A Review of Chemical Alternatives Analysis

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What is Chemical Alternatives Analysis?

CAA is "an emerging methodology for avoiding harm or potential harm associated with chemicals of known concern."

- Begins with recognition of an existing threat;
  - Chemical in an existing product system;
  - CMR / PBT; endocrine disruptor; other hazard traits;
  - on a list of dangerous chemicals;
- "Solution-based:" how else can we accomplish this goal?
- Precautionary: seek safer alternatives based on the existence of hazards rather than proof of harm.

The two objectives of CAA are:

1. Address the primary area of concern (why is the substance a threat?);
2. Avoid regrettable substitutions.

Adopt a life-cycle perspective to evaluate the relative benefits and drawbacks of potential alternatives.

History

Ancient history to present:

Individuals, businesses, and governments weigh possible alternatives.

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- Massachusetts: Toxics Use Reduction Act

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1990s: EPA addresses shortcomings of TSCA

- Voluntary measures (high production volume challenge program..);
- Design for Environment initiatives;
- Cleaner Technologies Substitutes Assessment laid a foundation for the methodical search for alternatives;

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1998 on:

- Wingspread Statement: the search for alternatives as precautionary action;
- "Green Chemistry: Theory and Practice," Anastas and Warner, 1998;
- "Making Better Environmental Decisions," O'Brien, 1999;

Lowell Center and TURI develop their methodology:

- 5 chemicals study;
- Lowell Framework for Alternatives Assessment;

Third party resources emerge:

- MBDC, ZeroWaste.org, GreenScreen, GreenList, others...

Parts of CAA

- Define the product system under study:
  - what role does the CoC play in meeting the product's function?
  - what is the nature of the threat presented?
- Develop alternatves:
  - drop-in substitutions;
  - process changes; management changes;
  - product or process redesigns;
- Alternatives Assessment:
  - understand the threats presented by the current system and alternatives;
  - do alternatives address the reason for concern?
  - do they carry any other potential benefits or drawbacks?
- Select a course of action:
  - Not just "choose a, b, or c;"
  - Understand benefits and drawbacks of different approaches;
  - Develop a plan for transitioning to a safer product or process.

Alternatives Assessment

Alternatives assessment is a process for studying an existing product system and various options for changing it. Common features of AAs include:

- Use of quantitative and qualitative information;
- diminished reliance on the results of risk assessment;
- description of the functional use of a chemical as a basis for developing alternatives;
- an iterative process of continuous improvement—
  part of a long-term shift to safer practices;

Some other features:

- often modluar (CTSA, Lowell);
- often helpful to involve stakeholders or the public;
- life cycle thinking can be beneficial.

EPA Design for Environment

- Cleaner Technologies Substitutes Assessment (1996):
  - A **Use Cluster** is an area of functionality where "the relative human health and environmental risk, performance, cost, and resource conservation alternatives can be compared."
  - Modular approach to evaluating the performance of different alternatives within a use cluster;
  - Intended primarily as an aid to gathering and organizing risk and performance information, not a decision tool.
- Later DfE projects: industry partnerships and case studies.
  - narrower focus; greater depth;
  - Emphasis on chemical substitutions;
  - Furniture Flame Retardants Alternatives Assessment: 2005.

Table 4-1 Screening Level Toxicology and Exposure Summary

L = Low hazard concern
M[1] = Moderate hazard concern
H = High hazard concern
N = No
Y = Yes
P = Yes for pure chemical
*Ongoing studies may result in a change in this endpoint
▲Persistent degradation products expected[2]
L, *M*[1], or *H* = Endpoint assigned using estimated values and professional judgment (Structure Activity Relationships)

Company	Chemical`	% in Formulation[3]	Human Health Effects							Ecotoxicity		Environmental		Potential Routes of Exposure							Reactive or Additive?
														Worker			General Population				
			Cancer Hazard	Skin Sensitizer	Reproductive	Developmental	Neurological	Systemic	Genotoxicity	Acute	Chronic	Persistence	Bioaccumulation	Inhalation	Dermal	Ingestion	Inhalation	Dermal	Ingestion	Aquatic	
Albemarle	ANTIBLAZE 180 and ANTIBLAZE 195																				
	Tris(1,3-dichloro-2-propyl)Phosphate CAS # 13674-87-8	95%	M	L	M	M	L	M	M	M	M	M	*L*	N	Y	Y	N	Y	Y	Y	Additive
Albemarle	ANTIBLAZE 182 and ANTIBLAZE 205																				
	Proprietary A Chloroalkyl phosphate (1)		M	L	M	M	L	M	M	M	M	M	*L*	N	Y	Y	N	Y	Y	Y	Additive
	Proprietary B Aryl phosphate		*L*	*L*	M*	M*	M	M*	*L*	H	*H*	*L*	*M*	N	Y	Y	N	Y	N	N	Additive
	Triphenyl Phosphate CAS # 115-86-6		*L*	L	L	L	L	M	L	H	*H*	L	L	Y	Y	Y	Y	Y	Y	Y	Additive
Albemarle	ANTIBLAZE V500																				
	Proprietary C Chloroalkyl phosphate (2)		*M*	M	*M**	*M**	L	M	L	M	M	M	*L*	N	Y	Y	N	Y	Y	Y	Additive
	Proprietary B Aryl phosphate		*L*	*L*	M*	M*	M	M*	*L*	H	*H*	*L*	*M*	N	Y	Y	N	Y	N	N	Additive
	Triphenyl Phosphate CAS # 115-86-6		*L*	L	L	L	L	M	L	H	*H*	L	L	Y	Y	Y	Y	Y	Y	Y	Additive
Albemarle	SAYTEX RX-8500																				
	Proprietary D Reactive brominated flame retardant		*L*	*M*	*L*	*L*	*M*	*M*	L	*M*	*M*	*L*▲	*L*	N	Y	Y	N	N	Y	Y	Reactive
	Proprietary B Aryl phosphate		*L*	*L*	M*	M*	M	M*	*L*	H	*H*	*L*	*M*	N	Y	Y	N	Y	N	N	Additive
	Triphenyl Phosphate CAS # 115-86-6		*L*	L	L	L	L	M	L	H	*H*	L	L	Y	Y	Y	Y	Y	Y	Y	Additive

TURI and Lowell Center

- TURI Five Chemicals Study:
  - Systematically review five different chemicals of concern and look for alternatives for their major uses;
  - Used TURA data to track uses rather than emissions;
  - Emphasized stakeholder involvement throughout the process;
  - (The work was still performed by the public agency)
  - Report results in qualitative terms to the general public.
- Lowell Center Alternatives Assessment Framework:
  - Open-source, modular toolset for evaluating uses of chemicals;
  - Decision maker provides the goals and measurable objectives, principles and decision making rules;
  - Develop alternatives based on end-use functions of the current chemical, and on desired attributes of new chemicals or products;
  - Evaluation is modular and emphasizes the use of already-existing tools.

Five Chemicals Study – Lead Wheel Weights

Table 3.4.2 L: Assessment Summary Alternatives for Lead Wheel Weights

Assessment Criteria		Lead (Reference)	Comparison Relative to Lead			
			Copper	Steel	Tin	Zinc
Technical/ Performance Criteria	Density	11.34 g/cm^3	-	-	-	-
	Malleability	Good	=	-	=	-
	Corrosion Resistance (with coating)	Good	=	=	+ (coating not required)	=
Environmental Criteria	Primary Drinking Water Standards (MCL Action Level)	15 g /l	+	+ (iron)	+ (FL & MN)	?
	Aquatic Toxicity: Water Quality Criteria (CMC) Freshwater Saltwater	65 g/L 210 g / L	- -	+ (iron) ?	? ?	+ -
Human Health Criteria	Carcinogenicity	EPA B2 IARC 2B	+	+	+	+
	Developmental Toxicity	Yes (Prop 65)	+	+	+	+
	Occupational Exposure: REL (8-hour TWA)	0.050 mg/m^3	+	+	+	+
Cost	Price per weight (coated, ¼ – 2 oz)	$0.25 - $0.43	-	= / +	-	=
	Available in clip-on & adhesive styles	Yes	-	=	-	=
	End-of-Life Cost (Auto Shredder)	Average	+	+	+	+

Comparison Key + Better = Similar - Worse ? Unknown

Choosing Among Alternatives

It is uncommon for one alternative to be superior to all others in all areas of concern. How do we select a course of action?

- Many different criteria that cannot be compared;
- Combination of quantitative and qualitative information;
- Possibly many stakeholders
- Possibly substantial uncertainty.

Decision making is an *inherently subjective* process.

- Develop a list of criteria which encompass all relevant qualities of the different alternatives:
  - *complete, minimal, balanced, operational*
- Make a rational decision which is in line with decision makers' preferences;
- Decision analytic tools can provide support for this process:
  - Qualitative (rule-based) or quantitative (scores and weights);
  - Aid in **documenting** the decision makers' preferences;
  - Provide **transparency**;
  - Provide a platform for **deliberation** and stakeholder involvement.

Examples – Green Screen

This chemical passes all of the criteria.

BENCHMARK 4

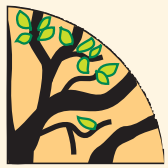
ready biodegradability (low P) + low B + low Human Toxicity + low Ecotoxicity (+ additional ecotoxicity endprints when available)

Prefer—Safer Chemical

BENCHMARK 3

a. moderate P or moderate B
b. moderate Ecotoxicity
c. moderate Human Toxicity
d. moderate Flammability or moderate Explosivenesness

Use but Still Opportunity for Improvement



If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 4

BENCHMARK 2

a. moderate P + moderate B + moderate T (moderate Human Toxicity or moderate Ecotoxicity)
b. high P + high B
c. (high P + moderate T) or (high B + moderate T)
d. moderate Human Toxicity for any priority effect or high Human Toxicity
e. high Flammability or high Explosiveness

Use but Search for Safer Substitutes

If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 3

BENCHMARK 1

a. PBT: high P + high B + high T[1] (high Human Toxicity[2] or high Ecotoxicity)
b. vPvB: very high P + very high B
c. vPT (vP + high T) or vBT (vB + high T)
d. high Human Toxicity for any priority effect[3]

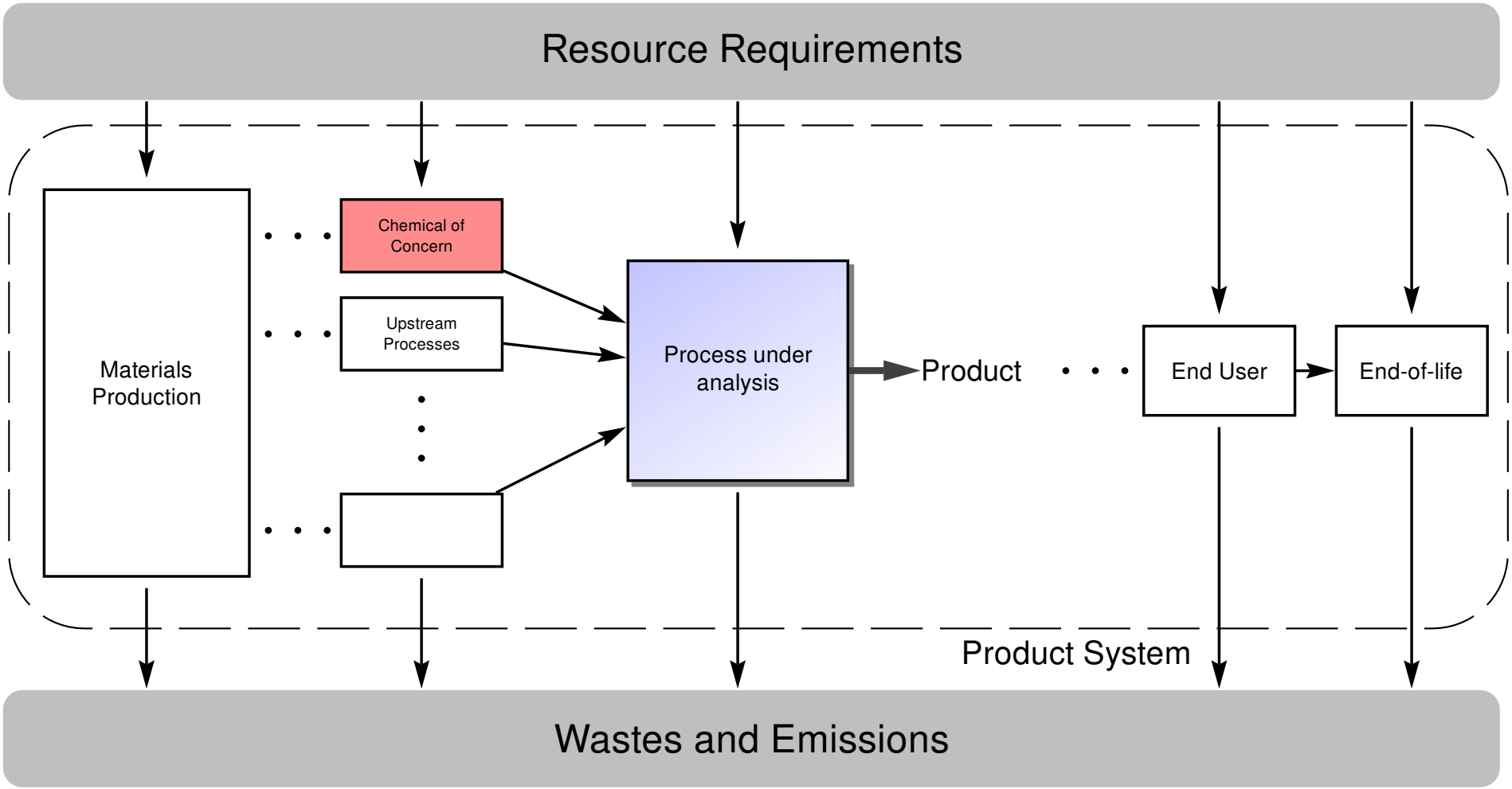
Avoid—Chemical of High Concern

If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 2

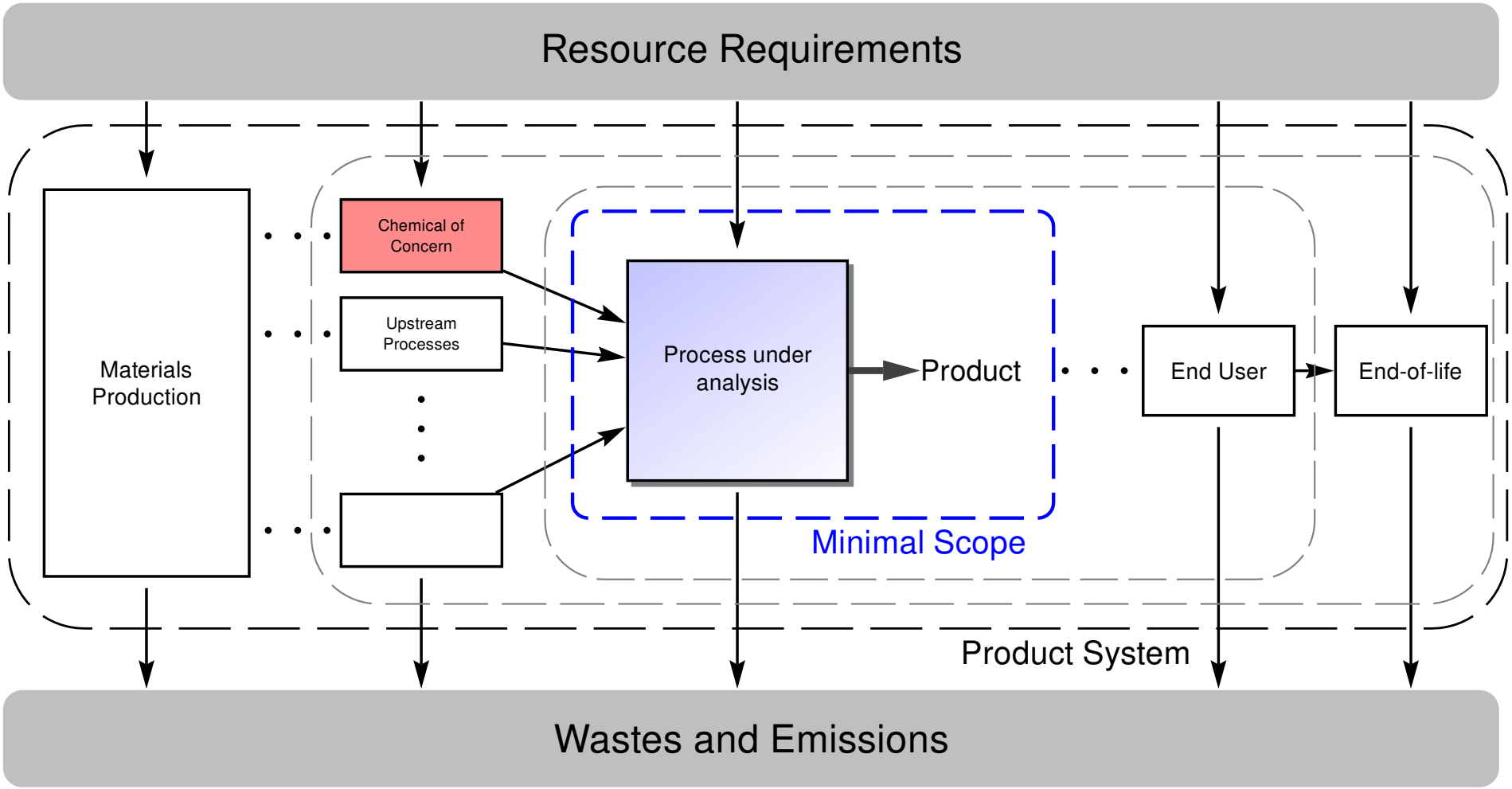
Examples

- C2C Protocol:
  - Developed by McDonough Braungart Design Chemistry; released to California;
  - C2C is a way to certify products as well as their production processes;
  - A set of binary (yes/no) evaluation criteria which use a combination of quantitative and qualitative rules;
  - Material Health, Material Reutilization / DfE, Energy, Water, Social Responsibility;
  - Certification requires commitment to ongoing improvement.
- GoodGuide:
  - Online consumer product database;
  - Products evaluated according to over 1,100 criteria in categories of Health, Environment, and Society;
  - Criteria arranged into a formal analytic structure;
  - Scores and weights are combined to result in a set of 0–10 ratings.

Life Cycle Thinking



Life Cycle Thinking – Scope of Analysis



Recommendations

- Use the broadest possible scope in developing potential alternatives:
  - Evaluate the function of the chemical of concern in the product;
  - Consider both presence of hazard and risk of exposure;
- Assess alternatives based on a range of criteria:
  - Evaluate how well each alternative affects the primary area of concern;
  - Look for benefits and drawbacks throughout the entire life cycle;
- Select a course of action:
  - Careful documentation of the decision process;
  - Complete, minimal, balanced criteria;
  - Find opportunities for mitigation;
  - Routine assessment as part of a program of continuous improvement.

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Thank you!