Chemicals and Materials Selection

DfE

One of the most important steps during product design and development is the selection of raw materials. Which chemicals or materials are used can determine how consumers perceive a product and its impact on human health and the environment. Of the over 70,000 chemicals that have been registered for use in the United States, which are of most concern? What are the alternatives? One method of monitoring which materials may be of concern is to note the ones cited by eco-label programs as chemicals to avoid.

Eco-label programs

A number of eco-labeling organizations that set criteria for and certify products and services with lower environmental impacts have been established throughout the world.

Eco-labels or environmental labels serve as a guide to consumers for choosing products and services that cause less damage to the environment.

One method of establishing a list of chemicals or materials to avoid using in products is to review eco-label program criteria. The chemicals and materials listed in a chart that follows are those cited most frequently by six international eco-labeling programs as the ones to avoid.

The eco-label programs reviewed for the development of this list include the Canadian "Environmental Choice," the "European Union Eco-label," India's "Ecomark," "Nordic Eco-labeling," Germany's "Blue Angel," and the United States' "Green Seal."

For more information on eco-label programs and their criteria, go to Global Action Network (GEN) at www.gen.gr.jp. GEN is a non-profit organization with eco-label members from around the world.

This map from the Global Ecolabelling Network web site (www.gen.gr.jp) displays the locations of various eco-label programs throughout the world.

Persistent Bioaccumlative Toxins

In addition to the chemicals listed most frequently by the eco-label programs, there are also lists of persistent bioaccumulative toxins (PBTs) and persistent organic pollutants (POPs). PBTs and POPs are of particular concern because they are toxic substances that build up in magnified concentrations as they move up the food chain and become especially concentrated in humans and whales. There are three PBT lists maintained by the Environmental Protection Agency. They can be found at: www.epa.gov/pbt/cheminfo.htm, www.epa.gov/tri/pbtrule-sum.pdf and www.epa.gov/epaoswer/hazwaste/minimize/chemlist/pdt-fact.pdf.

The United Nations' POPs list can be found at http://irptc.unep.ch/pops/newlayout/infpopsalt.htm.

Other Useful Lists

Detailed information about health and environmental effects of specific chemical compounds (including information about mutagenicity, carcinogenicity and teratogenicity) can be found on the European Union web site for dangerous substances (www.europa.eu.int/eur-lex/en/lif/dat/1998/en_398L0098.html). A list of EPCRA section 313 toxic chemicals that are required to be reported under the Right to Know Act if used over certain quantities can be found at www.epa.gov/ceppo/pubs/title3.pdf.

Chemical Design Software

The Environmental Protection Agency Office of Pollution Prevention and Toxics has information and a number of software programs available for calculating environmental and human hazard potential during chemical design. The Cancer Expert System and Green Chemistry Expert System (GCES) are two examples.

On the EPA web site, the Green Chemistry Expert System is described as a "tool currently under development by the U.S. EPA, which will allow users to build a green chemical process, design a green chemical, or survey the field of green chemistry." The Cancer Expert System is a tool that "analyzes chemical structures to determine the likelihood that they may cause cancer." For more information, go to www.epa.gov/oppt/software.htm#green.

A tool that allows chemical formulators to estimate the environmental persistance of a chemical called the PBT Profiler is available on the EPA web site at www.epa.gov/pbt/toolbox.htm.

Green Product Example

DesignTex fabric, made of natural wool and ramie fibers, is used in the manufacture of office furniture. Each ingredient used during the manufacture of this fabric in Switzerland, is analyzed prior to its use and held to strict environmental standards. Any substance that is known or suspected to be carcinogenic, mutagenic, teratogenic or bioaccumulative is eliminated from being used as a dye or process chemical. The water that comes out of the manufacturing plant is as clean and pure as the water coming in. Fabric scrap is made into non-toxic, compostable felt which is used in gardens to insulate crops. Gradually the felt decomposes and nourishes the earth, completing the circle of life. For more information on this green product, go to www.dtex.com/products/prd_wm01.htm.

DesignTex office furniture fabric is made from materials that are held to strict environmental standards. The fabric comes in a variety of colors and patterns.

Chemicals/Materials of concern with alternatives

Most Frequently Cited to Avoid by Six Eco-label Programs

Chemical or Material	Environmental or Health Concern	Common Uses	Alternatives
Toxic Metals (lead, mercury, cadmium, hexavalent chromium, nickel, copper) C,G,E,I,N,S[1]	Mercury and lead are neurotoxins and potential endocrine disrupters. Copper can adversely affect the lungs, liver, and kidneys. Hexavalent chromium is a potential carcinogen. Nickel compounds are potential carcinogens. All of these metals are persistent and bioaccumulate in the environment.	Inks, dyes, pigments	Use synthesized organic pigments (vs. inorganic pigments that contain these metals) or educate customers to choose alternative colors that do not contain toxic metals.
		Stabilizers in plastics	Consider using other materials such as glass, ceramics, or non-toxic metal instead of plastic for uses that demand durability from UV light or abrasion.

Table continued on next page

Chemicals/Materials of concern with alternatives *continued from previous page*

Chemical or Material	Environmental or Health Concern	Common Uses	Alternatives
Formaldehyde C,G,I,N,S	Respiratory irritant and potential carcinogen.	Adhesives in furniture, cabinets, and carpets	Use adhesives that are not formulated with formaldehyde.
		Paints, varnishes	Use aqueous based, high solids, or powder coating paints and varnishes that do not contain formaldehyde or other volatile organic compounds (VOCs).
Halogenated Organic Compounds	Refrigerants (CFCs and HCFCs) are ozone depleters.	Refrigerants	Alternatives include R-410A, 410B (HFCs), ammonia, carbon dioxide, nitrogen or water, hydrocarbons.[2]
C,G,E,I,N,S	Halogenated flame retardants (PBB, PBDE)[3] are persistent, bioaccumulative toxins that are suspected carcinogens and endocrine disrupters.	Flame retardants	Use non-flammable materials (ceramics or non-toxic metals) or use non-halogenated flame retardants including phosphorus based materials, metal hydroxide (magnesium hydroxide, aluminum hydroxide), borates, alkyne-based materials, alkyne-phosphates and boronic acids.[4]
	Industrial cleaners (trichloroethylene, methylene chloride) are potential carcinogens.	Industrial cleaners	Use water-based detergents or redesign processes to minimize contamination that requires cleaning.
Certain Azo dyes[5] E,G,N	May form carcinogenic aryl amines. May cause liver, kidney, and bladder cancer.	Dyes	Use dyes that do not form aromatic amines and do not contain toxic metals.
Chlorinated Polymers (PVC plastic) E,G,N,S	Potential to form dioxins and furans under incineration. Dioxins and furans are persistent, bioaccumulative toxins that are suspected carcinogens and endocrine disrupters.	Packaging	Use biodegradable polymers made from corn or soy resins or other plastic or resins such as polypropylene, polyethylene, polyester.
Phthalates with alkyl groups N,S	These plasticizers (soften plastic resins) are suspected carcinogens and endocrine disrupters.	Plasticizers	Use alternative types of plastic resins which do not depend on plasticizers for softening.
Benzene compounds E,C,S,I,N	Suspected carcinogens that can attack bone marrow, causing leukemia.	Industrial solvents and chemicals, paints, deinking solutions, glues	Use aqueous based substitutes.

1. Eco-label program that lists materials:
C = Canada's Environmental Choice Program *I = India's Ecomark*
E = European Union Eco-label *N = Nordic Eco-labeling*
G = Germany's Blue Angel *S = U.S. Green Seal*

2. See www.epa.gov/ozone/title6/snap/lists/homeac.html for more information on alternative refrigerants.

3. See Appendix 1: Brominated Flame Retardant list for compounds of concern.

4. A comprehensive list of non-halogenated flame retardants can be found in Kirk-Othmer Encyclopedia of Chemical Technology, 4th edition, edited by J. I. Kroschwitz, New York, NY; John Wiley & Sons Inc., 1993. Vol. 10, p 930-1022.
For additional expertise on flame retardants, contact the National Institute of Standards and Technology at 301-975-8295 or http://www.nist.gov/. Certain commercial equipment, instruments, materials, services, or companies are identified in this paper in order to specify adequately the experimental procedure. This in no way implies endorsement or recommendation by NIST.

5. See Appendix 2: Azo Dye list for compounds of concern.

Appendix 1

Brominated flame retardants in commercial use

Chemical group	Chemical name
Poly-brominated biphenyl (PBB)	Decabromobiphenyl (Deca-BB)
Polybrominated diphenyl ethers (PBDE)	Decabromo diphenyl ether (Deca-BDE) Octabromo diphenyl ether (Octa-BDE) Pentabromo diphenyl ether (Penta-BDE)
Substances similar to PBDE	Poly(2,6-dibromophenylene oxide) Tetradecabromodiphenoxbenzene 1,2-Bis(2,4,6-tribromophenoxy) ethane
TBA and derivatives	3,5,3',5'-Tetrabromo-bisphenol A (TBBA) TBBA, unspecified TBBA-epichlorhydrin oligomer TBBA-TBBA-diglycidyl-ether oligomer TBBA carbonate oligomer TBBA carbonate oligomer, 2,4,6,-tribromo-phenol terminated TBBA-Bisphenol A-fosgene polymer TBBA-bis-(2,3-dibromopropylether) TBBA-bis-(2-hydroxyethylether) TBBA-bis-(allylether) TBBA-dimethylether TBBA carbonate oligomer, phenoxy end capped
TBBS and derivatives	Tetrabrombisphenol S TBBS-bis(2,3-dibromo-propyl-ether)
Bromophenols	2,4-Dibromophenol 2,4,6-Tribromophenol Pentabromophenol
Cycloaliphatic brominated flame retardants	Hexabromocyclododecane (HBCD), unspecified 1,2,5,9,10-Hexabromocyclododecane (HBCD) Tetrabromcyclooctane 1,2-Dibromo-4-(1,2 dibromomethyl)cyclohexane
Tetrabromophtalic acid (TBPA) and derivatives	Diester of TBPA TBPA Na salt TBPA diol [2-Hydroxy-propyl-2(2-hydroxy-ethoxy)-Ethyl-tetrabromo-phthalate] TBPA, glycol and propylene oxide esters Tetrabromophthalic anhydride Diester diol of Tetrabromophthalic anhydride Bis(methyl) tetrabromophtalate Bis(2-ethylhexyl) tetrabromophtalate
Phtalimides and related substances	N,N'-Ethylene-bis-(tetrabromophthalimide) Ethylene-bis(5,6-dibromonorbornane-2,3-dicarboximide)
Bromine-containing alcohols and polyols	2,3-Dibromo-2-butene-1,4-diol Dibromoneopentylglycol (1,3-propanediol, 2,2-bis(bromomethyl) Dibromopropanol Tribromoneopentylalcohol

Brominated flame retardants in commercial use *continued from previous page*

Chemical group	Chemical name
Brominated polystyrene	Poly-tribromostyrene Tribromostyrene Dibromostyrene grafted PP Poly(dibromostyrene)
Brominated alkanes and alkenes	Bromo/chloro parafinns Bromo/chloro alpha olefin Vinylbromide
Brominated cyanurate derivatives	1,3,5-tris(2,3-dibromo-propoxy)-2,4,6-triazine (Tris-(2,3-dibromo-propyl)-isocyanurate
Bromine and phosphate-containing flame retardants	Tris(2,4-Dibromophenyl) phosphate Tris(tribromoneopentyl) phosphate Chorinated and brominated phosphate ester
Brominated toluenes	Pentabromotoluene Pentabromobenzyl bromide
Other brominated flame retardants	2,4,6-Tribromo-phenyl-allyl-ether Tribromo-phenyl-allyl-ether, unspecified 1,3-Butadiene homopolymer brominated Pentabromo-benzl-acrylate, monomer Pentabromo-benzl-acrylate, polymer Decabromodiphenylethane Tribromobisphenylmaleinimide

Taken from "Brominated Flame Retardants—A Global Status Report" by Robert Bloom, Andreas Eklund, Per Hedemalm, and Joachim Häggström (report 0023). Orango AB, Stora Badhusgatan 18-20, SE-411 21 Gothenburg, Sweden. http://www.orango.com/reports.htm.

Appendix 2

Azo-based dyestuffs that may give rise to cancerous aromatic amines

(those that form aromatic amines upon cleavage of an azo group)

	CAS-no.
4-Aminobiphenyl	92-67-1
Benzidine	92-87-5
4-Chloro-o-toluidine	95-69-2
2-Naphthylamine	91-59-8
o-Aminoazotoluene	97-56-3
5-Nitro-a-toluidine	99-55-8
p-Chloroaniline	106-47-8
4-Methoxy-m-phenylenediamine	615-05-4
4,4'-Methylenedianiline	101-77-9
3,3'-Dichlorobenzidine	91-94-1
3,3'-Dimethoxybenzidine	119-90-4
3,3'-Dimethylbenzidine	119-93-7
4,4'-Methylenedi-o-toluidine	838-88-0
6-Methoxy-m-toluidine	120-71-8
4,4'-Methylenebis(2-chloroaniline)	101-14-4
4,4'-Oxydianiline	101-80-4
4,4'-Thiodianiline	139-65-1
o-Toluidine	95-53-4
4-Methyl-m-phenylenediamine	95-80-7
2,4,5-Thrimethylaniline	137-17-

Source: Specified in the fifth amendment to the German Consumer Goods Directive: German ban on use of certain azo compounds in some consumer goods, ETAD information notice no.6, Ecological and Toxicological Association of Dyes and Organics, November 1995