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Review article

Occurrence of microplastics and its pollution in the environment: A review

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ABSTRACT

The pollution caused by microplastics in seas and fresh water is of growing environmental concern due to their slow degradability, biological ingestion by fish and other aquatic living organisms, and acting as carriers to concentrate and transport synthetic and persistent organic pollutants. As well as microplastics, chemical additives added to plastics during manufacture which may leach out upon ingestion, will enter food chains and potentially cause humans serious health problems.

Regulations in many counties/regions have been setup or to be implemented to ban the production/sale and use of primary microplastics (e.g., microbeads), which could reduce microplastics in the aquatic environment in certain level. However, the fragments from larger plastic items (second microplastics) are major contributors, and then new legislations have to be proposed and implemented in order to substantially reduce the amounts of microplastics in the environment and the associated environmental impact. Moreover, approaches and measures are to be taken by encouraging companies and all users to adopt the Reduce–Reuse–Recycle circular economy as this will represent a cost-effective way of reducing the quantity of plastic objects and microplastics particles entering and gathering in the marine/aquatic environment.

Keywords: Distribution and occurrence of microplastics; Environmental effects; Legislation; Reduce–Reuse–Recycle circular economy

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Microplastics are defined as plastic fragments with the size of less than 5 mm. A most recent study however, suggests that the definition of microplastics should consider fragments smaller than 1 mm (Browne et al., 2015). The pollution caused by microplastics in marine and freshwaters is of growing environmental concern due to their slow degradability, biological ingestion by aquatic living organisms, and acting as carriers to concentrate and transport synthetic organic

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Table 1 – Concentrations and weight of microplastics reported for various geographical areas.

Location	Maximum or average Concentration (average weight)	Reference
Open ocean, Northwest Atlantic	Maximum 67 000 particles/km^2	Colton et al. (1974)
Northwest Atlantic (offshore)	Average 67 items/m^2	Colton (1974)
Subtidal sediment, UK	Maximum 86 particles /kg	Thompson et al. (2004)
Industrial harbour sediment, Sweden	Maximum 3320 particles/L	Norén (2008)
Subtidal sediment, Maine	Maximum 105 particles/L	Graham and Thompson (2009)
Coastal waters, Sweden	Maximum 102 000 particles /m^3	Norén and Naustvoll (2010)
Beach, Malta	Maximum >1000 particles/m^2	Turner and Holmes (2011)
Beach, East Frisian Islands, Germany	Maximum 621 particles /10 g	Liebezeit and Dubaish (2012)
South Pacific subtropical gyre	Average 26 898 items/km^2 (70.96 g/km^2)	Eriksen et al. (2013a)
Yangtze estuary, China	Average 4137.3 ± 2461.5 items/m^3	Zhao et al. (2014)
NE Pacific Ocean	9 180 particles/m^3	Desforges et al. (2014)
La Graciosa Beach, Canary Islands	90 g/L	Juan et al. (2014)
Western Mediterranean	Average 135 items/m^2 (187 g/km^2)	Faure et al. (2015)
Mediterranean	Average 0.243 items/m^2 (423 g/km^2)	Cozar et al. (2015)

substances (e.g. persistent organic pollutants), from environment to aquatic organisms including fishes.

Although several published researches have detailed major issues on the topic of microplastics and the relevant environmental and health impact, there are a few of papers to explore the development of regulations and management policies to control widespread microplastics in the environment.

This paper thus does not only present updated information with regards to the sources/distribution/fate and potential adverse effects of microplastics, but provides a comprehensive review on the development of microplastics regulations and management policies. Although worldwide regulations developed propose to ban the production/sale and use of microbeads (type of primary microplastics), the fragments from larger plastic items (second microplastics) are major contributors, and then new legislations have to be proposed and implemented in order to substantially reduce the amounts of all plastic items into the environment. Additionally, advances in the development of approaches and methodology to monitor and analyse microplastics are introduced. Moreover, cost-effective ways of reducing the quantity of plastic objects and microplastics particles entering and gathering in the marine/aquatic environment are suggested. And finally, the research needs in this area are recommended.

1. Sources, distribution and occurrence of microplastics in the aquatic environment

Microplastics from primary sources entering aquatic systems through household sewage discharge (Fendall and Sewell, 2009) include polyethylene, polypropylene, and polystyrene particles in cleaning and cosmetic products. Other primary microplastics include those of industrial origin in spillage of plastic resin powders or pellets used for air-blasting (Gregory, 2009), and feedstocks used to manufacture plastic products (Lechner et al., 2014). Microplastics originating from secondary sources are those that are undergoing fragmentation processes (e.g., via ultraviolet light exposure) from larger plastic items, which are thought to be major contributors to the substantial amounts of microplastics presenting in the environment (Eriksen et al., 2014). Secondary microplastics arising as fibres from washing clothes, are mainly made of polyester, acrylic, and polyamide, and may reach more than 100 fibres per litre of effluent (Habib et al., 1998).

Table 1 shows examples of distribution and abundance of microplastics in oceans worldwide over the last four decades. Present on beaches, in surface waters, throughout the water column and the sediments, microplastics have pervaded even the most remote marine environments (Ivar do Sul et al., 2009). Analyses of ice cores collected from remote locations in the Arctic Ocean revealed levels of microplastics ranging between 38 and 234 particles/m^3 (Obbard et al., 2014), two orders of magnitude greater than those previously reported in the Pacific gyre (Goldstein et al., 2012). However, observations of floating microplastics in surface Antarctic and Arctic waters (Barnes et al., 2010), in the deep Arctic seafloor (Bergmann and Klages, 2012) and in stomachs of birds from the Canadian Arctic (Mallory, 2006; Provencher et al., 2009), further suggest polar areas as an additional global sink of plastics.

While a considerable amount of work is focusing on microplastics in the marine environment, relatively new studies suggest that microplastics present as equally ubiquitous in surface waters, urban estuaries and discharged municipal wastewater effluents. Table 2 summarizes distribution and abundance of microplastics in various surface waters, wastewater effluents and river sediment.

Data in Table 2 are mainly for the secondary microplastics but primary microplastics have been detected, too, in these resources. They are of household origin, of a similar size, shape, colour and elemental composition as microbeads from commercial facial cleansers, and have been confirmed in samples from North American Great Lakes (Eriksen et al., 2013b). Primary microplastics released from plastic production sites have been detected in samples from the Danube River, Lake Huron, and Lake Erie (Lechner et al., 2014). The data from Edgbaston Pool (Vaughan et al., 2017, see Table 2) represent the first sediment microplastic concentrations for a small lake which are relatively low, but factors used to determine their concentrations were similar to that for large waterbodies, e.g., site-specific lake characteristics; distribution and rate of sediment accumulation; prevailing wind directions; relationship with inflow streams and the properties of the microplastic particles themselves. In comparison with marine studies, the extraction of microplastics is likely to be more problematic for lake sediments due to the increased prevalence of organic matter and the greater discolouration of the microplastics (Vaughan et al., 2017).