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Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia

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ABSTRACT

Humans continue to increase the use and disposal of plastics by producing over 240 million tonnes per year, polluting the oceans with persistent waste. The majority of plastic in the oceans are microplastics (<5 mm). In this study, the contamination of microplastic fibers was quantified in sediments from the intertidal zones of one exposed beach and two protected beaches along Nova Scotia's Eastern Shore. From the two protected beaches, polychaete worm fecal casts and live blue mussels (*Mytilus edulis*) were analyzed for microplastic content. Store-bought mussels from an aquaculture site were also analyzed. The average microplastic abundance observed from 10 g sediment subsamples was between 20 and 80 fibers, with higher concentrations at the high tide line from the exposed beach and at the low tide line from the protected beaches. Microplastic concentrations from polychaete fecal casts resembled concentrations quantified from low tide sediments. In two separate mussel analyses, significantly more microplastics were enumerated in farmed mussels compared to wild ones.

1. Introduction

1.1. Origin and distribution of microplastics

Humans have been mass-producing plastics since the early 1940s, and production has increased extensively in subsequent years. Approximately 240–280 million tonnes of plastic have been produced annually since 2008, compared to an annual production rate of 1.5 million tonnes in 1950 (Cole et al., 2011; Wright et al., 2013). About 50% of plastic produced is disposed after one use, with packaging materials as the main contributor. Another 20–25% of plastics entering the natural environment have intermediate life spans and come from durable consumer products, such as electronics and vehicles (Hopewell et al., 2009). Most plastics are extremely durable and can persist from decades to millennia in their polymer forms (Hopewell et al., 2009; Thompson et al., 2004). Their durability causes plastics to persist and contaminate environments worldwide. Marine habitats are particularly affected (Lithner et al., 2011).

Microplastics constitute plastics that are <5 mm, as classified by the National Oceanic and Atmospheric Administration (NOAA), and they are present in a heterogeneous array of shapes and sizes (Betts, 2008; Hidalgo-Ruz et al., 2012; Wright et al., 2013). Some authors classify microplastics with an upper size limit of 1 mm (e.g. Browne et al., 2008); and, upper size limits of 1 mm and 5 mm are currently acceptable to describe microplastics in the literature. The most prominent microplastic forms contaminating the marine environment are spheres, pellets, irregular fragments, and fibers (Wright et al., 2013). They are ubiquitous throughout the global oceans, and microplastics (<1 mm) in the water column and seabed have been observed to weigh 100 times and 400 times more than macroplastic debris, respectively (Van Cauwenberghe et al., 2013). Microplastics are distributed throughout the water column, sediments, and the deep sea, with highest concentrations along populated coastlines and within mid-ocean gyres (Cole et al., 2011; Wright et al., 2013). A study conducted on the spatial distribution of microplastics revealed that accumulation is higher at downwind sites and in areas with decreased water flow. A relationship has yet to be observed between microplastic concentrations and grain size distribution (Browne et al., 2010, 2011). Although microplastics have been observed throughout the oceans globally, the extent of microplastic contamination to the marine environment is still largely unknown (Browne et al., 2009, 2011).

Plastics are synthetic organic polymers, created by polymerization of monomers extracted from crude oil and gas (Cole et al., 2011). Some of the most prominent plastic polymers found in the environment include polystyrene (most commonly used in packaging and industrial insulation), acrylic, polyethylene (used

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in facial scrubs), polypropylene (commonly used in fishing gear), polyamide (nylon), polyvinyl chloride (PVC), and polyester fragments (Browne et al., 2008, 2011). Primary microplastics are produced at a microscopic size, and are integrated into a variety of facial exfoliating cleansers, air-blasting boat cleaning media, and are increasingly used in medicine as vectors for drugs (Cole et al., 2011). Secondary microplastics form when macroplastics undergo mechanical, photolytic, and/or chemical degradation, resulting in fragmented microplastic pieces and fibers. There is evidence that a primary source of microplastics is synthetic fibers from garments. A study quantifying microplastic concentrations at 18 sites worldwide showed that a single synthetic clothing garment can release >1900 microplastic fibers per wash. These microfibers enter the marine environment via wastewater discharge. Marine habitats in close proximity to sewage discharge sites contain proportions of polyester and acrylic microplastic fibers resembling proportions used in synthetic clothing (Browne et al., 2011).

1.2. Potential harms

Harmful components of plastics reside in the monomer constituents, in the additives and plasticizers, and in hydrophobic Persistent Organic Pollutants (POPs) and metals that absorb in plastics in the marine environment (Koelmans et al., 2013). Contaminants can be transferred to organisms most commonly by ingestion, inhalation, and dermal sorption (Teuten et al., 2009). The danger lies in the fact that microplastics are ingested by a variety of marine biota, and therefore have the potential to translocate these harmful constituents to organisms. However, the toxicological effects of many of the plastic components are not yet well known (Hidalgo-Ruz et al., 2012). Over 180 species have been documented to ingest plastic debris (Teuten et al., 2009), and as plastics fragment into smaller pieces, the potential for ingestion and accumulation in animal tissues increases (Browne et al., 2008; Wright et al., 2013). It has been discovered in previous studies that amphipods (detrivores), lugworms (deposit feeders), barnacles (filter feeders), and mussels (suspension feeders) all ingest microplastics when present in their environments (Thompson et al., 2004; Browne et al., 2008).

Microplastics, especially in fiber form, pose threats to organisms that consume them as they can cause blockages in the digestive tract, become translocated to different tissues within the organism, and undergo accumulation (Wright et al., 2013). Once microplastics enter the marine environment, they can be subjected to density changes through biofouling, which increases microplastic density (Wright et al., 2013). As microplastic density changes, they become available to organisms at different depths in the water column and in the sediments. This indicates that marine life occupying surface water all the way down to the benthos are vulnerable to microplastic interactions and contamination.

Many organic contaminants have been shown to accumulate on and inside plastics. Some of the contaminants previously observed in microplastics include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, organochlorine pesticides, polybrominated diphenylethers, alkylphenols, and bisphenol A (BPA). BPA is also commonly used as a monomer in plastic polymerization (Teuten et al., 2009). Concentrations of PCBs on polypropylene pellets have been observed 10^6 times higher than in surrounding seawater (Mato et al., 2001).

Enhanced leaching of organic contaminants from microplastics has been demonstrated in the presence of organic matter. If organic matter contents are higher in an organism's gastric environment compared to the surrounding seawater, this could imply enhanced desorption of POPs within the organism (Betts, 2008). As well, a feeding experiment conducted with Shearwater chicks demonstrated that chicks consuming PCB concentrated polyethylene pellets undergo tissue contamination from the PCBs (Betts, 2008). Polyethylene, one of the most concentrated microplastics in the marine environment, has a relatively high capacity to uptake and release organic contaminants, making it more efficient at translocating contaminants than other plastics (Teuten et al., 2009). On the other hand, the study conducted by Koelmans et al. (2013) suggested that plastics may reduce bioaccumulation of POPs in organisms, as equilibrium partitioning between plastics and POPs can dilute free aqueous concentrations. This would decrease bioavailability and bioaccumulation of POPs. As well, if ingested plastic had lower concentrations of POPs than an organism's body tissue, plastic would absorb POPs from the organism tissue, thereby decreasing the concentration of POPs in an organism once the plastic is egested.

Some of the organic contaminants associated with plastics interfere with hormone regulation in animals. BPA monomers and alkylphenol additives have estrogenic effects, while phthalates (a primary plasticizer) have been associated with reducing testosterone production (Teuten et al., 2009). Both BPA and phthalates can act as endocrine disruptors by competing with or disrupting endogenous hormones (Fossi et al., 2012). Each plastic polymer has a different capacity to adhere to different organic contaminants in the water column, therefore each type of plastic and organic contaminant must be analyzed individually, to determine absorption capacities. It would also be relevant to analyze desorption mechanisms of various organic contaminants from plastics in a gastric environment, in order to help quantify the dangers of contaminated plastics.

1.3. Purpose of this study

Urban, intertidal environments are exposed to heightened risk of microplastic contamination because of proximity to microplastic sources. In addition, there are heightened risks of chemical contamination within microplastics, as chemical concentrations are high in urban intertidal environments as well. The goal of this study is to assess microplastic contamination in the intertidal environment of Halifax Harbor, which is an urban estuary on the Atlantic coast of Canada. Various intertidal organisms may be negatively impacted by microplastics, and indirectly, microplastics have the potential to impact humans through the food chain. The results from this study add to the growing body of literature on microplastic contamination around the world, and they are especially pertinent to urban, coastal environments.

The objectives of this research are as follows: the enumeration of microplastics in intertidal sediments as a function of beach location, elevation on the shoreline and grain size distribution; the enumeration of microplastics in the fecal casts of deposit feeders, which in this study are polychaete worm species; and the enumeration of microplastics in wild and farmed blue mussels (*Mytilus edulis*), which are suspension feeders. From 2 protected beach sites, polychaete worm fecal casts and live mussels were collected, processed, and analyzed for microplastic fiber content. In addition, live mussels from an aquaculture site off of Newfoundland and Labrador were purchased from a local grocery store to analyze and compare the microplastic content of wild and farmed mussels.

Cultured mussels are grown in coastal waters that are separated from population centers where adjacent human pollution could threaten the quality of the mussels. Given the relatively pristine nature of mussel culture sites compared to an urban harbor, one can hypothesize that the microplastic load should be lower in farmed mussels. Alternatively, because cultured mussels are grown in plastic sock nets that are suspended on polypropylene long lines (Mussel Farmer, 2013, personal communication), farmed mussels may be exposed to microplastic contamination. The aquaculture site is about 800 km from the wild sites. *M. edulis* is an important organism in the benthic community assemblage, and has been