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SL434

Contaminants in the Urban Environment: Bisphenol-A[1]

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This publication is part of a series titled ***Contaminants in the Urban Environment****. This series is intended to give state and local government officials, soil scientists, medical professionals, consulting engineers, Extension agents, and citizens (1) a basic understanding of the occurrence, toxic effects and source of various contaminants in the environment and (2) provide guidance on ways to protect human and environmental health.*

Introduction and Purpose

Bisphenol-A (BPA) is a man-made chemical produced in high volume worldwide because of its wide use as a component in many products of daily use in households, such as polycarbonate-type plastics, epoxy resins, and flame-retardants. Several decades ago, BPA was synthetized as an estrogenic compound (Dodds and Lawson 1936). Nowadays, many metallic canned foods are coated internally with resins containing BPA to avoid corrosion. Thus, BPA can leach and transfer to food present in cans, such as canned fish, vegetables, and infant formulas. Leaching of BPA from plastic bottles, such as baby bottles and reusable plastic bottles, has also been identified. As a result, BPA is now ubiquitous in the environment, found in water, soil, fish, and wildlife, as well as many human tissues (blood, umbilical cord, milk, and fat). Thus, our exposure to BPA is highly probable since it is present in many domestic products.

BPA is known to harm exposed animals in laboratory settings as well as in the wild, although its potential to harm humans remains controversial. Currently, both the FDA and its European equivalent, the European Food Safety Authority (EFSA), consider BPA safe as a food-contact substance. Several leading academic scientists have cast doubts about the FDA study results because the FDA researchers, themselves, state that their controls were contaminated with BPA. Also, both the FDA and the EFSA often used old methods, which are not sensitive enough to detect sub-lethal effects.

Compared with other persistent contaminants, BPA is easily degraded, so its occurrence is related more to the widespread use (quantity) of plastics containing BPA than its persistence in the environment. Because the chemical structure of BPA resembles the natural hormone estradiol (the primary female sex hormone), BPA is considered a synthetic hormone that can generate estrogenic response in cells and, therefore, is considered an endocrine disrupter chemical. Moreover, research has shown that BPA can alter cell activities and actions such as thyroid metabolism and androgen hormone pathways.

This publication will discuss the occurrence, use, and potential harmful effects of BPA and will suggest ways to reduce human and environmental exposure to BPA.

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What Is Bisphenol-A(BPA)?

BPA is a man-made organic chemical containing carbon, hydrogen, and oxygen (Figure 1). It is one of the many high—production—volume chemicals in the world. Due to the increasing demand for plastic, BPA production has grown consistently in the last few years. For example, the global demand increased from 3.2 million tons in 2003, to 3.9 million tons in 2006, and 5.5 million tons in 2011 (Flint et al. 2012; Huang et al. 2012). In the United States alone, 1.2 million tons (2.4 billion pounds) of BPA were produced in 2007 (US EPA 2010).

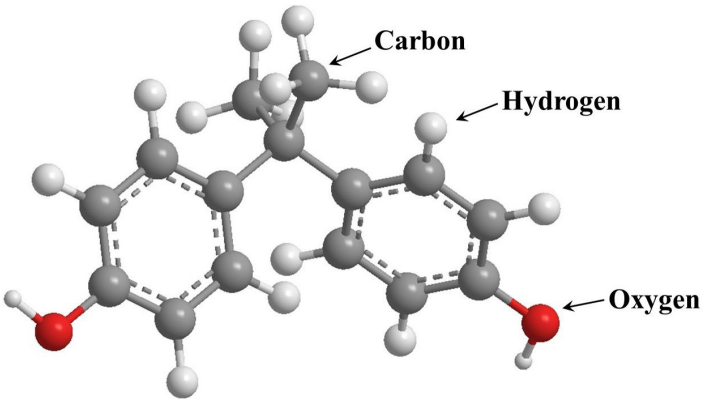

Figure 1. General structure of bisphenol-A (4,4′-(propan-2-ylidene) diphenol).
Credits: Yun-Ya Yang

What Are the Sources of BPA in the Environment?

BPA is released into the environment from (1) the breakdown and leaching of the many domestic products containing BPA, (2) disposal of industrial wastewater from industrial production facilities, and (3) burning of plastic. Release of BPA can occur during chemical manufacture, transport, and processing of plastics (Clarke and Smith 2011). Additionally, studies have shown that BPA contaminates the air near manufacturing plants mainly due to the burning of plastics (Bienkowski 2014). BPA is released into the atmosphere with a yearly estimation of hundreds of tons worldwide (Vandenberg et al., 2009). A study measured the levels of BPA aerosols from urban, rural, marine, and polar regions in the atmosphere and suggested that the open burning of plastics in domestic waste is a significant emission source of atmosphere BPA (Fu et al. 2010). Another airborne source to consider is indoor air dust. In some areas, indoor dust may contain measurable concentrations of BPA, though the dust contribution to the total human BPA intake is considered to be less than 1% (Loganathan and Kannan 2011).

About 95% of BPA produced is used to make polycarbonate plastics (~70%) and epoxy resins (~30%). Polycarbonate plastics are often used in plastic food-storage containers, reusable water bottles, and baby bottles (Figure 2). Epoxy resins are used to coat the inside of food, beverage cans, and water-supply pipes. BPA is also found in many daily-use products including digital media (e.g., CDs and DVDs), electronic equipment, sunglasses, thermal paper products (e.g., cash register receipts), and medical devices (e.g., dental sealants) (Huang et al. 2012). Consequently, BPA is found ubiquitously in environment throughout the world. Due to the widespread use in many commercial and industrial products, BPA has been frequently detected in various environmental matrices such as soil and water (Arnold et al. 2013; Clarke and Smith 2011; Li et al. 2010; Santhi et al. 2012).

Figure 2. Common sources of bisphenol-A.
Credits: Thinkstock.com

How Does BPA Affect the Environment and Human Health?

Because BPA degrades relatively easily, it is not present in high concentrations in bodies of water such as streams and rivers despite massive production of the compound. Thus, the long-term exposure (chronic toxicity) is not as important as the short-term exposure (acute toxicity). However, the short-term exposure to BPA can cause adverse effects at very low concentrations—this is why it is difficult to calculate a "no observed adverse effect level" (NOAEL) dose of BPA. In the 1980s, the EPA established that a reference dose of 50 µg/kg body weight/day for rats can cause effects; however, recent evidence from many studies suggests that BPA is a strong endocrine disrupter and may cause harm at levels lower than the reference dose (Pupo et al. 2014). The European Union has established a predicted no-effect concentration of 1.5 µg/L in water for aquatic organisms (European Commission 1998), which means that BPA can cause harm if concentrations exceed this value.

Effects on Laboratory Animals

In laboratory animals, a "low dose" effect has been observed with BPA. The observation is important because doses labeled "low dose" are within the concentration ranges of BPA found in most human blood due to regular environmental exposure. ("Low dose" means concentration below the dose used in laboratory animal toxicological studies for risk assessment. Also, low dose can refer to a dose that is within the range of typical human exposure but does not consider exposure in the workplace.) The effects of BPA on both terrestrial and aquatic animals have been determined in animals exposed to doses lower than the EPA reference dose of 50 µg/kg body weight/day; there are over 150 studies showing low-dose effects in animals (e.g., Vandenberg et al. 2007). The effects in adult laboratory animals exposed to BPA include neurobehavioral (Saili et al. 2012) and reproductive effects (Fernandez et al. 2009; Newbold et al. 2007; Li et al. 2010), such as abnormalities in reproductive organ function (irregular menstrual cycles, multiple ovarian cysts), placental dysfunction, increased incidence of miscarriage and neonatal mortality, precocious puberty, erectile dysfunction, decreased libido, and ejaculation difficulties. Researchers determined that a dose of 25 µg/kg body weight/day produced adverse effects in a mouse fetus (Vanderberg et al. 2007). Specifically, prenatal and/or neonatal exposure to low doses of BPA resulted in organizational changes in the prostate, breast, testis, mammary glands, body size, brain structure and chemistry, and behavior of laboratory animals (vom Saal et al. 2007). In addition to these effects, BPA may be carcinogenic (Keri et al. 2007), or may increase the susceptibility to cancer in animals, particularly breast and prostate malignancies (Prins et al. 2008). Finally, BPA can alter the "epigenetic programing" (protein regulation of the turning on and off of genes), which can produce effects later in the life of exposed individuals, long after the period of exposure has ended (Bromer et al. 2010).

Effects on Wildlife

In wildlife exposed to BPA, estrogenic responses similar and consistent to those observed in laboratory animals have been reported. These responses include reduced spermatogenesis (decreased production of male reproductive cells), vitellogenesis (production of the protein for producing eggs) in males, and the alteration of steroid (sex hormone) metabolism (Flint et al. 2012).

Effects on Humans

BPA is used in many products that we use every day. These may include reusable plastic bottles, feeding-bottles, plates, goblets, cups, microwave ovenware, storage containers, sunglasses, building materials, water pipes, medical devices, toys, dental materials, and thermal paper (Geens et al. 2007). As a result, more than 80% of the general population has absorbed BPA; BPA is in our blood, amniotic fluid, placenta, cord blood, breast milk, and urine. Researchers have stated that virtually every human living in the developed world has measurable BPA in their blood and/or urine (Kasper-Sonnenberg et al. 2012; vom Saal et al. 2007). For instance, a study carried out by the Centers for Disease Control, concerning the prevalence of the exposure of BPA in the United States during 2003–2004, identified that 92.6% of the 2500 participants had detectable levels of BPA in urine (Calafat et al 2008). The exposure levels tend to be higher in children and adolescents than adults (Rubin 2011).

Though BPA levels can be detected in humans, a controversy still exists in the scientific literature with regard to the BPA concentrations capable of causing deleterious effects in humans (Beronius et al. 2010; Vandenberg et al. 2009). Because BPA is rapidly metabolized and efficiently excreted from the body, bioaccumulation in the human body seems to be negligible (Völkel et al. 2002). However, BPA exposure has been related to several effects in humans, including abnormal urethra development in males, early sexual maturation in females, neurobehavioral problems such as attention deficit hyperactivity disorder (ADHD) and autism, obesity and Type 2 diabetes, decrease in sperm count, and hormonally mediated cancers such as prostate and breast cancers (see vom Saal et al. 2007). In humans, sensitivity to endocrine disruption varies extensively with the life stages (such as from infants to adults). Some more sensitive windows, such as early stages of embryo development, have been identified. The risk of BPA effects will vary from one individual to another and in different life stages.

On the other hand, the US Food and Drug Administration (FDA) has established (based on an ongoing safety review of scientific evidence) that BPA is safe as a food-contact substance (FDA 2014). Thus, despite evidence of the effects of BPA on laboratory animals, the fact that humans rapidly metabolize BPA and are less sensitive to the effects of BPA (compared to rodents), has led to doubts about the potential deleterious effects on humans. There are also several research publications with robust and scientifically sound data that show an absence of effects on rats and mice exposed orally to BPA (i.e. Ryan et al. 2009; Ema et al. 2001; Howdesshell et al. 2008). Why, then, do some researchers demonstrate that BPA is able to exert effects at environmentally relevant concentrations and others do not?

One particular example of the controversy in the scientific literature appears in a paper published by Ryan et al. (2009). This paper used a strain of rats (Sprague Dawley rats) that is considered to be insensitive to estrogens; the absence of effects found in the study could have been produced by this insensitivity, and therefore the results may not necessarily be an indication of the low impact of BPA. Also, rodents are less efficient in metabolizing BPA, which may also explain these differences. The FDA will continue to study BPA.

How Can You Minimize Your Exposure to BPA?

The main route of BPA exposure is oral intake via food and water. In addition, other potential sources of BPA include dental fillings and sealants and exposure via indoor air (Loganathan and Kannan 2011). Because BPA has been found in the breast milk of 90% of researched women, breast milk has been indicated as a route of exposure in neonates (Ye et al. 2006).

The following few steps can help you to reduce and avoid exposure to BPA:

1. Eliminate or reduce canned food use.
   Visit the following webpage to learn about the brands that use and do not use BPA in the cans http://www.ewg.org/research/bpa-canned-food?inlist=Y&utm_source=201506BPARelease&utm_medium=email&utm_campaign=201506BPARelease.

2. Eat fresh food and choose food items that do not come in contact with plastic packaging.

3. Read the plastic number! Most plastic products come with a number at the bottom of the item, known as the recycle code (see Figure 3). Avoid products that have number 7, which stands for "miscellaneous plastic," since this is more likely to contain BPA.

4. Do not use plastic containers to heat food in the microwave. Microwave heating can increase the amount of BPA that leaches from plastic to food. Use glass or ceramic containers in the microwave.

5. Do not use plastic coffee makers. Change to a glass French press or use other glass and stainless steel coffee makers.

6. Choose glass over plastic containers when purchasing liquid drinks (soda, juice, etc.).

7. Use glass bottles to feed babies because BPA-free baby bottles still contain BPA (Yang et al. 2011).

8. Avoid polycarbonate plastic. Plasticware such as kids' plastic plates, cutlery, and bottles can be a large source of BPA exposure to children.

9. Avoid plastic toys (or search for BPA-free toys), especially for kids under 2 years old.

10. If you will be breast-feeding, take all the previous steps to reduce your own exposure and avoid transferring BPA to your baby through breast milk.

Symbols	Description	Commonly found in
1 PETE	Polyethylene Terephthalate	Soda, water, and beer bottles; salad dressing containers
2 HDPE	High Density Polyethylene	Milk jugs; household cleaner containers; juice bottles; yogurt tubs
3 V	Vinyl	Shampoo bottles; cooking oil bottles; medical equipment; piping
4 LDPE	Low Density Polyethylene	Squeezable bottles; shopping bags; carpet; frozen food; food wraps
5 PP	Polypropylene	Yogurt containers; ketchup bottles; syrup bottles; medicine bottles
6 PS	Polystyrene	Meta trays; egg cartons; disposable plates and cups
7 OTHER	Miscellaneous	Sunglasses; iPod cases; computer cases; bullet-proof materials

Figure 3. Types of plastic symbols.
Credits: iStock/Thinkstock.com (ID: 25726818) http://naturalsociety.com/recycling-symbols-numbers-plastic-bottles-meaning/

Summary

- BPA is a ubiquitous chemical present in many plastic and canned food items. Its behavior is similar to estrogen, and that, combined with its effects at low-levels, make BPA a potentially harmful compound for the exposed population and the environment.
- Several harmful effects, from reproductive impairment to neurobehavioral conditions and cancer, have been identified in laboratory and wildlife animals. The effects of BPA on humans are still not well understood, and the issue is controversial. More research is needed to finally

understand how this molecule affects humans. The FDA is continuing its efforts to study BPA.

- In order to reduce exposure to BPA, switch your plastic kitchen utensils to wooden, glass, stainless steel, or ceramic. Avoid heating plastic in a microwave, since heat accelerates BPA leaching. Eat fresh food. Take extra care with regard to BPA exposure in children or a child in the womb.
- Dispose of your plastic properly. In doing so, you will reduce BPA in the environment. BPA-free plastic is harder to find, so avoid plastic as much as you can.
- For information on other contaminants of concern in everyday life, consult the *Contaminants in the Urban Environment* EDIS series (http://edis.ifas.ufl.edu/topic_seris_contaminants_in_the_urban_environment).

Further Reading

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