troj-(1,3-dwuchloroizopropylowy) [Polish]
  MDL number MFCD00083121 (NRC 2000, ChemSpider 2013; ECHA 2014).

- TDCPP meets the conditions specified in California Code of Regulations, title 22, section 69503.6(a) in that it appears on one or more of the authoritative lists in California Code of Regulations, title 22, section 69502.2(a)(1) and is one or more of the types of chemicals listed in California Code of Regulations, title 22, section 69502.2(a)(2):
  - TDCPP is listed as a carcinogen under the State of California's Proposition 65 law (Safe Drinking Water and Toxic Enforcement Action of 1986) (OEHHA 2014).
  - TDCPP is listed as a Priority Chemical by the California Environmental Contaminant Biomonitoring Program (CECBP 2013).

2. Physicochemical properties of the Chemical of Concern

(See California Code of Regulations, title 22, section 69503.3(a)(1)(D))

- Physical state: Viscous, clear liquid (ChemSpider 2013, HSDB 2013).
- Odor: Mild odor (HSDB 2013).
- Molecular weight: 430.90 g/mol (ChemSpider 2013, HSDB 2013).
- Density/Specific gravity: 1.48 kg/L at 25 °C (HSDB 2013).
- Boiling point: Between 236 and 237 °C at 5 mmHg (HSDB 2013).
- Melting point: 27 °C (OEHHA 2011).
- Flashpoint: 252 °C (Cleveland open cup method) (HSDB 2013).
- Vapor Pressure: 2.86 x 10^{-7} mmHg at 25 °C (estimated) (HSDB 2013). (Note: Different vapor pressures have been cited)
- Water Solubility: 7 mg/L at 24 °C (HSDB 2013).
- Solubility: Soluble in most organic solvents (HSDB 2013).
- Log Kow: 3.65 (HSDB 2013).
- Index of refraction: 1.5022 at 20 °C (HSDB 2013).

3. Hazard traits of the chemical of concern

(See California Code of Regulations, title 22, section 69501.1(a)(36), section 69502.2(a)(1), section 69502.2(a)(2), and section 69503.3 (a)(1)(A))

TDCPP is documented to exhibit a number of hazard traits, including carcinogenicity, genotoxicity, developmental toxicity, reproductive toxicity, neurotoxicity, endocrine toxicity and hematotoxicity. These are discussed in more detail below.

- Carcinogenicity
  - TDCPP is listed as known to cause cancer by the State of California (Proposition 65 list). Exposure to TDCPP above 5.4 µg/day exceeds OEHHA's "no significant risk level" (NSRL) for TDCPP (OEHHA 2013). This NSRL is based on liver, kidney, and testicular tumor incidence data in experimental animals (OEHHA 2012).

- TDCPP is classified as a Category 2 Carcinogen (H351 - Suspected of causing cancer) by the European Chemical Agency (ECHA) Committee for Risk Assessment under Regulation (EC) No 1272/2008 (ECHA 2010; ECHA 2014).
- A U.S. Consumer Product Safety Commission (CPSC) 2006 Preliminary Risk Assessment report on flame retardants concluded that TDCPP is a probable human carcinogen, based on sufficient evidence in animal studies (Babich 2006).
- A two-year study in male and female rats showed statistically significant increases in the incidence of tumors at multiple sites, including liver, kidneys, testes, and adrenal gland (Bio/dynamics 1981; WHO 1998; Freudenthal and Henrich 2000; OEHHA 2011; ATSDR 2012).

- Genotoxicity

  Genotoxicity has been seen in some studies but not in others (OEHHA 2011; ATSDR 2012). There is evidence that TDCPP is genotoxic based on studies showing mutations, chromosomal aberrations, and cell transformation in multiple types of cells in culture.

  - TDCPP readily bound to DNA and proteins in liver, kidney, and muscle in mice treated intravenously with TDCPP (Morales and Matthews 1980; OEHHA 2011).
  - TDCPP induced malignant cell transformation of Syrian hamster embryo cells in culture (Soderlund et al. 1985; OEHHA 2011).
  - Studies in Salmonella strains (TA 97, TA 98, TA1537, and TA 1538) indicate that TDCPP induces frameshift mutations (*i.e.*, a genetic mutation caused by a deletion or insertion in a DNA sequence that shifts the way the sequence is read), with or without metabolic activation (Gold et al. 1978; Babich 2006; OEHHA 2011).
  - Treatment of Salmonella strains TA 100 and TA 1535 (sensitive to base pair substitution mutations) with TDCPP resulted in mutations, with and without S9 metabolic activation (Gold et al. 1978; Babich 2006; OEHHA 2011).
  - TDCPP caused an increase in chromosomal aberrations (i.e., any irregularity or abnormality of chromosome distribution, number, structure, or arrangement) *in vitro* in mouse lymphoma and Chinese hamster fibroblast cells, but not in Chinese hamster ovary cells (Brusick et al. 1980; Ishidate 1983; Covance Laboratories Inc. 2004; OEHHA 2011).
  - In one study, TDCPP weakly induced sister chromatid exchanges (SCE) (*i.e.*, genetic damage demonstrated by the exchange of genetic material between sister chromatids during mitosis) in mouse lymphoma cells; another study did not reveal such changes (Stauffer Chemical Co. 1977; Brusick et al. 1980; OEHHA 2011).
  - In an *in vitro* rat hepatocyte DNA synthesis (UDS) assay, TDCPP induced a weakly positive response in the absence of, but not in the presence of, phenobarbital induction (OEHHA 2011).
  - In general, *in vitro* genotoxicity assays of TDCPP have been negative (Soderlund et al. 1985; OEHHA 2011).
  - Studies of TDCPP in *in vitro* mammalian cell assays for gene mutation gave both positive and negative results (Brusick et al. 1980; Inveresk Research International 1985; Soderlund et al. 1985; OEHHA 2011; ATSDR 2012).
  - TDCPP did not induce mutations in Saccharomyces cerevisiae (OEHHA 2011).

- Developmental Toxicity

  Recent scientific literature contains several animal studies on the effects of TDCPP exposure on embryonic development.

  - One *in vitro* study indicated that TDCPP has the potential to cause developmental neurotoxicity (Dishaw et al. 2011).
  - Studies in Zebrafish
    - Exposure of zebrafish embryos to various concentrations of TDCPP resulted in dose-dependent developmental toxicity, including decreased body weight, reduced hatching, reduced survival and heartbeat rates, and increased malformation (*e.g.*, spinal curvature) (Wang et al. 2013).
    - Study results indicate that TDCPP could alter mRNA expression of genes in zebrafish/larvae (Liu et al. 2013b).
    - TDCPP exposure post-fertilization negatively affected Zebrafish embryo development and formation. This was demonstrated by increased mortality, inhibited cell rearrangement, delay in epiboly, and abnormal fetal development (*e.g.*, short tail, reduced body size, trunk curvature, tail malformations, craniofacial malformations, decreased body length) mortality of zebrafish embryos/larvae (Liu et al. 2013a; Fu et al. 2013, McGee et al. 2012). [*Note: Epiboly is a cell movement that occurs in the early embryo, at the same time as gastrulation. It is one of many movements in the early embryo that allow for dramatic physical restructuring. The movement is generally characterized as being a thinning and spreading of cell layers.*]
  - Studies in Chickens
    - TDCPP exposure in the egg was associated with decreases in head- plus-bill length, embryo mass, and gall bladder size in chicken embryos. Further, the expression of certain metabolic enzymes was significantly induced in embryos treated with high dose TDCPP, and TDCPP-exposed chicken embryos had lower thyroid hormone levels (Farhat et al. 2013).
  - Studies in Rats
    - Two studies showed pregnant rats exposed to high doses of TDCPP had high mortality rates for the pregnant dams, decreased live births, and increased incidence of fetal death (Tanaka et al. 1981; Kawashima et al. 1983; EC 2008). Maternal toxicity was also demonstrated by decreased body weight and decreased food consumption (Kawashima et al. 1983).
    - One study in rats exposed to TDCPP during pregnancy showed no developmental effects, although dams showed significantly reduced weight gain and decreased food consumption, and fetal viability was significantly decreased in high dose rats. Maternal toxicity was noted as increased mortality at the high dose and decreased body weight and decreased food consumption at the mid- and high doses (Stauffer Chemical Co. 1981b; ATSDR 2012).
- Reproductive Toxicity
  - A 2010 study reported evidence that TDCPP concentrations in house dust may be associated with altered hormone levels and decreased sperm concentration in humans (Meeker and Stapleton 2010).
  - A higher incidence of small seminal vesicles and testicular enlargement in mid- and high-dose

TDCPP-treated male rats was reported in a two-year study (Stauffer 1981a; Freudenthal and Henrich 2000; EC 2008; OEHHA 2011).

- Fertility was not affected and sperm did not show significant alterations in male rabbits dosed with up to 200 mg/kg/day of TDCPP and then mated with untreated female rabbits (Anonymous 1977; ATSDR 2012).
- In a multi-dose study of TDCPP by gavage in rabbits, no changes in mating behavior, fertility, or sperm quality or quantity were noted (Babich 2006; Wilczynski et al. 1983; Brandwene 2001).
- A 2008 risk assessment report on TDCPP by the European Union states that there is no concern for male fertility due to TDCPP exposure based on the weight of evidence. The report further stated that there is a data gap regarding female reproductive toxicity related to TDCPP exposure (EC 2008).

- Endocrine Disruption

  Recent studies using human cells and zebrafish have indicated that TDCPP has the potential to cause endocrine disruption, including thyroid abnormalities and alterations in metabolism of estrogens and other steroid hormones.

  - In a study exposing zebrafish embryos to various concentrations of TDCPP, the results suggest that TDCPP exposure causes endocrine disruption of the thyroid system (Wang et al. 2013).
  - Endocrine disruption potential of TDCPP via human nuclear receptors was noted in an *in vitro* study (Kojima et al. 2013).
  - TDCPP could potentially cause endocrine disruption through multiple mechanisms, including steroidogenesis or metabolism of estrogen, as indicated in an *in vitro* and *in vivo* study using human cell lines and zebrafish (Liu et al. 2012).

- Neurotoxicity
  - One *in vitro* study reported that TDCPP may be as potent a neurotoxicant as chlorpyrifos, an insecticide whose use has been banned in most homes since 2001. In this study, TDCPP displayed concentration-dependent neurotoxicity (Dishaw et al. 2011).
  - As summarized in a CPSC preliminary risk assessment report, neurotoxicity of TDCPP was studied in hens and rats (Babich 2006). Exposure to high doses of TDCPP in rats led to clinical signs suggestive of neurotoxicity, such as hyperactivity and convulsions (Stauffer Chemical Co. 1981b; Babich 2006).
    - In a two-year study, TDCPP did not induce clinical signs or morphological alterations in the brain or spinal cord of rats from a dietary dose of TDCPP. In the same study, changes in measured red blood cell cholinesterase levels were inconsistent (Stauffer Chemical Co. 1981a; ATSDR 2012).

- Other Hazard Traits
  - Acute Toxicity - TDCPP also induces non-cancer chronic health effects in animals and is classified as “acutely toxic” under the Federal Hazardous Substances Act (FHSA) regulations. This includes acute oral and dermal toxicity as well as eye irritation (Babich 2006).

- Hepatotoxicity - An increased incidence of altered hepatocellular foci in high-dose female rats was reported following long-term dosing (Bio/dynamics 1981; Freudenthal and Henrich 2000; OEHHA 2011).
- Nephrotoxicity - An increased incidence of hyperplasia of the convoluted tubules of the kidney in male and female rats was reported (Bio/dynamics 1981; Freudenthal and Henrich 2000; OEHHA 2011).
- Hematotoxicity - Decreases in hemoglobin, hematocrit, and total erythrocyte counts were reported following high dose treatment of TDCPP in male and female rats (Bio/dynamics 1981; Freudenthal and Henrich 2000; OEHHA 2011).
- Ocular effects were seen in a two-year dietary study in rats -- an increased number of sacculations along the course of the retinal arterioles were observed (Stauffer Chemical Co. 1981a; ATSDR 2012).
- Dermatitis - In a morbidity survey conducted by Stauffer Chemical Co., a higher prevalence of dermatitis was reported for TDCPP-exposed workers than for non-exposed workers (Stauffer Chemical Co. 1983).

4. Environmental Fate

(See California Code of Regulations, title 22, section 69503.3(a)(1)(E))

TDCPP production and use as an additive flame retardant for polyurethane foams may result in its release to the environment and its entry into various waste streams.

Air

If released to air, at an estimated vapor pressure of 7.36 x 10^{-8} mmHg at 25 °C, TDCPP will exist in both the vapor and particulate phases in the ambient atmosphere. Vapor-phase TDCPP is degraded in the atmosphere by reaction with photochemically produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 21.3 hours. Particulate-phase TDCPP is removed from the atmosphere by wet and dry deposition (i.e., in dust and rain) (HSDB 2013).

Soil

In soil, TDCPP is expected to have slight mobility based upon an estimated Koc of 1,500. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 2.61 x 10^{-9} atm-m3/mole. Biodegradation is not expected to be an important environmental fate process in soil based upon a 0-4% BOD using the Japanese MITI test (HSDB 2013).

Water

In water, TDCPP is expected to adsorb to suspended solids and sediment based upon its estimated Koc. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant of 2.6 x 10^{-9} atm-m3/mole at 25 °C. Limited data suggest that TDCPP will be resistant to hydrolysis in most environmental waters. Bioconcentration factors (BCFs) ranging from 0.3 to 113, suggesting the potential for bioconcentration in aquatic organisms is low to moderate (HSDB 2013). TDCPP was found to have low degradability in leachate from a sea-based solid waste disposal site (Kawagoshi et al. 2002), which suggests that TDCPP may be persistent in solid waste disposal sites.

5. Human and Ecological Populations to Which the Chemical of Concern has the Potential to Contribute to or Cause Adverse Impacts

   (See California Code of Regulations, title 22, section 69503.3(a)(1)(F) and section 69503.3(a)(2))

- Infants and children
- Adults
- Daycare workers
- Office workers
- Fish and wildlife

6. Potential for TDCPP to Degrade, Form Reaction Products, or Metabolize into Another Candidate Chemical or a chemical that exhibits one or more hazard traits

   (See California Code of Regulations, title 22, section 69503.3(a)(1)(G))

   A number of metabolites and putative metabolites of TDCPP have been reported to be carcinogenic or exhibit other toxicity. The carcinogenic and mutagenic metabolites include 1,3-dichoro-2-propanol (1,3-DCP), 3-chloro-1,2-propanediol (3-MCPD), 1,3-dichloro-2-propanone, dichloroacetone, epichlorohydrin, and glycidol.

- Major metabolites of TDCPP
  - Diester, bis(1,3-dicholoro-2-propyl) phosphate (BDCPP) (Lynn et al. 1981; Nomeir et al. 1981; Sasaki et al. 1984; OEHHA 2011).
  - Monoester, 1,3-dichloro-2-propyl phosphate (MDCPP) (OEHHA 2011).
  - 1,3-dicholoro-2-propanol (1,3-DCP) (Ulsamer et al. 1980; Lynn et al. 1981; Nomeir et al. 1981; OEHHA 2011).
    - Mutagenic (Gold et al. 1978; Nomeir 1981; OEHHA 2011).
    - Listed as carcinogenic on Prop 65 list (OEHHA 2011; OEHHA 2014;).
    - Identified as a Group 2b carcinogen (*i.e.*, possibly carcinogenic to humans) by the International Agency for Research on Cancer (IARC) (IARC 2012a).
    - On the Candidate Chemicals list (DTSC 2013).
  - 3-chloro-1,2-propanediol (3-MCPD) (Nomeir et al. 1981; OEHHA 2011; ATSDR 2012).
    - Mutagenic (Lynn et al. 1981; Nomeir et al. 1981; OEHHA 2011).
    - Listed as carcinogenic on Prop 65 list (OEHHA 2011; OEHHA 2014).
    - Identified as Group 2b carcinogen (*i.e.*, possibly carcinogenic to humans) by IARC (IARC 2012b).
    - On the Candidate Chemicals list (DTSC 2013).
- Putative metabolite of TDCPP
  - 1,3-dichloro-2-propanone (Gold et al. 1978; Nomeir 1981; OEHHA 2011).

        - Strong, direct-acting mutagen (Gold et al. 1978; OEHHA 2011).
- Metabolites of 1,3-DCP (OEHHA 20110a; OEHHA 2011).
    - Dichloroacetone – a mutagen and tumor initiator (OEHHA 2010a; OEHHA 2011).
    - Epichlorohydrin – a genotoxic carcinogen (OEHHA 2010a; OEHHA 2011).
        - On the Candidate Chemicals list (DTSC 2013).
        - Listed as carcinogenic on Prop 65 list (OEHHA 2011; OEHHA 2014).
        - Identified as a Group 2A carcinogen (*i.e.*, probably carcinogenic to humans) by IARC (IARC 1999).
- Metabolites of 3-MCPD
    - Glycidol – a genotoxic carcinogen (OEHHA 2011; OEHHA 2010b).
        - On the Candidate Chemicals list (DTSC 2013).
        - Listed as carcinogenic on Prop 65 list (OEHHA 2011; OEHHA 2014).
        - Identified as a Group 2A carcinogen (*i.e.*, probably carcinogenic to humans) by IARC (IARC 2000).
    - Beta-chlorolactaldehyde (OEHHA 2011).

7. Adverse Impacts Associated with Structurally/Mechanistically Similar Chemicals

(See California Code of Regulations, title 22, section 69503.3(a)(3))

The following compounds have been identified as structurally similar to TDCPP (OEHHA 2011); each of these compounds can be used as a flame retardant.

- Tris(2,3-dibromopropyl) phosphate (TDBPP; Tris) - a brominated analogue of TDCPP
    - Carcinogenic in rats and mice (OEHHA 2011; IARC 1999; Gold et al. 1978).
    - Listed as carcinogenic on Prop 65 list (DTSC 2013; OEHHA 2014).
    - Identified as 2A Carcinogen by IARC (DTSC 2013).
    - Listed as reasonably anticipated to be a human carcinogen in the National Toxicology Program's 12th Repor on Carcinogens (DTSC 2013).
    - Identified as a Priority Chemical by the California Environmental Contaminant Biomonitoring Program (DTSC 2013; CECBP 2013).
    - Genotoxic *in vitro* and *in vivo* (Blum and Ames 1977; Gold et al. 1978; IARC 1999; OEHHA 2011).
    - On the Candidate Chemicals list (DTSC 2013).
    - Causes sterility in animals (Blum et al. 1978; Gold et al. 1978).
    - Absorbed through human skin (Gold et al. 1978).
- Tris(2-chloroethyl) phosphate (TCEP) – a chlorinated phosphate triester

  - Induces tumors in rats and mice (IARC 1999; OEHHA 2011).
  - Genotoxic *in vitro* and *in vivo* (IARC 1999; OEHHA 2011).
  - Listed as a carcinogen on Prop 65 list (OEHHA 2014).
  - Identified as a Priority Chemical by the California Environmental Contaminant Biomonitoring Program (DTSC 2013; CECBP 2013).
  - On the Candidate Chemicals list (DTSC 2013).
  - Classified by the European Commission as reproductive toxicants Category 1B in Annex VI to Regulation (EC) 1272/2008 (DTSC 2013).
  - Listed as a Substance of Very High Concern by the EU, due to reproductive toxicity and potential to impair fertility (ECHA 2009).
  - New York has enacted a law that will ban the use of TCEP in products intended for children under the age of three, due to the weight of evidence that suggests TCEP causes adverse health effects (Miller 2011).
- Tris(1-chloro-2-propyl) phosphate (TCPP) – a chlorinated phosphate triester
  - Genotoxic in *in vitro* but not in *in vivo* assays (EC 2008; OEHHA 2011).
  - Has not been tested in long-term studies for carcinogenicity (OEHHA 2011).
  - On the Candidate Chemicals list (DTSC 2013).
  - Identified as a Priority Chemical by the California Environmental Contaminant Biomonitoring Program (DTSC 2013; CECBP 2013).

8. Exposure Potential

(See California Code of Regulations, title 22, section 69503.3(b))

- Market Presence
  - TDCPP is a high production volume chemical (OEHHA 2011; US EPA 2006).
  - Approximately 10,000,000 to 50,000,000 lbs./year of TDCPP is produced in the United States (U.S. EPA 2013).
  - In a survey of 63 U.S. companies that manufacture and/or import and distribute infant products, approximately 1.8 million playards and greater than 2 million playards were sold in 2011 and 2012 in the U.S. (JPMA 2013). Approximately 500,000 and 570,000 cradles and bassinets were sold in the U.S. in 2011 and 2012 (JMPA 2013).
  - TDCPP is one of the most widely used flame retardants in polyurethane foam (MarketsandMarkets 2012).
  - Chlorinated flame retardants are largely used in infant products (MarketandMarkets 2012).
  - The global market for chlorinated flame retardants was estimated at 164.1 kilo tons in 2011 and is expected to reach 199.8 kilo tons by 2017 (MarketsandMarkets 2012).
- The occurrence, potential occurrence of exposure to the Chemcial of Concern in the Product

- TDCPP collects in adipose (fat) tissue (CECBP 2008). Levels of TDCPP were detected in adipose tissue at concentrations of 0.5-276 ng/g (LeBel and Williams 1983; LeBel and Williams 1986; LeBel et al. 1989) and in human seminal plasma at concentrations ranging from 5-50 ppb (Hudec et al. 1981).
- TDCPP has been measured in the lipids (fatty portion) of human breast milk in Sweden, with an average concentration of 4.3 ng/g and a maximum concentration of 5.3 ng/g (OEHHA 2011; Sundkvist et al. 2010).
- A metabolite of TDCPP (BDCPP) was detected in urine samples taken from 7 men in the U.S. over the course of 3 months; TDCPP in house dust may have been a source of exposure (Meeker et al. 2013).

- Potential exposures to the Chemical of Concern in the product during the products life cycle
- TDCPP was removed from children's pajamas in the 1970s due to concerns regarding mutagenicity, but it is still used in baby and children's products (Stapleton et al. 2011).
  - Routes of Exposure
    - Routes of exposure include inhalation, ingestion, and dermal absorption (ATSDR 2012).
    - Children's overall exposure to flame retardants may be influenced by their hand-to-mouth behavior, and frequent hand washing is associated with lower flame retardant levels on the hands (Stapleton et al. 2014).
    - CPSC has predicted that inhalation of flame retardants (such as TDCPP) contributes the greatest portion of total exposure (Babich 2006); however, newer studies indicate that dust ingestion is a major route of exposure.
    - TDCPP is readily absorbed through skin and the gastrointestinal tract (Nomeir et al. 1981).
    - Occupational exposure to TDCPP may occur through dermal contact and inhalation with this compound at workplaces where TDCPP is produced or used (HSDB 2013).
    - Monitoring data indicate that the general population may be exposed to TDCPP via ingestion of drinking water (HSDB 2013).
  - Studies on the Presence of TDCPP in Foam-Padded Products
    - TDCPP was the most common flame retardant detected (in 36% of samples tested) in a study which analyzed 101 polyurethane foam samples from commonly used baby products in the U.S. including car seats, changing table pads, sleep positioners, portable mattresses, nursing pillows, baby carriers, high chairs, and baby walkers (Stapleton et al. 2011).
    - The Center for Environmental Health (CEH) had foam samples from 24 children's nap mats analyzed for flame retardants. Detectable levels of at least one flame retardant were measured in 22 of 24 nap mats; 19 of 24 nap mats had two or more flame retardants; and 9 samples contained TDCPP (Cox 2013).
    - In a recent academic study, TDCPP was detected in 42 out of 102 polyurethane foam samples from U.S. couches (Stapleton et al. 2012).
  - Studies on the Presence of TDCPP in Indoor Dust
    - TDCPP has been detected in household, office, automobile, and commercial airplane dust

in the U.S. and abroad (Marklund et al. 2003; Marklund et al. 2003; Stapleton et al. 2009; Takigami et al. 2009; Meeker and Stapleton 2010; Bergh et al. 2011; OEHHA 2011; Van den Eede et al. 2011; Brommer et al. 2012; Ali et al. 2012; Dirtu et al. 2012; Dodson et al. 2012; Allen et al. 2013; Carignan et al. 2013).

- In a study of 30 homes in North Carolina in which children (ages 2-5) lived, TDCPP was detected in 100% of the house dust samples in concentrations of 0.621-13.1 µg/g (Stapleton 2014).
- In a study of dust from 16 homes in California taken in 2006 and 2011, concentrations of TDCPP were found in the range of 0.730 - 44 µg/g in dust, higher than previously reported in the U.S. (Dodson et al. 2012).
- In a study of 50 homes in Boston, MA, TDCPP was detected in dust with an average concentration of 1.89 µg/g and a maximum concentration of 56.08 µg/g. TDCPP was detected in > 96% of dust samples collected (OEHHA 2011; Stapleton et al. 2009).
- In a study conducted in Sweden, TDCPP was detected in dust and air samples taken from homes, daycare centers, hospitals, and offices (OEHHA 2011; Marklund et al. 2003).
- TDCPP was detected in air and dust samples taken from day care centers, workplaces, and homes in Sweden. The air concentrations of phosphate esters (including TDCPP) were 3-4 times higher in day care centers and workplaces than in homes. The phosphate ester concentrations detected in dust from day care centers were over 50 times higher than in homes (Bergh et al. 2011).
- Detected concentrations of TDCPP were higher in California child care facilities with foam nap mats compared to those without. TDCPP was detected in both the dust and air (Bradman et al. 2012).
- In a Boston, Massachusetts study assessing exposure of adult office workers to TDCPP, the chemical was detected in 99% of dust samples from office, home, and automobiles of workers, and TDCPP's metabolite BDCPP was detected in 100% of urine samples. Concentrations of TDCPP were higher in offices and vehicles than in homes, and TDCPP concentrations were higher in older office buildings compared to newer ones (Carignan et al. 2012).

- Studies on the Presence of TDCPP in Children's Handwipe Samples
  - In a study of 30 North Carolina homes, handwipe samples were taken from 43 children ages 2-5 years old and 96% of the handwipe samples contained TDCPP. Further, higher levels of flame retardants detected in house dust were consistently associated with higher handwipe levels (Stapleton 2014).
- Human Exposure Estimates
  - The U.S. EPA estimates that children ages 1-5 ingest an approximate average of 100-200 mg dust/day, whereas, adults ingest an approximate average of 20-50 mg dust/day (U.S. EPA 2002). Children may have a greater exposure to TDCPP than adults, due to children's higher ingestion rate of dust.
  - The calculated cumulative average exposure to flame retardants from dust is 1.6 µg/day for children and 0.325 µg/day for adults (Stapleton et al. 2009).

    - Stapleton et al. predict that infants may receive greater exposure to TDCPP from products containing polyurethane foam compared to exposure to an average child or adult receives from upholstered furniture (Stapleton et al. 2009).
    - It has been estimated that children's exposure to TDCPP from treated furniture is five times higher than the acceptable daily intake (ADI) for non-cancer endpoints (Babich 2006).
    - It has been estimated that the cancer risk for a lifetime of exposure to TDCPP-treated upholstered furniture is 300 per million. In children, the estimated cancer risk from exposure to upholstered furniture during the first two years of life alone is 20 per million — indicating a greater cancer exposure risk to TDCPP during childhood. CPSC considers cancer risks greater than one in a million relevant for regulatory consideration (Babich 2006).

- Containment of the Chemical of Concern within the Product
  - TDCPP in polyurethane foam is not chemically bonded to the foam; thus, it can easily escape from polyurethane foam-containing products into indoor environments and dust (Marklund et al. 2003).
- Potential for the Chemical of Concern to be Released into Environmental Media
  - TDCPP was detected in San Francisco Bay waters and sediment. Further, TDCPP is relatively abundant in San Francisco Bay sediment, with estimated concentrations comparable to those of polybrominated biphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in the same samples (SFEI 2013; Klosterhaus et al. 2013).
  - TDCPP was detected in over half of 139 streams studied across the U.S., including California, suggesting significant releases of TDCPP to the environment (Kolpin et al. 2002; OEHHA 2011).
  - TDCPP was detected in Swedish sewage treatment facilities in influents, effluents, and sludge (Marklund et al. 2005; OEHHA 2011).
  - TDCPP been detected in biological samples, including fishes, mussels and birds.
    - In Norway, fishes and mussels were observed to contain up to 8.1 and 30 ng/g of TDCPP, respectively (Norwegian Pollution Control Authority 2008, 2009; Takahashi 2013)
    - In bird blood/plasma and eggs respectively, TDCPP levels range from <0.11-0.16 and from <0.72-1.9 ng/g (Norwegian Climate and Pollution Agency 2010; Takahashi 2013).
    - In Sweden, freshwater fishes in lakes close to emission sources contained 49-140 ng/g TDCPP (Sundkvist et al. 2010; Takahashi 2013).

OTHER RELEVANT PRODUCT-CHEMICAL IDENTIFICATION AND PRIORITIZATION FACTORS

(See California Code of Regulations, section 69503.2(b)(1)(C))

1. Availability and reliability of information

- All toxicology and health-effects references in this profile meet the definition of "reliable information" pursuant to section 69501.1(a)(57), in that all reports and studies relied upon were either published in peer-reviewed literature, and/or published by a federal, state, or local agency that implement laws governing chemicals."

2. Other Regulatory Programs

(See California Code of Regulations, title 22, section 69503.3(a)(1)(F) and section 69503.3(b)(2))

- California Proposition 65: TDCPP was added to the list of chemicals known to the State of California to cause cancer for purposes of the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) on October 28, 2011 (OEHHA 2014).
- California Environmental Contaminant Biomonitoring Program: TDCPP is listed as a Priority Chemical in the California Biomonitoring Program for eventual data collection (CECBP 2013).
- California Department of Consumer Affairs, Bureau of Electronic Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI): BEARHFTI regulates flame retardancy of specific products (primarily upholstered furniture) under Technical Bulletin (TB) 117 and its successor regulation, TB 117-2013 (approved November 21, 2013). These Technical Regulations do not regulate mattresses, which are subject to federal CPSC regulation. At least 20 juvenile products, including nap mats, are exempt under TB 117 and TB 117-2013. Under the California Code of Regulations section 13742, the other exempt products are: strollers, infant carriers, nursing pillows, car seats, infant seats, booster seats, changing pads, floor play mats, high chairs, high chair pads, infant swings, bassinets, infant bouncers, nursing pads, playards, infant mattresses, infant mattress pads, and portable hook-on chairs (BEARHFTI 2013a). Crib mattresses are covered by Code of Federal Regulations (CFR) 1632/1633 (discussed below), which requires a finished product to pass the cigarette smolder test. Infant or children's mattress pads, such as those that go in a bassinet, are exempt from this federal mattress standard (BEARHFTI 2013b).
- U.S. Consumer Product Safety Commission, Title 16 CFR 1632/1633 and Mattresses and Mattress Pads: The CPSC regulates mattresses and mattress pads under Title 16 Code of Federal Regulations Part 1632 and Part 1633 (16 CFR 1632 and 1633). Part 1632 is the standard for the flammability of mattresses and mattress pads, while Part 1633 contains the standard for flammability (open flame) for mattress sets. Bed mattresses, including mattresses for hard sided cribs, are covered by 16 CFR 1632 and 1633. The requirements of 16 CFR 1632 and 1633 are performance-based. The regulation does not specify the use of flame retardant chemicals to meet the requirements. The regulation allows manufacturers to choose the means of complying with the regulation, which may include the use of inherently flame resistant materials, and/or barriers, and/or flame retardant chemicals, while requiring that mattresses meet strict performance requirements (CPSC 2014).

- Juvenile Product Pad Exemption from CFR 1632/1633: CPSC does not regulate "juvenile product pads" and provides examples of the exempt category in 16 CFR 1632.1(a)(2). Exempt products include "car bed pads, carriage pads, basket pads, infant carrier and lounge pads, dressing table pads, stroller pads, crib bumpers, and playpen pads" (16 FR 1632). Each of these "juvenile product pads" is further defined in 16 CFR 1632.8 (16 CFR 1632). Portable cribs with mesh or soft sides are not regulated under 16 CFR 1632 (Eggerstorfer 2013).

- New York's Tris-free Children and Babies Act (S3703/A4741) – This Act expands the Tris-free Children and Babies Act to include TDCPP. The amendment goes into effect on December 1, 2015 (New York State Assembly 2013).
- Government Exposure Criteria
  - OEHHA determined a no significant risk level (NSRL) for TDCPP of 5.4 µg/day (OEHHA 2014). The OEHHA NSRL for TDCPP is based on treatment-related increases in liver, kidney, and testicular tumor incidence data (OEHHA 2012).
  - The Agency for Toxic Substances and Disease Registry (ATSDR) derived a Minimum Risk Level (MRL) of 0.05 mg/kg/day for intermediate-duration oral exposure (15-364 days) to TDCPP based on increased absolute kidney weight in male rats, and an MRL of 0.02 mg/kg/day for chronic duration oral exposure (365 days and longer) to TDCPP based on renal tubule hyperplasia in male rats (ATSDR 2012).
  - CPSC calculated TDCPP exposures for non-cancer health effects were above the ADI (acceptable daily intake) of 0.005 mg/kg/day.

3. Alternatives to Children's Foam-Padded Sleeping Products Containing TDCPP[3]

(See California Code of Regulations, title 22, section 69503.2(b)(3))

Manufacturers of children's foam-padded sleeping products have several alternatives in lieu of using TDCPP:

1. manufacture the product without any chemical flame retardant or barrier fabric;
2. use a barrier fabric for flame retardancy between the polyurethane foam and the fabric cover; or
3. substitute TDCPP with other chemical flame retardants.

Among the numerous potential chemical alternatives to TDCPP, it is unclear to DTSC if any of them are "safer" alternatives, or whether each alternative has been thoroughly evaluated for safety. Some of these alternative chemicals are discussed below. Barrier fabric can be a substitute for chemical fire retardants; however, the barrier fabrics themselves may be treated with chemical flame retardants, albeit in lower volume than in foam.

[3] Under the Safer Consumer Product regulations, when deciding whether to list a product-chemical combination, the Department may also consider whether there is a readily available safer alternative that is functionally acceptable, technically feasible, and economically feasible (see California Code of Regulations, title 22, section 69503.2(b)(3)). The potential alternatives identified below are provided as examples only, and do not constitute a comprehensive list of all available alternatives applicable to every Priority Product type. Furthermore, the Department is not asserting that these potential alternatives are necessarily safer, functionally acceptable, technically feasible, or economically feasible. The Department seeks information on these and any other alternatives in the marketplace. The Department expects that responsible entities and stakeholders will identify and provide reliable information on the safety, functionality, and technical and economic feasibility of these and other alternatives.

The simplest option for manufacturers is likely to forgo the use of flame retardants altogether. In a 2012 memorandum by the CPSC on upholstered furniture, it was stated that "the fire-retardant foams did not offer a practically significant greater level of open-flame safety than did the untreated foams" (CPSC 2012).

Because "juvenile product pads" fall outside of CPSC's definition of "mattress," there is no law requiring flame retardants in flexible polyurethane foam used in children's foam-padded sleeping products. Therefore, DTSC knows of no regulatory requirement that would prevent flame retardants from being removed from these products. In fact, in the first settlement by the Center for Environmental Health (CEH) regarding lack of Prop 65 labeling for products containing TDCPP, defendant Peerless Plastics, Inc. pledged to cease manufacturing, distributing, or selling in California any nap mat that has been treated with TDCPP, and pledged not to purchase polyurethane foam treated with chemical flame retardants [Center for Environmental Health v. A Baby Inc. (Super. Ct. Alameda County, 2013, No. RG-13667688)].

- Alternative Chemical Flame Retardants in Polyurethane Foam:
  - Tris(2-choroethyl) phosphate (TCEP)
    - Induces tumors in rats and mice (IARC 1999; OEHHA 2011).
    - Genotoxic *in vitro* and *in vivo* (IARC 1999; OEHHA 2011).
    - Listed as carcinogenic on Prop 65 list (OEHHA 2014).
    - Listed as a Substance of Very High Concern by the Eurpoean Union (EU) due its reproductive toxicity and potential to impair fertility (ECHA 2009).
    - New York has banned the use of TCEP in products intended for children under the age of three, due to the weight of evidence that suggests TCEP causes adverse health effects (Miller 2011).
    - Very environmentally persistent (Van de Veen and de Boer 2012).
    - Neurotoxic and carcinogenic in rats (Bergh et al. 2011).
    - On DTSC's Initial Candidate Chemicals list (DTSC 2013).
  - Tris(chloropropyl) phosphate (TCPP)
    - Genotoxic in *in vitro*, but not *in vivo* assays (EC 2008; OEHHA 2011).
    - Has not been tested in long-term studies for carcinogenicity (OEHHA 2011).
    - On DTSC's Candidate Chemicals list (DTSC 2013).
  - Firemaster 550
    - Evidence of endocrine disruption and obesity in rats (Patisaul et al. 2013).
    - Proprietary mixture containing:
- Isopropyl phenyl diphenyl phosphate (Cox 2013).
- Triphenyl phosphate (Stapleton et al. 2011; Dodson et al. 2012).
  - On DTSC's Candidate Chemicals list (DTSC 2013).

- Di(isopropyl phenyl) phenyl phosphate (Cox 2013).
- 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB or EH-TBB) (Stapleton et al. 2011; Dodson et al. 2012; Cox 2013).
  - On DTSC's Candidate Chemicals list (DTSC 2013).
- Bis(2-ethylhexyl)-3,4,5,6-tetrabromophthalate (TBPH or BEH-TEBP) (Stapleton et al. 2011; Dodson et al. 2012; Cox 2013).
  - On DTSC's Candidate Chemicals list (DTSC 2013).
- Also contains several triaryl phosphate isomers that are trade secret (Stapleton et al. 2011).
  - Triphenyl phosphate (TPhP or TPP)
    - May cause contact dermatitis in humans (Bergh et al. 2011).
    - Potent inhibitor of human carboxyl esterase (Bergh et al. 2011).
    - On DTSC's Candidate Chemicals list (DTSC 2013).
  - Tricresylphosphate (TCP)
    - Toxic to aquatic organisms (Van der Been and De Boer 2012).
  - V6 (mixture)
    - Tetrekis(2-chloroethyl)dichloroisopentyldiphosphate (Van der Veen and De Boer 2012).
    - TCEP as 10% impurity (Stapleton et al. 2012).
- On DTSC's Initial Candidate Chemicals list (DTSC 2013).
  - Diphenylcresylphosphate (DCP)
    - Toxic to aquatic organisms (Van der Veen and De Boer 2012).
  - Diethylphosphinic acid
    - Very environmentally persistent (Van der Veen and De Boer 2012).
  - Resorcinol-bis(diphenylphosphate) (RDP)
    - On DTSC's Initial Candidate Chemicals list (DTSC 2013).
  - Bisphenol-A diphenyl phosphate (BADP)
    - On DTSC's Initial Candidate Chemicals list (DTSC 2013).
  - Melamine polyphosphate (U.S. EPA 2005)
  - Tribromoneopentyl alcohol (U.S. EPA 2005)

REFERENCES

1. Ali N. Dirtu AC, Van den Eede N, Goosey E, Harrad S, Neels H, Mannetje A, Coakley J, Douwes J, Covaci A. (2012) Occurrence of alternative flame retardants in indoor dust from New Zealand: indoor sources and human exposure assessment. Chemosphere. 88(11): 1276-1282.
2. Agency for Toxic Substances and Disease Registry (ATSDR). (2012) Toxicological Profile For Phosphate Ester Flame Retardants.
3. Allen JG, Stapleton HM, Vallarino J, McNeely E, McClean MD, Harrad SJ, Rauert CB, Spengler JD. (2013) Exposure to flame retardant chemicals on commercial airplanes. Environmental Health. 12:17 doi:10.1186/1476-069X-12-17. http://www.ehjournal.net/content/12/1/17
4. Anonymous. (1977) Health and safety data for 4 chemicals with cover letter dated 021089 (sanitized). Submitted to the U.S. Environmental Protection Agency under TSCA Section 8D. EPA86-8900001189. OTS0516689, p 1-Slide 10-14; p 4-Slide 214, 222, 223; p 5-Slide 271; p 13; Slide814-815 p 15; Slide 954-984 p 20; Slide 1227, 1253, 1278; p 25. [As described by ATSDR 2012.]
5. Babich MA. (2006) CPSC Staff Preliminary Risk Assessment of Flame Retardant (FR) Chemicals in Upholstered Furniture Foam. Bethesda, MD, pp. 1-129.
6. Bergh C, Torgrip R, Emenius G, Ostman C. (2011) Organophosphate and phthalate esters in air and settled dust—a multi-location indoor study. Indoor Air. 21: 67-76.
7. Bergh C, Torgrip R, Emenius G, Ostman C. (2011) Organophosphate and phthalate esters in air and settled dust - a multi-location indoor study. Indoor Air. 21(1): 67-76.
8. Bio/dynamics, Inc. (1981) A Two Year Oral Toxicity/Carcinogenicity Study on Fyrol FR-2 in Rats (Final Report). Volume V. Submitted to Stauffer Chemical Co. by Bio/dynamics, Inc. Project No. 77-2016. Sept. 21, 1981.
9. Blum A and Ames BN. (1977) Flame retardant additives as possible cancer hazards. Science. 195(4273): 17-23.
10. Blum A, Gold MD, Ames BN, Jones FR, Hett EA, Dougherty RC, Horning EC, Dzidic I Carroll DI, Stillwell RN, Thenot JP. (1978) Children absorb tris-BP flame retardant from sleepwear: urine contains the mutagenic metabolite, 2,3-dibromopropanol. Science. 201(4360): 1020-1023.
11. Bradman A, Gaspar F, Castorina R, Tong-Lin E, McKone T, Maddelena R. (2012) Environmental Exposures in Early Childhood Education Environments, Final Draft Report. Berkeley, CA, pp. 1-143.
12. Brandwene D (2001) High Production Volume (HPV) Challenge Program test plan and robust summary for tris(l,3-dichloro-2-propy1) phosphate. Akzo Nobel Functional Chemicals LLC, Dobbs Ferry, NY. March 2001. [As described by Babich 2006.]
13. Brommer S, Harrad S, Van den Eede N, Covaci A. (2012) Concentrations of organophosphate esters and brominated flame retardants in German indoor dust samples. J. Environ. Monit. 14(9): 2482-2487.
14. Brusick D, Matheson D, Jagannath D, Goode S, Lebowitz H, Reed M, et al. (1980) A comparison of the genotoxic properties of tris(2,3-dibromopropyl) phosphate and tris(1,3-dichloro-2-propyl) phosphate in a battery of short-term bioassays. J. Environ. Pathol. Toxicol. 3(1-2): 207.

15. Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI), Department of Consumer Affairs. (2013a) Initial Statement of Reasons for TB 117, page 3 http://www.bhfti.ca.gov/about/laws/isr.pdf (accessed December 12, 2013).

16. Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI), Department of Consumer Affairs. (2013b) Technical Bulletin 117-2013. Requirements, Test Procedure and Apparatus for Testing the Smolder Resistance of Materials Used in Upholstered Furniture. http://www.bearhfti.ca.gov/about_us/tb117_2013.pdf (accessed December 12, 2013).

17. California Environmental Contaminant Biomonitoring Program (CECBP). (2008) Brominated and chlorinated organic chemical compounds used as flame retardants. Materials for the December 4-5, 2008 Meeting of the California Environmental Contaminant Biomonitoring Program (CECBP) Scientific Guidance Panel (SGP). Agenda Item: "Consideration of Potential Designated Chemicals." http://www.biomonitoring.ca.gov/sites/default/files/downloads/120408flamedoc.pdf (accessed November 2013).

18. California Environmental Contaminant Biomonitoring Program (CECBP). (2013) Biomonitoring California Priority Chemicals May 2013. http://biomonitoring.ca.gov/chemicals/priority-chemicals (accessed November 2013).

19. Carignan CC, McClean MD, Cooper EM, Watkins DJ, Fraser AJ, Heiger-Bernays W, Stapleton HM, Webster TF. (2013) Predictors of tris(1,3-dichloro-2-propyl) phosphate metabolite in the urine of office workers. Environmental International. 55: 56-61.

20. Consumer Product Safety Commission (CPSC). (2014) Questions and Answers, Standard for the Flammability (Open Flame) of Mattress Sets 16 CFR Part 1633). http://www.cpsc.gov//PageFiles/113012/mattqa.pdf (accessed January 30, 2014).

21. Consumer Product Safety Commission (CPSC). (2012) Upholstered Furniture Full Scale Chair Tests – Open Flame Ignition Results and Analysis. Memorandum dated May 9. p. 23. http://www.cpsc.gov/PageFiles/129840/ufmemos.pdf (accessed January 2014).

22. Covance Laboratories Inc. (2004). Chromosomal aberrations in Chinese hamster ovary (CHO) cells (Unpublished report). [As described by European Commission 2009 and OEHHA 2011.]

23. Cox C. (2013) Naptime nightmares? Toxic flame retardants in child care nap maps. Center for Environmental Health Report. Oakland, CA, pp. 1-18.

24. ChemSpider, Royal Society of Chemistry. (2013) http://www.chemspider.com/Chemical-Structure.24388.html?rid=13019fad-1448-4962-8d0d-5b995e46becc (accessed October 8, 2013).

25. Department of Toxic Substances Control (DTSC), State of California. (2013) Candidate Chemical Database. http://cit.dtsc.ca.gov/scp/chemicalsearch/ChemicalSearch.aspx (accessed October 16, 2013).

26. Dirtu AC, Ali N, Van den Eede N, Neels H, Covaci A. (2012) Country specific comparison for profile of chlorinated, brominated and phosphate organic contaminants in indoor dust. Case study for Eastern Romania, 2010. Environment Internation. 49: 1-8.

27. Dishaw LV, Powers CM, Ryde IT, Roberts SC, Seidler FJ, Slotkin TA, Stapleton HM. (2011) Is the PentaBDE replacement, tris (1,3-dichloropropyl) phosphate (TDCPP), a developmental neurotoxicant? Studies in PC12 cells. Toxicology and Applied Pharmacology. 256(3): 281-289.

28. Dodson RE, Perovich LJ, Covaci A, Van den Eede N, Ionas AC, Dirtu AC, Brody JG, Rudel RA. (2012) After the PBDE phase-out: a broad suite of flame retardants in repeat house dust samples from California. Environ. Sci. Technol. 46: 13056-13066.

29. Eggerstorfer, Heather. (2013) Phone conversation between Eileen Sheehan of U.S. EPA and Heather Eggerstorfer (employee of the U.S. Consumer Product Safety Commission).

30. European Chemicals Agency (ECHA). (2009) Support Document for Identification of Tris(2-chloroethyl)phosphate as a Substance of Very High Concern because of its CMR Properties.

31. European Chemicals Agency (ECHA). (2010) Committee for Risk Assessment (RAC) opinon proposing harmonized classification and labelling at community level of TDCP (Tris[2-chloro-1-chloromethyl)ethyl]. ECHA/RAC/Doc. No. CLH-0-0000000953-71-03/F. Adopted 3 September 2010.

32. European Chemicals Agency (ECHA). (2014) Tris[2-chloro-1-(chloromethyl)ethyl] phosphate. http://apps.echa.europa.eu/registered/data/dossiers/DISS-9eb07130-1b0d-1644-e044-00144f67d031/DISS-9eb07130-1b0d-1644-e044-00144f67d031_DISS-9eb07130-1b0d-1644-e044-00144f67d031.html (accessed February 2014).

33. European Commission (EC). (2008) Tris[2-chloro-1-(chloromethyl)ethyl] phosphate (TDCP). European Union Risk Assessment Report. Prepared by Rapporteur Member States Ireland and United Kingdom. Final Report.

34. Farhat A, Crump D, Chiu S, Williams KL, Letcher RJ, Gauthier LT, Kennedy SW. (2013) In ovo effects of two organophosphate flame retardants—TCPP and TDCPP—on pipping success, development, mRNA expression, and thyroid hormone levels in chicken embryos. Toxicological Sciences. 134(1): 92-102.

35. Freudenthal RI, Henrich RT. (2000) Chronic toxicity and carcinogenic potential of tris-(1,3-dichloro-2-propyl) phosphate in Sprague-Dawley rat. International Journal of Toxicology. 19(2): 119-25.

36. Fu J, Han J, Zhou B, Gong Z, Santos EM, Huo X, Zheng W, Liu H, Yu H, Liu C. (2013) Toxicogenomic responses of zebrafish embryos/larvae to tris(1,3-dichloro-2-propyl) phosphate (TDCPP) reveal possible molecular mechanisms of developmental toxicity. Environmental Science & Technology. 47: 10574-10582.

37. Gold MD, Blum A, Ames BN. (1978) Another flame retardant, tris-(1,3-dichloro-2-propyl)-phosphate, and its expected metabolites are mutagens. Science. 200: 785-787.

38. Hazardous Substances Data Bank, National Library of Medicine (HSDB). (2013) http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+@rel+13674-87-8 (accessed October 8, 2013 and December 2013).

39. Hudec T, Thean J, Kuehl D, Dougherty RC. (1981). Tris(dichloropropyl)phosphate, a mutagenic flame retardant: frequent occurrence in human seminal plasma. Science. 211: 951-952.

40. International Agency for Research on Cancer. (1999) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 71. Re-Evaluation of Some Organic Chemicals, Hydrazine and Hydrogen Peroxide. Summary of Data Reported and Evaluation. Epichlorohydrin. http://monographs.iarc.fr/ENG/Monographs/vol71/volume71.pdf (accessed December 4, 2013).

41. International Agency for Research on Cancer. (2000) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 77. Some Industrial Chemicals. Summary of Data Reported

and Evaluation. Glycidol. http://monographs.iarc.fr/ENG/Monographs/vol77/volume77.pdf (accessed December 4, 2013).

42. International Agency for Research on Cancer. (2012a) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 101. 1,3-dichloro-2-propanol (1,3-DCP) http://monographs.iarc.fr/ENG/Monographs/vol101/mono101-011.pdf (accessed December 4, 2013).

43. International Agency for Research on Cancer. (2012b) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 101. 3-monochloropropane-1,2-diol (3-MCPD) http://monographs.iarc.fr/ENG/Monographs/vol101/mono101-010.pdf (accessed December 4, 2013).

44. Inveresk Research International. (1985) TDCP LV: Mouse lymphoma mutation assay (unpublished report). [As described by OEHHA 2011.]

45. Ishidate M (1983). Application of chromosomal aberration tests *in vitro* to the primary screening for chemicals with carcinogenic and/or genetic hazards. In: Tests courts de cancérogénèse: Quo vadis? S Garattini (Ed). Montpellier: Centre de Recherches Clin Midy, pp. 58-79. [As described in European Commission 2009 and OEHHA 2011].

46. Juvenile Product Manufacturers Association (JMPA). (2013) Juvenile Product Manufacturers Association 2013 Annual Industry Study – Final Report. Part 1 of 3: Manufacturer Data Summary. Manufacturer's Shipment and Sales Data from 2011 & 2012.

47. Kawagoshi Y, Nakamura S, Fukunaga I. (2002) Degradation of organophosphoric esters in leachate from a sea-based solid waste disposal site. Chemosphere. 48: 219-225.

48. Kawashima K, Tanaka S, Nakaura S, Nagao S, Endo T, Onoda K, Takanaka A, and Omori Y. (1983) Effect of phosphoric acid tri-esters flame retardants on the prenatal and postnatal developments of rats. J. Toxicol. Sci. 8(1): 339.

49. Kojima H, Takeuchi S, Itoh T, Iida M, Kobayashi S, Yoshinda T. (2013) *In vitro* endocrine disruption potential of organophosphate flame retardants via human nuclear receptors. Toxicology. 314: 76-83.

50. Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, Buxton HT. (2002) Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance. Environ. Sci. Tech. 36(6): 1202-1211.

51. Klosterhaus S, Yee D, Sedlak M, Wong A, Sutton R. (2013) Contaminants of emerging concern in San Francisco Bay: a summary of occurrence data and identification of data gaps. RMP Contribution 698. San Francisco Estuary Institute, Richmond, CA, p. 24-30.

52. LeBel GL and Williams DT (1983). Determination of organic phosphate triesters in human adipose tissue. J. Assoc. Off. Anal. Chem. 66(3): 691-699.

53. LeBel GL and Williams DT (1986). Levels of triaryl/alkyl phosphates in human adipose tissue from Eastern Ontario. Bull. Environ. Contam. Toxicol. 37: 41-46.

54. LeBel GL, Williams DT, Berard D (1989). Triaryl/alkyl phosphate residues in human adipose autopsy samples from six Ontario municipalities. Bull. Environ. Contam. Toxicol. 43(2): 225-230.

55. Liu C, Fu J, Han J, Zhou B, Gong Z, Santos EM, Huo X, Zheng W, Liu H, Yu H. (2013a) Toxicogenomic responses of zebrafish embryos/larvae to tris(1,3-dichloro-2-propyl) phosphate (TDCPP) reveal possible molecular mechanisms of development toxicity. Environ. Sci. Technol. 47(18): 10574-10582.

56. Liu C, Wang Q, Liang Kang, Liu J, Zhou B, Zhang X, Liu H, Giesy JP, Yu H. (2013b) Effects of tris(1,3-dicholoro-2-propyl) phosphate and Triphenyl phosphate on receptor-associated mRNA expression in zebrafish embryos/larvae. Aquatic Toxicology. 128-129: 147-157.

57. Liu X, Ji K, Choi K. (2012) Endocrine disruption potentials of organophosphate flame retardants and related mechanisms in H295R and MVLN cell lines and in zebrafish. Aquatic Toxicology. 114-115: 173-181.

58. Lynn RK, Wong K, Garvie-Gould C, Kennish JM. (1981) Disposition of the flame retardant, tris(1,3-dichloro-2-propyl) phosphate, in the rat. Drug Metab. Dispos. 9(5): 434-441.

59. MarketsandMarkets. (2012) Flame Retardant Chemicals Market By Type, Application & Geography – Market Estimates Up To 2017.

60. Marklund A, Andersson B, Haglund P. (2003) Screening of organophosphorus compounds and their distribution in various indoor environments. Chemosphere. 53: 1137-1146.

61. McGee SP, Cooper EM, Stapleton HM, Volz DC. (2012) Early zebrafish embryogenesis is susceptible to developmental TDCPP exposure. Environmental Health Perspectives. 120(11): 1585-1591.

62. Meeker JD, Cooper EM, Stapleton HM, Hauser R. (2013) Urinary Metabolites or organophosphate flame retardants: temporal variability and correlations with house dust concentrations. Environmental Health Perspectives. 121(5): 580-585.

63. Meeker JD and Stapleton HM. (2010) House dust concentrations of organophosphate flame retardants in relation to hormone levels and semen quality parameters. Environmental Health Perspectives. 118(3): 318-323.

64. Miller KL (2011) New York TCEP (Tris) Law. OLR Research Report. http://www.cga.ct.gov/2011/rpt/2011-R-0298.htm (accessed October 16, 2013).

65. Morales NM and Matthews HB. (1980) *In vivo* binding of the flame retardants tris(2,3-Dibromopropyl) phosphate and tris(1,3-dichloro-2-propyl) phosphate to macromolecules of mouse liver, kidney and muscle. Bulletin of Environmental Contamination and Toxicology. 25(1): 34-38.

66. National Research Council (NRC). (2000) Subcommittee on Flame-Retardant Chemicals Committee on Toxicology Board on Environmental Studies and Toxicology Commission on Life Sciences. Toxicological Risks of Selected Flame-Retardant Chemicals, Ch. 16 Tris (1,3-dichloropropyl-2) Phosphate http://www.nap.edu/openbook.php?record_id=9841&page=358 (accessed October 8, 2013).

67. New York State Assembly. (2013) Amendment to Tris-Free Children and Babies Act. http://assembly.state.ny.us/leg/?default_fld=&bn=A04741&term=2013&Text=Y (accessed December 2013).

68. Nomeir A, Kato S, Matthews H. (1981) The metabolism and disposition of tris (1,3-dichloro-2-propyl) phosphate (Fyrol FR-2) in the rat. Toxicology and Applied Pharmacology. 57(3): 401-413.

69. Norwegian Climate and Pollution Agency (KLIF). (2011) Screening of organophosphor flame retardants 2010.

70. Norwegian Pollution Control Authority (SFT). (2008) Screening of selected metals and new organic contaminants 2007.

71. Norwegian Pollution Control Authority (SFT). (2009) Screening of new contaminants in samples from the norwegian arctic. Silver, Platinum, Sucralose, Bisphenol A, Tetrabrombisphenol A, Siloxanes, Phtalates (DEHP) and Phosphororganic flame retardants.

72. Office of Environmental Health Hazard Assessment (OEHHA), California Environmental Protection Agency (Cal/EPA). (2011) Evidence on the carcinogenicity of Tris(1,3-dichloro-2-propyl)phosphate. July 2011.

73. Office of Environmental Health Hazard Assessment (OEHAA), California Environmental Protection Agency (Cal/EPA). (2012) Initial Statement of Reasons Title 27, California Code of Regulations. Proposed Amendment To: Section 25705(B) Specific Regulatory Levels Posing No Significant Risk. Tris(1,3-Dichloro-2-Propyl) Phosphate (TDCPP). http://www.oehha.ca.gov/prop65/law/pdf_zip/060112TDCPPISOR.pdf (accessed December 10, 2013).

74. Office of Environmental Health Hazard Assessment (OEHAA), California Environmental Protection Agency (Cal/EPA). (2014) Chemicals Known to the State to Cause Cancer or Reproductive Toxicity. http://www.oehha.ca.gov/prop65/prop65_list/files/P65single072911.pdf (accessed February 2014).

75. Patisaul HB, Roberts SC, Mabrey N, McCaffrey KA, Gear RB, Braun J, Belcher SM, Stapleton HM. (2013) Accumulation and endocrine disrupting effects of the flame retardant mixture Firemaster 550 in rats: an exploratory assessment. J. Biochem. Mol. Toxicol. 27(2): 124-136.

76. San Francisco Estuary Institute (SFEI). 2013. The Pulse of the Bay: Contaminants of Emerging Concern. SFEI Contribution 701. San Francisco Estuary Institute, Richmond, CA, p 68-69.

77. Sasaki K, Suzuki T, Takeda M, Uchiyama M. (1984) Metabolism of phosphate acid triesters by rat liver homogenate. Bull. Environ. Contam. Toxicol. 33: 281-288.

78. Soderlund EJ, Dybing E, Home JA, Hongslo JK, Rivedal E, Sanner T, et al. (1985) Comparative Genotoxicity and nephrotoxicity studies of the two halogenated flame retardants tris(1,3-dichloro-2-propyl)phosphate and tris(2,3-dibromopropyl)phosphate. Acta Pharmacol. Toxicol. (Copenh). 56(1): 20-29. [As described by OEHHA 2011.]

79. Stapleton HM, Klosterhaus S, Eagle S, Fuh J, Meeker JD, Blum A, Webster TF. (2009) Detection of organophosphate flame retardants in furniture foam and US house dust. Environmental Science & Technology. 43(19):7490-7495.

80. Stapleton HM, Klosterhaus S, Keller, A, Ferguson PL, Van Bergen S, Cooper E, Webster TF, Blum A. (2011) Identification of flame retardants in polyurethane foam collected from baby products. Environmental Science & Technology. 45: 5323-5331.

81. Stapleton HM, Misenheimer J, Hoffman K, Webster TF. (2014) Flame retardant associations between children's handwipes and house dust. Chemosphere. http://dx.doi.org/10.1016/j.chemosphere.2013.12.100 [Epub ahead of print]

82. Stapleton HM, Sharma S, Getzinger G, Ferguson PL, Gabriel M, Webster TF, Blum A. (2012) Novel and high volume use flame retardants in U.S. couches reflective of the 2005 pentaBDE phase out. Environ. Sci. Tech. 46(24): 13432-13439.

83. Stauffer Chemical Company. (1977) Mutagenicity evaluation of FR-2. (Unpublished report). [As described by European Commission 2008 and OEHHA 2011.]

84. Stauffer Chemical Company. (1981a) A two year study of Fyrol-2 in rats. In: A two-year oral toxicity/carcinogenicity study of Fyrol FR-2 in rats (Volume I-IV) (final reports) with attachments, cover sheets, and letter dated 093081. Submitted to the U.S. Environmental Protection Agency under TSCA Section 8E. EPA88-8100282. OTS0204911. [As described by ATSDR 2012.]

85. Stauffer Chemical Company. (1981b) Toxicity reports on Fyrol FR-2 (Volume I-II) with attachments and cover letters dated 020381. Submitted to the U.S. Environmental Protection Agency under TSCA Section 8E. EPA88-8100271. OTS0204911. [As described by ATSDR 2012 and Babich 2006.]

86. Stauffer Chemical Company. (1983) A mortality survey of workers employed at a Fyrol FR-2 manufacturing plant. (Unpublished report). Submitted to the U.S. Environmental Protection Agency under TSCA Section E. OTS0204911. [As described by ATSDR 2012 and European Commission 2009.]

87. Sundkvist AM, Olofsson U, Haglund P. (2010) Organophosphorus flame retardants and plasticizers in marine and fresh water biota and in human milk. Journal of Environmental Monitoring. 12(4): 943-51.

88. Takahashi S, Katsumasa A, Kera Y. (2013) Chapter 5. Microbial Degradation of Persistent Organophosphorus Flame Retardants. In: Environmental Biotechnology - New Approaches and Prospective Applications, Marian Petre, Ed., pp. 91-122.

89. Takigami H, Suzuki G, Hirai Y, Ishikawa Y, Sunami M, Sakai S. (2009) Flame retardants in indoor dust and air of a hotel in Japan. Environ. Int. 35(4): 688-693.

90. Tanaka S, Nakaura S, Kawashima K, Nagao S, Endo T, Onoda K, Kasuya Y and Omori Y. (1981) Effect of oral administration of tris(1,3-dichloroisopropyl)phosphate to pregnant rats on prenatal and post natal developments. Journal unknown (in Japanese). [As described by European Commission 2008.]

91. Title 16, Code of Federal Regulations, Part 1632. Standard for the Flammability of Mattresses and Mattress Pads (Ff 4-72, Amended). http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=2a2ff88d70b535b426f8603f16a6a076&r=PART&n=16y2.0.1.4.95 (accessed December 2013).

92. Title 16, Code of Federal Regulations, Part 1633. Standard for the Flammability (Open Flame) of Mattress Sets http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=2a2ff88d70b535b426f8603f16a6a076&r=PART&n=16y2.0.1.4.96 (accessed December 2013).

93. Ulsamer AG, Osterberg RE, McLaughlin JJ. (1980) Flame retardant chemicals in textiles. Clinical Toxicology. 17(1): 101-32.

94. U.S. Environmental Protection Agency (U.S. EPA). (2002) Child-Specific Exposure Factors Handbook. National Center for Environmental Assessment. EPA-600-P-00-002B.

95. U.S. Environmental Protection Agency (U.S. EPA). (2005) Furniture Flame Retardancy Partnership: Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam, Volume 1.

96. U.S. Environmental Protection Agency (U.S. EPA). (2006) U.S. Environmental Protection Agency Inventory Update for 2-propanol, 1,3-dichloro-, phosphate (3:1).

97. U.S. Environmental Protection Agency (U.S. EPA). (2013) U.S. EPA ChemView. U.S. EPA's High Production Volume Information System (HPVIS). http://java.epa.gov/chemview (accessed October 23, 2013).

98. Van den Eede N, Dirtu AC, Neels H, Covaci. (2011) Analytical developments and preliminary assessment of human exposure to organophosphate flame retardants from indoor dust. Environmental International. 37(2): 454-461.

99. Van der Veen I and De Boer J. (2012) Phosphorus flame retardants: properties, production, environmental occurrence, toxicity and analysis. Chemosphere. 88(10): 1119-1153

100. Wang Q, Liang K, Liu Jingfu, Yang L, Guo Y, Liu C, Zhou B. (2013) Exposure of zebrafish embryos/larvae to TDCPP alters concentrations of thyroid hormones and transcriptions of genes involves in the hypothalamic-pituitary-thyroid axis. Aquatic Toxicology. 126: 207-213.

101. Wilczynski SL, Killinger JM, Zwicker GM, Freudenthal RI. (1983) Fyrol FR-2 fertility study in male rabbits. The Toxicologist. 3: 22. (Abstract only). [As described in Babich 2006.]

102. World Health Organization (WHO). (1998) Environmental Health Criteria 209. Flame retardants: Tris(chloropropyl) phosphate and tris(2-chloroethyl) phosphate.