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An abbreviated alternatives assessment process for product designers: a children's furniture manufacturing case study

Kathryn H. Winnebeck*

New York State Pollution Prevention Institute, Rochester Institute of Technology, 111 Lomb Memorial Drive, Rochester, NY 14623, USA

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ABSTRACT

Alternatives assessment is becoming increasingly popular to evaluate the potential environmental and human health hazards of materials. A three step process was used to identify and evaluate alternative products for a children's furniture manufacturer. An alternatives assessment framework was developed to analyze alternative mattresses. The framework specifically addresses those environmental and safety attributes applicable to the product and the product components in accordance with the product's intended use. The result of the assessment allowed the manufacturer to select the most environmentally friendly alternative and eliminate polyvinyl chloride from their product.

1. Introduction

The safety of children's products has come under increased scrutiny due to the prevalence of product recalls caused by products not meeting requirements for lead and other toxic material content requirements set forth by the U.S. Consumer Product Safety Commission (CPSC). In response, the Consumer Product Safety Improvement Act (CPSIA) was signed into law in August 2008 and went into effect February 10, 2009. The Act places more stringent lead content restrictions and for the first time restricts certain phthalate content in products and articles intended for children under the age of twelve, including cribs, to 0.1%.

A combination of the Consumer Product Safety Improvement Act restrictions on phthalate content of children's products, increased awareness of the health and environmental concerns associated with polyvinyl chloride (PVC), and dedication to the environment led a New York State manufacturer of furniture and spaces designed for children to eliminate or greatly reduce the PVC content of its children's cribs. These cribs are used in daycare facilities across the United States and must meet stringent flammability and cleaning requirements. The manufacturer identified a selection of potential alternative materials but was uncertain if there were additional options and which alternative materials meet performance, regulatory, and company environmental criteria.

In response, a review of existing alternatives assessment methodologies was performed and a unique alternatives assessment methodology was developed. Potential alternatives were identified and assessed according to the methodology. The numerical and descriptor data points were translated into results that the manufacturer interpreted. As a result, the manufacturer has replaced all of its crib PVC-based components.

2. Alternatives assessment review

2.1. Background

Alternatives assessment is a tool used to compare and contrast the viability and attributes of potential replacements. Alternatives assessment can be used in the design phase to drive innovation and to evaluate identified alternatives. A significant amount of data must be collected to comprehensively evaluate alternatives. A number of human health and environmental data points are incorporated in the assessment process resulting in the generation of a significant amount of data. It can be difficult and cumbersome for product design teams to sort through the data, determine and apply their priorities to the data, and conclude the process with a viable alternative. Displaying the results in a simplified, easy to interpret manner designed for the user, is key to a successful alternatives assessment process.

* Tel.: +585 475 5390; fax: +585 475 5455.
E-mail address: kmhasp@rit.edu.

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Table 1
Summary of attributes included in select alternatives assessment processes.

Attributes Assessed	Environmental Effects	Human Health Effects	Other Effects
TURI 5 Chemicals Study[a]	*Environmental Effects*: Hazardous Air Pollutant Water Solubility Density Specific Gravity Vapor Pressure Henry's LawCoefficient Kd (soil sorption coefficient) Koc (adsorption coefficient) Log Kow (octanolwater partition coefficient) Persistence: Water, Soil, Sediment, Air Bioaccumulation Aquatic Toxicity Drinking Water Quality *Other Environmental Hazards*: Degradation Products Ozone Depleting (ODC) Greenhouse Gas	*Acute Human Health Effects*: Metabolites Dermal Absorption Lethal Dose concentration: Inhalation LC 50, Oral LD50, Dermal LD50 Occupational Exposure Limits: IDLH, PEL, REL, TLV, Ceiling/ST Irritation: Dermal, Ocular, Respiratory *Chronic Human Health Effects*: Reference Dose Mutagenicity Carcinogenicity Skin Sensitization Reproductive & DevelopmentalToxicity Target Organ	*Other Hazards*: Flammability Reactivity Corrosivity Flash Point
GreenScreen[b]	*Environmental Fate*: Persistence Bioaccumulation Potential *Ecotoxicity*: Acute Aquatic Toxicity Chronic Aquatic Toxicity	*Human Health*: Carcinogenicity Mutagenicity/Genotoxicity Reproductive Toxicity Developmental Toxicity Endocrine Disruption Neurotoxicity Acute Toxicity (oral, dermal, or inhalation) Corrosion/Irritation of the skin or eye Sensitization of the skin or respiratory system Immune system effects Systemic toxicity/organ effects (via single or repeated exposure)	*Physical/Chemical Properties*: Explosive Flammable
Column Model	Environmental hazards	Acute health hazards Chronic health hazards Exposure potential	Fire and explosion hazards Hazards caused by procedures
Safer Consumer Product Alternatives[c]	*Materials and resource consumption*: Amount of raw materials used - renewable and non-renewable Water consumption and conservation Production, in-use, and transportation energy inputs Energy consumption and efficiency Reusability and recyclability *Environmental impacts*: Water quality impacts including BOD, COD and TSS Air emissions including NOx's, SOx's, Toxic Air Contaminants Greenhouse gas emissions Stratosphere ozone depletion Waste and end-of-life disposal including solid waste, wastewater releases, liquid waste Other emissions: Noise, radiation, vibration, odor, waste heat Ecotoxicity (including both aquatic and terrestrial ecosystems) Any other hazard traits that relate to adverse impacts on the environment	*Public and occupational health impacts, including potential impacts to sensitive subpopulations. Toxicity and toxicological endpoints addressed shall include, but not be limited to all of the following*: Acute or chronic toxicity: Impacts that may result from single, intermittent or chronic use of, or contact with,the product, considering opportunities for dermal, oral and inhalation exposures during product use or other stages in the lifecycle of the product. Carcinogenicity Genotoxicity Teratogenicity Reproductive toxicity Developmental toxicity Neurolotoxicity Immunolotoxicity Endocrine disruption Organ or tissue system toxicity Respiratory effects Epigenetic effects Persistence Bioaccumulation Synergistic potential Any other hazard traits, as defined in Section 2, that related to adverse impacts on public health	*Economic impacts*: Capital investment Operations and maintenance cost Cost for resources Energy costs Waste disposal and treatment cost Non-compliance liability

(*continued on next page*)

Table 1 (*continued*).

Attributes Assessed	Environmental Effects	Human Health Effects	Other Effects
Cradle to Cradle™[d]	*Environmental health criteria:*	*Human health criteria:*	*Material Class:*
	Fish toxicity	*A. Priority:*	Organohalogen content
	Daphnia toxicity	Carcinogenicity	Heavy metal content
	Algae toxicity	Endocrine disruption	
	Persistence/biodegradation	Mutagenicity	
	Bioaccumulation	Teratogenicity	
	Climatic Relevance	Reproductive Toxicity	
	Other	*B. Additional:*	
		Acute toxicity	
		Chronic toxicity	
		Irritation of skin and mucous membranes	
		Sensitization	
		Other	

[a] Table 2.5.3: EH&S Parameters Considered in Assessing Alternative, Massachusetts Toxics Use Reduction Institute, Five chemicals alternatives assessment study, University of Massachusetts Lowell, 2006.
[b] Table 1 Threshold Values for Each Chemical Hazard Included in the Green Screen v 1.0, Clean Production Action, 2009, The GreenScreen for Safer Chemicals, Version 1.
[c] VI. Alternatives Assessments in California Environmental Protection Agency Department of Toxics Substances Control, 2010, Outline of Draft Regulations for Safer Products, http://www.dtsc.ca.gov, 1 May 2010.
[d] 4.3 Ingredient Characterization in McDonough Braungart Design Chemistry, LLC., 2008, Cradle to Cradle Certification Program, Version 2.1.1.

In the past decade, a number of alternative assessment processes have been developed and used to assess alternatives at the product, material, and chemical level. The Massachusetts Toxics Use Reduction Institute surveyed nine methods and tools that are available for alternatives assessment developed by government and private organizations in the US and Europe in 2005. Tools were divided into two categories – hazard data display methods where data on a range of chemical hazards is presented and the user must apply decision methods to the data and screening/decision methods which have decision rules built into the method, prioritize risk, and recommend alternatives (Civie et al., 2005).

2.2. *Five chemicals alternatives assessment study, Massachusetts Toxics Use Reduction Institute, June 2006*

In July 2005, the Commonwealth of Massachusetts requested that TURI assess safer alternatives for lead, formaldehyde, perchloroethylene, hexavalent chromium, and di(2-ethylhexyl) phthalate (DEHP). TURI developed an alternatives assessment process to identify alternatives and their associated environmental impacts, human health impacts, technical feasibility, and economic feasibility. TURI used three phases to achieve the goal. First, the uses of chemicals in Massachusetts were identified and subsets of uses were prioritized for in-depth analysis. Second, TURI identified alternatives for chemical use and chose priority alternatives for further study. Once alternatives and uses were prioritized, TURI researched the health, environmental, technical, and economic aspects of each alternative using information from publically available sources and industry experts. An important distinction of the TURI process is that it does not rank alternatives, but "provides information that will allow users to make informed decisions and in some cases, to design additional research to fill remaining information gaps" (TURI, 2006). The study chemical is used as a baseline that the alternative chemical is compared against. The process is not intended to assess the relative aspects of one alternative over another. The results are also difficult to sort through and interpret due to the sheer volume of data included as well as the presentation method. Large, multiple page tables present the data. Categorizing the data or assigning risk values may help to make the data easier to interpret and draw conclusions.

2.3. *GreenScreen for safer chemicals, Clean Production Action, March 2007*

The GreenScreen is a scientific way to analyze alternative chemicals for human health, environment, and safety aspects and also presents the results in a more easy to interpret manner. A set of four benchmarks are used. A set of environment, safety, and human health criteria exists at each benchmark and an alternative must pass all criteria at a given benchmark in order to move up to the next benchmark. Benchmark's start at the bottom with *1 (red) Avoid – chemical of high concern*, and move up to *2 (orange) Use but search for safer substitutes*, *3 (yellow) Use but still opportunity for improvement*, and *4 (green) Prefer – safer chemical*.

Whereas the TURI Five Chemicals Study presents a plethora of information that is not ranked or benchmarked, GreenScreen uses color coding and target values to benchmark alternatives against. This allows the decision maker to quickly identify the alternative with the least safety, health, and environmental concern and those areas which present concern, preventing the alternative from moving to a higher benchmark value.

2.4. Column model, the Institute for Occupational Safety (BIA), German federation institute for statutory accident insurance and prevention, September 2009

The Column Model is used to evaluate chemicals for their potential hazards. It is unique in that the data used to populate the alternatives assessment comes from the chemical's material safety data sheet and is based on the R-phrase. In Europe, R-phrases are used to indicate a specific hazard associated with a chemical or product, and are presented as a number. For example, R23 corresponds to "toxic by inhalation" (European Union, 1967). A table format is used with the potential risks along the top row with established criteria based on R-phrases established for five risk levels: very high risk, high risk, medium risk, low risk, and negligible risk. Each alternative is evaluated for the following hazards: acute health hazards, chronic health hazards, environmental hazards, fire and explosion hazards, exposure potential, and hazards caused by procedures. Each alternative is evaluated for each of the six hazards. The results of the assessment are not presented as a single score but rather a score in each of the six hazards. The user determines which hazard is most important and can base their decision on specific criteria important to the user.

2.5. Safer consumer product alternatives, draft outline for regulations, California Department of Toxic Substances Control (DTSC), April 2010

California has developed the draft outline in response to Senate Bill Number 509, which requires the department to "establish the Toxics Information Clearinghouse, which shall provide a decentralized, Web-based system for the collection, maintenance, and distribution of specific chemical hazard trait and environmental and toxicological end-point data" for consumer products sold in California. There is a six step process DTSC must follow to identify chemicals of concern, map those chemicals to the consumer products which use them, the manufacturer is required to perform an alternatives assessment for the chemical and submit the action plan to DTSC based on the results. As part of the Draft Outline for Regulations, DTSC has outlined the requirements for the alternatives assessment process, including the attributes which must be included in the evaluation. DTSC is taking a life cycle approach to the alternatives assessment, including impacts at the various stages of the product: raw materials mining; intermediary material processing; manufacturing and packaging; distribution, transportation and marketing; use; product end of life; and reuse and recycle. There are a total of thirty six indicators which must be included in the alternatives assessment. The indicators are organized into the following four categories: materials and resource consumption; public and occupational health impacts, including potential impacts to sensitive subpopulations; environmental impacts; and economic impacts. The decision to implement an alternative is left to the manufacturer, as the DTSC does not outline a prioritization or decision making scheme. The manufacturer must submit their action plan based on the results of the alternatives assessment for the approval of DTSC before moving forward.

2.6. Cradle to cradle certification program version 2.1.1, McDonough Braungart Design Chemistry (MBDC), LLC, September 2008

Cradle to Cradle is a voluntary, third party US based environmental product certification. Part of the certification assessment is an assessment of the product's ingredients. Assessment criteria are established for human health, environmental health, and material class. In order to receive certification, the manufacturer submits their list of ingredients to MBDC who then evaluates them against the criteria. The results are color coded and categorized from (green) little to no risk, (yellow) low to moderate risk, (red) high hazard and risk, and (grey) incomplete data. Color coding the results simplifies communication with product designers and managers who are not regularly versed in environmental and toxicity terminology. Criteria for each impact category have been developed at each risk level and remains proprietary information, making it difficult to evaluate the assessment process. (Table 1)

2.7. Alternatives assessment frameworks

2.7.1. Alternatives assessment framework of the Lowell center for sustainable production, University of Massachusetts Lowell, July 2006

In addition to the alternatives assessment processes summarized above, the Lowell Center for Sustainable Production at University of

Table 2
Product level analysis metrics.

Attribute	Pass	Fail
Critical Parameters		
Aesthetic	Attractive look and feel, "baby friendly", neutral color	Unattractive, harsh colors
Allergens	Does not contain known allergens or contains known allergens that are wrapped and sealed in the mattress	Contains known allergen exposed to surface of the mattress
Dimension	Available mattress sizes meet the crib dimensional requirements	Available mattress sizes do not meet the crib dimensional requirements
Firmness	Firm	Soft
Flammability	Meets CAL117 fabric standard	Does not meet CAL117 fabric standard
Cover material	Does not contain heavy metals, organohalogens, halogenated hydrocarbons, or polyvinyl chloride	Contains heavy metals, organohalogens, halogenated hydrocarbons, or polyvinyl chloride
Material Disclosure	Manufacture willing to disclose all materials used	Manufacture not willing to disclose all materials used
Smell	No smell; smell more benign than urethane foam	Definite unappealing smell
Preferential Parameters		
Cleanability	Water resistant; able to withstand daily cleaning with 10% bleach solution, green cleaners, and other popular cleaners and disinfectants daily	Water resistant; cannot withstand daily cleaning with 10% bleach, green cleaners, or other popular cleaners and disinfectants daily
Durability	Able to withstand daily cleaning for at least 5 years with no degradation	Product degrades due to cleaning within the first 5 years
Mattress Material	Mattress is made mostly of natural materials Mattress does not contain heavy metals, organohalogens, and halogenated hydrocarbons	Mattress is made from 100% man made materials Mattress does contain heavy metals, organohalogens, and halogenated hydrocarbons
Price	Costs no more than 20% more than current mattress	Costs over 20% more than current mattress

Table 3
Results of the product level analysis.

Attribute	Option A	Option B	Option C	Option D	Option E	Option F	Option G	Option H
Analysis result	Pass	Fail	Fail	Fail	Pass	Pass	Pass	Fail
Critical parameters								
Aesthetic	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Allergens	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Dimension	Pass	Fail	Pass	Pass	Pass	Pass	Pass	Fail
Firmness	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Flammability	Pass	Unsure	Pass	Unsure	Pass	Pass	Pass	Pass
Cover MATERIAL	Pass	Fail	Fail	Unsure	Pass	Pass	Pass	Pass
Material Disclosure	Pass	Fail	Fail	Fail	Pass	Pass	Pass	Pass
Smell	Pass	Fail	Fail	Pass	Pass	Pass	Pass	Pass
Preferential parameters								
Cleanability	Fail	Pass	Pass	Unsure	Pass	Pass	Fail	Fail
Durability	Fail	Pass	Pass	Unsure	Pass	Pass	Fail	Fail
Mattress material	Pass	Fail	Pass	Unsure	Pass	Pass	Pass	Pass
Price	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

Massachusetts, Lowell has developed a framework for developing an alternatives assessment process (Rossi et al., 2006). The goal is to develop an open source framework for quick "assessment of safer and more socially just alternatives to chemicals, materials, and products". The Comparative Assessment process is used to compare two existing alternatives and consists of the following steps: (1) identify target for replacement, (2) characterize and prioritize the end use of the replacement, (3) identify potential alternatives, (4) evaluate and compare alternatives, (5) select the preferred alternative, and (6) revisit and review the selected alternative to ensure it remains the preferred alternative. During the evaluation step, the Framework recommends incorporating human health, environment, and social justice impacts; economic feasibility; and technical performance. The Framework emphasizes using the assessment process by public policy and regulatory decision makers rather than product designers and industry.

2.7.2. States Alternatives Assessment Protocol Wiki, in process

A number of alternatives assessment experts throughout the United States have joined forces to create the States Alternatives Assessment Protocol Wiki. The Wiki was spearheaded by the Toxics Use Reduction Institute at University of Massachusetts Lowell with a goal to create a skeleton that states can use to perform an alternatives assessment and serve as a resource portal. The process evolves in real time, as the Wiki is Internet based, allowing the public to view information as it is created and edited and allowing experts to create and edit information in real time. The Wiki is a joint effort between a number of governmental and non-governmental bodies to work together to develop a scientifically acceptable method for performing alternatives assessment.

3. Using alternatives assessment to fulfill CPSIA requirements: children's furniture manufacturer case study

3.1. Problem

A children's crib produced by a New YorkState manufacturer uses a mattress consisting of a polyurethane foam core wrapped in polyvinyl chloride fabric. Polyvinyl chloride, commonly referred to as PVC, contains potentially toxic phthalates, used as plasticizers to make plastic soft and pliable. Phthalates are commonly found in toys, vinyl upholstery, shower curtains, inks, pesticides, and cosmetics (European Council for Plasticisers and Intermediates, 2010a). Di-2-ethyl hexyl phthalate (DEHP), diisodecyl phthalate (DIDP) and diisononyl phthalate (DINP) are the most commonly used phthalates, with DEHP dominating others due to its low cost (European Council for Plasticisers and Intermediates, 2010a). Animal studies have shown that high doses of phthalates cause endocrine disruption and can lead to birth defects (CDC, 2005). Children are more susceptible to potential effects due to their small size and development (Sathyanarayana et al., 2008).

The Silent Spring Institute analyzed indoor air and house dust samples from 120 Cape Cod Massachusetts homes and 50 Northern California homes for more than 89 different endocrine disrupting compounds. Sixty seven compounds were found in the Cape Cod homes, with an average of 24 per home while 104 compounds were found in the California homes. DEHP was detected in all Cape Cod homes sampled. Outdoor air samples were also taken in the California homes and higher concentrations of endocrine disrupting chemicals were found in indoor air than outdoor air (Dunagan et al., 2010).

Table 4
Hazard score definitions.

Number Assigned	Color Assigned	Hazard value
4	Red	Very high hazard
3	Red	High hazard
2	Orange	Moderate hazard
1	Yellow	Low hazard
0	Green	No or very low hazard
NA	Gray	Not applicable at product level
NP	White	Information is not provided by the data source
NE	White	Value is not established by the data source

Table 5
Definitions of ingredient level metrics.

Attribute	0 No or Very Low Hazard	1 Low Hazard	2 Moderate Hazard	3 High Hazard	4 Very High Hazard
Bioaccumulation & Persistence					
Fish ChV	Greater than 10 mg L Chemically inert	Not established	Between 0.1 and 10 mg L	Not established	Less than 0.1 mg L
Bioaccumulation Factor (BCF)	Not bioaccumulative Chemically inert BCF less than 1000	Not established	Bioaccumulative BCF between 1000 & 5000	Not established	Very bioaccumulative BCF greater than 5000
Water Persistence	Not persistent Chemically inert Less than 60 days	Not established	Persistent Between 60 & 180 days	Not established	Very persistent Greater than 180 days
Soil Persistence	Not persistent Chemically inert Less than 60 days	Not established	Persistent Between 60 & 180 days	Not established	Very persistent Greater than 180 days
Sediment Persistence	Not persistent Chemically inert Less than 60 days	Not established	Persistent Between 60 & 180 days	Not established	Very persistent Greater than 180 days
Air Persistence	Not persistent Chemically inert Less than or equal to 2 days	Not established	Not established	Not established	Very persistent Greater than 2 days
Dangerous for the Environment	Not listed	Not established	Not established	Not established	Listed
Greenhouse Gases	Not listed	Not established	Not established	Not established	Listed
Ozone Depleting Substance (ODS)	Not on EPA's Class I or Class II ODS lists	Not established	Not established	Not established	On EPA's Class I or Class II ODS lists
Regulatory Coverage					
FDA Food Additive Status	GRAS under any condition	Not established	Concentration restrictions in specific food groups	Not established	Not listed
EPA Hazardous Air Pollutant	Not listed	Not established	Not established	Not established	Listed
US National Drinking Water Regulations	Not listed	Listed & Maximum Contaminant Level of 0	Not established	Not established	Listed & Maximum Contaminant Level above 0
Federal or State Regulatory Program Lists or Other Chemical Blacklists	Not listed	Not established	Not established	Not established	Listed
Acute Toxicity					
Inhalation LC50	Not established	Minimal Toxicity Greater than 20 mg L	Low Toxicity Between 2 & 20 mg L	Moderate Toxicity Between 0.2 & 2 mg L	High Toxicity Less than 0.2 mg L
Oral LD50	Not established	Minimal Toxicity Greater than 5000 mg kg	Low Toxicity Between 500 & 5000 mg kg	Moderate Toxicity Between 50 & 500 mg kg	High Toxicity Less than 50 mg kg
Dermal LD50	Not established	Minimal Toxicity Greater than 20,000 mg kg	Low Toxicity Between 2000 & 20,000 mg kg	Moderate Toxicity Between 200 & 2000 mg kg	High Toxicity Less than 200 mg kg
Health Hazard					
EWG Hazard Rating	0 or 1	2 or 3	4 or 5	6 or 7	8, 9, or 10
Endocrine Disruption	Not recognized nor suspect	Not established	Not established	Suspected	Recognized
Symptoms	None	Irritation of eyes and skin	Irritation of respiratory tract	Difficulty breathing, weakness, dizziness	Unconsciousness or death
Allergies/Immunotoxicity	No evidence	Not established	Not established	Moderate evidence	Strong evidence
Recognized Health Hazard	No negative health effect	Skin and/or eye irritation	Not established	More than skin and/or eye irritation and less than a toxicant or carcinogen	Toxicant and/or carcinogen
Suspected Health Hazard	No negative health effect	Skin and/or eye irritation	Not established	More than skin and/or eye irritation and less than a toxicant or carcinogen	Toxicant and/or carcinogen
Carcinogenicity	Not recognized or suspect ACGIH A5 IARC Group 4	Not classifiable as a human carcinogen ACGIH A4 IARC Group 3	Possibly carcinogenic to humans ACGIH A3 IARC Group 2B	Probably carcinogenic to humans ACGIH A2 NTP B IARC Group 2A	Confirmed human carcinogen ACGIH A1 NTP A IARC Group 1

In addition to human health effects, PVC has a negative effect on the environment throughout its life cycle. Dioxin, a toxic persistent organic pollutant that bioaccumulates, is released into the environment during PVC production. PVC is both costly and difficult to recycle, so it typically ends up in a landfill or is incinerated for energy production. Both disposal scenarios release dioxin to the environment (Strutt, 1997 and Belliveau and Lester, 2004).

The CPSIA limits DEHP, DBP, and benzyl butyl phthalate (BBP) content to 0.1 percent or less by weight for any children's toy or article. Studies have shown that the phthalate content of PVC toys can range from 10 to 40% by weight with DINP and DEHP being the dominant phthalates detected (Stringer et al., 2000). In a June 2008 study performed by the Center for Health, Environment, and Justice, five vinyl shower curtains – similar to vinyl mattress covers – were evaluated for phthalate content (Lester et al., 2008). Of the curtains tested, DEHP was the primary phthalate in three curtains and ranged from 16% to 25% by weight while DINP was the primary phthalate in two curtains and was approximately 40% by weight.

To ensure that the children's crib product meets the CPSIA phthalate limits, the mattress' PVC-based cover must be replaced. In order to adequately find a replacement, an alternatives assessment method was developed to evaluate mattresses currently existing in the marketplace. The mattress was scheduled for replacement within one year and identifying viable alternatives had to be done quickly and efficiently to meet the implementation deadline.

In order to determine the technical feasibility and environmental attributes of the alternatives, a three step assessment process was developed incorporating aspects from a number of established alternatives assessment processes. Alternative mattresses were identified through research, the mattresses were assessed against priority attributes and screened at the product level, and the remaining mattresses were further evaluated according to attributes of the mattress components.

3.2. Identifying potential alternatives

In order to ensure the largest group of potential alternatives were assessed, mattresses that were not available from a manufacturer with a waterproof cover were not immediately rejected. Standalone waterproof covers are available in the marketplace for use with any mattress so the mattress system as a whole was evaluated. The system may be composed of a single piece mattress with attached waterproof cover or a non-waterproof mattress with a standalone waterproof cover.

The identification of alternative mattresses and covers were limited to commercially available models due to the manufacturer's quick implementation schedule. Potential alternative mattresses and cover materials were identified through brainstorming, Internet research, and discussions with children's furniture experts. Manufacturer websites were a useful source of information. Most alternative mattress manufacturers were contacted in order to obtain additional details about the mattress that were not readily available or to verify information on their website.

3.3. Product level analysis

3.3.1. Methodology

The product level analysis provides a method to quickly reduce a large number of potential alternative products to a smaller group of more appropriate and feasible alternatives that warrant further analysis. Critical parameters and preferential parameters and "pass" and "fail" criteria for each parameter are developed and the alternatives are analyzed against them. Parameters include product performance metrics and priority human health and environmental attributes. The Massachusetts Toxics Use Reduction Institute used a similar approach to prescreen alternatives when performing their Five Chemicals Alternatives Study (Eliason and Morose, 2010).

The prioritization of the human health and environmental parameters are dependent on a number of factors. The manufacturer had a number of specific requirements they wish to follow, such as eliminating the use of PVC. The parameters were also behavioral, such as the willingness of the mattress manufacturer to disclose the product components and share internal testing results. The critical parameters are those that alternatives must meet in order to be considered for use. In contrast, preferential parameters are those which are not required, but are preferred by the manufacturer.

Information to complete the product level analysis was retrieved from the manufacturer. Material safety data sheets and technical data sheets for mattress components, results of performance and environmental tests, and information available to the public from the furniture manufacturer was used to complete the assessment. Table 2 outlines the critical and preferential parameters used to assess the alternative mattresses at the product level.

3.3.2. Product level analysis results

Eight mattresses were identified as potential alternatives. Four mattresses passed the product level analysis. Two mattresses were unable to meet the dimensional parameters in addition to others, another mattress had a vinyl cover, and the manufacturer of the fourth mattress that failed the analysis was not willing to disclose information about the components of the mattress. The four remaining mattresses were evaluated at the component level. Results of the product level analysis are shown in Table 3.

3.4. Component level analysis

3.4.1. Methodology

Alternative mattresses that pass the product level analysis were screened at the component level. Each mattress was broken down into its successive components, including the core materials, wrapping or cover material, adhesives, and other small components, such as thread used to sew the cover.

The mattress' material safety data sheets, technical data sheets, and communication with the mattress manufacturers were used to identify individual components that comprise the product. The individual components of the alternative mattresses were evaluated independently of each other. This is an important distinction as the potentially additive and synergistic effects of the components were not evaluated. Previous research has shown that the effect of multiple chemical exposure may be synergistic (Christiansen et al., 2009) meaning exposure to the mixture is more hazardous than exposure to individual components of the mixture. This was taken into consideration by the research team and the crib manufacturer and decided that evaluating components of the alternatives as well as any laboratory test results would suffice at this time due to the time constraint and limited information available on the synergistic effects of chemical exposure. Future analysis of the alternative products would include an evaluation of potential synergistic effects.

In contrast to the product level metrics, those at the component level do not contain performance metrics. Component level metrics are based on environmental and human health impacts, are influenced by those included in other alternatives assessment processes, and are organized in four categories: bioaccumulation and persistence, regulatory coverage, acute toxicity, and the potential hazard to human health.

Transparency is key to the alternatives assessment and it is imperative that publically available data sources are used for each of

Table 6
Coded results of the component level analysis.

		Bioaccumulation & Persistence									Regulatory Status
		Fish ChV	Bioaccumulation Factor	Water Persistence	Soil Persistence	Sediment Persistence	Air Persistence	Dangerous for the Environment	Greenhouse Gases	Ozone Depleting Substance	FDA Food Additive Status
Mattress and Cover (All in One) Options											
Mattress 1	Component 1A	0	0	0	0	0	0	0	0	0	2
	Component 1B	0	0	0	0	0	0	0	0	0	4
	Component 1C	0	0	0	0	0	0	0	0	0	2
	Component 1D	0	0	0	0	2	4	0	0	0	0
	Component 1E	0	0	0	0	0	0	0	0	0	2
	Component 1F	NP	NP	NP	NP	NP	NP	0	0	0	0
Mattress 2	Component 2A	NP	NP	NP	NP	NP	NP	0	0	0	4
	Component 2B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Component 2C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Component 2D	0	0	0	0	0	0	0	0	0	0
	Component 2E	NP	NP	NP	NP	NP	NP	4	0	0	4
	Component 2F	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
	Component 2G	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Component 2H	NP	NP	NP	NP	NP	NP	0	0	0	4
	Component 2I	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
	Component 2J	4	3	3	3	3	3	0	0	0	4
	Component 2K	NP	NP	NP	NP	NP	NP	NP	NP	NP	4
	Component 2L	3	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Component 2M	4	NP	NP	NP	NP	NP	0	0	0	4
Mattress Only Options											
Mattress 3	Component 3A	NP	NP	NP	NP	NP	NP	0	0	0	2
	Component 3B	0	0	0	0	0	0	0	0	0	4
	Component 3C	0	0	0	0	0	0	0	0	0	4
Mattress 4	Component 4A	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
	Component 4B	NP	NP	NP	NP	NP	NP	0	0	0	4
	Component 4C	0	0	0	0	0	0	0	0	0	4
Cover Only Options											
Cover 1	Component 5A	0	0	0	0	0	0	0	0	0	2
Cover 2	Component 6A	NP	NP	NP	NP	NP	NP	0	0	0	4

the twenty-three attributes included in the analysis. Data points for five hazard levels, ranging from very high hazard to no or very low hazard, were established for each attribute and can be seen in Table 4. Each component of the mattress was evaluated in each of the twenty-three attributes. The evaluation results were then mapped to the established criteria at each hazard level as seen in Table 5.

In order for the results to be more easily understood by non experts, corresponding numerical values were established for each hazard level. The hazard levels were also color coded to further increase the visibility of the results. The results are presented in a table format, with a color and number assigned to each of the twenty-three attributes assessed for each component of the mattress.

Regulatory Status			Acute Toxicity			Health Hazard						
EPA Hazardous Air Pollutant	National Drinking Water Regulations	Federal or State Regulatory Program Lists or Other Chemical Blacklists	Inhalation LC50	Oral LD50	Dermal LD50	EWG Hazard Rating	Endocrine Disruption	Symptoms	Allergies/ Immunotoxicity	Recognized Health Hazard	Suspected Health Hazard	Carcinogenicity
Mattress and Cover (All in One) Options												
0	0	0	NE	2	NE	4	0	0	3	0	4	1
0	0	0	0	0	0	NE	0	0	0	0	0	0
0	0	0	NE	2	NE	3	0	0	4	0	4	1
0	0	4	0	2	0	1	2	0	0	0	4	0
0	0	4	NP	NP	NP	1	0	0	0	0	0	1
0	0	4	NE	NE	NE	0	0	1	0	0	0	0
0	0	0	NP	NP	NP	0	0	1	2	0	0	1
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	1	NA	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	4	NP	NP	NP	NE	NP	2	NP	0	0	0
NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0	NP	NP	NP	0	0	0	0	0	0	0
NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	0
0	0	4	0	1	0	1	0	2	0	4	4	2
NP	NP	NP	NP	NP	NP	0	0	2	0	0	0	0
NA	NA	NA	0	3	2	NA	3	4	3	0	0	0
0	0	0	NP	NP	NP	NE	3	NP	NP	0	4	0
Mattress Only Options												
0	0	0	0	0	0	2	0	1	4	3	0	0
0	0	0	0	0	0	0	0	1	3	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
0	0	0	NP	NP	NP	0	0	1	2	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0
Cover Only Options												
0	0	0	0	2	0	4	0	0	3	0	4	1
0	0	0	0	0	0	2	0	0	4	0	4	1

3.4.2. Component level analysis results

In addition to the four mattresses that passed the product level analysis, two standalone mattress covers were also included in the component analysis. The mattresses were broken down into their components based on information available from the manufacturer. Manufacturers were contacted and additional information was requested where it was not immediately available. Material safety data sheets for adhesives and fire barriers were obtained where possible and their components were included in the analysis.

The vast majority of chemicals available in the marketplace have not been evaluated or studied for potential environmental or human health concerns. When a significant amount of information is not available, it is up to the decision maker to determine how those null or not available data points will be evaluated while making comparisons. The lack of information for an attribute can be viewed as detrimental as a “high risk” attribute or it may simply not be included in the analysis. In this case, the lack of data was noted in the matrix and left to the furniture manufacturer to interpret as they see fit.

Color coding and assigning numerical values to the results allow the non-expert decision maker to view a short summary of the results and evaluate how the alternatives rank against each other. Rather than sorting through technical data that may not mean much to a decision maker, the color coded matrix in Table 6 shows that Mattress 2 is both missing a significant amount of data and has a significant number of high risk data points as compared to the other mattresses. Presenting the data in this manner instead of a single score system allows the user to make value decisions based on what is important to them and compare alternatives based on the value decisions.

As a result of the alternatives assessment, the manufacturer has replaced their vinyl covered mattress with a waterproof cotton mattress. The use of PVC has been eliminated and the alternative mattress is less hazardous to the environment and human health.

4. Conclusion

An alternatives assessment process is a valuable tool to systematically assess potential options and assist with the decision making process. The usability of the model is based on how rapidly and accurately the alternatives assessment process can be completed and how useful the results are. The alternatives assessment process was completed in approximately six months, allowing the manufacturer ample time to work with the alternative mattress manufacturer to ensure their transition deadline was met. The clarity and conciseness with which the results are reported ensures their usability. Detailed tables containing scientific information are useful for technical experts, but provide little to no value to product designers or other decision makers who are also interested in the results. Translating the results to easily identifiable ranks, such as colors or numbers, allows them to be understood by a larger group of readers, thus making them more useful.

4.1. Benefits of the alternatives assessment model

Developing a two step method allows those alternatives that don’t meet critical design parameters to be screened out of the assessment early on, reducing time and energy needed to complete the assessment. Building critical parameters such as cost and dimension into the product level assessment ensures those evaluated at the component level are all technically and financially feasible.

Color coding and assigning numerical values to the component results allows them to be understood by personnel with differing backgrounds. Product designers, marketing professionals, and others

that do not have a strong understanding of toxicology and environmental hazards can identify preferable alternatives and pinpoint potential concerns with considered alternatives. Presenting details behind the numerical values for each characteristic is overwhelming to the reader and technical jargon can be difficult to navigate.

Other alternatives assessment and environmental impact calculations combine attributes into one single, numerical score. On the outside, single score methods make it easy to compare multiple alternatives based on their scores. The concern is that single score methods do not allow the reader the flexibility to dig into the score and identify the areas of concern. The component level analysis in this alternatives assessment process allows the reader to see how an alternative performs in each individual attribute. The reader has the ability to make decisions based on components of the single score, rather than the single score itself.

Analyzing products at the component level allows the user to define what attribute is more important to them and evaluate alternatives as they wish. For example, if carcinogenicity and aquatic toxicity are important to the user, those attributes can be highlighted and assessed separate from the others.

4.2. Limitations of the alternatives assessment model

The assessment results do not determine a clear "best" alternative. Instead, the user is forced to look at all results and make a value judgment to determine which attributes are more important and weigh the pros and cons of each alternative. This is both a benefit and limitation of the model. One reader may accept a certain level of risk while another reader may not, making it difficult to agree on the best alternative.

The assessment model does not take into account the potential additive and synergistic effects of the components of the products evaluated. Research has shown that the effect of multiple chemical exposures may be synergistic. Because very limited information currently exists on the synergistic effects of chemicals, it is difficult to consider at this time. In the future, as more information and more accurate information becomes available, it can easily be incorporated into the model.

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Appendix A.

Glossary of hazards.

Bioaccumulation and Persistence	
Fish ChV (fish chronic value)	This value is used to estimate a chemical's relative toxicity. The value is estimated using EPA's ECOSAR (Ecological Structure Activity Relationship) program. The PBT Profiler compares the ChV of each chemical to its water solubility. If the solubility is less than the ChV, then there are no effects at saturation.[a]
BCF (bioconcentration factor)	The measure of the ability for a water-borne chemical substance to concentrate in fatty tissue of fish and aquatic organisms relative to its surroundings. EPA defines bioconcentration as the net accumulation of a substance by an aquatic organism as a result of uptake directly from the ambient water through gill membranes or other external body surfaces.[a]
Water, Soil, Sediment, Air Persistence	Ability of a chemical substance to remain in an environment in an unchanged form. The longer a chemical persists, the higher the potential for human or environmental exposure to it.[a]
Dangerous for the Environment	The European Economic Community first created a List of Dangerous Substances in 1967, classifying substances according to health hazards and physico-chemical properties. The list has subsequently been expanded, and the Nordic Council of Ministers conducted a special project to review available toxicity data in order to identify substances that should be classified as dangerous to the environment. The EEC assigns "risk phrases" to compounds depending on their adverse environmental effects, to support product labeling and risk reduction efforts. The risk phrases currently used to define dangerous to the environment emphasize hazards to the aquatic environment, because of the lack of data on other target ecosystems.[b]
Greenhouse Gases	A gas, such as carbon dioxide or methane, which contributes to potential climate change.[c] List of greenhouse gases comes from Annex A of the Kyoto Protocol.[d] Carbon dioxide (CO_2) Methane (CH_4) Nitrous oxide (N_2O) Hydrofluorocarbons (HFCs) Perfluorocarbons (PFCs) Sulphur hexafluoride (SF_6)
ODS (Ozone Depleting Substances)	Compounds that contribute to stratospheric ozone depletion.[c]
Regulatory Coverage	
FDA Food Additive Status	Any substance the intended use which results or may reasonably be expected to result – directly or indirectly – in its becoming a component or otherwise affecting the characteristics of any food. This definition includes any substance used in the production, processing, treatment, packaging, transportation or storage of food. The status indicates any use limitations for an additive.[e]

(*continued on next page*)

Appendix A. (*continued*).

Bioaccumulation and Persistence	
EPA Hazardous Air Pollutant	Air pollutants which are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride.[c]
US National Drinking Water Regulations	Legally enforceable standards that apply to public water system that protect public health by limiting the levels of contaminants in drinking water. Maximum Contaminant Levels are the maximum permissible level of a contaminant in water delivered to any user of a public system. MCLs are enforceable standards.[c]
Federal or State Regulatory Program Lists or Other Chemical Blacklists	Federal Regulatory Lists include: Air Contaminants (Occupational and Safety Health Act) Regulated Toxic, Explosive, or Flammable Substances (Clean Air Act) Criteria Air Pollutants (Clean Air Act) Extremely Hazardous Substances (Superfund) Hazardous Air Pollutants (Clean Air Act) Hazardous Constituents (Resource Conservation and Recovery Act) Hazardous Substances (Superfund) Inhalation Hazard Chemicals (Department of Transportation) Maximum Contaminant Levels (Safe Drinking Water Act) Priority Pollutants (Clean Water Act) State Regulatory Lists include: California Air Toxics "Hot Spots" Chemicals (Assembly Bill 2588) Air Contaminants (California Occupational and Safety Health Act) Maximum Contaminant Levels (California Safe Drinking Water Act) Public Health Goals and Action Levels (California Safe Drinking Water Act) Known Carcinogens and Reproductive Toxicants (California Proposition 65) California Toxic Air Contaminants (Assembly Bill, 1807) Other Chemical Blacklists include: Bioaccumulative Chemicals of Concern (U.S. Environmental Protection Agency) Dangerous for the Environment (Nordic Council of Ministers) Greenhouse Gases (Intergovernmental Panel on Climate Change) Ozone Depleting Substances (Montreal Protocol) Persistent, Bioaccumulative, and Toxic Chemicals (U.S. Environmental Protection Agency)
Acute Toxicity	
Inhalation LC50 (lethal concentration)	Median level concentration, a standard measure of toxicity. It tells how much of a substance is needed to kill half of a group of experimental organisms in a given time via inhalation.[c]
Oral LD50 (lethal dose)	The dose of a toxicant or microbe that will kill 50 percent of the test organisms within a designated period. The lower the LD 50, the more toxic the compound.[c]
Dermal LD50 (lethal dose)	The dose of a toxicant or microbe that will kill 50 percent of the test organisms within a designated period. The lower the LD 50, the more toxic the compound.[c]
Health Hazard	
EWG Hazard Rating (Environmental Working Group)	Represents a synthesis of known and suspected hazards associated with ingredients and products. Hazard ratings are shown as low, moderate, or higher concern categories, with numeric rankings spanning those categories that range from 0 (low concern) to 10 (higher concern).[f]
Endocrine Disruption	Exposure to chemical substances which causes adverse effects on the endocrine system.
Symptoms	Negative health effects which result from exposure.
Allergies/Immunotoxicity	Sensitivity to a substance which causes an inflammatory reaction or adverse effects on the functioning of the immune system that result from exposure to chemical substances.
Recognized Health Hazard	Recognized toxicants possess evidence that they do cause specific adverse health effects and are identified as recognized toxicants based on the hazard identification efforts of authoritative national and international scientific and regulatory agencies.[b]
Suspected Health Hazard	Suspected toxicants possess evidence that they can cause specific adverse health effects, but no authoritative hazard identification is currently conducted by regulatory agencies or scientific organizations for that health effect. Inclusion of a chemical on a "suspected" list should be viewed as a preliminary indication that the chemical *may* cause this effect, rather than a definitive finding that it does.[b]
Carcinogenicity	The ability of a material to cause cancer.

[a] United States Environmental Protection Agency, PBT Profiler, http://www.pbtprofiler.net/, 10 Jun. 2010.
[b] Scorecard, www.scorecard.org, 1 May 2010.
[c] US EPA, Terms of Environment: Glossary, Abbreviations, and Acronyms http://www.epa.gov/OCEPAterms/, 8 Jun. 2010.
[d] United Nations Framework Convention on Climate Change. Kyoto Protocol, http://www.unfccc.int, 10 Jun. 2010.
[e] United States Food and Drug Administration.
[f] Environmental Working Group, SkinDeep Cosmetic Safety Database, http://www.cosmeticsdatabase.com, 10 Jun. 2010.

Appendix B.

Hazard data sources.

Bioaccumulation and Persistence	
Fish ChV (fish chronic value)	US Environmental Protection Agency, PBT Profiler, http://www.pbtprofiler.net, Ver 1.203.
BCF (bioconcentration factor)	US Environmental Protection Agency, PBT Profiler, http://www.pbtprofiler.net, Ver 1.203.
Water, Soil, Sediment, Air Persistence	US Environmental Protection Agency, PBT Profiler, http://www.pbtprofiler.net, Ver 1.203.
Dangerous for the Environment	Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006. Nordic Council of Ministers, April 2002, N-CLASS Database on Environmental Hazard Classification, accessed via Scorecard, http://www.scorecard.org
Greenhouse Gases	Annex A, Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997, accessed via Scorecard http://www.scorecard.org.
ODS (Ozone Depleting Substances)	United States Environmental Protection Agency, Class I Ozone Depleting Substances, http://www.epa.gov/ozone/ods.html. United States Environmental Protection Agency, Class II Ozone Depleting Substances, http://www.epa.gov/ozone/ods2.html.
Regulatory Coverage	
FDA Food Additive Status	United States Food and Drug Administration, Food Additive Status List, http://www.cfsan.fda.gov/~dms/opa-appa.htm.
EPA Hazardous Air Pollutant	United States Environmental Protection Agency, List of Hazardous Air Pollutants, http://www.epa.gov/ttn/atw/188polls.html.
US National Drinking Water Regulations	United States Environmental Protection Agency, National Primary Drinking Water Regulations & National Secondary Drinking Water Regulations, http://www.epa.gov/safewater/contaminants/index.html#mcls.
Federal or State Regulatory Program Lists or Other Chemical Blacklists	Accessed via Scorecard, http://www.scorecard.org.
Acute Toxicity	
Inhalation LC50 (lethal concentration)	National Library of Medicine's Hazardous Substances Data Bank, http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. NIOSH Pocket Guide to Chemical Hazards, http://www.cdc.gov/niosh.
Oral LD50 (lethal dose)	National Library of Medicine's Hazardous Substances Data Bank, http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. NIOSH Pocket Guide to Chemical Hazards, http://www.cdc.gov/niosh.
Dermal LD50 (lethal dose)	National Library of Medicine's Hazardous Substances Data Bank, http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.
Health Hazard	
EWG Hazard Rating (Environmental Working Group)	Environmental Working Group, Skin Deep ingredient profiles, http://www.cosmeticsdatabase.com.
Endocrine Disruption	The following sources were accessed via Scorecard, http://www.scorecard.org Agency for Toxic Substances and Disease Registry. Minimal risk Levels for Hazardous Substances. January 2004. http://www.atsdr.cdc.gov/mrls.html BKH/European Commission. *Towards the establishment of a priority list of substances for further evaluation of their role in endocrine disruption: - preparation of a candidate list of substances as a basis for priority setting. Final report-November 2000*. http://europa.eu.int/comm/environment/docum/01262_en.htm#bkh. Category 1 chemicals from Annex 1: Candidate list of 553 substances. http://europa.eu.int/comm/environment/docum/bkh_annex_01.pdf Brucker-Davis, F. Effects of Environmental Synthetic Chemicals on Thyroid Function. *Thyroid*. 8(9): 827–856. 1998. US EPA, AirRisk Information Support Center. *Health Effects Notebook for Hazardous Air Pollutants*. http://www.epa.gov/ttnatw01/hlthef/hapindex.html US EPA. Announcement of the Draft Drinking Water Contaminant Candidate List; Notice. 62 *Federal Register* 52193–52219 (October 6, 1997). (Table 6). http://www.epa.gov/safewater/ccl/dwccl.pdf US EPA. Addition of Certain Chemicals; Toxic Chemical Release Reporting; Community Right to Know. Proposed and Final Rules. 59 *Federal Register* 1788 (Jan 12, 1994); 59 *Federal Register* 61432 (November 30, 1994). Guillette, L. J., and E. Guillette. Environmental Contaminants and Reproductive Abnormalities in Wildlife: Implications for Public Health? *Toxicology and Industrial Health*. 12(3): 537–550. 1996. Illinois EPA. Endocrine Disruptors Strategy. 1997. (Table 1: Preliminary List of Chemicals Associated with Endocrine System Effects in Animals and Humans or In Vitro). http://www.nihs.go.jp/hse/environ/illiepatable.htm Japanese National Institute of Health Sciences. Lists of Paradigmatic Chemicals. http://www.nihs.go.jp/hse/endocrine-e/paradigm/paradigm.html Keith, L.H. (ed.). *Environmental Endocrine Disruptors*. John Wiley & Sons, NY. 1997. http://www.wileyeurope.com/cda/product/0,,0471191450%7Cdesc%7C3037,00.html New Jersey Department of Health Services. Right to Know Program, NJDOH, Trenton, NJ. http://www.state.nj.us/health/eoh/rtkweb/rtkhsfs.htm California EPA, Office of Environmental Health Hazard Assessment. *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III: Technical Support Document "Determination of Noncancer Chronic Reference Exposure Levels"*. Includes all Chronic Reference Exposure Levels (CRELs) adopted by OEHHA as of August 2003 (http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html, plus draft CRELS proposed through March 2004 (http://www.oehha.ca.gov/air/chronic_rels/index.html. National Institute for Occupational Safety and Health's Registry of Toxic Effects of Chemical Substances. World Wildlife Fund. Our Stolen Future. Widespread Pollutants with Endocrine-disrupting Effects. http://www.ourstolenfuture.org/Basics/chemlist.htm. The WWF list is derived from references detailed at http://www.ourstolenfuture.org/Sources/chemsources.htm and was originally published in: Colborn, T., F.S. vom Saal, and A.M. Soto. Developmental Effects of Endocrine-Disrupting Chemicals In Wildlife and Humans. *Environmental Health Perspectives* 101(5): 378-384. 1993.
Symptoms	NIOSH Pocket Guide to Chemical Hazards (www.cdc.gov/niosh/npg/default.html)
Allergies/Immunotoxicity	Environmental Working Group, Skin Deep ingredient profiles, http://www.cosmeticsdatabase.com.
Recognized Health Hazard	Scorecard, http://www.scorecard.org
Suspected Health Hazard	Scorecard, http://www.scorecard.org
Carcinogenicity	American Conference of Governmental Industrial Hygienists, 2004, ACGIH cancer classification system. International Agency for Research on Cancer, Monographs on the Evaluation of the Carcinogenic Risks to Humans, http://monographs.iarc.fr/ENG/Classification/index.php US National Toxicology Program, Report on Carcinogens, http://ntp.niehs.nih.gov/index.cfm?objectid=72016262-BDB7-CEBA-FA60E922B18C2540

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Kathryn H. Winnebeck is an environmental health and safety specialist at NYSP2I. She assists companies with product stewardship and reductions in toxic chemical use initiatives and performs green product assessments, including evaluation of the product's environmental attributes, recyclability, and human health effects. She performs life cycle assessments to quantify environmental impacts and determine areas for improvement. Through affiliated programs, she helps companies develop effective safety management teams to reduce the use of hazardous materials and promote a safe work environment. Kathryn earned a bachelor's degree in environmental management and a Master's degree in environmental health and safety management from RIT.