



Consumer products as sources of chemical exposures to children: case study of triclosan

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Purpose of review

Consumer products are often overlooked as sources of children's exposures to toxic chemicals. Various regulatory bodies have developed lists of chemicals of concern that can be found in products contacted by children. However, this information has not been summarized for health practitioners. This review organizes such chemicals and products into four categories, with the antibacterial agent triclosan used to illustrate the potential risks to children from a common ingredient in consumer products.

Recent findings

Biomonitoring, house dust, indoor air, and product testing document children's exposures to a wide variety of chemicals. An increasing number of epidemiology studies have shown associations between these exposures and health effects in children. Triclosan is an example of a chemical contained in high contact products (e.g., soaps, lotions, and toothpaste) not necessarily designed for children. Triclosan exposure in children has been associated with increased responsiveness to airway allergens, with it also capable of endocrine disruption. However, the utility and necessity of this chemical in consumer products has not been demonstrated in most cases.

Summary

Triclosan and the other examples provided show that a changing marketplace with little regulatory oversight of chemical uses can lead to unanticipated exposures and potential health risks to children.

Keywords

consumer products, endocrine disruptors, flame retardants, phthalates, triclosan

INTRODUCTION

The regulation of toxic chemicals in consumer products has been less comprehensive than the regulation of other media, such as air, water, and soil, leading to the potential for children's exposure to numerous contaminants at home, in child care settings and at school. A wide variety of product classes can lead to exposures, from household pesticides, cleaning products, personal care products, paints/sealants, plastics, and products containing flame retardants, and perfluorinated (antistain and anti-stick) compounds. In some cases, chemicals of concern are formulated into toys or other products designed for use by children. Even if this is not the case, chemicals in general use products can mobilize into indoor air and house dust. As young children spend more time on the floor and have a higher skin surface area per unit of body weight, they can receive disproportionately higher exposures to contaminants in house dust. Biomonitoring studies suggest that chemicals migrating from consumer products are taken up by children,

although the relative importance of dietary exposure, direct product contact, indoor air, and house dust varies depending upon the chemical and how it is used [1^{••},2[•]]. The associated health risks are often not well understood because of inadequate testing and regulation of chemicals entering the consumer marketplace under the Toxic Substances Control Act [3]. This review provides examples of chemicals in consumer products which create the potential for exposure and health risks to children, highlighting the antibacterial agent triclosan.

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KEY POINTS

- Children's exposures to toxic chemicals come from a variety of sources, including consumer products.
- Products do not have to be designed for children to be sources of chemical exposures to children.
- Evidence of children's exposure from consumer products includes product testing, biomonitoring, indoor air and house dust testing.
- VOCs, phthalates, flame retardants, antibacterial agents, and acutely toxic chemicals from cleaning supplies and pesticides are some exposure sources from around the home.
- The antibacterial agent triclosan provides an illustrative case study of a chemical in consumer products that is associated with adverse health effects in children.

CATEGORIES OF PRODUCTS OF POTENTIAL CONCERN

The consumer products that can contribute to pediatric exposures are organized into four categories based upon the manner in which they may be a source of exposure (Table 1). Exposures can lead to acute health effects requiring immediate attention. In other cases, low-level exposures that accumulate after months or years can increase the risk of chronic health outcomes. Although most attention tends to be on products intended for children (category 2), the greatest exposures and health risks are often from products not marketed for children but to which they are unintentionally or unavoidably exposed (categories 1, 3, and 4). The case study chemical, triclosan, is an example of a category 3 chemical.

Acutely hazardous products

Cleaning products, especially those containing bleach, ammonia, and strong acids and bases, can cause poisoning and skin/eye damage in children who accidentally encounter these products. Household pesticides are also a source of unintentional overexposure in young children [4]. Child-proof containers and proper storage are essential to keeping children safe. Despite these measures, cleaning products are still a leading cause of overexposure and hospital visits in young children [4,5]. Moth balls are acutely toxic and can be swallowed by young children who mistake them for candy [6]. Laundry pods are a form of packaging that distributes unit quantities of detergent into small plastic packages that can be attractive to a young child.

When bitten into, the detergent can squirt into the mouth and eyes causing irritation and in some cases aspiration into the lungs [7]. Although our article does not focus upon immediate threats from products, there is an ongoing need to improve caregiver education and product safety to prevent acute toxicity in young children.

Products designed for children

The category includes clothing, car seats, furniture, personal care products (e.g., baby wipes and diaper rash creams), teething rings, toys, and school and art supplies. The greater vulnerability of children has generally led manufacturers of such products to be more thoughtful about ingredients and, in certain cases, federal and state laws address chemical content. Prime examples are removing lead, cadmium, and phthalates from children's toys, banning certain flame retardants from children's sleepwear, removing nitrosamine-containing rubber from bottle nipples, and removing bisphenol A from baby bottles and infant formula cans. However, phthalates are still common in children's plastic toys (e.g., loom band charms [8], and polyvinyl chloride-based binders and other school supplies [9]). Flame retardants are common in children's foam products, including changing table pads, bumper pads, car seats, and soft toys [10]. Methylisothiazolinone, a contact allergen and known sensitizing agent, can be found as a preservative in baby wipes [11]. Volatile organic compounds (VOCs) are in art supplies (glues and markers), and questions have been raised about the safety of artificial turf fields because of the use of recycled tires as a cushioning agent [12]. Children's exposures to flame retardants can be elevated at gymnastics centers because of foam blocks, used for cushioning, that contain high levels of halogenated flame retardants [13]. Several states have focused on chemicals in children's products and developed lists of high concern chemicals. Washington State developed a manufacturer/retailer reporting inventory documenting which children's products contain the listed chemicals (Washington State 2013 – Children's Safe Products Reporting Rule, available at <https://fortress.wa.gov/ecy/publications/documents/173334.pdf>).

Products that children contact frequently but are not 'children's products'

Unless a product is designed specifically for children, it is not considered a children's product and is less likely to have consideration given to children's unique vulnerabilities. Yet children can receive just as much if not more exposure than adults to

Table 1. Examples of chemicals in consumer products of potential health concern to children

Product type	Chemicals and products	Exposure pathways
Category 1: acute hazards	Cleaning products: bleach, ammonia, acids, and detergent Moth balls: naphthalene Pesticides: pyrethrins	Unintentional ingestion, inhalation, dermal absorption
Category 2: children's products	Toys, foam pads, clothing: phthalates, flame retardants Markers and glues: volatile organic compounds Baby wipes: preservatives and antimicrobial agents	Mouthing of toys and clothing, inhalation, dermal absorption
Category 3: high contact products not specifically designed for children	Toothpaste and lotions: fluoride, triclosan, phthalates, fragrance, and parabens Sunscreen: oxybenzone Insect repellent: N,N-diethyl-m-toluamide Antiflea pet treatment: pyrethroids Electronics: phthalates, and flame retardants	Ingestion, inhalation, dermal absorption
Category 4: products that contaminate house dust and indoor air	Flooring, wall treatments, shower curtains: phthalates Nonstain carpeting, nonstick cookware: perfluoroalkyl substances (PFAS) Couches and foam products: flame retardants Pressed wood products: formaldehyde Household pesticides: pyrethrins	Ingestion of house dust, inhalation of indoor air

chemicals in common household products. For example, children are often given general use sunscreen products and there is no special regulation of 'baby' sunscreen; any of these products can contain ultraviolet radiation-absorbing chemicals, which have raised concerns over endocrine disruptive activity (e.g., oxybenzone) [14,15²²]. Similar to sunscreen, insect repellents, toothpaste, and soaps are products typically designed for adults but young children can have extensive contact to these products. In the case of insect repellent, the American Academy of Pediatrics advises against using N,N-diethyl-m-toluamide (DEET) on children under 2 months of age and using lower concentrations in children (no more than 30% N,N-diethyl-m-toluamide) than in adults. Concerns over children's exposure to arsenic leaching from pressure-treated lumber that was built into decks and play structures led to the removal of the preservative chromated copper arsenate from wood treatment in 2003. Sources less well addressed include: exposure to personal care products because of children's use of adult products, or contact with a parent who wears cosmetics [16²³]; transfer of pesticides used on pets for flea treatment [17]; ingestion of perfluorinated compounds from microwave popcorn and other dietary items [18]; and handling/mouthing of

upholstery and electronics that contain phthalates and flame retardants.

Products that contribute to indoor air or house dust

Lead-based paint is an obvious example of a consumer product not designed for or used by children but which affects children's health through contamination of the indoor environment. Although lead-based paint is no longer on the market, its presence in older homes still leads to hazardous levels of lead in paint chips and house dust. Paint can also be a source of inhalation exposure as the volatile components cure, leading to indoor air contamination. Studies of children in recently painted homes show an increase in respiratory infections and poorer airway performance, even if water-based paints are used [19–21]. Pressed wood products can off-gas formaldehyde and lead to elevated formaldehyde concentrations in homes with a high content of these fabricated wood products [22,23]. Although VOCs from paint and pressed wood are expected sources of indoor air contamination, many semivolatile ingredients in home furnishings can also off-gas, leading to concentrations in indoor air with an equilibrium established with house dust

[24]. Polyvinyl chloride flooring and other high surface area plastic materials around the home (e.g., shower curtains) can off-gas phthalates whereas foam products can off-gas flame retardants in this manner [25,26[¶]]. Pesticide sprays can lead to long-term residues in house dust and indoor air, creating an exposure source well after the spray event [27]. Chlorine-based cleaning products off-gas carbon tetrachloride and trihalomethanes [28] whereas other cleaners and air fresheners can release indoor air contaminants including naphthalene, phenol, glycol ethers, terpenes, and fragrance [29,30].

House dust is increasingly being used as a marker of contamination of the home environment, with changes in content over time reflecting changes in the chemicals used in consumer products [31]. In France, a list of 160 contaminants in house dust were prioritized with respect to concentration and toxicity [32] and children's exposures to house dust chemicals were evaluated in homes and day care settings in Taiwan, Sweden, Denmark, Germany, and California [25,33–36]. In several cases, greater respiratory symptoms were found in children more heavily exposed to house dust contaminants [37,38,39^{¶¶}]. Further research is needed to identify the specific products responsible for house dust and indoor air concentrations of contaminants measured in these studies.

CASE STUDY OF TRICLOSAN

Triclosan (2,4,4'-trichloro-2'-hydroxydiphenyl ether) is an ingredient used widely in products not intended specifically for children but to which children still have considerable exposure (category 3). Its distribution across the consumer marketplace occurred rapidly and without substantial regulatory oversight. Triclosan was initially used in clinical settings to sterilize surfaces that might harbor bacteria. Its increasing use in consumer products has been spurred by an interest in preventing the spread of infection in home, office, and school environments. However, the safety and efficacy of these applications had not been thoroughly evaluated and has led to considerable human exposure without proper risk evaluation. The US Environmental Protection Agency (EPA) has jurisdiction over triclosan, which it regulates as a pesticide. The US Food and Drug Administration (FDA) has jurisdiction over triclosan use in certain consumer products such as antibacterial soaps and toothpaste. The registration and review status of triclosan with these agencies is discussed below.

Triclosan is a chlorophenol disinfectant whose structure is similar to that of highly toxic

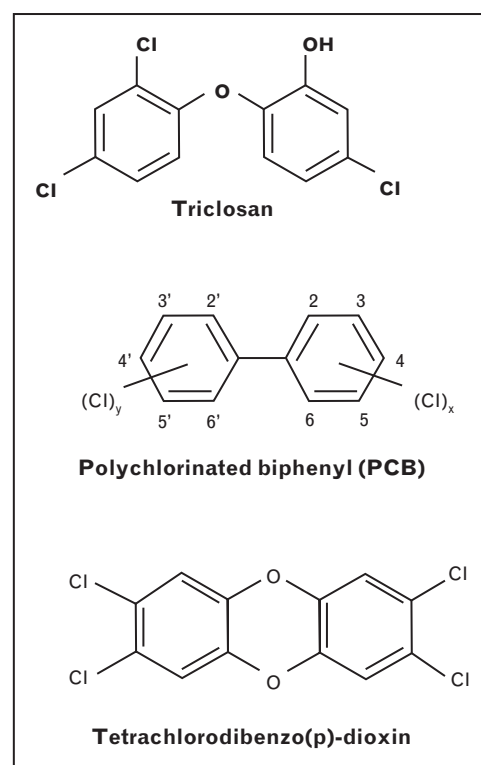


FIGURE 1. Structures of the antimicrobial agent triclosan, the banned industrial chemical polychlorinated biphenyl and the environmental contaminant 2,3,7,8-tetrachlorodibenzo(p)-dioxin.

organochlorines such as polychlorinated biphenyls and dioxins (Fig. 1). Although triclosan clearance from the body is much faster than these other organochlorines, it shares with them similar antithyroid and immunologic effects that raise public health concerns. Hydroxylated metabolites of polychlorinated biphenyls are especially similar to triclosan in chemical structure; these metabolites have been associated with toxic effects including impaired brain development *in vivo* and endocrine disruption *in vitro* [40,41]. There are also concerns that triclosan and other antibacterial chemicals may contribute to the development of drug-resistant bacteria [42].

These issues have spurred manufacturers and hospitals to eliminate triclosan. Johnson & Johnson and Procter & Gamble announced phase-outs from their personal care products. Kaiser Permanente phased triclosan out of its 37 hospitals, substituting alcohol-based disinfectants. However, triclosan remains in many products today. These developments have spurred several states to take action to limit triclosan exposures with a ban on its use in personal sanitizers in Minnesota and a fact sheet to educate consumers issued by the Connecticut Department of Public Health [43].

TRICLOSAN USE AND EXPOSURE

Triclosan has been a widely used antibacterial agent over the last 20 years. It is found in antibacterial soaps, body washes, skin cleansers, deodorants, lotions, creams, toothpaste, toothbrushes, mouthwash, and laundry detergents. It may be embedded in cutting boards, clothing, and plastics used in furniture, toys, and sporting equipment. Environmental data from sediment cores in urban rivers show its detection beginning in 1964 with increasing concentrations since then [44]. Triclosan is absorbed through skin with human studies documenting a 5–10% uptake rate [45]. Compared with adults, young children have a greater skin surface area per unit of body weight; thus, they may receive greater doses across skin. Because young children swallow more toothpaste than adults, young children could be highly exposed if they use triclosan-containing toothpaste. Triclosan is readily detected in urine, excreted as both free parent and conjugated metabolite, with these markers suitable for biomonitoring studies. Triclosan was found in 75% of urine samples in a national study of 2517 participants aged 6 years and older [46]. The main source of exposure appears to be personal care products as biomonitoring results track with the use of such products [47,48]. In a study involving a broad age range, a trend of increasing exposure with increasing age through adolescence and into adulthood was evident [49]. This may reflect increasing use of personal care products over this age range. A significant percentage of exposure in early life may be from house dust as triclosan is commonly found in dust at concentrations up to 2 parts per million (ppm) [50].

TRICLOSAN TOXICITY

Triclosan is not highly toxic in traditional toxicology studies [45]. There is, however, evidence of endocrine disruption as it interferes with estrogen, androgen, and thyroid systems in animal testing [51–54,55[■]]. In-vitro endocrine disruption assays suggest that triclosan can interact with the estrogen receptor at relatively low (nanomolar) concentrations [55[■],56]. Data from US EPA's ToxCast program show that triclosan was one of the few compounds tested that produced effects at cellular levels in the range of that anticipated for the general population [57].

Studies in mice show a carcinogenic potential in the liver, although this was not found in rat and hamster studies, and triclosan does not appear to be genotoxic [45]. Although human studies are limited, associations between triclosan and allergy in children have been reported in several cases

[58,59,60[■]]. Children in the highest category of triclosan exposure had twice the risk of being allergic to common airway allergens. A follow-up study showed an elevated risk of asthma exacerbation in association with triclosan exposure in 7300 individuals 6 years and older sampled from the US population [61[■]]. A study in mice lends support to the evidence of allergy in humans; skin exposure (simulating lotion or deodorant) increased an animal's reactivity to an allergen placed into its airways [62]. The mechanism for this immune alteration involved changes in gene expression and cytokine levels in affected mice [63[■]].

RISK IMPLICATIONS

Figure 2 combines population exposure estimates for triclosan based upon biomonitoring studies with effect levels in epidemiology, animal, and cell culture studies. As described above, epidemiology studies from the United States and Europe show that the most sensitive effect thus far was respiratory allergy in children. Figure 2 shows that current exposures from consumer products may in some cases be high enough to raise the possibility of altered immune functioning in children and perturbation of cellular systems at the molecular level. Somewhat higher exposures have been associated with endocrine disruption and internal organ damage in animal testing [51–54]. Although the endocrine effect levels are well above estimates of current population exposure, the dose response for these, as well as the immune effects, require further study. Although standard developmental testing has not shown teratogenic effects, the effects of early life exposure on brain and hormonal development are not well studied [45]. These uncertainties are of particular concern for a chemical so widely distributed in consumer products and in humans.

NECESSITY

The widespread use of triclosan in soaps and other consumer products does not have proven benefit. There is no evidence that antibacterial soaps containing triclosan have an advantage over washing with regular soap and water [42]. There is no evidence that triclosan in personal care products decreases the spread of infection around the home. The Mayo Clinic stated that triclosan-embedded cutting boards do not prevent the spread of harmful bacteria and do not take the place of separate cutting boards when handling high-bacteria foods (e.g., raw meat) [64]. Rather, widespread use may promote growth of bacteria resistant to triclosan and certain antibiotics [42]. The one consumer use which has a

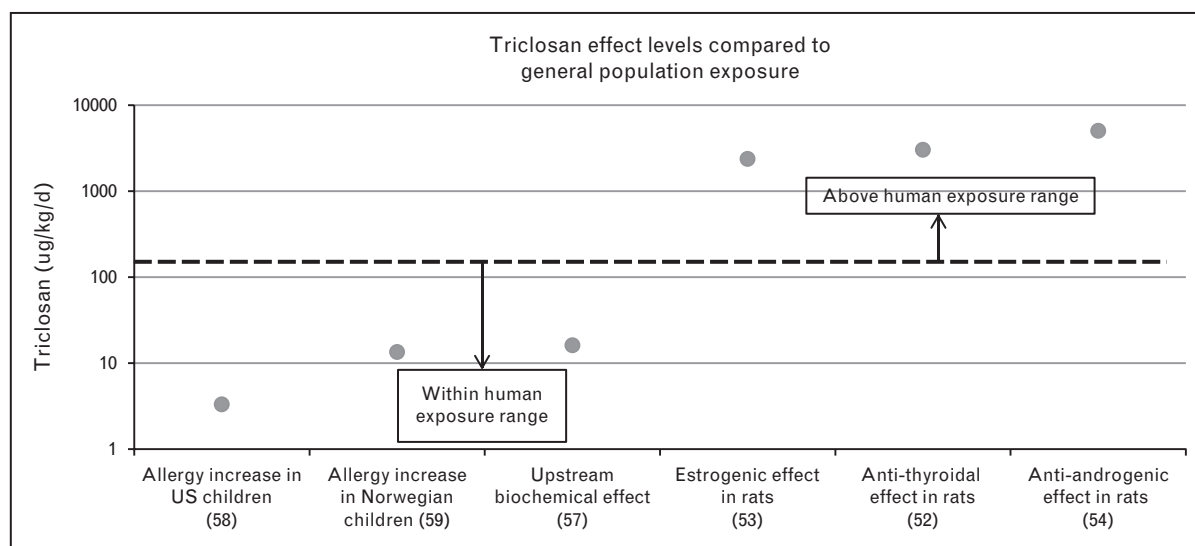


FIGURE 2. Triclosan effect levels compared with general population exposure. Numbers in parentheses refer to reference number for study. Dashed line represents 99th percentile of triclosan exposure distribution as adapted from the National Health and Nutrition Examination Survey (NHANES) [46].

demonstrated benefit is prevention of gingivitis in adults when triclosan is present in toothpaste [65].

GOVERNMENTAL AND INSTITUTIONAL REVIEWS

The EPA registered triclosan as an antimicrobial pesticide in 1969 and reaffirmed its safety for this purpose in 2008. The EPA is undergoing a review of triclosan safety based upon emerging health effects and biomonitoring data [66]. The FDA raised concerns about emerging scientific evidence (endocrine disruption and potential for bacterial resistance) and is undertaking a special review. This review resulted in a decision to eliminate the ‘generally recognized as safe and effective (GRASE)’ designation from triclosan and requires manufacturers to demonstrate efficacy and safety if their product contains this antimicrobial [42]. The European Union determined that triclosan in individual personal care products is not a risk but that cumulative effect from multiple products can be a health concern. This assessment did not consider young children’s exposure. In 2000, the American Medical Association stated that it may be prudent to avoid triclosan and similar antimicrobial agents in consumer products [67].

RECOMMENDED ACTIONS FOR HEALTH PRACTITIONERS

As a drug and pesticide, triclosan must be listed on the label of ingredients. Clinicians can instruct patients and parents to read labels to avoid triclosan-containing products and opt for alternatives.

Key among these is common sanitation practices based upon soap and water washing of hands, counters, sinks, and floors. Household disinfectants based upon simple alcohols and hydrogen peroxide are also effective alternatives. Triclosan-containing toothpaste should be used in consultation with a dentist and at no time should such toothpaste be within reach of young children.

SUMMARY

Consumer products as causes for adverse health effects in children are obvious when it comes to the acutely toxic category 1 products. However, the long-term cumulative effects of exposures to flame retardants, PFAS, phthalates, environmental phenols (e.g., triclosan), toxic metals and allergens in consumer products are not obvious and require an active research program, ideally prior to the introduction of products into the marketplace. Such proactive research has not been forthcoming and, as noted by the American Academy of Pediatrics, the regulation of chemicals under Toxic Substances Control Act ‘is widely recognized to have been ineffective in protecting children, pregnant women, and the general population from hazardous chemicals in the marketplace’ [3]. Triclosan is an example of a chemical that was not thoroughly assessed. Now, because of widespread exposure and suggestive allergic and endocrine effects, it is undergoing extensive review by regulatory agencies. Manufacturers are gradually shifting away from using this agent but there is still widespread exposure. It is essential to make sure that any replacement antimicrobial ingredients are safe and used only where

necessary. As health practitioners increasingly seek approaches to preventing disease, it is important to recognize the role that consumer products play in creating exposures that can increase public health risks. Triclosan illustrates that a changing marketplace with little regulatory oversight of chemical uses can lead to unanticipated exposures and potential health risks in children.

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Conflicts of interest

There are no conflicts of interest.

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- of special interest
- of outstanding interest

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