



CTA-198-Where did the plastic go?

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The missing 99%: why can't we find the vast majority of ocean plastic?

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US news

What scientists can see and measure, in the garbage patches and on beaches, accounts for only a tiny fraction of the total plastic entering the water

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Plastic retained in front of an extended cork line in the Pacific ocean. A Dutch inventor says that after setbacks his system for catching plastic floating in the Pacific between California and Hawaii is now working. Photograph: AP

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Every year, 8m tons of plastic enters the ocean. Images of common household waste swirling in vast garbage patches in the open sea, or tangled up with whales and seabirds, have turned plastic pollution into one of the most popular environmental issues in the world.

But for at least a decade, the biggest question among scientists who study marine plastic hasn't been why plastic in the ocean is so abundant, but why it isn't. What scientists can see and measure, in the garbage patches and on beaches, accounts for only a tiny fraction of the total plastic entering the water.

So where is the other 99% of ocean plastic? Unsettling answers have recently begun to emerge.



Humans have made 8.3bn tons of plastic since 1950. This is the illustrated story of where it's gone

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What we commonly see [accumulating at the sea surface](#) is “less than the tip of the iceberg, maybe a half of 1% of the total,” says Erik Van Sebille, an oceanographer at Utrecht University in the Netherlands.

“I often joke that being an ocean plastic scientist should be an easy job, because you can always find a bit wherever you look,” says Van Sebille. But, he adds, the reality is that our maps of the ocean essentially end at the surface, and solid numbers on how much plastic is in any one location are lacking.

It is becoming apparent that plastic ends up [in huge quantities](#) in the deepest parts of the ocean, buried in sediment on the seafloor, and caught like clouds of dust deep in the water column.

Perhaps most frighteningly, says Helge Niemann, a biogeochemist at the Royal Netherlands Institute for Sea Research, it could fragment into such small pieces that it can barely be detected. At this point it becomes, Niemann says, “more like a chemical dissolved in the water than floating in it”.

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The 276 miles of coastline that runs from the narrow mouth of San Francisco Bay, past the open water of Monterey Bay to the scenic mountains and redwood forests of Big Sur, is the land border of America's largest National Marine Sanctuary. To anyone visiting the beaches near Santa Cruz or driving the coastal highways, it appears remarkably unspoiled. That is not the whole story.



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Plastic waste and trash is seen on Versova beach in Mumbai, India. Photograph: Punit Paranjpe/AFP via Getty Images

For the past two years, scientists from the nearby Monterey Bay Aquarium Research Institute have been using customised remote-control submersibles to take samples of the near-invisible plastic drifting far below the surface. “Just because you don’t see it, doesn’t mean it isn’t there” says Anela Choy, a professor of oceanography at the University of California San Diego, and the lead researcher on the project. Below what she calls the “skin surface” of the ocean, the submersibles carefully filter seawater and take a snapshot of what’s in it.

Her [team found that at a depth of 200m](#), there were nearly 15 bits of plastic in every liter of water, similar to the amount found at the surface of the so-called garbage patches. The remote samplers were still finding plastic at their maximum depth of 1km. But it is just the start of the hunt. “After two to three years of work the honest truth is we have only one set of samples from one portion of the world’s entire ocean,” she says.

The group’s work is among the first to count the exact amount of plastic below the ocean surface, and to show that plastic waste is abundant at lower depths. Scientists have speculated about this for years. Richard Thomson, the oceanologist who first coined the term “microplastic” in 2004 to describe difficult-to-capture bits under 2mm in length, has suggested that large amounts could be found in the deep ocean and sea floor.

And a 2017 paper from Van Sebille’s group predicted that, based on the amount of plastic entering the ocean and the potential ways it is known to sink, 196m tons of plastic may have settled from the surface into the deep ocean since 1950.

The next steps are to show where the plastic comes from, and to ascertain how it moves from the surface, where it is relatively easy to both find and track, to the depths.

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The conventional view is that it is very hard to track ocean microplastic back to its source. But even very small bits of plastic don't necessarily look the same. By examining how laser light scatters when it hits different bits of plastic, researchers can create a fingerprint. The plastic found in Monterey Bay, for example, didn't resemble the plastics used in local fishing equipment, but was mostly Polyethylene terephthalate (PET), a polymer used in disposable packing, indicating it probably came from land.

How plastic descends to the deep ocean is, for the most part, a mystery. Because of its low density, most commercial plastic floats. It needs help to get below the surface. Plastic can become attached to ocean detritus that sinks, or fragment under the sun or waves, or find its way into something's stomach.

Choy's team identified two kinds of animals, red crabs and translucent, filter-feeding creatures called giant larvaceans, which consume plastic and moving it to deeper water – either by eating it near the surface and expelling it lower down, or in the case of the larvaceans, in a layer of mucous they periodically discard and let sink.

This sort of unwitting animal transit has been observed in many species. A 2011 study examining plastic in fish in the north Pacific Ocean estimated that they ingested around 12,000 tons a year. In a later paper Van Sebille's group noted that if the number held across the entire ocean, 100,000 tons of plastic could be inside animals at any one time.

The search for the missing maritime plastic has opened new frontiers of research. A decade ago the discovery of microplastics sparked a radical shift in the conception of plastic pollution. Scientists revealed the existence of billions of pieces of plastic almost too small to see, definitely too small to catch, and easily eaten by the tiniest sea creature. Now they are making startling new discoveries about the extent of plastic pollution.



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Plastic waste washed up at Greta Beach, Christmas Island, Australia. Photograph: Daniela Dirscherl/Getty Images/WaterFrame RM

On a cool, gray June day in London, Alexandra Ter Halle, a researcher with Paul Sabatier University, in France, was on a sailboat just below Tower Bridge taking samples of water from the Thames. It was the crew's first stop on a tour of 10 European estuaries, and the other scientists on board were doing familiar work, counting microplastic particles with microscopes, and characterising the bacteria in the samples.

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Ter Halle's samples, though, would have to wait until she was back at her university, where she has specialized equipment for the detection of nanoplastics – plastics that have broken down to sizes below a thousandth of a millimeter, smaller than a single cell.

Two years ago her group was the first to detect these particles in seawater. Ter Halle employs techniques similar to those used by forensic scientists to detect chemicals at crime scenes: the samples are ignited into a gas, bombarded with electrons, and separated across an electric field to measure their weight and charge. They can't be conventionally seen, only detected.

Nanoplastic research is still in its infancy. But laboratory tests show that unlike microplastics, nanoplastics are small enough to accumulate within the bloodstreams and cell membranes of a range of organisms, even passing the blood-brain barrier in a test on Japanese medaka fish, and cause various toxic effects, including neurological damage, and reproductive abnormalities.

"This question of where is all the plastic in the sea ... For 40 years we sought out plastic we could see. Now we reach the nanoscale, which is very particular, very reactive, and we have to begin again," says Ter Halle.

The huge amounts of plastic on the ocean surface were what originally sparked public and scientific interest in the plastic problem. In this way, they acted like a buoy, pointing the way to something much larger beneath the surface. The deep ocean is, as Choy puts it, "the world's largest habitat". We're just beginning the accounting of how much of our plastic has ended up there.

- This article was amended on 2 January 2020 to set out the full name of the Monterey Bay Aquarium Research Institute.

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