UF IFAS Extension UNIVERSITY of FLORIDA

SL429

Contaminants in the Urban Environment: Dioxins[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, 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) guidance on ways to protect human and environmental health.*

Introduction and Purpose

Dioxins are well known environmental contaminants because they are among the most toxic chemicals on the earth. Dioxins are by-products of a number of human activities such as combustion of fuels and wastes containing polyvinyl chloride (PVC), chlorine bleaching of paper products, and selected industrial processes (US EPA 2001). Natural activities—such as volcano eruption and wild fires—can also generate some dioxins. Generally, current releases of dioxins by humans are due to the combustion of fuels and burning of household trash. The good news is that levels of dioxins in the environment have decreased in the United States throughout the past 30 years due to the improved emission controls and regulatory activities. However, as dioxins break down slowly, they can still remain in the environment for a long time and thus accumulate in the food chain. Long-term exposure to dioxins can cause harmful effects such as impairment of immune system, nervous system, endocrine system, and reproductive functions.

This publication discusses the sources, emission trends, and impacts of dioxins as well as the ways to minimize exposure to dioxins. 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).

What Are the Dioxins?

The term "dioxins" refers to a group of chlorinated organic compounds that have two benzene rings (6 carbon atoms joined in a ring) in the structure by two oxygen atoms (Figure 1). In a dioxin, chlorine atoms can be attached on eight different places on benzene rings (these places are numbered 1 to 4 and 6 to 9 in Figure 1).

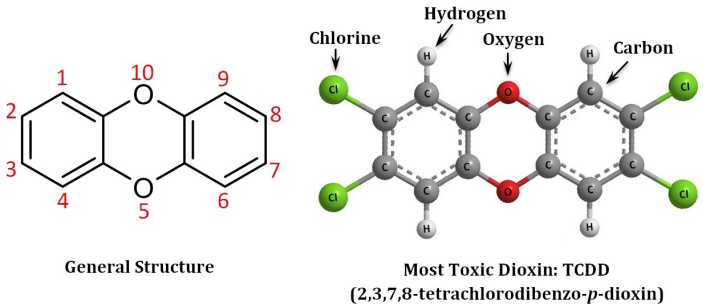

Figure 1. General structure of dioxins and the most toxic dioxin (TCDD)
Credits: Yun-Ya Yang, UF/IFAS

Depending on the number and positions of the chlorine in a dioxin, it is possible to have 75 chemically different dioxin congeners (i.e., dioxins occurring in different forms). The toxicity of dioxins differs among congeners.

1. This document is SL429, one of a series of the Soil and Water Science Department, UF/IFAS Extension. Original publication date July 2015. Visit the EDIS website at http://edis.ifas.ufl.edu.

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For example, congeners with chlorine in the 2, 3, 7, and 8 positions (such as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin commonly referred to as TCDD) are more toxic than the others. To assess the overall toxicity of dioxins, their concentrations are commonly converted into units of toxic equivalent (TEQ), which is then compared to the most toxic dioxin known (i.e., TCDD).

What Are the Sources of Dioxins in the Environment?

There are multiple sources of dioxins in the environment. Dioxins were never produced intentionally as marketable products. In fact, most of the dioxins are formed unintentionally due to human activities and are unwanted by-products of industrial combustion processes, chlorine bleaching of pulp and paper, and household trash burning (US EPA 2003; Figure 2). In some cases, dioxins are produced during natural combustion events such as forest fires and volcanic eruption.

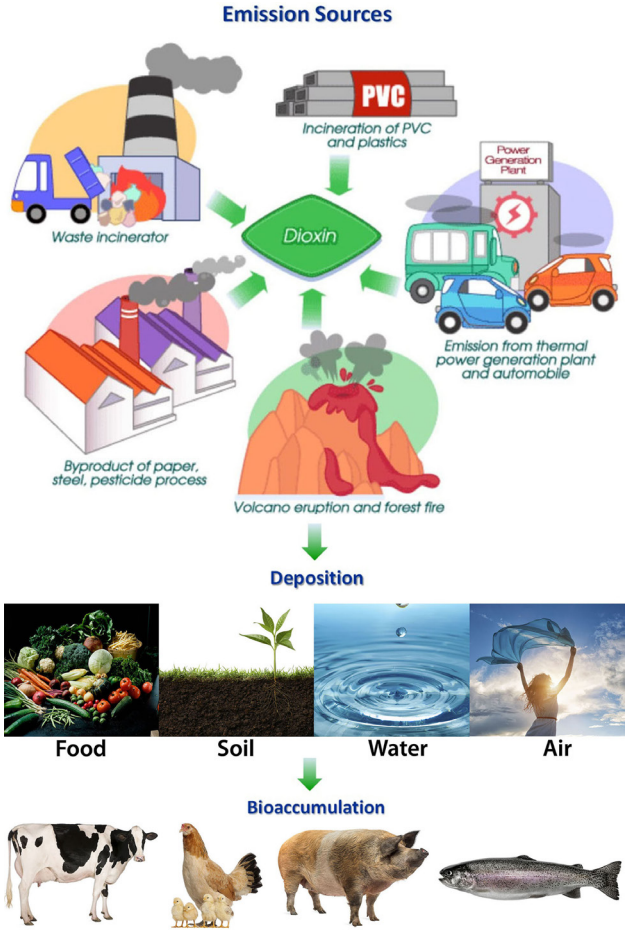

Figure 2. Sources and pathways of dioxin release and accumulation in the environment
Credits: Thinkstock.com; "Emission Sources" image by Samsung Engineering's Eco-Generation, via Tunza Eco-Generation (http://tunza.eco-generation.org/resourcesView.jsp?boardID=air&viewID=22)

Dioxins have been detected in all primary matrices (soil, surface waters, sediment) and secondary matrices (plants, food supply, consumer goods) in the world (Mukerjee 1998). Dioxins enter the food chain due to the release from dioxin sources. For example, dioxins can be released into the air when garbage is burned and may be transported long distances before being deposited on soil, water bodies, and plants. When released into the environment, dioxins are broken down slowly and can be further transported and ingested (bio-accumulated) in aquatic organisms or animals (Figure 2). Because dioxins are lipophilic (fat-loving), they dissolve more readily in fatty compounds than in water, which causes dioxins to bio-accumulate in the food chain (Van den Berg et al. 2006). In spite of their low water solubility, dioxins are found in the water bodies due to the deposition with rainfall and direct discharges of industrial and municipal effluents (Kim et al. 2002).

Why Are Dioxins Widespread in the Environment?

Figure 3 shows that the release of dioxins in the environment decreased by approximately 90% (or tenfold) in the United States between 1987 and 2000 (US EPA 2006) and by approximately 75% between 1987 and 1995. These reductions in dioxin emissions were achieved through a combination of regulatory activities, improved emission controls, and voluntary actions on the part of industry (US EPA 2006). Among different dioxin sources, the most significant decline was from the industrial activities (Figure 3). With the decline in dioxin emissions from industrial sources, the percentage of dioxin contribution increased from unregulated sources such as household trash burning or uncontrolled burning of residential trash. For example, in 1987 household trash burning contributed only 4% of total inventory, which increased to 35% in 2000 (Figure 3).

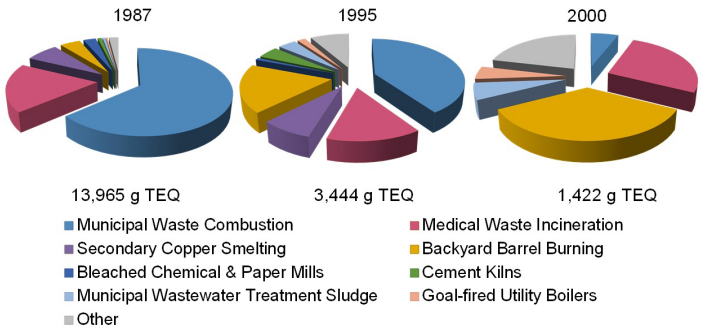

Figure 3. Sources of dioxin release and amount reduced (grams toxic equivalent; TEQ) for years 1987, 1995, and 2000
Credits: Data from US EPA (2006; http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=159286)

As observed in the United States, worldwide trends also indicate a reduction in dioxin emissions ranging from 44% to 89% during 1990–2005 (Figure 4). The emissions from municipal waste and medical waste incineration—which were historically the predominant sources in the United States, Netherlands, Canada, UK, and European Union—are now a minor contributor, with the reduction ranging from 60% to 99% for municipal waste and 22% to 100% for medical waste (Douben 1997; Environment Canada 1999; Quaβ et al. 2004; RIVM/TNO 1991; US EPA 2006). Overall, the changes in the manufacturing process and increased environmental controls are the main reasons for lower dioxins release during the past few decades.

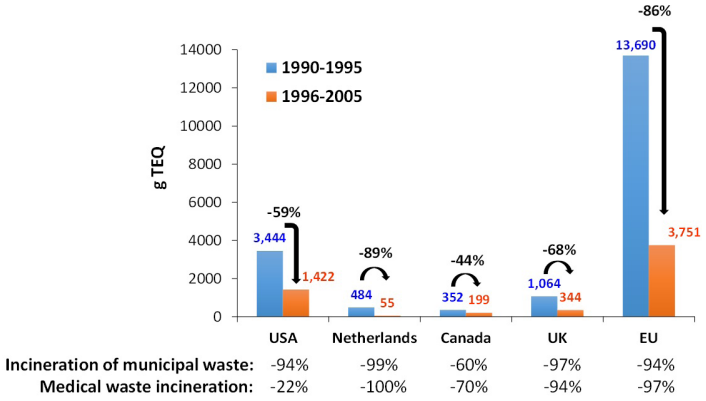

Figure 4. Global emission (g TEQ = grams toxic equivalent) trends of dioxins during 1990–2005

Credits: Data from Douben (1997); Environment Canada (1999); Quaβ et al. (2004); RIVM/TNO (1991); and US EPA (2006).

How Can You Be Exposed to Dioxins?

Once released into the environment, dioxins often bind to other particles, such as ash from incinerators. Some dioxins can be transported long distances and thus can attach to surfaces of grass, vegetables, and crops. Dioxins accumulate in the bottom mud and sediments in aquatic systems—such as lakes, streams, rivers, and estuaries—where they can have a long half-life (which is a measure of how long it takes for 50% of dioxin to degrade or decompose through chemical, biochemical, and photochemical processes). Half-life estimates for dioxins in the top 0.1 cm of surface soil range from 9 to 15 years; whereas, the half-life in subsurface soil (below 0.1 cm) may range from 25 to 100 years (ATSDR 1998). As dioxins are slowly broken down in the environment, they can bio-accumulate in the aquatic organisms. For example, dioxin concentration in fish has been reported to be 100,000 times higher than in the surrounding environment (Center for Health, Environment & Justice 1999). Dioxin accumulation in blue crab has been found in northwest Florida estuaries (Liebens et al. 2011).

Further, animals that feed on dioxin-contaminated grass or crops can also concentrate dioxins, which will appear in the meat from those animals.

Human beings can be exposed to dioxins via three routes: (1) direct ingestion, (2) absorption through the skin, and (3) inhalation (Figure 5). Eating contaminated food, in particular animal products, is the primary pathway for dioxin exposure (WHO, 2014). Skin contact or breathing typically represents a minor dioxin exposure pathway.

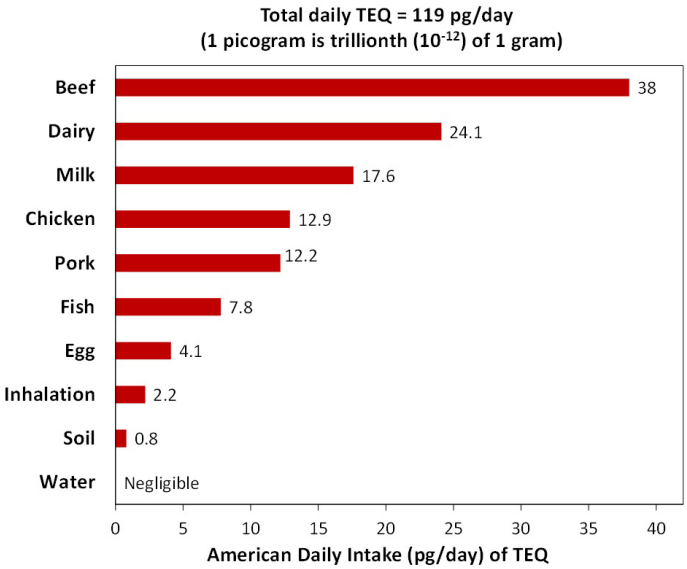

Figure 5. Routes of dioxins exposure from different sources in the United States

Credits: Data from Schecter et al. (2001)

Oral Intake: More than 90% of overall exposure of the general public to dioxins is through diet, especially foods containing fats of animal origin (WHO 2014) (Figure 5). When calculating human exposure, dioxins are measured in daily mass picograms (pg). (One pg is a trillionth [10^{-12}] of 1 gram [g]). Meat (beef, poultry, and pork) contributes the largest share (53%) of total daily TEQ in American diet, followed by dairy foods (38%), and fish (4%). The estimated average fish consumption in the United States was 1.8 kg per person from 2000 to 2009, while the average consumption of beef, chicken, and pork were 18, 15, and 13 kg per person, respectively (ProCon.org 2015).

Because dioxins do not dissolve in water, humans are generally not exposed to dioxins via drinking water and surface water. Fruits and vegetables normally do not take up dioxins through roots, except for some species such as pumpkin, cucumber, and carrot (Hulster et al. 1994). However, dioxins can accumulate in small amounts on the outer surfaces of fruits and vegetables from contaminated dust. Dioxin levels in foods vary depending on where the food is grown. For example, a study conducted in northwest

Florida found that the dioxins TEQ in the hepatopancreas (digestive gland) of blue crab (*Callinectes sapidus*) were similar to the TEQ in sediments from the same study sites (Liebens et al. 2011). They found that dioxins TEQ were higher in Bayou Chico (32.7 ng/kg in sediment vs. 15.3 ng/kg in crab) than in other waters due to the presence of number of industrial facilities such as chemical, scrap metal recycling, marinas, and ship building facilities.

Dermal Intake: The least possible way to be exposed to dioxins is from skin contact with dust contaminated by dioxins.

Inhalation Intake: Dioxins are also found in cigarette smoke, car exhaust, and household trash burning. Thus, exposure can also occur by incidentally consuming dioxins from the air we breathe. However, exposure of dioxins via inhalation is considered a negligible pathway mainly because of the low concentration of dioxins in the air and the absence of any accumulating mechanism. For example, the daily inhalation intake of dioxins for an American only account for 2% of total daily TEQ (Figure 5).

What Are the Effects of Dioxins on Animal and Human Health?

Both short-term and long-term exposure to dioxins can affect human health (Figure 6). Short-term exposure of humans to high levels of dioxins can cause skin lesions, such as chloracne (acne-like eruption of blackheads, cysts, and nodules), patchy darkening of the skin, and altered liver function (US EPA 2012; WHO 2014).

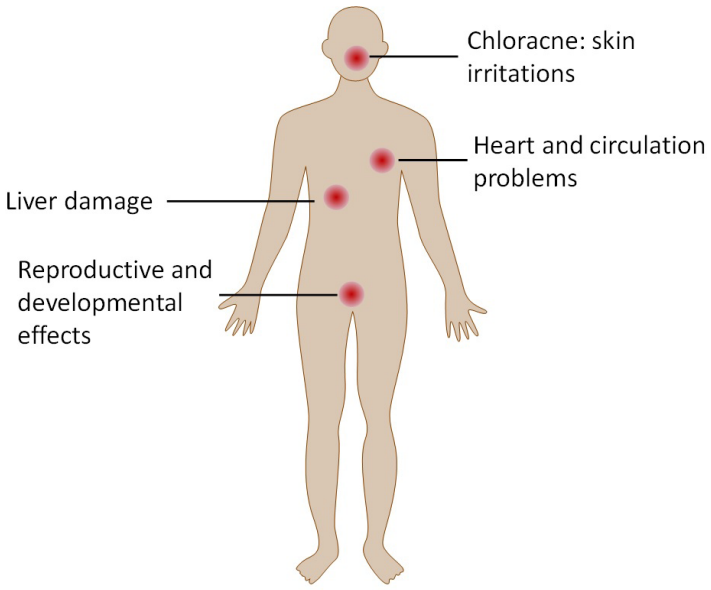

Figure 6. Human health effects of dioxins
Credits: Yun-Ya Yang, UF/IFAS

Long-term exposure to dioxins can lead to the impairment of immune system, nervous system, endocrine system, and reproductive functions.

Four of the most serious results of dioxin exposure—cancer risk, hormonal effects, reproductive and developmental effects, and immune system effects—are described in the following sections.

Cancer: Several studies suggest that exposure to dioxins increases the risk of cancer in humans and animals (WHO/UNEP 2013). In the United States, the Department of Health and Human Services (DHHS) and the US EPA have determined that dioxins may cause cancer (ATSDR 1998). For example, a study conducted in Michigan showed association between TCDD exposure and elevated breast cancer risks (Dai and Oyana 2008).

The US EPA (1994) draft reassessment of health effects of TCDD exposure estimated that the lifetime risk of getting cancer from exposure to TCDD is 1 in 10,000 individuals for the general American population and is 1 in 1,000 individuals for the highly exposed members of population (e.g., individuals consuming high levels of dioxin-containing foods).

Hormonal Effects: Exposure to dioxins has a variety of effects on hormone function in animals and humans. Dioxins behave like hormones, which mean that dioxins can mimic or block the action of the body's hormones. For example, a negative relationship between TCDD exposure and serum testosterone levels has been observed (Gupta et al. 2006). Egeland et al. (1994) also observed a decrease in testosterone and an increase in gonadotropin concentrations (protein hormone) in workers exposed to TCDD. Some other adverse effects observed in humans exposed to dioxins include diabetes, altered levels of reproductive hormones, and thyroid disease (Kogevinas 2001).

Reproductive and Developmental Effects: The reproductive and developmental effects in children exposed to dioxins include defects in permanent teeth, adverse effects on thyroid hormones, and increased respiratory disease (Mocarelli et al. 2008; Yonemoto 2010).

Immune System Effects: Based on both animal studies and human studies, US EPA (2012) concluded that even low exposure to dioxins may attack the immune system. This attack is likely due to the effects of dioxins on the endocrine system.

Note that these adverse health effects are likely to occur with high dose of dioxins. For more information on human health reassessment of dioxins, consult US EPA (2003, 2012) and the World Health Organization (WHO 2014) website (http://www.who.int/mediacentre/factsheets/fs225/en/).

How Can You Minimize Your Exposure to Dioxins?

Almost every living organism may have been exposed to some levels of dioxins. For humans, the average time to remove half of the dioxins from the body is highly variable and may take from 7 to 12 years (ATSDR 1998). The major route of dioxin exposure is from food sources, particularly consumption of contaminated food containing animal fats. Thus, the best way to reduce your personal dioxin level is to reduce consumption (ingestion) of dioxins in the diet. For most people, following the existing Federal Dietary Guidelines (USDA 2010, 2015; FAO/WHO 2006) will reduce fat consumption and dioxin exposure, as summarized in the following section.

Reduce Oral Exposure:

- Eat a balanced diet to help avoid excessive exposure from a single contaminated food source
- Eat meat and dairy products that are lean (i.e., naturally low in fat), low fat, or fat free
- Remove skin from fish and poultry
- Reduce the amount of butter or lard used in the preparation of foods and cooking methods
- Barbecue, broil, or bake meat on an elevated rack to allow the fat to drip away
- Thoroughly wash, pare, or peel any garden product before eating

Reduce Dermal and Inhalation Exposure: Currently, the burning of residential trash is thought to be among the largest sources of dioxins in the environment in the United States. There are many small things that we can all do to help reduce dioxin levels in the environment:

- Do not burn household trash, especially construction materials that may contain wood preservatives or plastics
- Reduce the use of dioxin-containing products such as PVC and other chlorinated chemicals

Summary

- In recent decades, dioxins have received increased scrutiny due to their persistence, bio-accumulative nature, and toxicity. The good news is that dioxins emissions have been reduced dramatically in the United States and in other parts of world as a result of regulations and voluntarily industry efforts. However, dioxins are still present in our environment because they slowly break down.
- The health effects associated with dioxins depend on specific factors, including the level and time period of exposure. Levels of dioxins in the human population are primarily influenced by prevailing environmental levels, and most of our intake of dioxins is derived from consumption of contaminated (with dioxin) fatty foods of animal origin.
- Reducing dioxin intake (as this can be a major exposure pathway) is a good health strategy and the best way to avoid concerns of dioxin exposure. Most important for each of us is to become knowledgeable about various contaminants present in our modern day lives and share the message. 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).

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