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

Introduction and Purpose

Plastic, plastic everywhere! We live in a world where we are surrounded by plastic: from packaging materials and cutlery to plastic appliances and medical devices. Since the mid-twentieth century, plastic has been a boon to humanity and an integral part of our modern lives. However, plastic debris is a major concern due to its abundance and persistence in the environment. For example, 32 million tons of plastic waste was generated in the United States alone in 2012 (US EPA 2014). Of total plastic, the major products are containers and packaging materials (44%), followed by durable goods such as appliances (34%), and non-durable goods such as plates and cups (22%).

Jambeck et al. (2015) estimated that approximately 275 million metric tons (1 metric ton = 1000 kilograms) of plastic was generated in 192 coastal countries in 2010. This amount is the equivalent of five grocery bags of plastic for every foot of shoreline in the countries studied. Of this, 99.5 million metric tons (36%) was generated in coastal regions (population living within 5 km of the coast), with 31.9 million metric tons (12%) classified as mismanaged. An estimated 4.8 to 12.7 million metric tons (2 to 5%) of plastic waste entered the oceans. Of the top 10 items collected during the International Coastal Cleanup, organized by the Ocean Conservancy, six are pure plastic (beverage bottles, bottle caps, straws, plastic bags, grocery bags, plastic cups and plates). The top two items, cigarette butts and food wrappers, also contain plastic.

Plastic waste can enter the environment from poorly managed landfills or by carelessly discarded plastic products. Plastic contaminants not only include plastic debris characterized by large size but also small pieces of plastic in the millimeter size range. Inconspicuous plastic debris—called "microplastics" —has become a major concern because of its widespread presence in different environmental matrices (surface waters, oceans, sediments) and diverse organisms. This publication discusses the sources of microplastics, their effects on the environment, and ways to minimize microplastics pollution and exposure.

What Are Microplastics?

Microplastics include plastic particles with an upper size limit of 5 mm or 1/5 of an inch (Figure 1; Wright et al. 2013). Microplastics include (1) pieces from the degradation of larger plastic items made from polyethylene (plastic bags, bottles), polystyrene (food containers), nylon, polypropylene (fabrics), or polyvinyl chloride (water pipes); (2) nurdles, which are pre-production resin pellets used to

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manufacture plastic items and as fillers for toys and squishy pillows; and (3) microbeads, which are added to many personal care products (such as toothpaste) for color, shine, or as fillers.

Sources of microplastics in the environment include primary plastic products (original) and/or secondary products (derived from the degradation of primary sources), as shown in Figure 2. Most microplastics in aquatic systems are derived from secondary sources (Moore 2008), although water samples collected from Great Lakes were found to contain large numbers of microplastic spheres, which were comparable in composition to those found in facial scrubs (Eriksen et al. 2013).

Primary Microplastics: Plastics manufactured to be less than 5 mm in size are called primary microplastics (Cole et al. 2011). These include industrial pellets as well as plastic fragments and beads included in personal care products such as toothpaste, shower gels, and skin care products (Figure 2).

Secondary Microplastics: These are formed by chemical (such as oxidation), physical (such as heat, UV light, mechanical action) and/or microbial degradation of plastic products (Figure 2; Cole et al. 2011). With time, a combination of chemical and physical forces can reduce the structural integrity of plastic items, allowing the plastic to fragment and generate smaller particles classified as microplastics (Cole et al. 2011; Rillig 2012).

- Nurdles are pre-production resin pellets used to manufacture plastic items and as filters in some stuffed toys and squishy pillows
- Secondary microplastics are unintentionally produced as a consequence of breakdown of larger pieces of plastic into small fragments
- Toothpaste plastics are tiny polyethylene plastic fragments found in toothpaste
- Microbeads are tiny plastic beads found in many personal care products for color/shine, and fillers

Figure 1. Various types of microplastics.
Credits: Maia McGuire

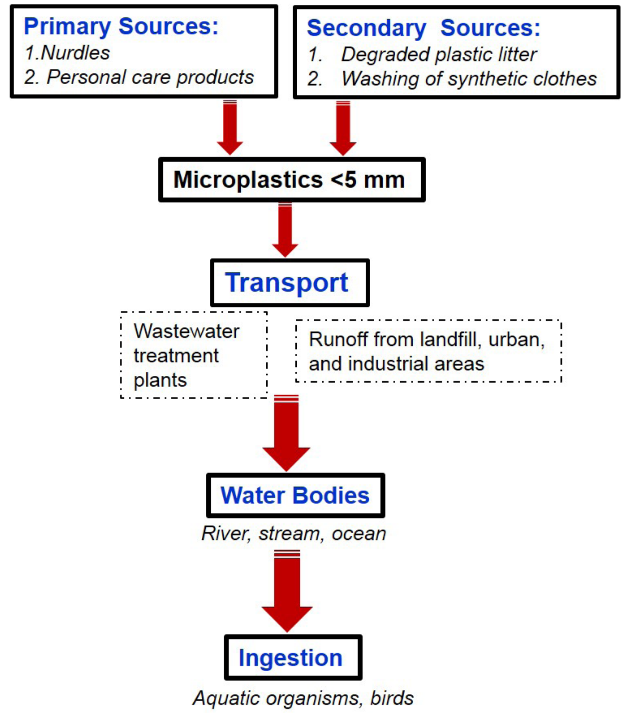

Figure 2. Sources and pathways of microplastics release in the environment.
Credits: Yun-Ya Yang

What Are the Sources of Microplastics in the Environment?

Major sources of microplastics in water bodies include wastewater from wastewater treatment plants (WWTPs) and runoff from urban, landfill, and industrial areas, as shown in Figure 2 (Cole et al. 2011; do Sul and Costa 2014; Eriksen et al. 2013; Law and Thompson 2014). For example, microplastics additives in some personal care products and microplastics fibers from synthetic fabrics such as polyester and polyamide are discarded during clothes washing and end up in wastewater (Figure 2). These microplastics are often not removed in WWTPs due to their small size and buoyancy, and thus are released into water bodies such as rivers, lakes, and oceans as part of the WWTP effluent (Browne et al. 2011; Fendall and Sewell 2009). For example, Browne et al. (2001) investigated the spatial extent of microplastics across the shores—at 18 sites worldwide—of six continents to examine the sources and sinks of microplastics in various habitats. Microplastics were extracted from effluent discharged by WWTPs and compared with sediments from disposal-site to examine the role of sewage as a source. They found that more than 100 microplastics fibers were present in one liter of wastewater and on average more than 1,900 fibers can be discarded by a synthetic clothing garment during one washing. In addition, polyester and acrylic fibers found in sewage-effluent resembled microplastics contaminating sediments from shores and disposal-sites (Browne et al. 2011). Studies have shown that microplastics fibers found in wastewater came mainly from wastewater from washing synthetic clothes rather than from fragmentation of plastic waste (Browne et al. 2011; Law et al. 2010) or from personal care products containing microplastics (Browne et al. 2010; Fendall and Sewell 2009).

Another potential source of microplastics includes runoff of debris from urban, landfill, and industrial areas (Figure 2; Browne et al. 2011; Law and Thompson 2014). Because synthetic fibers (removed from clothing during laundering) are unlikely to degrade, these fibers also persist in the sewage sludge (also called biosolids). One study found synthetic fibers in several soils in the United States to which sludges (dewatered, pelletized, composted, alkaline-stabilized) had been applied (Zubris et al. 2005). Landfill areas contain different types of plastic products, which also have the potential to contribute microplastics to the environment (Barnes et al. 2009).

Accidental release is another notable source of microplastics. For example, accidental losses of industrial plastic resin pellets (industrial raw material) during shipping activities have been reported to be a source of microplastics in the ocean (do Sul and Costa 2014; Moore 2008). Larger plastics eventually undergo some form of degradation and fragmentation into smaller pieces. Parts of plastic waste (such as plastic bags) may wind up in the environment due to their low buoyancy. Wind can also move microplastics, affecting their distribution in the environment. Researchers have discovered that wind pushes and mixes the lightweight plastic particles down into the water (Lusher et al. 2014). As plastics fragment and disintegrate, microplastics become available for ingestion by a wide range of aquatic organisms and can potentially cause harm (Figure 2). This example video demonstrates the possibility of microplastic uptake by zooplankton, which are among the smallest feeders in our seas: http://www.onearth.org/earthwire/plankton-feeding-on-plastic?utm_source=fb&utm_medium=post&utm_campaign=socialmedia

What Are the Effects of Microplastics in the Environment and on Human Health?

Effects on Aquatic and Terrestrial Organisms

The wide use and degradation of plastics have resulted in the wide-spread distribution of microplastics in the environment. Concern about the many decades' worth of plastic deposition in the marine environment has been increasing because of the exposure of marine organisms to the plastics. Some microplastics are small enough to be ingested by animals low in the food chain, such as plankton. The most likely impact of microplastics ingestion is physical obstruction of the digestive system, which causes the animal to stop eating because it feels full. Animals that eat too much plastic die of starvation (Cole et al. 2013).

In laboratory studies, nanoplastics have been shown to inhibit photosynthesis in the microscopic algae *Chlorella* (Bhattacharya et al. 2010). A significant decrease in carbon dioxide (CO_2) depletion, at a polystyrene concentration of 1.8 mg/L of algal solution, was observed as the dosage of polystyrene beads added to *Chlorella* was increased. The effect of microplastics on aquatic organisms may be a cause for concern because plastics that are this tiny in the marine environment have not been measured and because algae are primary producers at the base of the food web in water bodies. The presence of microplastics in seafood has been demonstrated. van Cauwenberghe and Janssen (2014) investigated the presence of microplastics in commercially grown bivalves (*Mytilus edulis* and *Crassostrea gigas*). Their results showed that *Mytilus edulis* originating from the North Sea contained on average 0.36 ± 0.07 (wet weight) particles per gram of tissue at time of consumption, while an average plastic load of 0.47 ± 0.16 particle per gram was detected in *Crassostrea gigas*.

Chemical toxins in the marine environment have been found to adsorb to the surface of plastics at concentrations one-million times higher than the concentrations found in seawater (Mato et al. 2001). These toxins include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and the pesticide DDT (Hirai et al. 2011; Mato et al. 2001). Additionally, some potentially toxic chemicals (e.g., bisphenol-A) are used in the manufacturing of plastic. A second concern related to microplastics ingestion is the adsorption of all of these types of toxins into animal tissues (Engler 2012). For example, seals have been found with PCB concentrations in their fat tissue as high as 1370 ng/g (part per billion) because seals consume both fish tainted with toxic chemicals and plastic particles themselves (Letcher et al. 2010). Leaching from plastic particles could present a long-term source of chemicals into tissues.

The risks for vertebrates (animals with backbones, including humans) are similar to those for invertebrates, but there is an additional concern for vertebrates because of the potential accumulation of plastics or plastic-associated toxins up the food chain. Sub-lethal effects of microplastics consumption in vertebrates can include reduced reproductive fitness, reduced predator avoidance, and poor feeding ability. Damage to the skin and ulceration of internal layers of organs have been reported in marine vertebrates. Accumulation of microplastics may lead to the transfer of harmful contaminants that are either present in microplastics (such as bisphenol-A) and/or carried with microplastics (due to adsorption) from water to organism. The potential adverse effects of microplastics depend on the size of the particles (Wright et al. 2013). For example, nanomaterials (smaller than 0.000003937 inches) can cause lung damage, inflammation, and cell damage in mice (Shvedova et al. 2005).

The issue of microplastics pollution is the subject of much current scientific research and scrutiny. There is limited information about environmental impacts of microplastics, and most of what is known comes from the marine environment. Little information is known about whether microplastics bio-accumulate in the food web (small organisms to fish, mammals, and birds). There is little published research investigating the leaching of contaminants (such as bisphenol-A) from microplastics to organisms. Koelmans et al. (2014) used biodynamic modeling to investigate the potential for bisphenol-A to leach from ingested polycarbonate into aquatic species. They proposed that a continuous ingestion of plastic containing 100 mg/kg of bisphenol-A would lead to a very low steady-state concentration of 0.044 ng/kg of bisphenol-A in fish.

In summary, the secondary microplastics in the environment are produced by degradation of plastics by sunlight, mechanical forces. Then, zooplankton and fish ingest microplastics, which potentially cause digestive problems.

Effects on Humans

The connections between environmental microplastics and human health have not yet been fully addressed but are a subject of much interest and debate. Today, there is no evidence that microplastics originating from marine or terrestrial debris that end up in the food chain are taken up by humans, and there is no evidence that they have biological effects on humans. Rather, the impact of microplastics exposure on humans is not yet understood, leaving many questions unanswered. Some unanswered questions include whether significant bioaccumulation and trophic transfer for microplastics occur in the environment; the effects of aging on physico-chemical properties and subsequent toxicity of plastics; retention rates of microplastics in the environment; and the relative importance of various sources, spatial trends in distribution and abundance (Thompson 2015; Galloway 2015). The answers to these questions are required to build on current knowledge to develop a clearer picture of the impact of microplastics on the environment and human health.

How Can You Minimize Your Exposure to Microplastics?

The best way to reduce microplastics in the environment is to limit their release at the source, and that can only be achieved through our actions. Some steps you can take to reduce microplastics in the environment are as follows:

- Cut back on the use of plastic, especially single-use plastics like water bottles, straws and cups (reduce, reuse, recycle, refuse).
- Changing habits and products. You can learn and understand the use of microplastics in daily life by searching for personal care products that contain plastic (i.e. polyethylene) at this webpage: http://householdproducts.nlm.nih.gov/
- If possible, wear clothing made from natural materials rather than synthetic fabrics.

Public education about microplastics is a critical part of creating changes at the societal level. 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).

Summary

Plastic has brought many societal benefits, but it is evident that our current approaches to plastic use and disposal have resulted in the widespread occurrence of microplastics in the environment. Microplastics are difficult to remove during the wastewater treatment process because they are small, buoyant, and easily carried with wastewater to water bodies. Microplastics are consumed by a wide range of organisms, impairing the ability of organisms to eat and causing harm. There is also a concern that toxic chemicals such as PCBs, PAHs, and bisphenol-A in the plastics themselves may transfer to biota via ingestion of microplastics, although research is scarce. Despite concerns raised by ingestion, the effects of microplastics ingestion in natural populations and the implications for food webs are not understood. Our understanding of potential future trends in the abundance of microplastics is limited, while contamination by microplastics is likely to continue to grow. Work is needed to reduce and eliminate sources and pathways of microplastics exposure.

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