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 and water 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. One example: 34.5 million tons of plastic waste was generated in the United States alone in 2015 (US EPA 2018).

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. 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. This amount is the equivalent of about five grocery bags of plastic for every foot of shoreline in the 192 countries studied. In 2017, all of the top 10 items collected during the International Coastal Cleanup, organized by the Ocean Conservancy, were made of or contained plastic (Ocean Conservancy 2018.) These items were cigarette butts, food wrappers, beverage bottles, bottle caps, straws, plastic bags, grocery bags, plastic take-out containers, plastic lids, and foam take-out containers.

There are many ways plastic waste can enter the environment. These can include poorly managed landfills or carelessly discarded plastic products. Plastic debris can include items large enough to be easily seen by the naked eye, but can also include 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 microplastic pollution and exposure.

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What are microplastics?

Microplastics include plastic particles with an upper size limit of 5 mm or ⅕ of an inch (Figure 1; Arthur et al. 2009). Microplastics can be either primary microplastics (deliberately made to be less than 5 mm in size) or secondary microplastics (pieces from the degradation of larger plastic items). Different forms of plastic can be found as microplastics. Some common plastic types and common products made from these plastics are shown in Table 1.

Primary microplastics include nurdles, which are pre-production resin pellets used to manufacture plastic items and as fillers for toys and squishy pillows, and microbeads, which are added to many personal care products (such as deodorant, mascara, or eye shadow) for color, shine, or as fillers. Microbeads are most commonly made from polyethylene. Recent legislation to limit the use of plastic microbeads in the United States is described in the section "Efforts to reduce plastic pollution" later in this document.

Secondary microplastics are formed by chemical (such as oxidation), physical (such as heat, UV light, or mechanical action), and/or microbial degradation of plastic products (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

What are the sources of microplastics in the environment?

Most microplastics in aquatic ecosystems are derived from secondary sources (Moore 2008), although water samples collected from the 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).

Major transport mechanisms that can carry microplastics into water bodies include wastewater from wastewater treatment plants (WWTPs), stormwater runoff from urban, landfill, and industrial areas, and wind (Auta et al. 2018). For example, microplastic additives in some personal care products and microplastic fibers from synthetic fabrics such as polyester and nylon can end up in wastewater. These microplastics are not completely removed in WWTPs due to their small size and buoyancy, and thus can be released into water bodies such as rivers, lakes, and oceans as part of the WWTP effluent (Browne et al. 2011; Fendall and Sewell 2009).

Synthetic fibers, which are shed from clothing during laundering, represent another major source of microplastics to the environment as they are unlikely to degrade. These fibers are abundant in sewage sludge, which is also called biosolids. Biosolids are often applied to soil as a fertilizer. 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). Stormwater runoff can transport microplastics from fields, landfills, or urban/residential areas into aquatic systems.

Accidental release of primary microplastics is another notable source of microplastics. For example, accidental losses of industrial plastic resin pellets, or nurdles, during shipping activities have been reported to be a source of microplastics in the ocean (Moore 2008, do Sul and Costa 2014).

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 microplastics form and/or are transported into the environment, they become available for ingestion by a wide range of aquatic organisms and can potentially cause harm. Microplastics have been found in the guts of a wide range of marine organisms, including many that are commonly eaten by humans. They are also found in shoreline and deep-sea sediments, in surface and deep waters around the globe, and in polar ice (review in Auta et al. 2017).

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 widespread 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 plastics. Some microplastics are small enough to be ingested by animals low in the food chain, such as plankton. Plastics can impact animals in physical and/or chemical ways.

Larger plastic items can entangle marine animals and may cause death by drowning (e.g. air-breathing sea turtles) or by causing fatal injuries. Another way that plastics can impact larger marine animals is by causing physical damage to the digestive tract, especially when sharp-edged or pointed plastic items are eaten (Laist 2006). At this time, it is impossible to say whether microplastics have similar impacts on microscopic marine organisms. Some studies and anecdotal observations show that many microplastics are ingested and then excreted by the animals (Watts et al. 2015). This observation may indicate that microplastics have less chance of causing a blockage of the digestive system than larger plastics that are eaten by marine organisms. However, there may be an energetic cost to the animal associated with passing plastic through the digestive system without obtaining any nutritional value (Hirai et al. 2011).

A second concern related to microplastic ingestion is the transfer of various types of toxins from the plastic into animal tissues (Engler 2012). Some potentially toxic or hormone-disrupting chemicals (e.g., bisphenol A, plasticizers called phthalates and flame-retardants) are used to manufacture many plastic items. Additionally, chemical toxins in the marine environment have been found to adsorb to the surface of plastics at concentrations up to 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). When plastics are eaten by animals, these chemicals can leach from the plastic into the animal's body. For example, seals have been found with PCB concentrations in their fat tissue as high as 1370 ng/g (parts per billion) because seals consume both fish tainted with toxic chemicals and plastic particles themselves (Letcher et al. 2010).

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. Sublethal effects of microplastic 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 the organism.

The issue of microplastic pollution is the subject of much current scientific research and scrutiny. There is limited information about the environmental impacts of microplastics, and most of what is known comes from the marine environment. Almost all of this research comes from lab studies, which may not accurately represent what is happening in the environment. There is some indication that ingestion of plastic may have a negative impact on reproduction in the Pacific oyster (Susarellu et al. 2016) and larval development in brown mussels (Silva et al. 2016). The mechanism of these impacts on organisms is not currently known. Little information is known about whether microplastics bioaccumulate 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. However, research involving filter-feeding megafauna (fin whales and basking sharks) seems to suggest that both leaching and bioaccumulation of contaminants and microplastics are occurring (Fossi et al. 2014).

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. Microplastics (primarily fibers) have been found in various beverages, including tap water, bottled water, and beer. They have also been found in sea salts and various seafoods. In 2018, a pilot study found microplastics in fecal samples from all eight individuals tested (Parker 2018). It seems very likely that people are ingesting microplastics, but there is currently no evidence that these plastics have biological effects on humans. The impact of human exposure to microplastics 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 plastic aging on physico-chemical properties and subsequent toxicity; retention rates of microplastics in the environment; and the relative importance of various sources and 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.

Efforts to Reduce Microplastic Pollution

In 2014, Illinois became the first state to ban the sale of cosmetics containing plastic microbeads. The legislation gave manufacturers a phase-out period between 2017–2019. Over the next 18 months, another eight states passed similar legislation. However, in late 2015, the US Congress passed the Microbead-Free Waters Act of 2015, which was then signed into law in December 2015. This superseded the individual state legislations. The Microbead-Free Waters Act took full effect in July 2018. It bans the sale of rinse-off cosmetics that are designed to exfoliate or cleanse the human body (including toothpastes) if those products contain plastic microbeads. Microbeads are defined as solid plastic pieces that are less than 5 mm in size. Many other countries have since passed or are developing similar legislation (Dauvergne 2018).

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).
- Change habits and products. You can learn whether your personal care products contain microplastics by reading the ingredients labels and looking for the word polyethylene or other common forms of plastics (see Table 1).
- 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 and 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 on or in the plastics themselves may transfer to biota via ingestion of microplastics. Despite concerns raised by ingestion, the effects of microplastic 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 environmental and human exposure to microplastics.

References

Arthur, C., J. Baker, H. Bamford. 2009. "Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris". Sept 9-11. 2008. *NOAA Technical Memorandum* NOS-OR&R-30.

Auta, H.S., C.U. Emenike, and S.H Fauziah. 2018. "Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions". *Environmental International.* 102: 165-176.

Barnes, D.K.A., F. Galgani, R.C. Thompson, and M. Barlaz. 2009. “Accumulation and Fragmentation of Plastic Debris in Global Environments.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 364: 1985-1998.

Browne, M. A., P. Crump, S. J. Niven, E. Teuten, A. Tonkin, T. Galloway, and R. Thompson. 2011. “Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks.” *Environmental Science & Technology* 45: 9175–9179.

Cole, M., P. Lindeque, C. Halsband, and T. S. Galloway. 2011. “Microplastics as Contaminants in the Marine Environment: A Review.” *Marine Pollution Bulletin* 62: 2588–2597.

Dauvergne, P. 2018. “The power of environmental norms: marine plastic pollution and the politics of microbeads”. *Environmental Politics* 27(4): 579-597.

do Sul, J. A. I., and M. F. Costa. 2014. “The Present and Future of Microplastic Pollution in the Marine Environment.” *Environmental Pollution* 185: 352–364.

Engler, R. E. 2012. “The Complex Interaction between Marine Debris and Toxic Chemicals in the Ocean.” *Environmental Science & Technology* 46: 12302–12315.

Eriksen, M., S. Mason, S. Wilson, C. Box, A. Zellers, W. Edwards, H. Farley, and S. Amato. 2013. “Microplastic Pollution in the Surface Waters of the Laurentian Great Lakes.” *Marine Pollution Bulletin* 77: 177–182.

Fendall, L. S., and M. A. Sewell. 2009. “Contributing to Marine Pollution by Washing Your Face: Microplastics in Facial Cleansers.” *Marine Pollution Bulletin* 58: 1225–1228.

Fossi, M.C., D. Coppola, M. Baini, M. Giannetti, C. Guerranti, L. Marsili, C. Panti, E. de Sabata, S. Clò. 2014. “Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: The case studies of the Mediterranean basking shark (*Cetorhinus maximus*) and fin whale (*Balaenoptera physalus*)”. *Marine Environmental Research* 100: 17-24.

Galloway, T. S. 2015. “Micro- and Nano-Plastics and Human Health.” In: Bergmann M., Gutow L., Klages M. (eds) *Marine Anthropogenic Litter*. Springer, Cham.

Hirai, H., H. Tagada, Y. Ogata, R. Yamashita, K. Mizukawa, M. Saha, C. Kwan, C. Moore, H. Gray, D. Laursen, E. R. Zettler, J. W. Farrington, C. M. Reddy, E. E. Peacock, and M. W. Ward. 2011. “Organic Micropollutants in Marine Plastics Debris from the Open Ocean and Remote and Urban Beaches.” *Marine Pollution Bulletin* 62: 1683–1692.

Jambeck, J. R., R. Geyer, C. Wilcox, T. R. Siegler, M. Perryman, A. Andrady, R. Narayan, and K. L. Law. 2015. “Plastic Waste Inputs from Land into the Ocean.” *Science* 347: 768–771.

Laist, D. 2006. “Overview of the biological effects of lost and discarded plastic debris in the marine environment.” *Marine Pollution Bulletin* 18 (6B): 319-326.

Letcher, R. J., J. O. Bustnes, R. Dietz, B. M. Jenssen, E. H. Jørgensen, C. Sonne, J. Verreault, M. M. Vijayan, and G. W. Gabrielsen. 2010. “Exposure and Effects Assessment of Persistent Organohalogen Contaminants in Arctic Wildlife and Fish.” *Science of the Total Environment* 408: 2995–3043.

Lusher, A. L., A. Burke, I. O’Connor, and R. Officer. 2014. “Microplastic Pollution in the Northeast Atlantic Ocean: Validated and Opportunistic Sampling.” *Marine Pollution Bulletin* 88: 325–333.

Mato, Y., T. Isobe, H. Takada, H. Kanehiro, C. Ohtake, and T. Kaminuma. 2001. “Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment.” *Environmental Science & Technology* 35 (2): 318–324.

Moore, C. J. 2008. “Synthetic Polymers in the Marine Environment: A Rapidly Increasing, Long-Term Threat.” *Environmental Research* 108 (2): 131–139.

Ocean Conservancy. 2018, July. “Building a Clean Swell.” Retrieved from https://oceanconservancy.org/wp-content/uploads/2018/07/Building-A-Clean-Swell.pdf.

Parker, L. 2018, October 2. “In a first, microplastics found in human poop.” Retrieved from https://www.nationalgeographic.com/environment/2018/10/news-plastics-microplastics-human-feces/

Rillig, M. C. 2012. “Microplastic in Terrestrial Ecosystems and the Soil?” *Environmental Science & Technology* 46: 6453–6454.

Silva, P.P.G., C.R. Nobre, P. Resaffe, C.D.S. Pereira, and F. Gusmão. 2016. “Leachate from microplastics impairs larval development in brown mussels”. *Water Research* 106: 364-370.

Sussarellu, R., M. Suquet, Y. Thomas, C. Lambert, C. Fabioux, M. E. J. Pernet, N. Le Goïc, V. Quillien, C. Mingant, Y. Epelboin, C. Corporeau, J. Guyomarch, J. Robbens, I. Paul-Pont, P. Soudant, and A. Huvet. 2016. “Oyster reproduction is affected by exposure to polystyrene microplastics”. *Proceedings of the National Academy of Sciences of the United States of America* 113 (9): 2430-2435

Thompson R.C. 2015. “Microplastics in the Marine Environment: Sources, Consequences and Solutions.” In: Bergmann M., Gutow L., Klages M. (eds) *Marine Anthropogenic Litter*. Springer, Cham.

United States Environmental Protection Agency (US EPA). 2018, July 19. “Plastics: Material-Specific Data.” Retrieved from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

Watts, A.J.R., M.A. Urbina, S. Corr, C. Lewis, and T.S. Galloway. 2015. “Ingestion of Plastic Microfibers by the Crab *Carcinus maenas* and Its Effect on Food Consumption and Energy Balance”. *Environmental Science & Technology* 49: 14597-14604.

Zubris, K. A. V., and B. K. Richards. 2005. “Synthetic Fibers as an Indicator of Land Application of Sludge.” *Environmental Pollution* 138: 201–211.

Table 1.

Plastic type	Recycle code (number)	Common consumer products made from this type of plastic
Polyethylene terephthalate (PET)	1	Beverage bottles, polyester fabric
High density polyethylene (HDPE)	2	Grocery/shopping bags, shipping pillow-packs, plastic wrappers
Polyvinyl chloride (PVC)	3	Water pipes
Low density polyethylene (LDPE)	4	Grocery/shopping bags, shipping pillow-packs, plastic wrappers
Polypropylene (PP)	5	Beverage bottle caps, fabric
Polystyrene (PS)	6	Foam cups, food clamshell containers
Cellulose acetate	Not recyclable	Cigarette butts, photographic film
Nylon	Not recyclable	Fabric