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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, packaging, 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 Iceland (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.

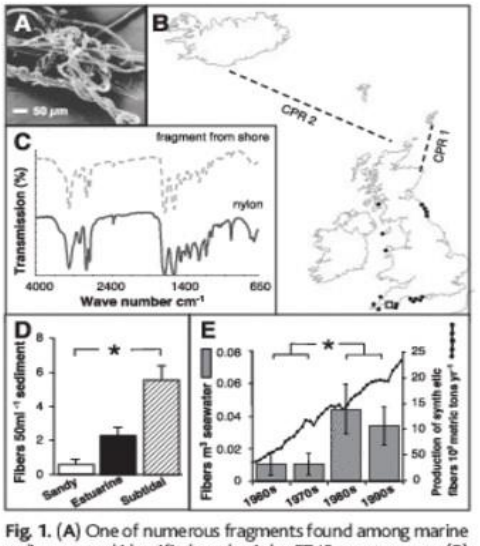

Fig. 1. (**A**) One of numerous fragments found among marine sediments and identified as plastic by FT-IR spectroscopy. (**B**) Sampling locations in the northeast Atlantic. Six sites near Plymouth (□) were used to compare the abundance of microplastic among habitats. Similar fragments (●) were found 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 ($F_{1,24} = 5.18$, $P < 0.05$).

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.

References and Notes

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7. Materials and methods are available as supporting material online on *Science* Online.
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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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In the past 60yrs, it is estimated we have made more than 8.4 billion Ton of plastics. Most of it has now ended up in landfills or directly in our natural environment of land, air & sea. In fact, only 9% of the plastic used today is recycled & recycling cost is so huge it is usually sitting in a dumpster somewhere.

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For more information refer to GSCE website to get the latest updates
Enquiries : Shankar (HP: 9248 7875) / Lok (HP:9149 8652)
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Microplastics in the Ocean

We can pinch ourselves to see if the plastic industry did more harm than good or vice versa. There are indications the ship captain jumped the ship as the environmental news & articles fill up many spaces in the net saying the situation is dire unless the plastic production is braked immediately.

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Up to 12 Million Ton of plastic enter the oceans every year. This corresponds to one garbage truck per minute. Plastic waste on the streets can also get into the ocean via drainage networks or rivers (illegal dumping).

According to estimates, the world's major rivers transport up to 2.41 MTon of plastic into the sea each year, which corresponds to 100,000 garbage trucks.

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- Plastics (polymers, microplastics or plastics) are the causes of the global environmental pollution.
- Floating plastic continents in several oceans, plastic bag-eating turtles, dead whales with plastic garbage stomachs are shown everywhere in the last few years and have received serious media coverage and attention.

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- Microplastics were first detected in large numbers in the world's oceans in 2004. That made one thing very clear, the violator bought and paid off any obstacles on their way.
- Technology developers do not perform adequate environmental risk assessment or have considered any methodology for plastic recycling or disposal capability.

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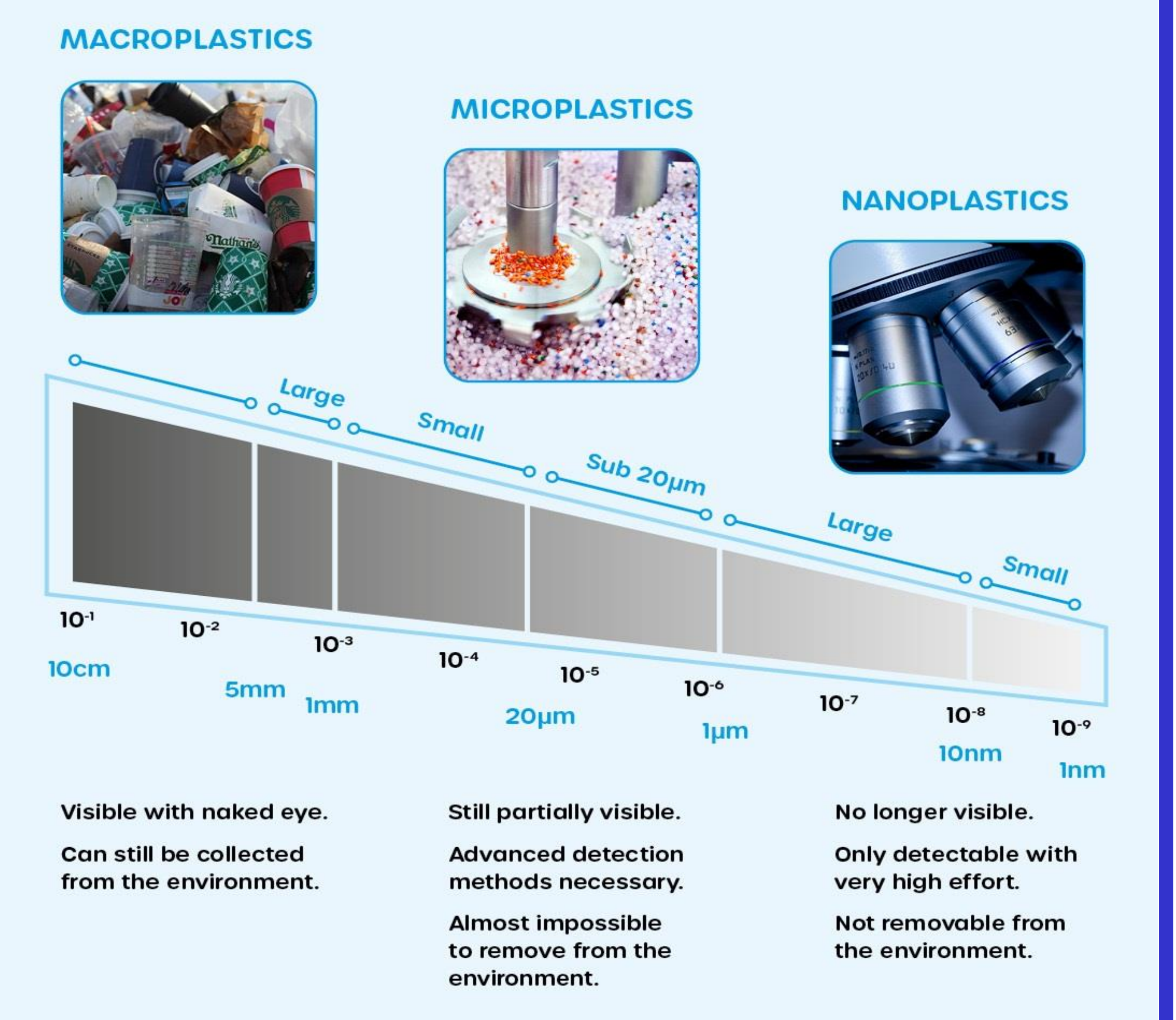

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• *Where do we stand when it comes to microplastics?*

Microplastics is a new research area with many known hazards left dangling. Science, industry, and politics are facing enormous challenges in order to grasp the phenomenon in all its complexity and to find effective solutions against the further spread of microplastics. If we want to understand what is hidden behind the term and research field of microplastics, we must direct our attention to the way we deal with plastics: from production and use to disposal or reuse. Here we have put together a few facts about the current situation.

There are different definitions of microplastics and differentiations from, for example, nano plastics. In the meantime, however, there is broad consensus that plastic fragments smaller than 5 mm should be referred to as microplastics.

The current definition *of the term microplastics is as follows*

•**Microplastics** describes the entirety of all synthetic plastics and their products, which are **smaller than 5 mm in size and which are either released directly into the environment or formed indirectly in the environment**.

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- *What* types *of microplastics are there and what are examples of them?*.
- ***Microplastics*** – *Microplastic plastics < 5mm*
- ***Primary Microplastics Type A*** *- Microbeads, pellets, polymer abrasive*
- ***Primary Microplastics Type B*** *- Tyre and fiber abrasion*
- ***Secondary Microplastics*** *- Littering, weathering of microplastics in the environment*

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Primary Microplastics Type A categorizes and regards microplastics as a chemical.
This category includes the types that are added directly to products (e.g. personal care products, cleaning agents, paints, etc.). This proportion is already often replaced by water-soluble polymers ("liquid microplastics"). Products are then often "advertised" with the addition "free of microplastics" or "without microplastics".

The category **Primary Microplastics Type B** includes plastic particles that are created through the use of plastic products and that are directly (without detours) released into the environment as microplastics

Secondary microplastics include all microplastic particles that are formed in the environment as a result of the slow decay of large plastic parts. This can happen through all kinds of external influences, e.g. through the influence of UV rays, bacteria or friction.

What is behind the terms primary and secondary microplastics?

Microplastics in the environment: how does it get into the environment, how is it distributed and why is it becoming a global environmental problem?

In general, a distinction is made between indirect and direct entry routes. Indirect entry paths are found when plastic objects break down into smaller and smaller components due to UV radiation, oxidation and / or mechanical effects. Ultimately, millions of microplastic particles are created in our ecosystems (Law et al., 2014). Depending on their individual composition, they distribute quickly or slowly in water, soil, and the air.

Microplastics can also get into the environment directly: through tire abrasion, synthetic textile fibers that are released when clothes are washed, care products such as peelings that contain microplastic particles. Industrial wastewater is also one of the major sources of input. (Boucher et al., 2017)

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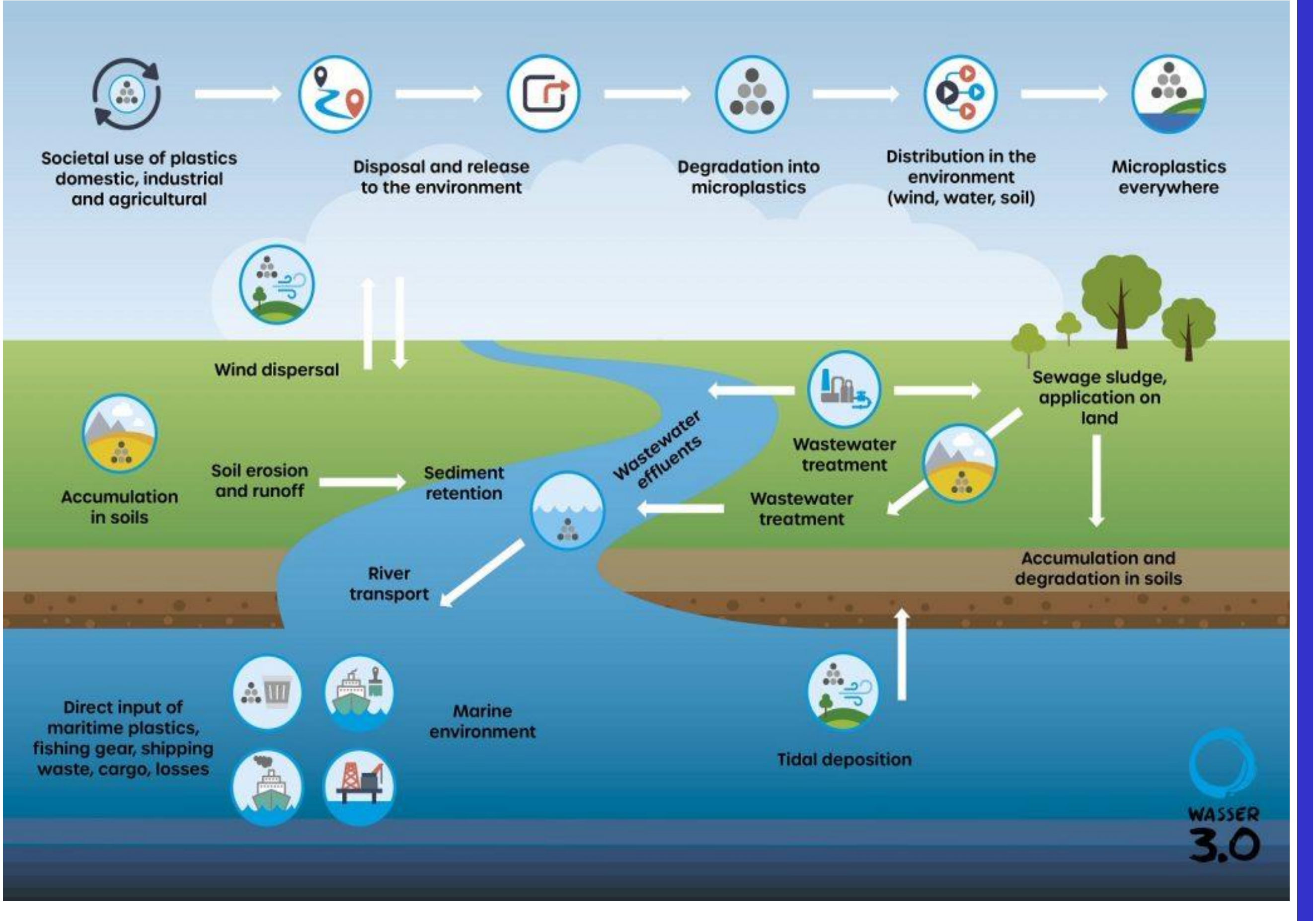

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The proximity to heavily populated areas and inadequate waste management lead to particularly high levels of contamination. Point sources such as sewage treatment plants or the plastics industry are also important influencing factors. Furthermore, contamination with microplastics is influenced by transport processes such as wind, water currents, ebb and flow and surface runoff from rain.

In general, limnic ecosystems are more heavily contaminated with microplastics than marine ecosystems, since microplastics can be distributed more widely in the enormous volume of marine ecosystems. Plastic and microplastics collect in so-called "garbage patches" because of converging ocean currents.

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How dangerous are microplastics?

There is heated discussion and research about how dangerous microplastics are for humans, animals, and the environment. Mainly due to their small size (≤ 5 mm), microplastics pose a threat to animals and the environment, as they are accessible to many organisms and are kept and eaten for food, for example. In addition, each microplastic particle has an individual composition due to previous production, use and disintegration processes. Extremely harmful micropollutants such as residues of plasticizers, heavy metals, PFOS or pharmaceuticals can adhere to microplastics. This increases the risk of physical and toxicological damage to organisms and ecosystems caused by microplastics (Law et al., 2014).

Microplastics are also transported or accumulated within the food chain. They also get into the human body (FAO, 2016). The nature of the consequences for human health and how harmful this will ultimately be cannot currently be foreseen.

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What can we do to reverse the damage?

- Banks to perform proper environmental risk assessments and to study the recycling & bio-degradability of any new materials introduced prior lending or writing off insurance
- The equator principal guidelines shall be adopted to prevent the environmental damage

- Properly qualified and trained environmentalist along with qualified material engineers to take charge of any new materials being developed. The industries & investors shall not be making decisions for the banks.
  There shall only non-polluting and 100% recyclable products in the development phase for any products.
- Aluminium shall be used where possible
- Al can be used for blow moulding to replace polyethylene bags

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What can we do about the crisis

- we can select alternative recyclable material comparable to plastic
- do proper environmental risk assessment to cover equatorial principle and identify the threats and dodge the bullets
- search and re-cap all the genies which are running aimless back to the bottle
- recyclable materials such as steel shall be studied to perform advanced mixing to reduce metal weight lower with certain low density by alloying for containers