

## Lost at Sea: Where Is All the Plastic?

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Millions of metric tons of plastic are produced annually. Countless large items of plastic debris are accumulating in marine habitats worldwide and may persist for centuries (1–4). Here we show that microscopic plastic fragments and fibers (Fig. 1A) are also widespread in the oceans and have accumulated in the pelagic zone and sedimentary habitats. The fragments appear to have resulted from degradation of larger items. Plastics of this size are ingested by marine organisms, but the environmental consequences of this contamination are still unknown.

Over the past 40 years, large items of plastic debris have frequently been recorded in habitats from the poles to the equator (1–4). Smaller fragments, probably also plastic, have been reported (5) but have received far less attention. Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (6). Many “biodegradable” plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (6). Some cleaning agents also contain abrasive plastic fragments (2). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

To quantify the abundance of microplastics, we collected sediment from beaches and from estuarine and subtidal sediments around Plymouth, UK (Fig. 1B). Less dense particles were separated by flotation. Those that differed in appearance to natural particulate material (Fig. 1A) were removed and identified with Fourier Transform infrared (FT-IR) spectroscopy (7). Some were of natural origin and others could not be identified, but about one third were synthetic polymers (Fig. 1C). These polymers were present in most samples (23 out of 30), but were significantly more abundant in subtidal sediment (Fig. 1D). Nine polymers were conclusively identified: acrylic, alkyd, poly (ethylene:propylene), polyamide (nylon), polyester, polyethylene, polymethylacrylate, polypropylene, and polyvinyl-alcohol. These have a wide range of uses, including clothing, packag-

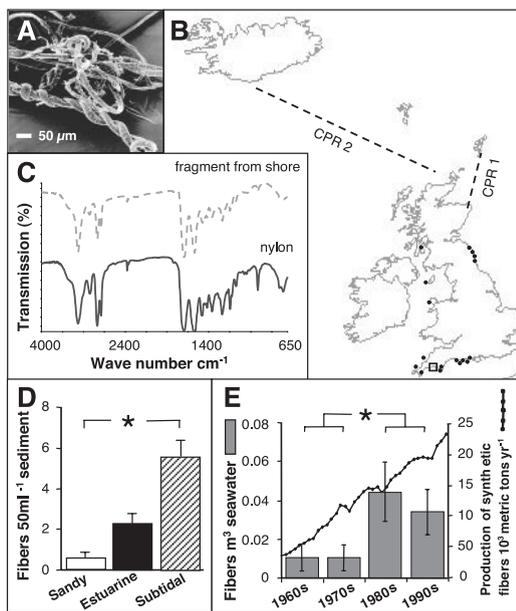
ing, and rope, suggesting that the fragments resulted from the breakdown of larger items.

To assess the extent of contamination, a further 17 beaches were examined (Fig. 1B). Similar fibers were found, demonstrating that microscopic plastics are common in sedimentary habitats. To assess long-term trends in abundance, we examined plankton samples collected regularly since the 1960s along routes between Aberdeen and the Shetlands (315 km) and from Sule Skerry to Ice-

land (850 km) (7) (Fig. 1B). We found plastic archived among the plankton in samples back to the 1960s, but with a significant increase in abundance over time (Fig. 1E). We found similar types of polymer in the water column as in sediments, suggesting that polymer density was not a major factor influencing distribution.

It was only possible to quantify fragments that differed in appearance from sediment grains or plankton. Some fragments were granular, but most were fibrous, ~20 μm in diameter, and brightly colored. We believe that these probably represent only a small proportion of the microscopic plastic in the environment, and methods are now needed to quantify the full spectrum of material present. The consequences of this contamination are yet to be established. Large plastic items can cause suffocation and entanglement and disrupt digestion in birds, fish, and mammals (3). To determine the potential for microscopic plastics to be ingested, we kept amphipods (detritivores), lugworms (deposit feeders), and barnacles (filter feeders) in aquaria with small quantities of microscopic plastics. All three species ingested plastics within a few days (7) (fig. S1).

Our findings demonstrate the broad spatial extent and accumulation of this type of contamination. Given the rapid increase in plastic production (Fig. 1E), the longevity of plastic, and the disposable nature of plastic items (2, 3), this contamination is likely to increase. There is the potential for plastics to adsorb, release, and transport chemicals (3, 4). However, it remains to be shown whether toxic substances can pass from plastics to the food chain. More work is needed to establish whether there are any environmental consequences of this debris.



**Fig. 1.** (A) One of numerous fragments found among marine sediments and identified as plastic by FT-IR spectroscopy. (B) Sampling locations in the northeast Atlantic. Six sites near Plymouth (□) were used to compare the abundance of microplastic among habitats. Similar fragments (●) were found on other shores. Routes sampled by Continuous Plankton Recorder (CPR 1 and 2) were used to assess changes in microplastic abundance since 1960. (C) FT-IR spectra of a microscopic fragment matched that of nylon. (D) Microplastics were more abundant in subtidal habitats than on sandy beaches (\*,  $F_{2,3} = 13.26$ ,  $P < 0.05$ ), but abundance was consistent among sites within habitat types. (E) Microscopic plastic in CPR samples revealed a significant increase in abundance when samples from the 1960s and 1970s were compared to those from the 1980s and 1990s (\*,  $F_{3,3} = 14.42$ ,  $P < 0.05$ ). Approximate global production of synthetic fibers is overlain for comparison. Microplastics were also less abundant along oceanic route CPR 1 than along CPR 2 ( $F_{1,24} = 5.18$ ,  $P < 0.05$ ).

### References and Notes

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### Supporting Online Material

www.sciencemag.org/cgi/content/full/304/5672/838/DC1  
Materials and Methods  
Fig. S1  
References and Notes

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Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (6). Many biodegradable plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (6). Some cleaning agents also contain abrasive plastic fragments (2). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris. (E) Microscopic conclusively identified: acrylic, alkyd, plastic in CPR samples revealed a significant increase in poly (ethylene:propylene), polyamide abundance when samples from the 1960s and 1970s were compared to those from the 1980s and 1990s (\*, F3,3 (nylon), polyester, polyethylene, poly- 14.42, P 0.05). Where is all the plastic? Because plastic has such a low density compared to water, it is easily transported far and wide by ocean currents, winds and rivers. Whether it drifts along the surface or is carried along the seafloor, there is no part of the ocean that has not been touched by plastic pollution. "At least 267 different species are known to have suffered from entanglement or ingestion of marine debris including seabirds, turtles, seals, sea lions, whales, and fish." It becomes frozen into icebergs and Arctic sea ice. Plastic is even affecting volcanoes, creating new rocks that are going to scar our world for millions of years. Large volumes of plastic accumulate within five oceanic "garbage patches", also known as gyres, located in the Atlantic, Indian and Pacific Oceans. Thompson, Richard C. ; Olsen, Ylva ; Mitchell, Richard P. ; Davis, Anthony ; Rowland, Steven J. ; John, Anthony W G ; McGonigle, Daniel ; Russell, Andrea E. / Lost at Sea : Where Is All the Plastic?. In: Science. 2004 ; Vol. 304, No. 5672. pp. 838. @article{c266b0e78ae0463ba0eddac8dbe4b9cf, title = "Lost at Sea: Where Is All the Plastic?", author = "Thompson, {Richard C.} and Ylva Olsen and Mitchell, {Richard P.} and Anthony Davis and Rowland, {Steven J.} and John, {Anthony W G} and Daniel McGonigle and Russell, {Andrea E.}", year = "2004" Research output: Contribution to journal Article. Ty - jour. T1 - Lost at Sea. T2 - Where Is All the Plastic? AU - Thompson, Richard C. AU - Olsen, Ylva.