Unwelcome enrichment in the Arctic

Microscopic plastics infiltrate Arctic sea ice with unknown consequences for the ecosystem.

By Michon Scott

The Great Pacific Garbage Patch between California and Hawaii might evoke images of a trash heap floating on the ocean, but it consists of particles too small to be seen by the naked eye. Those particles are plastic.

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Fifty years ago, global annual plastic production was less than 50 million tons; in 2015, production was nearly 450 million tons. Every year, between 5 and 14 million tons of plastic reach the ocean, and that is just from coastal regions.

Plastic polymers are molecular chains that repeat the same simple links. Common examples include polyester clothing, nylon toothbrushes, polycarbonate DVDs, and polyethylene shopping bags. Besides everyday conveniences, plastics such as inflatable life vests and single-use medical devices save lives. Plastics are inexpensive, lightweight, and durable, but their durability poses a problem because they take several hundred years to decompose. Scientists now wonder about the effects of plastics on wildlife and human health.

In the ocean, wind, waves, temperature swings, and sunlight break plastics into microscopic bits. In 2004, marine ecologist Richard Thompson coined a term for these particles: microplastics. Anything smaller than five millimeters (about a fifth of an inch) is considered a microplastic, but microplastics can get much smaller—down to a fraction of the width of a human hair. Even biodegradable plastics leave microplastics behind, and microplastics reach locations as remote as the Arctic.

A plastic particle smaller than five millimeters (about a fifth of an inch) is defined as a microplastic, but many microplastics are too small to be seen with the naked eye. (Courtesy National Oceanic and Atmospheric Administration)

Small size, big trouble

Ilka Peeken is a senior scientist at the Alfred Wegener Institute (AWI) in Bremerhaven, Germany. She originally trained as a phytoplankton ecologist, but switched her focus to the Arctic and the threats posed to it by climate change. “A lot of people don’t know this, but sea ice has its own ecosystem. You have tiny algae, worms, and copepods that live in the sea ice and depend on that habitat for food. The organisms living in the sea ice are a big source of food for the higher levels in the polar food chain,” she said. Plastic has now been found in this habitat. “Plastic particles are very tiny, and the organisms can’t differentiate between plastic and food they should be eating.”

Ingested microplastics may leave animals feeling full while offering no nutrition. The particles may obstruct diminutive digestive tracts. Particles inside smaller organisms can be ingested by larger organisms. Peeken said, “But it gets worse because the next step is nanoplastics.”

The smallest plastic particles are best measured in microns and nanometers. A millimeter is a thousandth of a meter, a micron is a thousandth of a millimeter, and a nanometer is a thousandth of a micron. For reference, a human hair is somewhere around 50 to 75 microns in diameter. What constitutes a nanoplastic is still debated, but is probably anything less than a micron across, and getting eaten and excreted by some animals can push plastics from one category into another. Passing through a small gut might break particles with a diameter of 31.5 microns down to a single micron across.

Peeken explained what is so scary about these tiniest plastics. “They’re able to penetrate cells,” she said.

Geir Wing Gabrielsen of the Norwegian Polar Institute echoed Peeken’s concerns, saying, “Nanoplastics embedded in phytoplankton get eaten by zooplankton and then by fish. Those particles are getting into the fish’s blood, passing through the blood-brain barrier, and affecting behavior.” Research has already shown nanoplasticinduced mortality in small crustaceans, and brain infiltration in fish. Other effects remain poorly understood. What is no longer mysterious is how widespread microplastics have become in global oceans.

Plastic is everywhere.

Nicknamed the water flea, *Daphnia magna* is a tiny crustacean that frequents freshwater environments. Research has indicated that nanoplastic particles can be fatal to these animals. (Courtesy Dieter Ebert/Wikimedia)

Cores of the problem

Microplastics in ocean water end up in sea ice when that water freezes. Peeken and her colleagues designed a study to identify the extent to which microplastics have penetrated Arctic sea ice. She explained that counting microplastics in sea ice offers some advantages over studying microplastics in the water column. “If you do water sampling, you have to make sure you don’t contaminate your samples,” she said. “In the lab, it’s easier to control the temperature and keep dirt out of the air. Then you can look for what is in the ice.”

In June 2014, and June and August 2015, the German icebreaker *Polarstern* collected ice cores from five locations. The expeditions drilled cores in sea ice in Fram Strait, north of Svalbard, and in the Nansen Basin. One of the locations in Fram Strait was from landlocked ice; the others were from drifting ice. Back at the lab, researchers cleaned the cores from the outside then let them melt. Next, they filtered the water and subjected the particles to infrared radiation. “Once you bombard each particle, it has a certain absorption or reflection, and that allows you to identify the optical fingerprint of each type of microplastic. It’s different for paint particles versus fishing gear particles,” Peeken said.

Peeken’s team found up to 12,000 particles per liter of sea ice—two to three orders of magnitude higher than the findings of a previous study that relied more on visual inspection. Most of the microplastics Peeken’s team found were smaller than 50 microns across, and the infrared microscope could detect particles as little as 11 microns. That was not down to the level of nanoplastics, but it was a more in-depth sample than in the previous study.

Peeken and her colleagues were surprised at the quantity of microplastics. “We found huge numbers compared to what is in the water column,” she said. Sea ice accumulates more than its fair share of microplastics, a process known as enrichment.

Researchers on the German research icebreaker *Polarstern* collected multiple sea ice cores in June 2014, and June and August 2015 to assess microplastic concentrations. (Courtesy Stefanie Arndt/Alfred Wegener Institute)

Retracing steps

The ice cores were illuminating, but they only told part of the story. Sea ice does not circulate as quickly as seawater, but it does travel. All the ice cores Peeken's team examined were collected along the Transpolar Drift, part of a larger circulation pattern in the Arctic. Except for the landlocked ice core, the cores did not form where they were extracted—different core sections came from different parts of the Arctic Ocean.

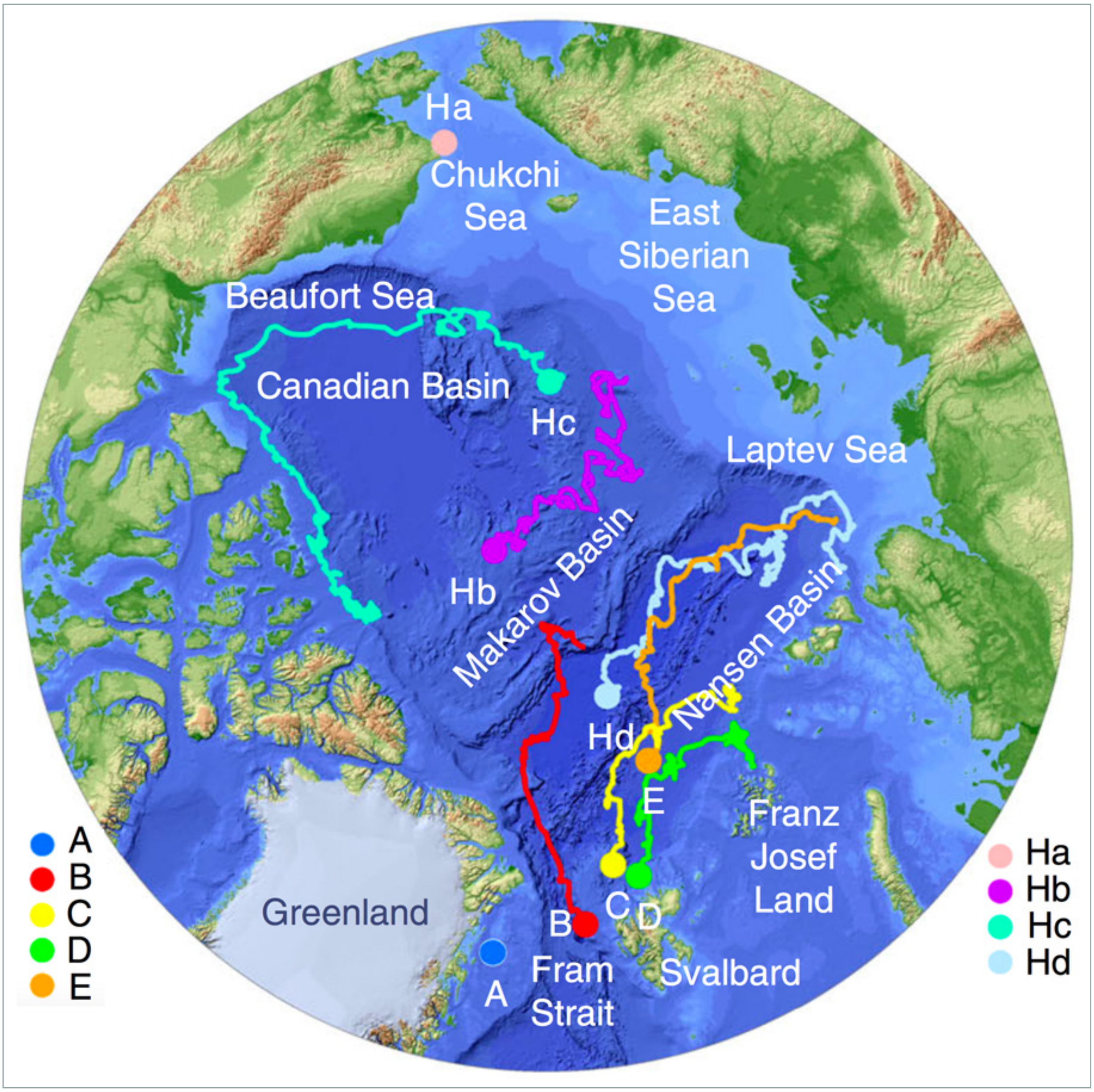
To figure out where the ice cores were at various stages in their formation, the team used multiple data sets. “We use sea ice motion to find the microplastic source areas,” said Thomas Krumpen, one of Peeken's coauthors and a fellow senior scientist at AWI. One data set that helped the team backtrack the microplastics' journeys was the Polar Pathfinder Daily 25 km EASE-Grid Sea Ice Motion Vectors, available from NASA's National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC). Drawing from a range of buoy and satellite observations, these data provide monthly, weekly, and daily sea ice motion and velocity. By identifying ice features in separate satellite images, and measuring the change in a feature's location and the time difference between the images, researchers can estimate ice movement. The time series runs from October 1978 through February 2017. Krumpen wrangled ice locations to follow sea ice movement during the Northern Hemisphere summers. “Even a low-resolution data set provides an approximation of the ice source,” he said. “It enables us to link observations in the field with ice movement observed by satellite.”

Movement through the Arctic is complicated, but in a rough sense, water enters the Arctic from the Pacific, traveling through the Bering Strait. Water and ice exit the Arctic via the Fram Strait east of Greenland. NSIDC DAAC sea ice data sets enable researchers to better estimate ice location at a particular time. Combining ice core samples and backtracked ice movement enabled the researchers to identify microplastic sources.

“You can envision the ice formation depending on where the ice travels,” Peeken said. “We found extremely high polyethylene in the central Arctic.” These are plastics used in bags and packing material, and the most likely source is the Great Pacific Garbage Patch. "What we totally didn't expect was to have such a huge variability with the polymer types," she said. Instead, the team found over a dozen different plastic polymer types, including polymers linked to paint and nylon, likely originating from sources in the Arctic, where transport and fishing are on the rise. Increased human presence is becoming more apparent in the Arctic Ocean. Already modeling studies suggest another garbage patch may be forming in the Barents Sea north of Siberia.

Toxicology specialist Gabrielsen was not involved in Peeken's study, but he was as surprised as Peeken at the high numbers of nanoplastic particles, especially in the Fram Strait. As the Arctic's exit ramp, the Fram Strait is the conduit for nearly all the plastic contamination in Arctic sea ice. He now wonders how much plastic animals living in and on the ice are consuming. "It's something we really need to clarify," he said.

Peeken hopes to better understand why nano- and microplastics concentrate more in sea ice than in sea water. Because most of the Arctic food chain in some way depends on sea ice, plastic enrichment in the ice leads to plastic enrichment in the food chain. Meanwhile, Krumpen anticipates using NSIDC DAAC data more often to understand ice transport in general. But Peeken and Krumpen are both sobered by the findings of this study. "There's basically no place on Earth anymore where you don't find microplastics in the ocean," said Peeken. "I think that's important for people to know. Otherwise they don't change their behavior."



This ice-core location map shows the reconstructed sea ice movement for cores collected by the *Polarstern* crew in 2014 and 2015 (A through E), and cores collected by earlier expeditions, in 2005 and 2010 (Ha through Hd). Cores A and Ha came from sea ice holding fast to a shoreline, but other cores came from drifting sea ice. Ice velocity and ice motion data helped the researchers reconstruct ice motion from the core samples. (Courtesy I. Peeken, et al., 2018, *Nature Communications*)

For more information

NASA National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC)

NASA Aqua Earth-Observing Satellite Mission

Advanced Microwave Scanning Radiometer for EOS (AMSR-E)

Advanced Very High Resolution Radiometer (AVHRR)

SMMR, SSM/I, and SSMIS Sensors

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About the remote sensing data	
Satellites	Aqua; Defense Meteorological Satellite Program F8, F11, F13, and F17; National Oceanic and Atmospheric Administration-9, -11, -12, and -14; Nimbus-7
Platforms	Buoys

About the remote sensing data	
Sensors	Advanced Microwave Scanning Radiometer for EOS (AMSR-E) Advanced Very High Resolution Radiometer (AVHRR) Scanning Multichannel Microwave Radiometer (SMMR) Special Sensor Microwave Imager (SSM/I) Special Sensor Microwave Imager/Sounder (SSMIS)
Data set	Polar Pathfinder Daily 25 km EASE-Grid Sea Ice Motion Vectors (NSIDC-0116)
Resolution	25 kilometer
Parameters	Ice velocity, sea ice motion
DAAC	NASA National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC)