Microplastics in the Arctic, a Growing Concern.

By Cesar A. Garcia

Clear evidence of the presence of plastic waste in the Arctic.

https://cdn.theatlantic.com/thumbor/lkl3iJS7CmhJVQp_EwCEOglh-h4=/0x51:2066x1213/720x405/media/img/mt/2017/04/RTX131B9/original.jpg

Lately, plastic has been making headlines. One that you may have heard about recently is how in New York City, starting March 1st of this year, it is no longer legal for stores to distribute plastic bags to their customers (https://www.dec.ny.gov/chemical/50034.html). Stores there will now charge 5 cents for paper bags instead, or customers can provide their own reusable bag. Cities, states (e.g. California, USA https://www.calrecycle.ca.gov/plastics/carryoutbags), and even entire countries (e.g. Costa Rica https://borgenproject.org/costa-rica-bans-single-use-plastics/) around the world have been enacting similar bans on single use plastics such as bags and Styrofoam food containers.

Plastic has also been in the news due to the fact that Asian countries such as China and Malaysia, are no longer accepting shipments of plastics from other countries (https://www.cbsnews.com/news/recycling-after-chinas-plastic-ban-american-cities-face-recycling-crisis/). This is a problem because most of the plastic that people put in recycling bins does not get recycled in the US, as it is not profitable to do so. It was cheaper to ship it to other countries and let them either recycle or dump it. Since China stopped accepting plastic in 2017, US city and town recycling programs have been stuck with all the plastic. The communities now have to figure out what to do with it. Past evidence suggests that some of it will probably end up in landfills, and at least a portion will end up in the world's oceans.

Ad for ban on plastic bags. https://www.iheartoswego.com/media/k2/items/cache/d12208b2

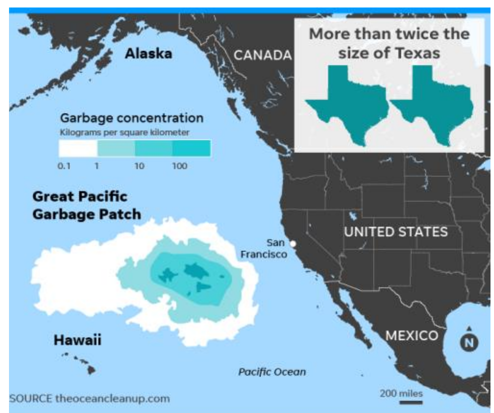
Plastic being deposited at a landfill.

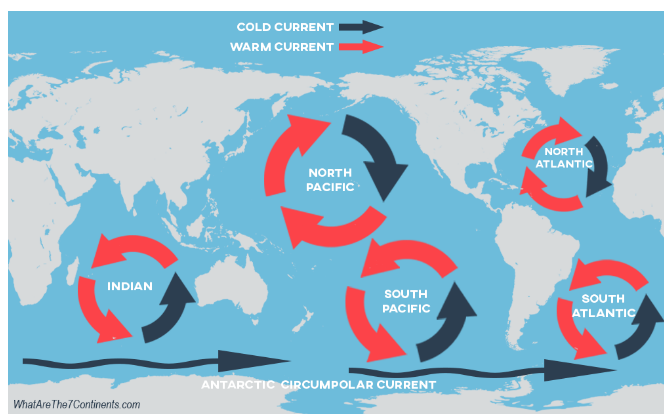
https://cdn.downtoearth.org.in/library/large/2019-05-08/0.70805800_1557322314_te.jpg

Plastic in the Oceans

We have known about plastic ending up and accumulating in the world's oceans, since the 1970's (Barnes et al., 2009). It was then that people began to notice the how plastic garbage was ruining scenic views on land and in the ocean. Barnes et al. (2009) states that it was not long after that people began to become concerned about wildlife becoming entangled in the plastic.

Unfortunately, due to its durability, inexpensiveness, and almost unlimited applications, plastic production has been increasing ever since the 1950's. The resulting plastic waste increased as well, leading to the present day situation where huge amounts of plastic can be spotted floating at sea. You have probably heard about one such location, "the great Pacific garbage patch", and how it is supposed to be as big as the state of Texas. That garbage patch is located in one of five areas of the world known by





Top: Representation of the "Great Pacific Garbage Patch"

Bottom: The location of 5 oceanic gyres, where plastic is commonly found.

https://www.gannett-cdn.com/media/2018/03/21/USATODAY/USATODAY/636572386247113311-032118-great-garbage-patch-Online.png scientists as oceanic gyres. These are areas of the world where large circular oceanic currents are formed by the Earth's rotation as well as global wind patterns. Due to oceanic circulation, plastic that falls into the ocean eventually makes its way to one of these gyres.

Plastic reaches the ocean in various ways. Some falls off of ships, and some, breaks off from fishing equipment like nets and ropes. However, a large portion of the plastic in the oceans came to rest there after being discarded on land, and being carried by wind and water into rivers which carried it to the sea. Sewage systems deliver large amounts of plastic that comes off of clothes when it is washed, as well as plastic that is contained in some cosmetic items (Desforges et al., 2015). This results of human activity explain why large amounts of plastic can be found near most heavily populated centers on or near coastlines.

Plastic floating at the surface of a body of water. This is a common site in many places in the world.

https://angeles.sierraclub.org/sites/angeles.sierraclub.org/files/plasticgyre.jpg

Microplastics in the Oceans

For a long time and even to this day, when most people thought about plastic as a problem in the ocean, they thought about how it negatively affects the beauty of beaches and therefore the tourism industry. They also thought about images they have seen of wildlife getting entangled in it plastic. In fact these are two of the main reasons that are brought up in support of the recent bans on plastic. A much less recognized problem was the effects that plastic pieces smaller than 5 mm known as microplastic, may have on oceanic ecosystems. This has been changing over the last decade or so.

Researchers are now recognizing the large amount of microplastic that is entering the ocean. It has been calculated that in 2014 there was at least 5 trillion pieces of plastic in just the top 10 cm of the world's oceans (Forrest and Hindell, 2018). Another study found that as much as 8 million metric tons of plastic entered the ocean in the year 2015, and that the number will increase to 32 million metric tons by 2050 (Fang et al., 2018). This number includes all sizes of plastic, but microplastic is known to make up 92% of total marine plastic.

Microplastic comes from two sources, the first is known as primary microplastic, this is plastic that was originally produced as less than 5 mm. These primary MP is used in common as abrasives in cosmetics, as well as in industry.

Left: Cosmetic wash advertising its use of micro-beads.

Right: Close up the plastic micro-beads found in cosmetic washes. These beads are released into wastewater and then into the environment.
https://d2eehagpk5cl65.cloudfront.net/img/c800x450-w800-q80/uploads/2019/08/zumaamericasfifteen293955-800x450.jpg

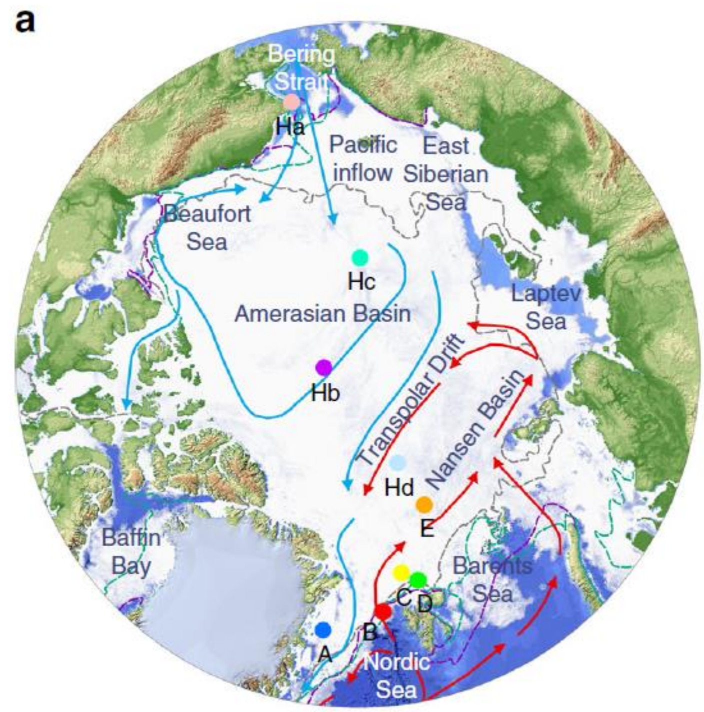
The other source is when pieces of plastic larger than 5 mm breaks down. The break down can be due to factors in the environment such as from intense sunlight exposure, freeze thaw action, and collision with rocks, corral, other plastic items etc. In the case of MP fibers, they can be released from clothing when it is washed. Microfibers have been found on the shores of all the worlds' continents (Waller et al., 2017).

Examples of secondary microplastic. https://journals.openedition.org/factsreports/docannexe/image/5290/img-2-small580.jpg

Is Microplastics Present in the Arctic?

Microplastic is usually thought to be located near large human population centers (Waller et al., 2017). However, it has been found at both the North and South Poles (Barnes et al., 2009), neither of which have large human populations. Not only has it been found, but according to some researchers (Lusher et al., 2015) the levels in some areas of the Arctic Ocean are even greater than at the Pacific Gyre.

How can this be? Researchers believe that due to their low densities microplastic particles are easily transported by the ocean currents. So microplastic may be entering Artic waters from the North Pacific through the Bering Strait, and from the North Atlantic through the Fram Strait and Barents Sea (Peeken et al., 2018). There is also the possibility that some microplastic may reach Artic waters by way of rivers that discharge into it, but this would not be a major source due to the already mentioned lack of a large human population in the area and along those rivers (Obbard et al., 2014).



Currents entering Arctic Ocean. Adapted from Peeken et al., 2018

What does Climate Change have to do with it?

Break up of sea ice.

https://www.carbonbrief.org/wp-content/uploads/2018/09/Arctic-sea-ice-minimum-2018-1550x804.jpg

Microplastic in the Arctic Ocean has been found floating on the surface, below the surface, within sediments at the bottom, and even encased in sea ice (Fang et al., 2018). In fact, researchers believe that sea ice may be have a big effect in the quantity of microplastic present in the Arctic. One interesting aspect of the roll of sea ice in relation to microplastic is that it may not only freeze microplastic, but it may be actively accumulating it. Obbard et al. (2014) explains that sea ice is formed by separating fresh water ice crystals from saltwater, and growing downward. As the ice crystals grow they take up small particles in the water around them. They explain that due to its irregular shape and low density, microplastic is easier to capture and keep than natural particles like sand and silt. This process causes the sea ice to contain higher numbers of microplastic than the surface waters around it, more than twice as much! A separate study by German researchers supports these findings (Peeken et al., 2018). Both of these studies believe that this is one way which microplastic may be transported further into the Central Arctic Basin.

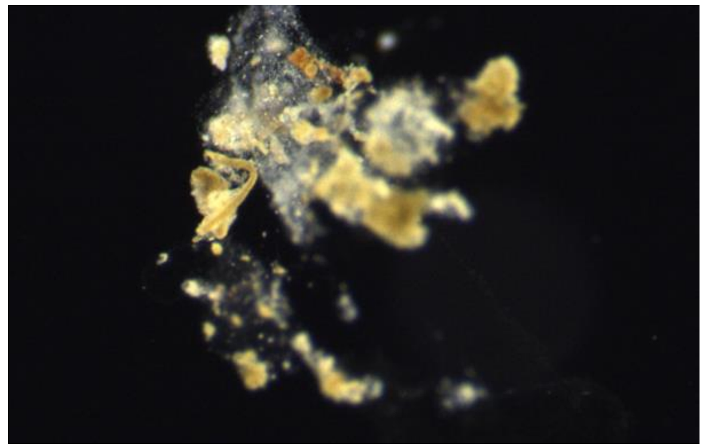
The researchers studying microplastic within sea ice believe that sea ice can block some microplastic from entering the Artic. This would happen when extensive sea ice is present and blocks surface mixing, such as during the Arctic winter. Unfortunately, global warming has reduced the extent, thickness, and duration of Arctic sea ice. This means that currents coming from the plastic heavy North Pacific, which normally would have been blocked for large periods of time are now regularly entering the Arctic and bringing more plastic with them.

The microplastic that does make it through the Baring strait and into the Artic surface waters is now available to be captured within sea ice when temperatures are cold enough. This also occurs with water coming in from the North Atlantic, which also contains large amounts of plastic. This plastic heavy sea ice not only serves to store the plastic, but also to transport it throughout the Arctic, as was demonstrated in the study by Peeken et al. (2018). This means that the microplastic may be able to travel farther than it would have otherwise. Once temperatures warm up enough for the sea ice to melt, large quantities of microplastic are released back into the water.

Microplastic distribution in the Arctic Ocean

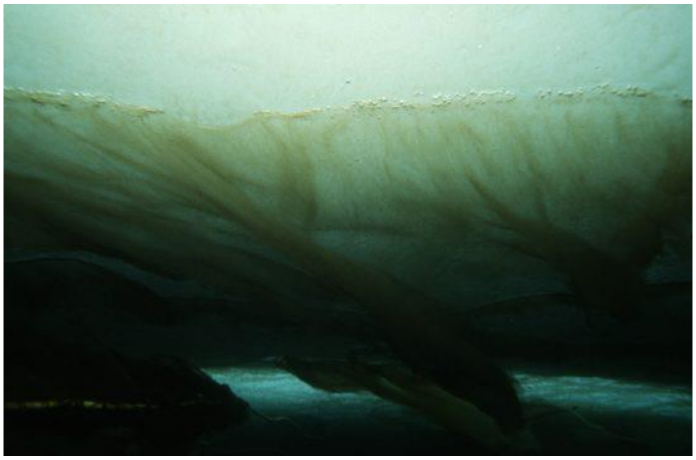
Now that we have established how a warmer climate can help to distribute microplastic in the Arctic environment, let's see how it is distributed vertically. We can do this by continuing to follow the microplastic that was released from the sea ice. Heavier plastics such as PVC, nylons, and PET, which can be found in everything in everyday items such as furniture, tubing used in plumbing, and toys, will sink without assistance. Microplastic with lower densities such as polyethylene (used in plastic bags), polypropylene (used in food containers such as yogurt cups), and polystyrene (used in foam packaging, as well as food and beverage containers) can normally remain at the surface, but will eventually sink by various methods (Bergmann et al., 2017).

Kanhai et al. (2018) describes the following mechanisms for the sinking of microplastic: 1) In fecal pellets - Microplastic ingested by marine organisms can be excreted in densely packed fecal pellets. The pellets can sink to the bottom or be ingested by other marine organisms as they sink. 2) Biofouling – the microplastics accumulate contaminants from the environment which increases its density, causing it to sink. 3) Marine aggregates – clusters of some species of algae have been shown to envelope and concentrate microplastics particles causing both the microplastic and the algae to sink.



Marine Aggregate (Marine Snow)
https://www.oceanblogs.org/capeverde/wp-content/uploads/sites/6/2019/12/Marine_Snow_01.jpg

The last method mentioned bears further examination. Bergmann et al. (2017) found a relationship of the presence of chlorophyll a to that of microplastic particles. This supports the marine aggregate mechanism. This mechanism could be an important one in Arctic waters, where "the ice algal diatom known as *Melosira arctica* forms dense aggregates beneath the sea ice" (Bergmann et al., 2017). The researchers states that when the sea ice melts, the microplastic might be enveloped by the aggregates and sunk rapidly to the bottom. They mention at least one other form algae (*Phaeocystis pouchetii*), that produces a gel that can absorb microplastics.



Melosira Arctica https://blog.mares.com/wp-content/uploads/2016/01/2-4-550x360.jpg

Although more research is needed in order to explain how exactly microplastic is reaching the sea floor, it is clear that it is doing so. Various studies around the world have found microplastic in sediments from shallow seas, shelfs, and abyssal plains (Fang et al., 2018). This has now been confirmed to also be the case in the Arctic (Bergmann et al., 2017; Fang et al., 2018).

It is logical that if microplastic has been found in the surface waters as well as in the sediments of the Arctic marine environment, then the subsurface waters in between must also contain microplastic. Various studies have touched on this topic (Auta et al., 2017; Fang et al., 2018; Kanhai et al., 2018).

So there is Microplastic in the Arctic Marine Environment, why does it matter?

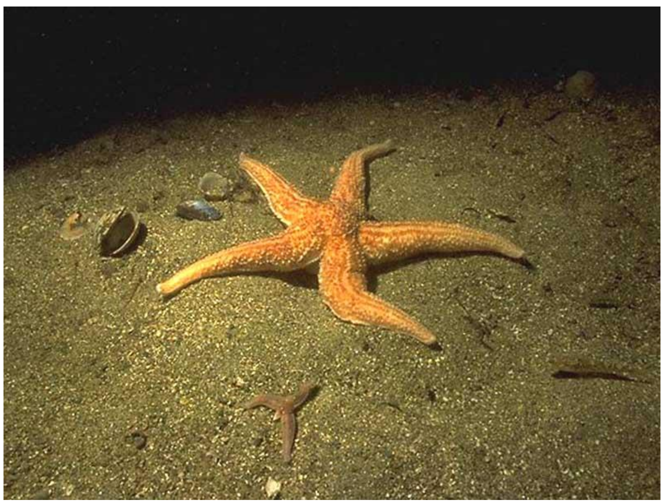
The Arctic is a unique environment. What makes it so? Kanhai et al. (2018) lists the following reasons: 1) The presence of perennial pack ice at its center. 2) Extremes in its exposure to sunlight, from constant daylight in the summer, to eternal night in the winter. 3) Extreme amounts of ice and snow cover. 4) Low temperatures. 5) The layer of lower salinity water that results from ice melt laying above denser saltier water. These factors all combine to provide an ecosystem which although being difficult to live in, provides a home to many forms of live that are found nowhere else and thrive there. Some of these Arctic organisms, such as phytoplankton, are crucial to the food chain, providing nutrition to local higher tropic organisms such as zooplankton, and to migratory organisms such as whales, which go there specifically for the high amounts of plankton present (Auta et al., 2017). Human beings also depend on many of the resources of the Arctic. Indigenous people to the area depend nutritionally and culturally on the hunting walrus, seals, and whales, as well as on fishing (Demuth, 2019). People that live outside the Arctic also depend on some of the organisms there, some for income as seasonal workers on fishing boats, and others for nutrition from the fish, crabs, and other benthic organisms that are exported to lower latitudes (Bergmann et al., 2017).

Organisms exposed to microplastic through the Arctic food web.

How does microplastic affect Arctic organisms?

Microplastic has been found in the feces, stomach, tissues, and gills of various marine organisms. They have been found in foraminifera, bivalves, starfish, fish, rays, sharks, seals, whales, and seabirds to name only a few. The effects of microplastic on Arctic marine life is still being studied, but there are already some negative effects which have been noted, such as: clogging digestive tracts, decreasing mobility, a decrease in algal photosynthesis and growth, reduced feeding and energy reserves in lugworms, reduced filtering activity in mussels, reduced feeding and reproduction in copepods, as well as stress on the liver and endocrine disruption in fish. In addition to the damage that the microplastic itself can do, it can also carry pathogens, chemicals, and heavy minerals that can all lead to negative effects such as cancer, malformations, and even death of Arctic species. People are also susceptible to these negative effects (Auta et al., 2017).

The higher up the food chain you go, the higher levels of microplastic you are likely to find. This is simple to understand. If each mussel only contains 1 particle of microplastic, a walrus that eats 100 mussels will automatically have eaten 100 pieces of plastic. Although the walrus will probably eliminate some of the microplastic with its feces, it is highly probable that due to the high numbers of microplastic it takes in, it will probably retain at least a few.



Common Starfish (*A. Rubens)* an apex benthic predator found to ingest microplastic.

Conclusion

Microplastic is definitely present in the Arctic. While it may not be clear how bad of an effect it will have on Artic Ecology, it will definitely affect at least some life there. Although it seems to not cause any harm to some organisms in which it just passes through their digestive system (Desforges et al., 2015), it definitely does have negative effects on others, such as how it can lower the energy and reproduction of some benthic organisms, and how it can cause inflammation and stress in the liver and other organs in fish (Auta et al., 2017). All of these confirmed negative effects are likely to increase as the number of particles entering the Arctic environment increases due to the warming temperatures melting the sea ice. As the sea ice melts it will release microplastic which has been stored within. The melting ice will also allow more microplastic to be transported into the Arctic from the North Pacific and the North Atlantic, both of which we have established as having large amounts of plastic. This is an added stress to creatures already having to deal with changes in reduced sea ice, increased water temperature, increased acidity, and introduction of new species that are arriving from lower latitudes. Much more work needs to be done in establishing the sources and destinations of microplastic within the Arctic, as well as in understanding the full extent of effects it causes.

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