

Microplastics in Polar Regions: The role of long range transport

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Abstract

Microplastics (particles <5 mm) pose a threat to the marine ecosystem that is disproportionate to their tiny size. They have been found in high numbers in sea water and sediments, and are interacting with organisms and the environment in a variety of ways. Recently their presence has been confirmed in Polar water, sediment, and sea ice. We review the recent literature on microplastic distribution and transport in marine environments, primarily in the Northern Hemisphere, summarize current understanding, identify gaps in understanding, and suggest future research priorities.

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Current Opinion in Environmental Science & Health 2018, 1:24–29

This review comes from a themed issue on **Micro and Nanoplastics**

Edited by **Dr. Teresa Rocha-Santos**

For a complete overview see the [Issue](#) and the [Editorial](#)

<https://doi.org/10.1016/j.coesh.2017.10.004>

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Keywords

Microplastic, Ocean, Pollution, Polar, Arctic, Transport.

Introduction

Given the ubiquity of plastics, no one should be surprised that they have made their way into the most remote environments. Microplastics, manmade polymers <5 mm in their largest dimension, have been found in seawater, sea ice and sediment in Polar Regions [1,2*,3*,4]. Because these regions are thinly populated and remote, long range transport must play a key role.

Microplastics are common in other parts of the world's oceans. They have been found in over 90% of surface water samples worldwide, as well as in coastal and benthic sediments [5,6]. They are taken up by marine organisms, including many that are commercially fished, and cause direct physical and toxicological harm. Their potential act as vectors for other organic pollutants is also of enormous concern [7–15].

In order to address the problem, we need to better understand how microplastics are distributed in the Polar Regions, both geographically and within the marine

ecosystem. Long range transport is an important part of the picture not only because it supplies the Polar Regions, but also because it affects the size distribution of debris. In short, while it is taking place, debris is fragmented into more pieces, which can affect more organisms [16].

Over the past 42 years, there have been many efforts to collect marine microplastics, the majority in the North Atlantic and North Pacific accumulation zones, but increasingly in other parts of the world. The recent study by Munari et al. [4] is the first to document microplastic presence in the Antarctic, but there is overall far less data available for the Southern Hemisphere. Thus here we will draw examples from the Northern Hemisphere and the Arctic. It can be assumed that transport of microplastics to Antarctica is taking place through similar mechanisms. Because it is farther from major sources of production and use, transport to that region may take longer and fragments may be on average smaller. This may mean that biofouling, sedimentation and uptake will yield differences in the amounts, sizes and locations of microplastics found there. But the basic long range transport mechanisms and our reasons for concern remain the same.

Data: microplastic types and sources

Types of microplastics in the environment

Microplastics are found in every part of the marine environment: in the air, water, coastal and deep sea sediments, and in marine animals [6,7,17–19]. There are fragments of larger plastic objects that have been broken by mechanical (e.g. wave) action, films from plastic bags or other packaging, and pellets from pre-production plastics and personal care products. Fibers, which are defined by a width to length ratio of 1 to ≥ 1.5 , and include polypropylene (PP), polyester, polyamide, acrylic, and polyethylene (PE), come from clothing, disposable diapers, cigarette filters, and marine industry [20,21*]. Common types of synthetic plastics are PE, PP, Nylon 6.6, polystyrene butadiene styrene (SBS), polyvinyl chloride, polystyrene, thermoplastic polyurethane, and ethylene propylene rubber. Anthropogenic sources also contribute fibers of natural polymers, such as wool, cotton, bamboo, silk and rayon. The objective of a given study will determine whether these are important to include or not.

Quantity and sources of microplastics in the environment

The annual PlasticsEurope report [22] is a widely used source of annual worldwide production. In 2015, 269 million metric tons (MT) of thermoplastics and

polyurethanes, the largest categories, were manufactured. If we include thermosets (most rubber products) as well as adhesives, coatings and sealants, there were 322 million MT of plastic manufactured in 2015.

Most plastic debris enters the sea through waste streams, but it's difficult to determine exactly how much the waste stream carries, and even more difficult to know how much of that makes it into the ocean. Efforts to do so have been based in large part on solid waste management figures and population density. Using these and economic variables, Jambeck et al. [23] estimated that 275 million MT of plastic waste was generated in 192 coastal countries in 2010, 4.8 to 12.7 million MT of which entered the ocean through the waste stream. Lebreton et al. [24] have developed a global model that puts the riverine input at between 1.15 and 2.41 million MT [24]. Other, lesser sources include fishing boats (losses of nets and line) and input from sporadic natural disasters such as floods [25]. Plastics that are denser than seawater soon sink unless filled with air (e.g. disposable water bottles made of polyethylene terephthalate). But buoyant polymers travel long distances [26].

Finding and identifying microplastics in the Polar marine environment

Globally, many efforts have been made to sample microplastics in water, sediments, and marine organisms. Attempts to aggregate this data, however, are hampered by the different sampling methods used [27**]. While spatial and temporal heterogeneity in source and polymer type produces uncertainty on the input side, sampling methods can bias our understanding of the microplastic budget in transport. Most devices used to sample microplastics were designed for other purposes; and capture and separation techniques differ for each part of the marine ecosystem: surface water, the water column, coastlines, benthic sediment, biota, and ice. Different sampling techniques capture different sized particles. Even for a specific marine environment, sampling methods can differ from study to study, depending on the location being sampled, the reason for sampling, and the available equipment.

In this section, we discuss collection methods in general and give examples from Polar Regions. We do not include sampling from marine biota, but there is growing knowledge on ingestion of plastics by fish that could lead to an estimate of the biological reservoir and potential for transport [27**].

Water

Unlike larger debris, which may float proud of the surface and be subject to wind stress, microplastic particles are entirely submerged, and this slows their transport [28]. It can take many months or even years for microplastics to cross the Pacific Ocean, for example [25].

In the ocean, surface collection is generally done by towing a plankton, manta, or neuston net. Mesh sizes range from 0.1 to 3 mm, 0.333 or 0.335 mm are common, so smaller microplastic particles may be missed and the total quantity of microplastics underestimated [21*,27**]. On the other hand, nets can capture, and researchers may count, particles larger than 5 mm [29]. Sampling can also be done using a vessel's on board sea water pump, but these are typically located at depths of 4–6 m so don't capture the surface fraction [25].

Recently, Cózar 2017 reported that most of the surface ice-free waters in the Arctic Polar Circle are slightly polluted with plastic debris, which is abundant and widespread in the Greenland and Barents Seas [3*]. They also found 37% of the samples in the circumpolar track were entirely free of plastic, but it's possible that this is related to the collection method - they used a 0.5 mm mesh net, and excluded fibers from their count - or to the size-segregation processes discussed later.

It is difficult to compare or combine the results of studies using different sampling methods. Statistical methods can be used to resolve sampling method biases [27**]. Van Sebille [27**] did this to produce a standardized data set from 27 floating debris studies over all major ocean basins, except the Arctic, over the 42 years ending in 2013.

Sediment

Marine sediment includes sand collected on beaches and benthic sediment collected from depths of tens or hundreds of meters. Microplastics are separated from sediment by density-based extraction and filtration, and solvents used to segregate manmade polymers from biota. Once this is done, polymer types can be identified using Fourier Transform Infrared Spectroscopy or Raman spectroscopy [29].

Many coastline sediment surveys have been conducted around the world [e.g. [30]]. Just as is the case with surface water sampling, they're not conducted in any geographically systematic manner. To our knowledge, none have been done in the Arctic Basin.

Munari et al. [4] used a Van Veen grab (surface area 0.18 m²) to collect benthic sediment from locations near Italy's research station in Terra Nova Bay (Ross Sea, Antarctica). They found higher concentrations of microplastics at the locations closest to shore, which perhaps unsurprisingly contained a high fraction of SBS, a hard durable rubber used for boot soles and vehicles. About half of all manufactured plastics have a density higher than that of seawater and therefore a higher settling velocity - these are less likely transported long range (>1000 km). However, Munari et al. [4] also found nylon in all samples, which could have come from local or remote sources.

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