

CHEMICALS IN COMMON PRODUCTS: RISKY BUSINESS FOR CHILDREN'S HEALTH

In response to the explosion of new allergy and asthma cases among children in recent years, there has been a great deal of attention given to researching causes and treatments, raising awareness, and removing triggers from indoor environments such as allergens, dust mites, endotoxins, mold and combustion products. What is not as well understood, but also has the potential for causing serious health problems among children, including respiratory illnesses like allergies and asthma, are chemicals used to manufacture common everyday products, such as food containers, cleaners, personal care products, electronics, furniture, flooring, paints, textiles, pesticides, toys, clothing and jewelry.

This significant threat to children's health is becoming a critical issue, fueled by modern lifestyles, global sources of manufactured products and the proliferation of energy efficient homes and schools. Children overall spend the majority of their time indoors, and breathe air that typically contains pollutants at levels two to five times higher than what is found in the outdoor air. As parents and facility managers tighten up homes and buildings in an effort to conserve energy, pollutants that originate from products used to decorate, furnish or clean buildings remain in the indoor air and also settle on small dust particles. Further, many products are manufactured and sourced globally from locations where raw materials and manufacturing processes are not well vetted for their health impact on children. This white paper reviews why children are at increased risk from industrial chemicals, how children are exposed, which chemicals are of concern, how these chemicals may impact children's health, which products have potentially harmful chemicals and what efforts are underway to reduce or eliminate exposure.

HEALTH RISKS FROM EXPOSURE: CHILDREN ARE NOT LITTLE ADULTS

With respect to determining the risk of exposure to industrial chemicals, researchers emphasize: "Children are not little adults" (Tickner and Hoppin 2000). Physical differences, socioeconomic status and activity patterns are among the key reasons why children are more vulnerable to exposure and face greater health risks from industrial chemicals than adults. The following is an overview of the primary factors that contribute to these risks:

Rapid periods of growth. Human cells, tissues, organs and body systems grow at different rates, with the most rapid periods of growth occurring in utero, infancy and puberty. Many organ systems also undergo differentiation during the first years of life. During these rapid periods of growth, developmental processes can be easily disrupted, at which time minute exposures can create irreversible, lifelong effects (Tickner and Hoppin 2000).

Age-related differences. In children, biochemical and physiologic functions are immature; for example, the nervous system does not completely develop until the age of 18. The reproductive system also is particularly vulnerable, especially in school-age children and adolescents. Children have different proportions of fat, water, protein and mineral content in their bone, blood and tissues than adults, which results in children having less ability to detoxify and excrete certain substances. In addition, children may absorb toxic substances from the gastrointestinal tract differently and to a greater degree than adults (Tickner and Hoppin 2000).

Another major organ that can be significantly impacted is the developing brain, which is much more vulnerable to chemical exposures than the mature brain. Compared with other organs, the human brain

forms over a long period of time, beginning in the first weeks after conception. Brain weight at birth is about one-third of adult weight. There is a brain growth spurt from the third trimester of pregnancy until about the age of two years. Most of the basic brain structure is laid down before birth, with considerable postnatal activity in the development of connections, brain transmitter systems and the production of myelin. Also of significance is the blood-brain barrier is not complete until about six months after birth, which has major implications for chemicals that are transported to the fetus through the placenta and children's exposures in the first few months of life (McElgunn 1999a).

Physical differences. Because of their lower body weight, children breathe in a relatively greater volume of air than adults. Newborns breathe through their mouths, as do many older infants and children — more so than do adults. Also, children's breathing zones are much closer to the ground, and as a result, heavier airborne chemicals pose more of risk to children than to adults. Another significant difference is children have a higher heart rate than adults, which allows substances that are absorbed into the blood to permeate tissues faster (Flynn et al 2000, Tickner and Hoppin 2000).

By and large, children consume more food and water than adults per kilogram of body weight. The 1993 US National Academy of Sciences report, *Pesticides in the Diets of Infants and Children*, found that infants consume up to seven times the amount of water on a milligram per kilogram of body weight than is consumed by adults. Children also consume fewer types of foods, which may result in receiving a higher exposure to a chemical contained on or in a favorite food (McElgunn 1999b, National Research Council 1993). Consequently, children may have significantly greater exposure to chemicals in water, food and air than adults.

Socio-Economic Differences. In the US, more children live in poverty than any other age group. As a result, these children are more likely to live in public housing or blue-collar neighborhoods in close proximity to industry, which is a primary source of outdoor air pollution that can be brought indoors via heating, ventilating and air-conditioning (HVAC) systems. As a part of the Minnesota Children's Pesticide Exposure Study, researchers confirmed that higher outdoor VOC concentrations in urban areas contributed to higher VOC concentrations in urban homes (Adgate 2004).

Children living in poverty also may not take advantage of health care services as often as other socioeconomic groups, so underlying chronic illnesses may not be diagnosed (Flynn et al 2000). For example, a study of Detroit, Michigan school children in the third to fifth grades found that 14.3 percent might be under diagnosed for asthma (Joseph 1996).

Children's Activity Patterns. Time of exposure is another risk factor for adverse health impacts. Results of a California Air Resources Board (CARB) study on children's activity patterns in that state found that overall children spend on average 85 percent of their time indoors; 70 percent of that time is spent at home. In this study, 1,200 English speaking children 11 years of age or younger were interviewed from spring 1989 to winter 1990. The participants were asked if they used or were near sources of pollution, such as environmental tobacco smoke (ETS), solvents, pesticides, paint and gas appliances. The results from the CARB study agree with estimates from other studies in the US and other industrialized nations (Wiley et al 1994). For more information about this study, see the AQS research report *Indoor Air Quality & Sensitive Populations Groups*, which may be accessed free of charge from the AQS Aerias IAQ Resource Center, under the Premium Content tab, at www.aerias.org.

Table 1 summarizes the distinct stages of childhood and unique physiologic and age activity characteristic associated with each stage.

Table 1. Physiologic and Age Activity Characteristics of Stages of Childhood*

Stage	Physiologic Characteristics	Age Activity Characteristics
In Utero	Fetal lungs immature, placental transfers of nutrients and	Totally dependent on mother's activities

	chemicals, prolific cell growth	
Infancy, Early Childhood	<p>Newborns: Lungs immature, highly permeable gastrointestinal tracts and skin</p> <p>Toddlers: Nervous system developing, immature metabolic pathways and less ability to detoxify chemicals.</p>	Breastfeeding, crawling close to the ground, mouthing everything, eat and drink more than adults in body weight, eat different proportions of foods
School Age	Maturing organs and systems, especially reproductive, musculoskeletal	Exposure to new environments; exposure to chemicals used in schools, such as in cleaning products, solvents, personal care products, air fresheners and pesticides
Adolescence	Maturing organs and systems, especially hormonal, reproductive, musculoskeletal	Exposure to new environments; exposure to chemicals used in personal care products and scents and occupational exposure

*From the Allergy, Sensitivity & Environmental Health Association website:
www.asehaqld.org.au.

All of these factors combine to create a higher body burden of chemical pollutants for the same amount of exposure. Researchers note that the combination of disproportionately heavy exposure plus biologic vulnerability makes children very susceptible to adverse health effects (Landrigan et al 1999). Also of note, exposures early in life can lead to a greater risk of chronic health effects that become apparent years later (Tickner and Hoppin 2000).

HEALTH EFFECTS FROM EXPOSURE TO CHEMICALS

As with adults, children can be exposed to indoor air pollutants via inhalation, ingestion and external contact. Unlike adults, as noted above, developing fetuses can be exposed through the placenta and babies through breastfeeding. In other words, a mother's exposure also can have a significant impact on her baby's developing organs and systems.

Exposure to some indoor air pollutants, especially volatile organic compounds (VOCs), can cause eye, nose, throat and skin irritation. Others produce odors that may be objectionable. While these effects are by no means insignificant, what has healthcare professionals and researchers worried is the impact of chemical exposures on children's respiratory health and immune systems. Results from a growing body of research outside the US suggest that chemical emissions from common indoor materials and finishes have a variety of adverse effects, including increased risk of asthma, pulmonary infections and allergies. These health problems were associated with exposure to formaldehyde, benzene and phthalate esters; indoor materials or finishes such as flooring, paint and plastics; and indoor activities related to these materials (Mendell 2007).

Chemicals in cleaning products and some personal care products also have been implicated. Henderson et al (2008) reported an association between mothers' use of household chemical products during pregnancy and persistent wheeze in school-aged children (age 7). Results from another study found that the frequent use of hairspray in infants' bedrooms was associated with increased risk of asthma in children when they were seven years old (Ponsonby et al 2000). The data are not conclusive and more

research is needed, but there may be sufficient evidence to caution people about indiscriminate use of cleaning products indoors, especially during pregnancy and around small children (Franklin 2008). See *Products of Concern, Cleaners* below for more information.

What happens when chemicals enter the bloodstream and are deposited into major organs is also very worrisome. In some cases, health effects associated with these chemical exposures do not become apparent for many years. In a discussion of how best to monitor exposure to environmental chemicals for the National Children's Study, Barr et al explained that once the chemical has been absorbed, it is distributed to primary deposition sites where its concentration is in equilibrium in the blood. To maintain equilibrium, the chemical is slowly released from the deposition or storage site. It is then metabolized, usually in the liver, and eliminated from the blood in urine or feces. Some chemicals, such as VOCs, may be excreted through the alveoli or in exhalation. Other chemicals can be excreted as tears, saliva, sweat or milk in lactating mothers. During the metabolism and removal process low concentrations may reach target organs (Barr et al 2005).

In a 2006 review study, researchers from the Harvard School of Public Health and the Mount Sinai School of Medicine systematically examined publicly available data on industrial chemicals with the goal of identifying which chemicals are the most likely to damage developing brains. The researchers found that 202 commonly used industrial chemicals have the capacity to damage the human brain, and they concluded that chemical pollution might have harmed the brains of millions of children worldwide. About one-half of them are considered high-volume production chemicals. The authors also concluded that the toxic effects of industrial chemicals on children have generally been overlooked (Grandjean and Landrigan 2006, Grandjean and Perez).

Schettler et al and others have identified a wide range of chemicals that cause adverse reproductive, developmental and neurotoxic effects. These include metals (lead, mercury, manganese, arsenic and cadmium); organic solvents (methylene chloride, glycol ethers and trichloroethylene); pesticides (DDT, atrazine, chlorpyrifos, parathion and lindane); ETS and nicotine; and polychlorinated biphenyls (PCBs). Chemicals identified as endocrine disruptors include dioxins, PCBs, alkylphenols, bisphenol A, phthalate esters and various pesticides (Schletter et al 1999, Schletter et al 2000). Flame retardants also are suspected of being an endocrine disruptor. Some of these chemicals have been phased out, such as DDT and PCBs but are still present in the outdoor environment.

An especially striking finding is some chemicals may have health impacts at extremely low levels, which are not seen at higher levels. Minute levels of phthalates, which are used to make toys, building materials, drug capsules, cosmetics and perfumes, have been linked to sperm damage in men and genital changes, asthma and allergies in children (Waldman 2005, Bornehag et al 2004).

Other studies have found that exposure to very small traces of VOCs and some industrial chemicals in homes and schools can disrupt the endocrine system (hormones), gene activation and brain development. Researchers at the University of London suspected that small amounts of some industrial chemicals may have a dramatic effect on hormone levels. They tested the hormonal strength of 11 common chemicals, known to mimic estrogen. Alone, each chemical was very weak, but when low doses were mixed with natural estrogen, the strength of estrogen doubled (Waldman 2005, Rajapakse et al 2002). High levels of estrogen are associated with some forms of cancer and developmental problems during puberty. For more information about results of studies linking environmental contaminants to illnesses, see Cohen 2006.

CHEMICALS OF CONCERN

The discussion above provided an overview of health risks associated with industrial chemicals used in everyday products and how children can be exposed to them. The next two sections go into more detail about the primary chemicals of concern and the products in which they may be found.

Arsenic. In a survey of children's products conducted by HealthyToys.org, arsenic was detected in about 1.4 percent of children's products (HealthyToys.org 2009). Exposure is associated with lower IQ scores in school-aged children. Prenatal and early childhood exposures also can increase the risk of lung cancer

and respiratory disease later in life (Wisconsin Department of Health Services 2007). In addition, exposure can cause nerve and skin damage and increase the risk for lung, bladder, kidney and liver cancers.

Bisphenol A. This chemical is a primary ingredient in polycarbonate plastic, which is used to make a variety of common products, including baby and water bottles, sports equipment, medical and dental devices, dental fillings and sealants, eyeglass lenses, CDs and DVDs, and household electronics. Some epoxy resins containing bisphenol A are used as coatings on the inside of food and beverage cans. Bisphenol A also has been used as flame retardant and fungicide (NTP CERHR 2007). Widespread and continuous exposure to low levels of bisphenol A is primarily through food, but also through drinking water, dental sealants, dermal exposure and inhalation of household dusts (CDC 2009a).

In 2007, the Centers for Disease Control and Prevention (CDC) published results of its analysis of urine samples from 2,517 people, aged 6 years and older who took part in the National Health and Nutrition Examination Survey (NHANES) from 2003 and 2004. The results showed that bisphenol A is present in nearly 93 percent of the people tested. The results also demonstrated that females had a significantly higher level in their urine than males. Children had the highest levels, followed by teens and adults (CDC 2009a).

Results from a number of studies have implicated bisphenol A as having significant health effects in experimental animals, including endocrine disruption, impaired immune system function, brain damage, developmental toxicity, learning disabilities, diabetes, behavioral changes, early puberty, reduced sperm count, cancer, obesity and neurotoxicity (Environmental California 2004), liver damage, disrupted pancreatic β -cell function and thyroid hormone disruption (Lang et al 2008). The evidence from these studies prompted the National Toxicology Program Center for the Evaluation of Risks to Human Reproduction (NTP CERHR) to initiate a two-year analysis. The researchers reviewed a very limited number of available human studies along with nearly 1,000 studies of experimental animals on the health effects from exposure to bisphenol A. In September 2008, the NTP CERHR released its findings that the evidence from experimental animal studies raised “some concern” that current levels of exposure to human fetuses, infants and children may result in developmental changes in the prostate gland and brain and diminish sexually dimorphic behaviors. The NTP CERHR report also raised a “minimal concern” for possible changes in the mammary gland and earlier age of attaining puberty in females (Bucher 2009, NTP CERHR 2007, 2008).

Since then, other studies of human exposure to bisphenol A have been published that continue to raise concern. For example, in a cross-sectional study of almost 1,500 adults, Lang et al found high bisphenol A levels in urine were significantly associated with heart disease, diabetes and abnormally high levels of certain liver enzymes (Lang et al 2008). There still is a great deal of uncertainty about the health effects of exposure to bisphenol A in humans. The NTP is working in collaboration with the CDC and academic investigators to evaluate exposures to bisphenol A in infants in neonatal care settings and in children less than six years of age.

Consumer groups recommend that people wishing to lower their exposure to bisphenol A avoid canned food and polycarbonate plastic containers, which share resin identification code 7 with many other plastics — unless the packaging indicates the plastic is bisphenol A-free. The National Toxicology Panel recommends avoiding microwaving food in plastic containers, putting plastics in the dishwasher or using harsh detergents to avoid leaching. There also are efforts to ban bisphenol A, including legislation being proposed in the US Congress and in state legislatures. Major manufacturers of baby bottles have voluntarily stopped using bisphenol A in their product formulations, as have manufactures of pacifiers and sippy cups.

Flame Retardants. Polybrominated diphenyl ethers are a class of widely used brominated flame retardants (BFRs) that are added to the plastics used in televisions, computers and other electronic products; building materials; furniture; foams; textiles and clothing. Electronics and electrical equipment make up more than 50 percent of BFR applications. Brominated fire retardants are one of five “families” of flame retardants, including brominated, chlorinated, phosphorous containing, nitrogen containing (melamine) and inorganic (antimony, aluminum and tin compounds). Of the 75 different commercial BFR

compounds, the following are the most commonly used; the last three in the list make up the PBDE class of fire retardants:

- Tetrabromobisphenol-A (TBBPA)
- Hexabromocyclododecane (HBCD)
- Brominated polymers, such as brominated epoxy, brominated polystyrene, brominated polycarbonate, poly (brominated acrylate) and brominated polyois
- Polybrominated biphenyls (PPB) — worldwide manufacturing ceased in May 2000
- Decabromodiphenyl oxide/ether (Deca-BDE)
- Octabromodiphenyl ether (Octa-BDE)
- Pentabromodiphenyl ether (Penta-BDE)

The primary reason for the concern over PBDE safety is that a variety of chemicals, including BFRs (PBDEs), have been found to disrupt the endocrine systems in experimental animals. These endocrine disruptions also may damage nerve cells during brain development, which in humans continues up to two years after birth (EPA 2004). Also fueling the debate is the PBDE chemical structure closely resembles PCBs, which have well-established toxic effects, including birth defects, cancer, thyroid imbalances and neurologic damage. Rather than containing chlorine, PBDEs contain bromine. Since PCBs were banned in 1979, BFRs have become more widely used. As of 2000, BFRs accounted for 38 percent of the global demand share of bromine, a significant rise from just 8 percent in 1975 (Birnbaum and Staskal 2004).

According to the CDC, studies of health effects to date have focused solely on animals; for example, rats and mice that ingested food with moderate amounts of PBDEs for a few days had effects on the thyroid gland. Those that ate smaller amounts for weeks or months also had effects on the thyroid and the liver. Preliminary evidence suggests that PBDEs also may cause neurobehavioral changes and affect the immune system in animals (ASTDR 2004).

Because PBDEs dissolve readily in fat, they can accumulate in breast milk and can be transferred to infants and young children. They also can cross the placenta and reach the fetus. Exposure to PBDEs in the womb and through nursing has caused thyroid effects and neurobehavioral alterations in newborn animals, but no birth defects. In addition to breast milk, researchers worry that infants and toddlers may ingest dust particles containing PBDEs. For more information, see the AQS white paper *PBDE Flame Retardants and Indoor Environments: Where There's Smoke There's Fire*, which is available free of charge from the Premium Content section of the AQS Aerias IAQ Resource Center, under the Premium Content tab, at www.aerias.org.

Formaldehyde. Formaldehyde is widely used to manufacture building materials and numerous household products and also is a by-product of combustion and certain other natural processes. Primary sources include pressed wood products such as particleboard, plywood, and medium density fiberboard (MDF); finished furniture, shelving, and cabinetry made with composite boards and certain coatings; decorative fabrics and textiles; and paper products. It also may be used as a biocide in certain paints and coatings, adhesives and personal care products.

Based on more than 300 measurements collected in residences and schools, Air Quality Sciences (AQS) studies have found typical concentrations range from 0.05 ppm to 0.08 ppm in homes. An average level of 0.04 ppm has been found in schools, with new or recently renovated or refurbished school environments reaching 0.14 ppm. To avoid acute respiratory symptoms, the levels found in schools are higher than the 0.027 ppm (27 ppb) limit recommended by the state of California's Environmental Protection Agency for residential exposures.

Available clinical and epidemiological data indicate that individual responses to formaldehyde may vary substantially. Irritation may occur at levels of 0.08 ppm or less, and odor detection has been measured as low as 0.03 ppm. When formaldehyde is present in the air at levels exceeding 0.1 ppm, some people may experience watery eyes; burning sensations of the eyes, nose, and throat; coughing; wheezing; nausea; and skin irritation. Some people are very sensitive to formaldehyde, while others have no reaction to the same level of exposure. Other health effects include coughing, fatigue and severe allergic reactions. High concentrations may also trigger asthma attacks.

Mendell reviewed 20 studies that investigated associations between health effects to allergies and asthma in infants and children (up to age 16) and indoor environments or activities considered to be risk factors for chemical exposures. His summary included studies that found associations of formaldehyde with asthma, adverse changes in lung function, lung inflammation and chronic bronchitis. Formaldehyde emissions from particleboard, plasticizers or plastic materials and recent painting were among the most frequently identified risk factors for residential exposures to industrial chemicals (Mendell 2007).

Another study of note found that children exposed to formaldehyde at levels as low as 16 ppb in indoor air were more likely to show allergic sensitization and respiratory symptoms. In addition, 16 percent of children in homes with formaldehyde less than 16 ppb had asthma as compared 44 percent of children with asthma living in homes with formaldehyde concentrations greater than 40 ppb (Garrett et al 1999).

Lead. Lead is a soft, heavy, blue-gray metal. In the US, lead is no longer used in paint or gasoline, but lead is still present in products used indoors such as batteries, solder, pipes and unglazed pottery (CDC 2005). In the HealthyToys.org survey, lead was found in approximately 20 percent of children's products (HealthyToys.org 2009). Lead may be used in two aspects of toy manufacturing.

- **Paint:** Lead may be found in the paint on toys. In 1978, the US banned lead in house paint, on products marketed to children, and in dishes or cookware; however, it is still widely used in other countries. As a result, lead paint can still be found on imported toys and on older toys made in the US before the ban.
- **Plastics:** The use of lead in plastics has not been banned. It softens the plastic and makes it more flexible so that it can go back to its original shape. Lead also may be used in plastic toys to stabilize molecules from heat. When the plastic is exposed to substances such as sunlight, air and detergents, the chemical bond between the lead and plastics breaks down and forms a dust. Children get this dust on their hands and toys through normal hand-to-mouth activity (CDC 2009b).

Lead is also found in some children's metal jewelry. The Consumer Product Safety Commission (CPSC) and the CDC encourage parents to throw metal jewelry away. Children who swallow metal jewelry with lead are at risk for health problems. In addition, the CPSC has recalled numerous products, primarily manufactured outside the US, because of the presence of lead (Kids in Danger 2008).

According to the CDC, there is no safe blood lead level. For infants and young children, lead levels of 10 micrograms or more in a deciliter of blood (about one-half cup) can damage a child's ability to learn. Young children are at higher risk from exposure to lead, because their bodies absorb lead more easily than adults. Pregnant women and women of childbearing age also should avoid exposure to lead because lead ingested by a mother can affect unborn children (CDC 2005). Low levels of lead in the body can lead to reduced IQ and attention span, impaired growth, reading and learning disabilities, hearing loss and other health and behavioral problems. At higher levels, lead can cause mental retardation, coma, convulsions and death (National Safety Council 2009).

Mercury. This metal is toxic to the nervous systems and can also adversely affect the kidneys (US EPA 2009). Exposure to high levels of metallic, inorganic or organic mercury can permanently damage the brain, kidneys and the developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short-term exposure to high levels of metallic mercury vapors may include lung damage, nausea, vomiting, diarrhea, increases in blood

pressure or heart rate, skin rashes and eye irritation. Also, very young children are more sensitive to mercury than adults (ATSDR 1999).

The HealthyToys.org survey found mercury in one (1) percent of children's products (HealthyToys.org 2009). Another potential source of exposure in indoor environments is compact fluorescent light bulbs (CFLs), which if broken allow mercury to escape as a vapor into indoor air or collect in settled dust.

As a part of ongoing efforts to save energy, the US EPA is encouraging homeowners to switch from traditional light bulbs to CFLs. According to the US EPA, CFLs, which qualify for the ENERGY STAR label, use up to 75 percent less energy (electricity) than incandescent light bulbs and last up to 10 times longer. Mercury is an essential part of CFL technology. The light bulbs do not emit mercury during operation, but — as noted above — if broken mercury vapor can escape into the environment (US EPA 2008a). Mercury levels in the air can be quite high for about an hour after a bulb breaks. Eventually, most of the mercury will disperse, especially if a window is left open. Some mercury vapor will liquefy into tiny beads that settle on surfaces. Wood floors can be cleaned thoroughly, and will most likely be mercury-free within four days. Carpets and fabric are harder to clean, however (Environmental Working Group 2008).

In response to this concern, members of National Electrical Manufacturers Association have voluntarily agreed to cap the amount of mercury in CFLs to 5 mg per light bulb for those that use less than 25 watts of electricity and 6 mg per light bulb for those that use 25 watts to 40 watts of electricity. As a result of this and other initiatives, the average mercury content in CFLs has been reduced by least 20 percent since 2007. Some manufacturers have dropped mercury content in their CFLs to 1.4 mg to 2.5 mg per light bulb (US EPA 2008a, NEMA 2007). To prevent release of mercury into the environment from CFLs, the US EPA encourages homeowners to recycle the light bulbs and some states require recycling by law.

While this is a good start, some watchdog groups say the US EPA guidelines do not go far enough. According to the Environmental Working Group, for example:

- ENERGY STAR's guidelines require manufacturers to include a notice on the label that their CFLs contain mercury. The guidelines do not require that the labels state how much mercury is contained in the bulbs.
- ENERGY STAR's 5 mg mercury cap is higher than necessary, as the estimated industry-wide is estimated to be between 3 mg and 4 mg of mercury per bulb. The Environmental Working Group found CFLs with 1 mg to 2.7 mg of mercury.
- Some CFLs that bear the ENERGY STAR label cannot legally be sold in Europe, where the European Union has capped mercury content at 4 mg per bulb for CFLs (Environmental Working Group 2008).

The CFL technology is rapidly advancing. Watchdog groups, such as the Environmental Working Group, are encouraging the US EPA to revise its guidelines accordingly.

Phthalates. Also called "plasticizers," phthalates are a group of industrial chemicals used to make plastics like polyvinyl chloride (PVC) more flexible or resilient and also as solvents. They are used in hundreds of products, including vinyl flooring; adhesives; detergents; lubricating oils; automotive plastics; plastic clothing such as raincoats; and personal care products, such as soap, shampoo, hair spray and nail polish. Before 1999, phthalates were used in pacifiers, soft rattles and teething rings (CDC 2005).

Phthalates have been found to disrupt the endocrine system. Several phthalate compounds have been associated with reduced sperm counts, testicular atrophy and structural abnormalities in the reproductive systems of male test animals. Results of other studies have linked phthalates to liver cancer (CDC 2005). Some phthalates also have been associated with increases in persistent symptoms of allergies and diagnoses of rhinitis, eczema and asthma (Mendell 2007). Although the CDC contends the health

hazards of phthalates to humans have not been definitively established, the US EPA regulates phthalates as water and air pollutants.

Their use is so widespread that researchers have found phthalates in almost all of the US population, with the highest levels in children ages 6 to 11 years and in women. Using products that contain phthalates, breathing contaminated dust or having a medical treatment, such as a blood transfusion or dialysis that uses equipment made of plastics, are possible exposure pathways (CDC 2005).

Volatile Organic Compounds. Among the most prevalent of all indoor air constituents are VOCs, with as many as 100 to 1,000 different VOCs in the air where children can easily inhale them. As noted above, some VOCs can cause eye, nose and throat irritation; cough; headache; general flu-like symptoms, skin irritation and some may cause cancer. Others produce odors that may be objectionable. Complicating matters is the potential for interactions of VOCs with other chemical compounds to form additional compounds that may also be a threat. As a result, even though the concentrations of individual VOCs may be well below odor thresholds or known toxic levels, their occurrence in complex mixtures may lead to perceived poor IAQ, irritation among those exposed or effects not yet known or defined.

Some VOCs, such as toluene, benzene and dichlorobenzene, have been reported with increases in asthma diagnoses, obstructive bronchitis, pulmonary infections associated with asthma attacks, sensitivity to some foods and eczema. Other VOCs, such as hexane and decane were associated with increased sensitization to foods. In addition, total VOC concentration has been associated with increases in the number of asthma diagnoses, but not with persistent wheezing (Mendell 2007).

Air Quality Sciences has measured VOC levels in more than 200 US schools and found 345 typical VOCs in the indoor air. Table 2 lists the 14 most common VOCs found in these schools. Other frequently found VOCs of concern in schools include perchloroethylene and methylene chloride, potential carcinogens related to spot cleaners, degreasers and art supplies. By extension, these VOCs also may be present in daycare facilities where very young children may be exposed.

Table 2. Common VOCs found in schools

VOC	Source(s)	VOC	Source(s)
Toluene	Cleaners, construction materials	Hexanal	Cleaners, adhesives, deodorizers, cabinetry
Xylenes	Cleaners, construction materials	2-Butoxyethanol	Wood cabinetry, cleaners, paints
Siloxanes	Waxes, polishes, deodorants	Ethanol	Cleaners, disinfectants
Formaldehyde	Furniture, ceiling tile, wood shelving, cabinetry	TXIB	Plastics, paints
Hexane	Markers, cleaners	Acetaldehyde	Plastics, paints, foam insulations
Acetone	Markers, art supplies	Longifolene	Cleaners, wood products, flooring
1,4 Dichlorobenzene	Cleaners, deodorizers	Naphthalene	Adhesives, art supplies, rubber flooring

In homes, primary VOC sources include furniture, furnishings, carpets and flooring, beds and bedding, plastics, paints, wood cabinets, cleaning and personal care products.

PRODUCTS OF CONCERN

Although children can be exposed to chemicals from a wide variety of products, furnishings and building materials used in homes and schools, the products highlighted in this white paper are those that children

are likely to be in close contact or contain industrial chemicals that can be particularly damaging to children's health.

Bedding. For a number of years, the primary focus on children's health and bedding has been on dust mites, which can trigger allergy and asthma attacks. While this is an important issue, chemical emissions from mattresses and bed furniture also have the potential to significantly impact children's health. An often-cited study evaluated groups of mice that breathed VOC emissions from four brands of crib mattresses for two one-hour periods. The results showed that the emissions caused various combinations of upper airway irritation, such as sensory irritation, pulmonary irritation and decrease in airflow velocity (Anderson and Anderson 2000).

Although mattresses may contain slightly different components, most have three basic parts: tickling or covering fabric, padding and a supporting core. Most covering fabrics are made with synthetic thermoplastic fibers, such as polyester, nylon, polypropylene, acrylic and PVC. Some are a blend of synthetic fibers and cotton. The covering fabric receives a number of chemical applications during manufacturing, such as dyes, stain and water repellants, wrinkle-resistant treatments, anti-fungicides, pesticides, fire retardants and antimicrobial coatings (Bader 2007).

The padding layers insulate the mattress and add structure and support. These layers are most often comprised of polyurethane foam, convoluted foam, synthetic fiber pads and/or polyester fibers. During the manufacturing process, the fibers also may be treated with an artificial resin of acrylates, which helps to bind the fibers together and prevent fiber migration. The supporting cores are made from latex, polyurethane foam or steel innersprings. Most mattresses sit on a foundation, such as a wood foundation, box spring or grid foundation (Bader 2007).

Polyurethane foam is made by combining isocyanates and polyols with other chemicals, which act as stabilizers, catalysts, surfactants, fire retardants, colorants and blowing agents. The most widely used isocyanate in mattresses is toluene diisocyanate, which is made from chlorine, toluene, phosgene, sulfuric acid and nitric acid. These VOCs are associated with a number of health effects, including pulmonary injury, reduced lung function and lung diseases; nausea and vomiting; and allergic reactions. The National Toxicology Program and the International Agency for Research on Cancer list toluene diisocyanate as a potential carcinogen (Bader 2007).

Another isocyanate — 4-methylenediphenyl diisocyanate — has become popular in the construction of polyurethane foams. It is made from formaldehyde, sulfuric acid, nitric acid, phosgene and benzene. The US EPA reports that short-term inhalation of high concentrations of this chemical may cause sensitization and asthma (Bader 2007).

Most baby mattresses, including crib, cradle, bassinet, porta-crib and co-sleeper mattresses contain PVC, generally referred to as vinyl, as the surface material or covering. Vinyl chloride, an intermediate component in the manufacturing of PVC, is a combination of petroleum and chlorine, and is a known human carcinogen (Ion 2008).

Boric acid also is applied to mattresses to reduce flammability of cotton fibers. While boric acid has been used since antiquity for fireproofing cloth, it also is a potent pesticide and insecticide. The US EPA warns that the use of boric acid can result in reproductive, developmental and neurologic damage. Other health risks include genital damage, brain damage, anemia, infertility, birth defects and death (Bader 2007).

Until very recently, brominated flame retardants, especially PBDEs, were one of the primary chemicals used to reduce the speed with which the plastic components of consumer goods, including mattresses, couches, chairs and electronics, could be consumed by fire. However, growing evidence shows that PBDE compounds are escaping from the products they protect and making their way into the products' users and cause health problems (see Flame Retardants above for details on how these chemicals can impact children's health).

Two new standards from the US Consumer Product Safety Commission (CPSC) are opening the door for innovative approaches for protecting consumer goods containing polyurethane foam from fire. The first

took effect last year for mattresses. This standard is innovative in being the first in the United States to focus on the rate of heat release, which fire safety experts recognize is the main determinant of how quickly a fire can spread out of control to the flashover point (Betts 2008).

The mattress industry worked with NIST to develop the new standard test method to meet the CPSC regulation, which stipulates that no mattress may generate a peak heat release rate greater than 200 kilowatts when subjected to gas burners that mimic burning bedding. The CPSC estimates the new standard will prevent as many as 270 fire-related deaths and 1,330 injuries every year. Since this is a performance standard rather than a prescribed mattress design, it allows manufacturers to choose how to fabricate mattresses that comply with the regulation (Betts 2008).

One approach mattress manufacturers are using to meet the standard is to employ what is known in the industry as a barrier material, says Tom Ohlemiller, who was the project leader for the NIST team that developed the mattress test method. The barrier materials themselves may be inherently nonflammable, such as polyamides like Kevlar. Flammable barriers may be protected with proprietary fire retardant treatments such as decaBDE. However, Ohlemiller says the standard does not require such treatments for the polyurethane foam padding beneath the barrier, which some scientists believe is the source of some of the PBDE flame retardants that have escaped into people's homes. Over the past year, scientists have reported detecting other flame retardants used in polyurethane foam in household dust (Betts 2008).

Another chemical of note used in bedding is formaldehyde, which as noted below, is used not only in furniture but also to reduce wrinkling and fix color in permanent press fabrics, including linens, draperies and clothing. Laundering linens and clothing before use can reduce formaldehyde emissions by about 60 percent (CARB 2004). See the discussion of *Chemicals of Concern, Formaldehyde* above and the discussion on *Furniture and Furnishings* below for more information.

Cleaners. Cleaning is done at some level by nearly all adults, which means most people are exposed to cleaning chemicals for at least a portion of every day (Wiley et al 1991, Jenkins et al 1992), including children. While cleaning is effective for reducing the level of viruses, bacteria, particulates, endotoxins, molds and allergens (Kildesø and Schneider 2000), results from a number of studies have demonstrated that the very products and processes that are used to keep indoor environments clean also may contribute to indoor pollution (Rumchev et al 2004; Shendell et al 2004; Zock et al 2001; Wolkoff et al 1998). In many cases, VOC emissions from cleaning products and application processes are the primary cause of concern. See the discussion on *Volatile Organic Compounds* above for details about potential health effects.

Results of AQS' indoor air quality testing of hundreds of offices, schools and homes have confirmed the potential for high levels of VOCs, and have identified numerous VOCs associated with cleaning products and processes. The results also showed that within two hours of certain cleaning processes, the total VOC levels (TVOC) in these environments can increase significantly, ranging from 40 $\mu\text{g}/\text{m}^3$ to 25,000 $\mu\text{g}/\text{m}^3$, and reach levels higher than the acceptable value (500 $\mu\text{g}/\text{m}^3$ or 0.5 mg/m^3) for VOC emissions from cleaning products, established by the GREENGUARD Environmental Institute. For more information and a list of some common VOCs found in offices, schools and homes and the types of cleaning products in which they are found, see the AQS white paper *Cleaning Chemicals and Their Impact on Indoor Environments and Health*, available free from the Aerias AQS Indoor Air Quality Resource Center (www.aerias.org) in the Premium Content section.

Researchers at the University of California, Berkeley, and Lawrence Berkeley National Laboratory have reported that common household cleaners and air fresheners may emit pollutants at levels that may lead to health risks. The investigators focused on products with ethylene-based glycol ethers, which are common, water-soluble solvents used in a variety of cleaning agents, latex paints and other products. The US EPA 1990 Clean Air Act Amendments classifies ethylene-based glycol ethers as hazardous air pollutants and by California's Air Resources Board as toxic air contaminants (Nazaroff et al 2006).

Other studies have shown that certain VOCs may react with ozone to produce a number of toxic compounds. For example, d-limonene and other terpene compounds, used in polishes, scented

deodorizers, cigarettes, fabrics and fabric softeners, can readily react with low concentrations of ozone, brought in from the outdoors or produced by ionizing air cleaners. This reaction creates aldehydes and ultrafine particles, which can be irritating (Sarwar et al 2002; Weschler and Shields 1999; Wolkoff et al 2000, Apte and Erdmann 2002). The results from another study demonstrated that a mopping agent containing terpene generated vast numbers of ultrafine particles in a reaction with ozone. The results also showed that 10 minutes of mopping with this agent influenced indoor particle concentration for more than 8 hours (Long et al 2000).

As noted, the effect of maternal use of cleaning chemicals during pregnancy on wheezing and lung function in children also is a concern. In addition to the studies cited above, results of two studies found a correlation. In the Avon Longitudinal Study of Parents and Children (ALSPAC), researchers determined the frequency of use of 11 chemical based domestic products from questionnaires completed by women during pregnancy. Four mutually exclusive wheezing patterns were defined for the period from birth to 42 months and a follow-up study to 7 years of age based on parental questionnaire responses (never wheezed, transient early wheeze, persistent wheeze, and late onset wheeze). A subsequent study also tested children at age 8 for lung function and allergy. The results showed that greater exposure to cleaning chemicals used in homes during pregnancy was associated with persistent wheeze and lung function abnormalities in non-allergic children (Henderson et al 2008, Sherriff et al 2005). These are important findings, because they illustrate that children who do not have allergies or asthma also can be significantly impacted by exposure to cleaning chemicals.

A number of state governments, recognizing the potential for health problems in children associated with cleaning chemicals, have required the use of green cleaning products in schools and in state buildings. To assist commercial users and consumers in making informed decisions, several green cleaning standards from Green Seal, the Environmental Choice Program (ECP) and the GREENGUARD Environmental Institute have been developed. Both Green Seal and the ECP focus primarily on VOC content, while GREENGUARD Certification focuses exclusively on VOC emissions from cleaning products and their impact on the air people breathe. Manufacturers are also encouraged to create safer, lower emitting products.

GREENGUARD Certification requires that products undergo VOC emission performance testing for more than 10,000 individual chemicals. All individual VOCs detected must not exceed acceptable risk levels established by key global public health organizations and programs including the American Conference of Government Industrial Hygienists (ACGIH); the International Agency on Research of Cancer; National Toxicology Program; California's Proposition 65 (CA Prop 65) and Section 01350 environmental requirements; and the US EPA.

The revised Green Seal Standard GS-37 for institutional cleaners includes the GREENGUARD Children & Schools Certification for Cleaners and Cleaning Maintenance Products and Systems inhalation criteria and dynamic chamber test method as one of two options for assuring low VOC emissions for Green Seal certification. For more information, see the white paper, *Cleaning Chemicals and Their Impact on Indoor Environments and Health*. Also see a more detailed discussion of the GREENGUARD Children & Schools standard in the *Model for Action* section below.

Clothing. Children's sleepwear has been the subject of controversy since the 1970s. The original rules for baby pajamas were adopted by the US Department of Commerce in 1971 and the enforcement was subsequently transferred to the Consumer Products Safety Commission (CPSC). Polyester was a common fabric for baby pajamas at this time and met the requirements for flame resistance due to its inherent qualities. Other fabrics needed to be treated, and one of the first chemicals developed for this function was tris (2, 3-dibromopropyl) phosphate, commonly referred to as TDBPP, tris-BP or just TRIS. This process was short lived, as research uncovered that it caused cancer and sterility in animals. This chemical was officially banned in 1977 (eSSORTMENT 2009).

The CPSC amended the sleepwear regulations in 1996 to allow infant sleepwear in sizes up to 9 months to be made of non-flame-resistant natural fabric (such as cotton) or flame-resistant fabric. Children's sleepwear in sizes 9-months or above must be flame-resistant or snug fitting, because close-fitting clothes do not burn readily. In recent years, polyester and untreated cotton have been the predominant

types of children's pajamas. In general, garments are referred to as "flame resistant" if the fabric meets the CPSC guidelines without needing treatment, while the term "flame retardant" is used if a chemical has been added. The following is an overview of the three most commonly available types of sleepwear:

- **Polyester:** Polyester is considered to be "inherently" flame resistant. Flame retardants are chemically inserted during the manufacturing process and become part of the molecular composition of the fabric. The resulting polymer is very stable, so there is little likelihood that any chemicals will be released from the garment. The main complaint about polyester pajamas is that the fabric does not breathe and can thus contribute to overheating and rashes.
- **Cotton treated with flame retardants:** Many major lines of children's clothing market 100 percent cotton flame-retardant pajamas. They are treated with PROBAN from the chemical tetrakis hydromethyl phosphonium chloride (THPC), which is added to the fabric or garment in the finishing stages. During the process, the flame retardant molecules penetrate the cotton fibers. The fabric is then dried and cured, which causes a water insoluble polymer to form, essentially trapped inside the core of each fiber. The end result maintains all the desirable qualities of cotton, such as softness and moisture absorbency. If a flame comes into contact with PROBAN-treated cotton, an insulating char forms and protects the fabric from further damage. Results of studies indicate that the treated fabric has low migration of any chemicals and does not cause any skin irritation. There is concern, however, about THPC being linked to genetic abnormalities, damage to the liver, skin and nervous system and promoting the growth of cancerous tumors in experimental animals.
- **Untreated cotton:** Cotton pajamas meet CPSC guidelines if they are snug fitting. Many parents prefer this choice as it eliminates any concerns regarding chemical treatment either during or after the manufacturing process. Some parents prefer organic cotton sleepwear, which is made using no pesticides (eSSORTMENT 2009).

Electronics. Children of all ages are avid users of electronics, particularly computers. Scientific literature has focused primarily on electronic office equipment, but as many of the same products are used in homes and schools, the following information has relevance. Results from a number of studies have shown that computers emit a range of VOCs; although in most cases the emission rates are relatively low, suggesting that computers are not as a big contributor as other sources. Computers also do not seem to be a source for ozone. Desktop computers emit polycyclic aromatic hydrocarbons (PAHs), alkanes, alcohols, ketones and formaldehyde. Emission rates are lower for notebook computers, both when they are in idle or operating conditions. For notebooks, VOCs emitted include alcohols, carboxylates and ketones (Hoshino et al 2003). Plastic covers of video-display units emit triphenylphosphate flame retardants (Carlsson et al 2000).

Results of recent study showed that between 4.0 mg and 6.3 mg of dust per day can be released during computer operation, which suggests that children working near this equipment could possibly be exposed to chemicals that are found in the dust, such as PAHs. This study also found that the amount of PAHs in dust samples collected from the inside of computers was three times higher than what was measured in outdoor air samples (Ren et al 2006). Of note, no study as yet has quantified the exact contribution of office equipment emissions to indoor levels of PAHs. Also of note is computers do not generate particulates, but will release fine particles of dust that have collected in their interiors.

In general, VOC emission rates from photocopiers are much higher than for printers and multifunctional devices, such as those that include a fax machine, printer and copier all in one. Printers and copiers also have higher emission rates than computers, particularly for styrene, toluene, xylene and other alkylbenzenes. The heating of toner during printing is among the sources of VOC emissions. Results from a number of studies have shown that laser printers and photocopiers generate ozone in varying amounts (Destailats et al 2008).

Researchers also have investigated emissions of ultrafine particles from toner and paper dust formed during the laser printer and copier operation (Wensing et al 2006, Lee et al 2001, Kagi et al 2007, He et al 2007, Lee and Hsu 2007). Recent studies, conducted by researchers from Queensland University of

Technology in Australia, characterized particle emissions (PM_{2.5}) of 62 office printers. The results showed that approximately 60 percent of the printers did not emit submicrometer particles, and of the 40 percent that did, 27 percent were high particle emitters. Particle emission characteristics from the three laser printers studied in the environmental chamber showed that particle emission rates are printer-type specific and are affected by toner coverage and cartridge age. Results of earlier studies echo the findings of the studies cited above, including the following:

- Aromatics and siloxanes are emitted by computer circuit boards, monitors and printer toner (Brooks and Davis 1992).
- Esters and acrylates may be used as coalescing agents or as monomers in polymer-based products (Wolkoff et al 1993).
- Particles may become airborne as copiers and printers transfer toner to the printed page.
- Ozone may be generated from office machines through the use of electric charging devices during the copying and printing processes.
- Phthalates may be released from resins in circuit board and component materials. Carbon black also can be released from toners, which are generally a mixture of plastic resin, carbon black and other additives (London Hazard Centre 2002). Carbon black consists of particles and impurities that can be inhaled.

For more information, see the AQS white paper *Meeting Green: The Office Equipment Industry's Guide to Managing Product Emissions*, which is available free of charge from the AQS Aerias IAQ Resource Center, under the Premium Content tab, at www.aerias.org.

Furniture and Furnishings. For many years, formaldehyde has been a key ingredient in most adhesives used to make composite wood products, including furniture for children's rooms. Its reactive nature allows formaldehyde to cross-link with other ingredients to form a strong, cost-effective bond. To minimize wrinkling, formaldehyde also is used to make permanent press draperies and other fabrics used for room decorations.

The Environment California Research & Policy Center evaluated 21 products typically found in a baby's nursery. These products contained composite wood or permanent press fabrics, all of which are potential sources of formaldehyde. Of the 21 products, six brands of cribs and changing tables emitted formaldehyde at levels high enough to increase the risk of children developing allergies and asthma. Almost all of the other items studied, including lamps, shelves, window valances, wall hangings and a doll made with permanent press fabric, emitted formaldehyde but at lower rates than the six brands of cribs and changing tables. The authors also noted that there is a cumulative effect of formaldehyde emissions if more than one formaldehyde-emitting product is placed in a nursery or child's bedroom (Madsen and Gibson 2008).

Further, results of a recent study found that children between 6 months and 3 years of age who are chronically exposed to formaldehyde at levels higher than 50 ppb showed an increased prevalence for asthma. This study evaluated a group of children with doctor-diagnosed asthma and a group of children of similar age without asthma. They tested the children's bedrooms and living rooms for formaldehyde emissions, controlling for temperature and humidity. In homes with formaldehyde concentrations greater than 50 ppb, a child's risk of needing treatment for asthma increased by 39 percent. The risk increased as the levels of formaldehyde increased (Rumchev et al 2002).

The California Air Resources Board (CARB) responded to results from scientific studies demonstrating that inhalation of formaldehyde from composite wood products containing urea formaldehyde resins is one of the primary sources of human exposure by enacting a new regulation. Effective January 2009, with full implementation by 2012, the regulation is the toughest, most comprehensive production standard in

the world for formaldehyde emissions from composite wood products. According to the CARB regulation, the following products that are sold or used in California must comply:

- All hardwood plywood (HWPW), particle board (PB) and medium density fiberboard (MDF) panels
- Hardwood plywood made with a veneer core (HWPW-VC)
- Hardwood plywood made with a composite core (particle board or MDF) (HWPW-CC)
- All finished products containing composite wood products for sale or use in California (CARB 2008)

Table 3 lists the Phase 1 and Phase 2 formaldehyde emission standards for HWPW, PB and MDF products, based on the primary test method, ASTM E 1333-96(2002).

Effective Date	Table 3. Phase 1 (P1) and Phase 2 (P2): Emission Standards (ppm)*				
	HWPW-VC	HWPW-CC	PB	MDF	Thin MDF
Jan 1, 2009	P1:0.08		P1: 0.18	P1: 0.21	P1:0.21
Jul 1, 2009		P1:0.08			
Jan 1, 2010	P2:0.05				
Jan 1, 2011			P2:0.09	P2:0.11	
Jan 1, 2012					P2:0.13
Jul 1, 2012		P2:0.05			

*Composite Panel Association 2008

The new CARB regulation requires manufacturers to have their composite wood products tested by a CARB approved Third Party Certification (TPC) agency to verify compliance with the emission standards and proper product labeling. Mills must undergo initial qualification, do regular quality tests and submit to quarterly third party audit / emission verifications by a TPC. Fabricators of finished products must specify and use compliant composites and label their products according to the CARB regulation. Retailers must stock composite wood products and/or fabricated products that comply with the CARB labeling, emission and certification requirements. A strict chain of custody is mandatory, obliging manufacturers, fabricators, importers, distributors and retailers to keep detailed records (CARB 2008).

In response to a petition from 25 organizations and 5,000 individuals, the US EPA is considering adopting a federal regulation based on the CARB regulation to reduce formaldehyde emissions from composite wood products. Other states are watching carefully, as they, too, consider following California's lead (US EPA 2008b).

Also of concern are VOC emissions from paints, wallcoverings and other decorative materials. Historically, paint and coatings manufacturers have responded to environmental concerns by limiting VOC content, which is an important consideration in protecting the outdoor environment. Controlling VOCs by weight or content, however, does not give a clear picture of how much of a particular VOC or the total amount of VOCs from a product may be getting into the indoor environment. Nor does it give an accurate picture of how the VOCs emissions from a product will affect the total VOCs in the area in which the paint is being applied.

The results of an AQS comparative study of VOC content / emissions illustrates how even products marketed as having low or no VOCs can still emit VOCs into the indoor air (see Table 4).

Table 4. Comparative Study of VOC Content and Emissions from Paints

	VOC Content per label (g / L)	VOC Content per ASTM (g / L)	TVOC Emissions (mg / m ²)	Predicted Air Levels (24 hr) (mg)

				/ m ³)
Flat Latex 1	0	32	18	0.02
Flat Latex 2	118	201	19212	4
Flat Latex 3	< 250	166	7179	1
Semi Gloss 1	0	22	26	0.06
Semi Gloss 2	121	169	581	6
Semi Gloss 3	< 250	261	4843	34
Gloss 1	< 250	245	3114	35
Gloss 2	< 250	271	32594	721
Gloss 3	< 250	103	2374	0.6

For more information, see the AQS white paper *Beneath the Surface*, which is available free of charge from the Aerias AQS Indoor Air Quality Resource Center (www.aerias.org) in the Premium Content section.

Jewelry. Metal jewelry, including inexpensive children’s jewelry, can contain dangerously high levels of lead. Lead-containing jewelry poses a particular concern because children are prone to placing jewelry in their mouths, which can result in dangerous amounts of lead getting into their bloodstreams. According to the results of a 2008 study that tested 15,000 popular toys, children’s jewelry is five times more likely to contain lead above 600 ppm than other products. Overall, jewelry is twice as likely to contain detectable levels of lead than other products that were tested (HealthyToys.org 2008). Recalls of lead-contaminated jewelry sold in discount stores, gift shops and vending machines have increased people’s awareness of the health hazards associated with lead in jewelry (California Department of Toxic Substances 2009).

In response to these concerns, the US Consumer Product Safety Improvement Act of 2008 sets strict limits on the amount of lead in products (see *Federal and State Government Legislation / Regulation* below for more information). In addition, California restricts the lead content in jewelry, for both children and adults. The California’s Lead-Containing-Jewelry Law prohibits persons from manufacturing, shipping, selling or offering for sale jewelry for retail sale or for promotional purposes in California unless certain lead-restricting requirements are met. For example, the law requires manufacturers to use specific classes of materials in jewelry that do not typically contain lead or which contain limited amounts of lead (California Department of Toxic Substances 2009).

Pesticides. Results of some studies have suggested that children are exposed to the highest concentrations of pesticides through household and school dust. A study of major pathways and routes of exposure assessed the accumulation of chlorpyrifos on toys and other objects, such as pillows. The results showed that it was found to be present long after the re-entry period and to represent a significant chronic exposure pathway from dermal and non-dietary ingestion, via hand-to-mouth activity of infants and children (Bukowski and Levy 1998).

Tobacco Products. Although becoming less of an issue in public buildings, environmental tobacco smoke (ETS) is still found in many homes, which can be particularly dangerous for children. Exposure to passive smoke or ETS is well documented as a major risk factor for respiratory problems and cancer, and the US Surgeon General has determined that there is no risk-free level of exposure to ETS (CDC 2006). Environmental tobacco smoke alone contains more than 4,700 airborne substances, including gases and particles from incompletely burned tobacco, of which 243 are known carcinogens. Children, who are exposed to ETS, are more likely to develop lower respiratory tract infections, bronchitis, pneumonia, middle ear disease, sudden infant death syndrome (SIDS) and respiratory symptoms (CDC 2006). Secondhand smoke (ETS) can also play a role in the development and exacerbation of asthma.

According to the CDC, nearly 60 percent (22 million) of children ages 3 to 11 years are exposed to secondhand smoke and about 25 percent of those children live with at least one smoker, as compared with seven percent of nonsmoking adults (CDC 2006). Younger boys (ages 0 to 2 years) spend more time around ETS than older boys, and more girls spend more time around ETS than boys, all which are indicative of children's typical activity patterns. Girls and younger children spend more time indoors than boys and older children (Wiley et al 1994).

Cigarette smoke is also a major exposure source of cadmium. Maternal smoking has been linked to altered auditory functioning and reading abilities, impulsive behavior and lower IQ scores (McElgunn 1999a).

Toys. The Ecology Center, a Michigan-based consumer safety organization, recently had more than 1,500 popular children's toys tested for lead, bromine, mercury, cadmium, arsenic, chlorine (as a marker for polyvinyl chloride), antimony (a metal used in flame retardants) and tin. The results of the study showed that 62 percent of the products contained low levels of these chemicals and more than 300 contained no chemicals of concern. The results also showed that one-third of the toys tested contained potentially harmful levels of lead, mercury and other chemicals. Lead was detected in 20 percent of the toys. In this 2008 study, 45 products tested (2.9 percent) contained bromine at levels greater than 1,000 ppm. Bromine is a key ingredient in flame retardants (HealthyToys.org 2009).

Other chemicals found in toys included cadmium, arsenic and mercury. Cadmium was found at levels greater than 100 ppm in 1.9 percent of products tested. Arsenic was detected at levels greater than 100 ppm in 1.4 percent of products tested. Mercury was found above 100 ppm in 1 percent of products tested. In addition, many children's toys are made of PVC plastic. Of the non-jewelry products tested, 27 percent contained PVC. Phthalates are very commonly added to PVC to make it soft and flexible; however, they can leach out of the plastic. Lead, cadmium and other metals are also commonly added to PVC products (HealthyToys.org 2009).

FEDERAL AND STATE GOVERNMENT LEGISLATION / REGULATION

Consumer Product Safety Commission. More than 30 years ago, the US Congress passed the Toxic Substances Control Act (TSCA) to authorize the US EPA to control chemicals that pose an unreasonable risk to human health or the environment. Presently, there are more than 80,000 chemical compounds registered for use in the US, with 62,000 of them grandfathered under the TSCA without mandatory testing. According to California Policy Research Center, about 2,000 new compounds that may pose hazard to human health are introduced into commercial use each year. Under TSCA, the US EPA has required testing on fewer than 200 chemicals and restricted only five chemicals (Wilson et al 2006).

The Consumer Product Safety Commission has jurisdiction over more than 15,000 types of consumer products, and is charged with protecting consumers from products that pose fire, electrical, chemical, or mechanical hazards or can injure children. In 2008, the CPSC assumed extra duties as Congress passed, and the President George W. Bush signed, the Consumer Product Safety Improvement Act of 2008 (CPSIA) (see below for more details). Once fully implemented, this landmark legislation will ensure that children's products will be tested for safety prior to sale and are free of known chemical or design hazards.

In its annual examination of children's product recalls, recall effectiveness at the CPSC and the implications for child safety, the Kids in Danger organization reported the following for 2008:

- In 2008, 394 products were recalled by the CPSC, 190 (48 percent) of which were children's products, including toys, clothing, furniture, nursery items, sporting goods or art and school supplies. This rate of just more than 3.6 children's products a week is down slightly from 2007, but still significantly higher than any previous year.
- Toys were the largest category of recalled children's products, representing 41 percent of the children's products recalled last year and were 20 percent of all product recalls. Most toys were

recalled for lead or choking hazards. The next largest groups at 15 percent each were nursery items, such as cribs, high chairs and bassinets for entrapment and lead, and clothing, mostly for drawstrings and choking hazards.

- Despite the scrutiny on lead in 2007, 36 percent of the recalls were for lead paint, including jewelry, toys and a crib.
- Children's products recalled in 2008 were manufactured in 21 different countries. More than two-thirds (69 percent) of the products were made in China, followed by 7 percent in Taiwan, and 4 percent each in the United States, Hong Kong and India. Three-fourths (75 percent) of the products recalled for lead were from China, but there were also lead-tainted products from Hong Kong, Indonesia, Taiwan, India, Korea, Peru and Trinidad (Kids in Danger 2009)

The Kids in Danger organization also expressed concern about the effectiveness of the CPSC recall effort and recommended the following steps be taken:

- The Consumer Product Safety Commission should immediately begin to plan and execute a database with product and injury data.
- Congress should immediately fully fund CPSC at the levels requested in CPSIA.
- Given the poor results of CPSC's current recall effectiveness reporting, Congress should call for annual reports on the year's recall and their effectiveness.
- The Consumer Product Safety Commission also should require more effort from companies in the event of a recall to retrieve or fix the faulty products (Kids in Danger 2009).

Consumer Product Safety Improvement Act of 2008. While this legislation significantly strengthens the CPSC's hand in protecting consumers and children from hazardous products, it only addresses a few of the industrial compounds that can adversely impact children's health. For example, the Title 1 of the CPSIA, Children's Product Safety bans products for use by children under 12 years of age that have lead concentrations higher than 600 ppm after 180 days (February 2009), 300 ppm after one year (August 2009) and 100 ppm after three years (August 2011). The CPSC has the authority to alter the lowest lead level allowed, if it is determined to not be technologically feasible to achieve the levels set forth in the legislation. There are exceptions for some electronic devices and certain product parts where it can be proven that lead will not be absorbed into the body. Title 1 of the CPSIA also establishes a more stringent limit on the amount of lead allowed in paint by reducing the maximum allowable concentration of lead in paint from 600 ppm to 90 ppm one year after enactment (August 2009) (Congressional Research Service 2008, Michigan Network for Children's Environmental Health 2009).

In addition, Title 1 of the CPSIA requires that before importing any children's products, a manufacturer must have the products tested by an accredited third party. Further, Title 1 of the CPSIA has specific requirements regarding some phthalates and toys (for children up to 12 years of age) and childcare products (for children up to 3 years of age). Specifically, childcare products and toys containing the phthalates Bis-2-diethyl hexyl phthalate, Dibutyl-n-butyl phthalate and Butyl benzene phthalate (DEHP, DBP and BBP) in concentrations higher than 0.1 percent per phthalate (1,000 ppm) were banned after 180 days (February 2009). Childcare products and toys containing the phthalates Di-isononyl phthalate, Di-n-octyl phthalate, and Di-isodecyl phthalate (DINO, DnOP and DIDP) in concentrations higher than 0.1 percent per phthalate (1,000 ppm) were provisionally banned after 180 days (February 2009). Title 1 of the CPSIA also requires the CPSC to appoint a Chronic Hazard Advisory Panel to study the effects on children's health of all phthalates and phthalate alternatives that are used in children's toys and childcare products (Congressional Research Service 2008, Michigan Network for Children's Environmental Health 2009).

The CPSIA does not address other chemicals found in children's products such as bisphenol A, formaldehyde or VOCs. It also does not address other heavy metals such as mercury and substances such as arsenic. One other positive note: The CPSIA requires the CSPC to establish and maintain a

consumer safety database that is publicly available, searchable and accessible through the CSPC website (Congressional Research Service 2008, Michigan Network for Children's Environmental Health 2009).

State Legislation / Regulation. In a review of state environmental legislation and regulation in the prevention of neurodevelopmental disabilities and asthma, Zajac et al (2009) found that with the exception of lead, states rarely address children specifically in environmental legislation and regulations; however, many state regulations seek to protect the general public by minimizing exposures to environmental hazards, including PCBs, dioxins, mercury, arsenic, pesticides, diesel exhaust and ETS. States are beginning to recognize indoor environmental hazards as having a strong impact on children's health and are starting to enact regulations and legislation to limit children's exposure to indoor air pollutants (Zajac et al 2009).

Several states, including Connecticut, West Virginia and Wisconsin, have set specific IAQ standards for schools. Of the nine states that have policies for IAQ monitoring and/or assessment for public and/or private dwellings, only five states have established specific IAQ standards or guidelines. Oregon is the only one of these states that has enacted regulations that require an adequate margin of safety for sensitive populations. Nine states have included IAQ improvements in the definition of energy saving measures that are eligible for tax breaks, other financial incentives or exempt from regulatory limitations (Zajac et al 2009).

With respect to products, five states have set exposure limits for VOC emissions from indoor materials or consumer products that are more stringent than the US EPA. Of these, California and Rhode Island have implemented a model regulation that protects children by banning the sale or manufacture of products with VOC levels greater than state standards, while Maine bans the sale or manufacturing of any "architectural or industrial maintenance coating," manufactured after January 2006 that contain VOCs in excess of specific standards (Zajac et al 2009).

Zajac et al emphasized that they limited their analysis to those chemicals in the environment that have been associated with an increased risk in developmental disabilities and asthma. They also noted: "There are no doubt other important policies that states have pursued to limit other exposures of concern for children" (Zajac et al 2009). For more information about strategies and resources for improving IAQ in schools, see the AQS white paper Reviewing and Refocusing on IAQ in Schools, which is available free from the Aerias AQS Indoor Air Quality Resource Center (www.aerias.org) in the Premium Content section.

MODEL FOR ACTION

Barbara McElgunn, health policy officer for the Learning Disabilities Association of Canada, describes how an intervention for lead poisoning is an excellent model for addressing risks from other environmental chemicals and metals:

"In the 1960s, interventions for lead poisoning began when the child had a blood level of 60 micrograms per deciliter ($\mu\text{g}/\text{dL}$). In 1979, Dr. Herbert Needleman's study of the neurophysical effects of low lead exposure found that children believed to be asymptomatic for lead poisoning had lower IQs and lower scores on measure of auditory-verbal processing and attention... Between 1970 and 1985, the action level for lead was reduced to 30 $\mu\text{g}/\text{dL}$, and as more research evidence accumulated that level was lowered twice to the present level of 10 $\mu\text{g}/\text{dL}$.

"The point of the story is that if we hadn't had a careful and expensive epidemiological research on lead, the limit for interventions would still be at 60 $\mu\text{g}/\text{dL}$, lead would not have been removed from gasoline and other sources, and many children would be experiencing subclinical lead poisoning that would seriously affect their academic and life potential. There are many more 'leads' out there that have not yet been researched..." (McElgunn 1999b).

The National Children's Study, sponsored by the US EPA and the CDC, is one study of particular note that is evaluating chemical exposures in children. This study is in progress with results expected in 2010. By the time it is completed, about 100,000 children at various ages from birth to puberty will have participated. Among the primary goals is to investigate the associations between exposures to environmental pollutants, such as VOCs among others, and health problems, especially asthma, autism, attention deficit disorder and alterations at puberty caused by hormonal disruptions and other neurobehavioral and neurocognitive disorders (Özkaynak et al 2005).

Another recent study also offers insight into how to study indoor VOC exposures in children. As a part of the Minnesota Children's Pesticide Exposure Study, researchers measured VOC concentrations in 284 homes with children over a six-day period. They also compared outdoor, indoor and personal measurements in 72 of these homes. The results confirmed previous research that homes with attached garages and the presence of ETS had higher indoor VOC concentrations associated with these sources, such as benzene and styrene. The results also showed that higher outdoor concentrations in urban areas contributed to higher concentrations in urban homes. Personal concentrations among children were not substantially higher than the indoor residential concentrations, which may be due to children spending time away from microenvironments with strong sources, such as ETS and occupational exposures that contribute to higher personal exposures in adults. Even so, the results demonstrated that given the strong influence the indoor residential environment had on personal exposure in children, it may be possible to estimate exposure over time using indoor residential monitors and time-activity diaries (Adgate et al 2004).

While researchers continue to identify which chemicals and products may pose health risks for children, they can be protected through the use of low-emitting products and building materials. Several green product certification programs are available to help specifiers, maintenance personnel and parents determine which products are safe to use around children. With respect to schools and daycare facilities, only one, the GREENGUARD Certification Children & SchoolsSM, created by the GREENGUARD Environmental Institute (GEI), takes the sensitive nature of children and the unique building characteristics and maintenance conditions found in these buildings into consideration and presents the most rigorous product emissions criteria to date. This standard is an extension of the established GREENGUARD Indoor Air Quality Certification Program. Table 5 summarizes key provisions in the standard.

Table 5. GREENGUARD Emission Standard for Children & Schools (see bullets following the table for important notes)

Chemical	Allowed Emission Contributions
TVOC	< 215 µg/m ³
Formaldehyde	< 0.0135 ppm
Total Aldehydes	< 0.043 ppm
Individual VOCs	< 1/100 TLV or • CA Chronic REL (whichever is less)
Total Phthalates	< 10 µg/m ³
Total Particles (< 10µm)	< 22 µg/m ³

Notes:

- Total phthalates include dibutyl (DBP), diethylhexyl (DEHD), diethyl phthalate (DEP), dibenzyl phthalate, (DBzP), diisobutyl phthalate (DIBP), and diethyl (DEP), common material related phthalates.
- Identified VOCs measured in mass spectrometric scan of C₆ - C₁₆ hydrocarbon range, evaluated for presence on ACGIH/TLV list and CA CREL list. TVOC includes all measured VOCs in scan range calibrated to toluene.
- Total aldehydes include 2-Butenal, Acetaldehyde, Benzaldehyde, Benzaldehyde 2, 5-dimethyl, Benzaldehyde 2-methyl, Benzaldehyde 3- and/or 4-methyl, Butanal, Butanal 3-methyl, Formaldehyde, Hexanal, Pentanal, and Propanal.
- Particles applicable to fibrous, particle-releasing products with exposed surface area.

Products certified to the GREENGUARD Children and Schools standard can be found in the free, online product guide at www.greenguard.org. These products listed have been tested and found to meet the standard. In addition, certified products participate in quarterly quality testing and annual re-verification of the product's performance. Additional information on indoor air quality and health is provided by the GREENGUARD Environmental Institute at www.greenguard.org and the Aerias AQS IAQ Resource Center, www.aerias.org.

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