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Microplastics in the Ocean

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Abstract Since their ubiquity in the ocean and marine organisms was first revealed, global concern about microplastics has grown considerably. The North Pacific Ocean and the adjacent marginal seas have high levels of microplastic contamination compared with the global average. This special issue on microplastics was organized by the North Pacific Marine Science Organization to share information on microplastic pollution in the North Pacific region. The special issue highlights high levels of contamination in the North Pacific both on shorelines and at the sea surface. Particularly high levels of contamination were reported on the western and southern coasts of Korea. Sources, including sewage discharge, aquaculture, and shipyards, were implicated. With the direction and energy of surface winds and currents have an important influence on shoreline patterns of distribution. The special issue also demonstrates potential for ingestion of microplastic by small planktonic organisms at the base of the food chain. A wide range of chemicals are associated with plastic debris and concerns are expressed about the potential for these chemicals to transfer to biota upon ingestion. As an introduction to the topic, this paper provides a brief background on microplastic contamination, highlights some key research gaps, and summarizes findings from the articles published in this issue.

This article represents an introduction to a Special Issue on ‘Microplastics’ in Archives on Environmental Contamination and Toxicology.

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Background

Marine pollution by plastic litter has been a major global environmental issue in recent decades, and global concern over the problems resulting from end-of-life plastic have grown rapidly since the presence of microscopic plastic particles in the ocean and an increasing trend in their abundance were documented in the early 2000s (Thompson et al. 2004, but see also earlier work (Carpenter et al. 1972; Colton et al. 1974; Ryan and Moloney 1990)). Small fragments of plastic litter in the environment present different challenges to larger items, which has been widely documented since the 1960s. As large items fragment into microplastics, the abundance of litter increases, and this effectively increases their availability (encounter rate) to wildlife. In addition, decreasing particle size increases the range of organisms that can ingest the debris (Law and Thompson 2014). Hence, smaller plastics become more bioavailable (or ingestible) particularly to small organisms. In addition, this increased surface area increases the potential for leaching or desorption of additive or adsorbed chemicals to an organism upon ingestion. However, because of their size detecting the presence of microplastics and adverse biological effects, if any, becomes considerably more challenging. In addition, the persistence of plastic particles in the environment can increase because small plastic particles would be extremely difficult to remove from the environment manually.

Engineered micro-sized plastics (primary microplastics), such as cosmetics scrubbers and abrasive beads used in sandblasting, can be introduced directly into aquatic environments by discharge after use or in accidental spills. Microplastics can be generated in the environment via the fragmentation of larger plastic items and litter (secondary microplastics). Global annual plastic production has increased drastically, reaching 299 million tons in 2014 (PlasticEurope 2015). An estimated 4.8–12.7 million tons of plastics entered the ocean from land-based sources in 192 coastal countries in 2010 (Jambeck et al. 2015). If ocean-based sources, such as fisheries and shipping activities, are included, the total input of plastics to the oceans is considerably higher. One estimate for the minimum total quantity of floating plastic litter (>0.33 mm in size) in the oceans is 0.27 tons (5.25 trillion particles), with microplastics (0.33–4.75 mm in size) accounting for 92 % by number of plastic particles and 13 % by weight (Eriksen et al. 2014). However, these data do not include plastics on the seabed (Woodall et al. 2014) and beaches (Browne et al. 2010) or those of particle size 0.001–0.33 mm, which account for the majority of the total abundance of microplastics (Song et al. 2014).

Microplastics have been observed on the shore, sea surface, and seabed from the coast to the open ocean, including the Arctic (Obbard et al. 2014) and Antarctic Oceans (Law and Thompson 2014). They are ingested by diverse biota, such as invertebrates, turtles, fish, birds, and marine mammals (Wright et al. 2013b) and approximately 10 % of the reports of encounters between marine litter and species now relate to encounters with microplastic debris (Gall and Thompson 2015). After ingestion, microplastics could have adverse physical (Wright et al. 2013a, b) and chemical (Browne et al. 2013; Rochman et al. 2013) effects on these organisms due to their small size and associated toxicants (Lithner et al. 2011; Lee et al. 2013), and there are concerns that they could affect the safety of seafood (Seltenrich 2015).

Research Gaps

Since tiny plastic particles were first recorded in surface water and fish in the early 1970s (Carpenter and Smith 1972), little attention was paid to their presence until they were highlighted as “microplastics” in the early 2000s (Thompson et al. 2004). A number of recent review papers and reports have summarised current research gaps and priorities in detail (Thompson et al. 2009; Andrady 2011; Cole et al. 2011; Engler 2012; Syberg et al. 2015; GESAMP 2015; Eerkes-Medrano et al. 2015; Van Cauwenberghe et al. 2015). Although studies have examined the distribution, fate, ingestion, and effects of microplastics to fill knowledge gaps and the number of scientific publications has increased exponentially over the past decade (GESAMP 2015), more questions than answers remain. Among the many important topics, a key issue is to determine how harmful current and anticipated future levels of microplastic pollution in the coastal and open ocean actually are. This can only be achieved by considering the probability of encounter and the severity of any effects resulting from encounter in a risk assessment matrix. This needs to be considered for wildlife, natural habitats, and human health.

Such risk assessments require data on the exposure and effects of the various sizes, shapes, and polymer types of microplastics and their associated toxic chemicals on various marine organisms and humans. The factorial combination of these parameters requires vast datasets that need to be generated using harmonized or standardized experimental approaches. Furthermore, although research has examined the occurrence and distribution of microplastics in the environment and organisms, and their adverse biological effects studied in laboratories, considerable inconsistencies remain in the sampling and hence quantification of microplastics in the environment. Whereas for microplastics in sediments very small particles have been isolated (Hidalgo-Ruz et al. 2012), floating microplastics are typically monitored using a >0.33-mm neuston net and only a few studies have examined plastics of tens of μm in size due to the technical barriers in sampling and analysis. By contrast, the effects of microplastics have mostly been studied in plastic particles ranging in size from nanometers to tens of micrometers, and it has been suggested that these could be more likely to have detrimental effects on the biota. Consequently, it is currently very challenging if not impossible to compare field monitoring data with laboratory toxicity data. This could be resolved by studying the combined physical and chemical effects of microplastics by simulations of the natural environment. However, this requires the development of test materials including standardised microplastics of various known sizes, shapes, polymer types, and chemical additive. Nanoplastics have not been quantified in the environment but are likely to be present in considerably greater numbers than micro- and millimeter-sized plastics. Successful detection and quantification of nanoplastics in the environment could provide an entirely new perspective on the scale of microplastic pollution. In addition, few studies have examined the processes, rates, and conditions for generating secondary microplastics from diverse large plastic litter in the environment. Much remains unknown regarding the environmental consequences of microplastic pollution, and more detailed studies are required to assess the ecological and human health risks.

Papers Presented in this Special Issue

This special issue on microplastics follows the session on marine plastic litter held by the North Pacific Marine Science Organization (PICES) in Yeosu, South Korea, October, 2014. The North Pacific Ocean and its marginal seas have the highest microplastic contamination levels in the world (Eriksen et al. 2014; Song et al. 2014; Cózar et al. 2015). Therefore, it is important to collect and share information on microplastic pollution in the North Pacific region among global scientific and policy audiences. Eleven papers, including this one, were selected for publication in this issue, focusing mainly on the occurrence and distribution of microplastics in surface water and on the seashore in Far-east Asia, and in zooplankton or sediment samples in the Northeast Pacific or North America. The highest levels of global seawater microplastic contamination, including micro-sized paint resin particles, were reported along the western (Chae et al. 2015) and southern (Song et al. 2015) coasts of Korea. High accumulation of microplastics in the sea-surface microlayer was found, and intensive monitoring in near shore waters combined with polymer composition profiles revealed varied input sources, such as sewage discharge, aquaculture farms, and shipyards (Chae et al. 2015; Song et al. 2015). The highest microplastic contamination in the world was recorded on sand beaches in Korea, and a significant relationship was found among the meso- (5–25 mm in size) and large micro-plastics (1–5 mm) (Lee et al. 2015). The inter- and intra-beach microplastic abundance and distribution were influenced by the direction and transporting energy of winds and currents (Kim et al. 2015a). Accumulation of microplastics in sediments increased the ammonium concentration in the overlying water in laboratory experiments (Cluzaud et al. 2015). Ingested microplastics fibers were found in copepods and euphausiid zooplankton collected from the Northeast Pacific Ocean (Desforges et al. 2015). Pretreatment method was proposed to identify microplastics in fish stomach using Raman spectroscopy, and microplastics were detected in three fish from European seas (Collard et al. 2015). The potential impact of microplastics on zooplankton feeders also was assessed by measuring the ratio by abundance of neustonic microplastics to zooplankton in the Southern Sea of Korea (Kang et al. 2015). More than 200 chemicals were detected in marine plastic debris and their original products, and a comparison of them indicated the leaching or absorption of chemicals from or to plastic debris (Rani et al. 2015). The total unaccounted mass of high- and low-density polyethylene in the marine environment in Korea was estimated at 28 million tons for the period 1995–2012 (Kim et al. 2015b).

These papers substantially increase our understanding about levels of contamination and potential effects on biota. It is clear from this volume and other recent studies (Obbard et al. 2014; Woodall et al. 2014) that some locations and habitats contain substantial accumulations of microplastics; yet estimates of the quantity of plastic debris in the environment indicate that there may still be unreported additional sinks for microplastic debris. Such data are essential to inform risk assessments, because it will facilitate appropriate calculation of encounter rate. We also need to better understand the potential for physical or toxicological harm associated with such encounters. Research in this volume helps to illustrate the complexity of this issue and the challenges in assessing harm. For instance, they are the multiple permutations of size, shape, and potential toxicant burden both by concentration and chemicals and issues associated with interactions among the complex mixtures of chemicals that are found in the environment. Resolving these complex interactions between biological encounter and types of harm will be particularly challenging. Yet, there are indications of substantial accumulation in the environment and based on laboratory studies illustrations of the potential for physical and toxicological harm. Plastics bring many societal benefits, yet nearly all of these can be achieved without the emissions of end-of-life plastic to the ocean. To focus scientific endeavour, it is important to engage with policy makers to identify the key evidence required to move toward solutions that reduce inputs of debris to the oceans. Solutions are known and some would argue that a key challenge is balancing the need for more information about impacts with the need to take action to reduce inputs (Koelmans et al. 2014).

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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