THE SASAKAWA PEACE FOUNDATION
THE OCEAN POLICY RESEARCH INSTITUTE
「海の論考」 OPRI Perspectives

OPRI Perspectives No.10 [2020]

Marine Plastic Pollution in the Arctic

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NOTE:
・The following is an English translation of an original Japanese article issued in July 2020.
・The English version includes some updates in the light of changes in the situation after the original article was published.

1. Introduction

In recent years, marine pollution caused by plastic waste and its impact on the ecosystem have been receiving much attention as a new environmental issue. The total volume of plastic waste that has flowed into the sea to date is approximately 150 to 400 million tons, and it has been estimated that an additional 8 million tons flows into the ocean every year.[1] As plastic does not decompose, it is crushed into small particles by the action of ultraviolet radiation and waves, and can be carried everywhere by ocean currents and other means. Ultimately, they leave an impact even in remote places like the polar regions and the deep ocean bottom.

Research on plastic pollution in the Arctic has been growing rapidly in recent years. This paper provides an overview of the existing information on plastic pollution in the Arctic, based on a review of the scientific literature. It then discusses efforts made by the international community to resolve the plastic waste problem in the Arctic, and the future outlook.

2. Current Status of Plastic Pollution in the Arctic

The first scientific report on plastic pollution in the Arctic region can be traced back to the 1970s. This was a report on a survey of 10 km of sandy beaches on Amchitka Island in the Aleutian Islands, which led to the observation of about 2,000 to 5,300 pieces of plastic waste.[2] According to the report, most of these were fishing gear discarded by Russian and Japanese fishing vessels. In recent years, in a study conducted with citizen scientists and participation of passengers of leisure cruise ships in 2016, a total of 991 kg (on average, 102±84g/m^2) of plastic waste was recovered from six beaches on the Svalbard Islands in the Arctic Circle.[3] The majority of this waste was comprised of fishing gear, such as fishing nets and buoys. Furthermore, based on photographs taken by the participants of this study, eight species of wildlife having contact with plastics were observed during the survey, such as a seal with a rope wrapped around it, and a polar bear with a plastic bag in its mouth (Figure 1). These studies show that plastic pollution in the Arctic region caused by fishing gear

[1] Jambeck, J. R. et al. Plastic waste inputs from land into the ocean. Science 347, 768–771, https://doi.org/10.1126/science.1260352 (2015).
[2] T.R. Merrell Jr. Accumulation of plastic litter on beaches of Amchitka Island, Alaska, Mar. Environ. Res. 3 (3) 171-184. (1980).
[3] M. Bergmann, B. Lutz, M.B. Tekman, L. Gutow. Citizen scientists reveal: marine litter pollutes Arctic beaches and affects wild life, Mar. Pollut. Bull. 125 (1) 535-540. (2017).

continues to be a serious concern after 50 years.

The two examples described above are studies on relatively large-sized macroplastics, but research has also advanced on pollution caused by microplastics that are 5mm or smaller, which cannot be easily observed visually. A study was conducted by Barrows *et al*.[4] in which seawater samples were collected from various locations around the world by citizen scientists and the quantity of microplastics contained was measured. Surprisingly, the concentration of microplastics in seawater was higher in the open ocean than in coastal waters in all regions, and the concentration in the Arctic Ocean was significantly higher than that of the Antarctic Ocean, which had the second highest concentration (Figure 2). According to the results of the study, The result suggests that microplastics that have flowed into the ocean are carried by ocean currents and may ultimately accumulate in the polar regions. Another study conducted by Lusher *et al.*[5] surveyed the ocean area south of the Svalbard Islands, and reported that microplastic debris was found in more than 90% of the samples collected from the sea surface and at a depth of 6 m below the surface. Thus, it can be seen that microplastics are present not only on the sea surface, but also in the water column.

Figure 1: Images taken by citizen scientists showing interactions of Arctic biota with marine litter on Svalbard beaches (Bergmann *et al*. 2017)

[4] Barrows, A. P. W., Cathey, S. E. & Petersen, C. W. Marine environment microfiber contamination: Global patterns and the diversity of microparticle origins. Environmental Pollution 237, 275–284, https://doi.org/10.1016/j.envpol.2018.02.062 (2018).
[5] Lusher, A.L., Tirelli, V., O'Connor, I., Officer, R., Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples. Sci. Rep. 5, 14947. (2015).

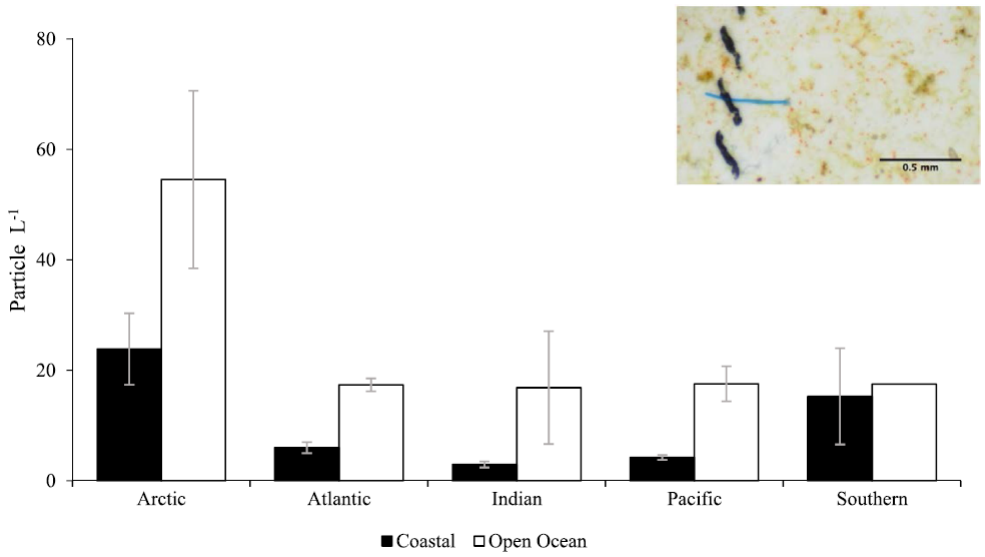

Figure 2: Average microplastic concentration in seawater samples along the coast and offshore of five main ocean areas (Barrows *et al.*, 2018)

Furthermore, microplastics are contained not only in seawater, but also in Arctic snow. Bergmann *et al.*[6] collected samples of snow that had built up on floating ice in the Fram Strait, an urban area of Germany, and the Swiss Alps, and examined the microplastic concentration in the samples. The results showed that while snow from the Fram Strait contained relatively lower concentrations of plastic than samples from Europe, the Arctic snow contained 14,400 pieces of microplastics per liter at the highest. This result suggests that microplastics move from populated areas to the polar regions through the atmosphere. Although these snow samples also contained a large number of micro particles of natural origin (i.e. plant fragments, animal fur, charcoal, sand, etc.), on average, 12% of the micro particles was made up of microplastics including synthetic fibers. The method used in this study could not detect micro particles below 11μm, so most of the microplastics detected ranged from 11 to 25 μm. Therefore, it can be inferred that even more microplastics below the detection limit of 11μm may be present in the samples. As for smaller nano-sized plastics, no research has been conducted in the Arctic.

In addition, microplastics have also been detected in core samples of Arctic ice.[7] Obbard *et al.*[8] examined sea ice collected from three sampling locations of the Arctic Ocean, and found many pieces of microplastic as well as micro fragments of synthetic fibers below 2mm. When seawater freezes, the concentration of plastics becomes condensed due to the coagulation of

[6] M. Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdts, G. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Sci. Adv. 5, eaax1157 (2019).
[7] Peeken, I., Primpke, S., Beyer, B. et al. Arctic sea ice is an important temporal sink and means of transport for microplastic. Nat Commun 9, 1505 (2018).
[8] Obbard, R.W., Sadri, S., Wong, Y.Q., Khitun, A.A., Baker, I., Thompson, R.C. Global warming releases microplastic legacy frozen in Arctic Sea ice. Earths Future 2(6), 315–320. (2014).

the ice. For this reason, a higher concentration of microplastics is built up in ice than in the surrounding seawater. This suggests the possibility that the microplastics condensed in ice could be released into seawater when the ice melts under the impact of global warming. Obbard *et al*. surmised, based on the patterns of the ocean currents and other factors, that seawater containing these microplastic debris came from the Pacific Ocean.

3. Origin and fate of the Arctic plastic

Generally speaking, the plastic waste present in the Arctic has two types of sources. One is from local sources, waste from plastic that was consumed locally in the Arctic and discharged into the environment. The other is the plastic waste that was carried to the Arctic from other regions. Along with the population increase and growth of economic activity in the Arctic Circle in recent years, such as fisheries, aquaculture, tourism, shipping, and resource exploitation, the volume of marine plastic waste generated from local sources is expected to increase.[9] However, the actual situation remains unclear as quantitative studies have not been carried out on the amount of waste discharged from these sources into the ocean.

Moreover, as described above, plastics are also being carried from remote populated areas into the Arctic region via ocean currents and wind. The plastics that reach the Arctic are presumed to be eventually ingested into the bodies of living organisms, sealed into the ice, or sinks into the deep sea. A research paper by Cozar *et al.*[10] suggests that plastic waste is transported by thermohaline circulation. It is hypothesized that plastic waste flows from the Atlantic Ocean into the Barents Sea; from there, as the seawater cools, it sinks to the seabed bringing down the plastic waste, which then accumulates on the seabed of the Arctic Ocean. To support this hypothesis, Tekman *et al.*[11] are monitoring the plastic waste on the seabed at a depth of 2,500 m, east of the Fram Strait. They reported that the volume of waste has been increasing every year since 2011.

4. Impact on marine life and ecosystems

With regard to the impact of plastic waste on living organisms in the Arctic, little information is available with the exception of a few species. Thus there is a huge information gap and further study is much needed. In particular, there is a lack of information on marine mammals such as polar bears, whales, and seals, except for anecdotal sightings of affected animals.

[9] Halsband, C., Herzke, D. Plastic litter in the European Arctic: what do we know? Emerging Contaminants 5, 308–318.(2019).
[10] Cozar, A., Martí, E., Duarte, C. M., García-de-Lomas, J., van Sebille, E.,Ballatore, T. J., Eguíluz, V. M., Gonzalez-Gordillo, J. I., Pedrotti, M. L., Echevarría, F., Trouble, R., Irigoien, X. The Arctic Ocean as a dead end for floating plastics in the north Atlantic branch of the thermohaline circulation, Sci. Adv. 3 (4). (2017).
[11] Tekman M.B., Krumpen T., Bergmann M. Marine litter on deep Arctic seafloor continues to increase and spreads to the north at the Hausgarten observatory. Deep Sea Res I 120, 88–99 (2017).

Much of the available information is on seabirds such as the northern fulmar, and fish such as the Arctic cod. Of these, research on seabirds is the most abundant, since they are particularly vulnerable to plastic pollution.

According to a study by Poon *et al.*[12], the degree of susceptibility to the impact of plastic waste varies among different species of seabirds. Compared to species that dive into the water to capture prey, such as the thick-billed murre (*Uria lomvia*) and black guillemot (*Cepphus grille*), a higher percentage of species that capture their prey on the water surface, such as the northern fulmar (*Fulmarus glacialis*) and black-legged kittiwake (*Rissa tridactyla*), were ingesting plastics. Among these, the northern fulmar is probably the most well-studied species. For example, in a study carried out on the Svalbard Islands, an average of 15.3 pieces of plastic were found in the stomachs of 35 out of 40 individuals (87.5%).[13] Similarly, in a study conducted in the Canadian Arctic, plastic fragments were found in the stomachs of 84% of individuals.[14] The percentages are much higher in comparison to the thick-billed murre in the Canadian Arctic, in which plastics were found in the stomachs of only 11% of individuals.[15] Since the northern fulmar is highly susceptible to the impact of plastics pollution, it is used as an indicator species to monitor the degree of environmental pollution.

As for fish, the research team of Kuhn *et al.*[16] examined the stomach contents of 72 Arctic cod (*Boreogadus saida)* caught in the Arctic Ocean, and found microplastics in 2 of the fish (2.8%). Although the percentage is relatively low, it may have an impact on other species through the trophic chain since the Arctic cod is a keystone species in the Arctic ecosystem. It is also pointed out, although not limited to the Arctic, that harmful organic pollutants such as DDT are absorbed by plastic and might affect living organisms when ingested.[17]

5. International Initiatives and Future Outlook

With regard to international initiatives working on marine plastic pollution, specific targets are being discussed for the Post-2020 Global Biodiversity Framework among the parties to the Convention on Biological Diversity. There are also various other initiatives such as the Osaka Blue Ocean Vision, which was put forward by Japanese government at the G20 Osaka Summit. Among these, the international initiatives that are specifically related to the Arctic are the OSPAR Convention and the Protection of the Arctic Marine Environment (PAME)

[12] Poon, F. E., Provencher, J. F., Mallory, M. L., Braune B.M., Smith P.A. Levels of ingested debris vary across species in Canadian Arctic seabirds, Mar. Pollut. Bull. 116 (1-2), 517-520. (2017).
[13] Trevail, A.M., Gabrielsen, G.W., Kühn, ., Van Franeker, J.A. Elevated levels of ingested plastic in a high Arctic seabird, the northern fulmar (*Fulmarus glacialis*), Polar Biol. 38 (7), 975-981. (2015).
[14] Provencher, J.F., Gaston, A.J., Mallory, M.L. Evidence for increased ingestion of plastics by northern fulmars (*Fulmarus glacialis*) in the Canadian Arctic, Mar. Pollut. Bull. 58 (7): 1092-1095. (2009).
[15] Provencher, J.F., Gaston, A.J., Mallory, M.L., O'hara, P.D., Gilchrist, H.G. Ingested plastic in a diving seabird, the thick-billed murre (*Uria lomvia*), in the eastern Canadian Arctic. Mar Pollut Bull. 60(9):1406-1411. (2010).
[16] Kühn, S., Schaafsma, F.L., van Werven, B., Flores, H., Bergmann, M., Egelkraut-Holtus, M., Tekman, M.B., van Franeker, J.A. Plastic ingestion by juvenile polar cod (*Boreogadus saida*) in the Arctic Ocean, Polar Biol. 41 (6) :1269-1278. (2018).
[17] Zarfl, C., Matthies, M. Are marine plastic particles transport vectors for organic pollutants to the Arctic? Mar. Pollut. Bull. 60 (10), 1810-1814. (2010).

Working Group of the Arctic Council.

The purpose of the OSPAR Convention is to protect the marine environment in the Northeast Atlantic, and its contracting parties are the 15 European countries that face the Northeast Atlantic Ocean as well as the European Union (EU). Its target region includes the Arctic Ocean. The OSPAR Convention prescribes ecological targets ("EcoQO") for the conservation of the marine environment, and monitoring is carried out in accordance with the Convention. With regard to marine plastics, the aforementioned northern fulmar is used as an indicator. The Convention has established the goal of reducing the percentage of northern fulmar having more than 0.1 g plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars found, to less than 10%.[18] However, there are some opinions that this target value was determined on a political basis rather than on an ecological basis.[19]

The Arctic Council is a high-level forum comprising eight countries of the Arctic Circle as its members. It was established in 1996 as a forum for engaging in international consultations on issues related to economic activities and environmental protection in the Arctic. Countries outside of the Arctic Circle also participate in the Council as observers. There are six Working Groups under the Council, one of which is PAME, which aims to preserve the marine environment. PAME is currently preparing an action plan on marine plastic pollution.[20]

Furthermore, several of the countries in the Arctic Circle have keen interest in this issue and are taking action. For example, Norway is implementing a research project on plastic pollution in the Arctic over the five-year period from 2018 to 2023.[21] In the United States, the Woodrow Wilson International Center for Scholars, a private thinktank, and Harvard University co-hosted an international workshop on Arctic plastic pollution entitled "Policy and Action on Plastic in the Arctic Ocean," in October 2019.[22] The government of Iceland, which is the present co-chair of the Arctic Council, is also deeply concerned about resolving the plastic pollution problem. It has established the Icelandic Recycling Fund, which is taking initiatives to promote proper waste management through economic incentives, as well as initiatives to collect used fishing gear for free of charge in cooperation with fishery operators and turn them into recycled plastic.[22] The government of Iceland had also planned to host the first large-scale international symposium on marine plastic pollution in the Arctic region in its capital of Reykjavík in April 2020, but this symposium has been postponed to March 2021 due to the COVID-19 pandemic.

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[18] The OSPAR system of Ecological Quality Objectives for the North Sea, a contribution to OSPAR's Quality Status Report 2010. https://www.ospar.org/documents?v=7169

[19] Provencher, J.F., Bond, A.L., Avery-Gomm, S., Borrelle, S.B., Rebolledo, S.B., Hammer, S., Kuhn, S., Lavers, J.L., Mallory, M.L., Trevail, A., van Franeker, J.A. Quantifying ingested debris in marine megafauna: a review and recommendations for standardization, Anal. Methods 9 (9), 145－1469. (2017).

[20] PAME https://pame.is/index.php/projects/arctic-marine-pollution/regional-action-plan-on-marine-litter

[21] Halsband, C., G. Broström, Ø. Andersen, S. Bourgeon, P. Graczyk, B. E. Grøsvik, I. Hallanger, et al. 2018. "Plastic in the Arctic." Framsentret. FRAM–High North Research Centre for Climate and the Environment. http://www.ifram.no/getfile.php/4306766.2368.usumpmn7mswzb7/Plast+i+Arktis+vitenskapelig+plan+2018-2023_published.pdf

[22] https://www.wilsoncenter.org/publication/policy-and-action-plastic-arctic-ocean

Eriksen *et al.*[23] recommend the following three countermeasures against marine plastic pollution in the Arctic: (i) Optimization of waste management in human communities within the Arctic Circle; (ii) Measures to deal with abandoned/lost/discarded fishing gear; (iii) Prevention of plastic pollution originating from the tourism industry. With regard to (i), it is said that approximately 4 million people live in the Arctic Circle. However, many regions are not collecting and processing waste adequately due to limited accessibility and high costs, which is exacerbating the problem. As for (ii), abandoned, lost, or otherwise discarded fishing gear, known by the acronym "ALDFG," it causes serious harm to wildlife as illustrated above. In order to conserve the Arctic environment and its biodiversity, it is urgently needed to put in place measures to reduce the disposal of fishing gear. This includes educating fishery operators working in the Arctic Circle as well as the North Pacific and North Atlantic Oceans. As for (iii), the Association of Arctic Expedition Cruise Operators (AECO), whose members are business operators managing leisure cruises in the Arctic region, is voluntarily carrying out initiatives such as preparing guidelines for the preservation of the Arctic environment, reducing the use of plastic products on their ships, and organizing beach-cleaning activities by tourists.

Haarr *et al.* [24] reported that as a result of continued beach-cleaning and monitoring activities carried out by local volunteers between 2011 and 2018 at more than 200 beaches on the Lofoten archipelago of Norway, the amount of beach litter has decreased. This example shows that it is possible to reduce plastic pollution, at least to some extent, by raising awareness among local communities and putting in steady and earnest efforts. The issue of marine plastic pollution in the Arctic is, of course, not a problem that can be resolved by the countries of the Arctic Circle alone. As mentioned earlier, the plastic waste generated by the Japanese people flows into the Pacific Ocean, and may be carried by ocean currents into the Arctic where it pollutes the Arctic seas. As it happens, the Third Arctic Science Ministerial (ASM3) is scheduled to be held in Japan in May 2021, which marks its first convention in Asia. During the same period, the Arctic Circle Japan Forum will also be held in Tokyo, co-hosted by the Ocean Policy Research Institute and the Arctic Circle Secretariat. It is a good opportunity for us to consider what we can do to reduce plastic waste in our everyday lives.

[23] Eriksen M, Borgogno F, Villarrubia-Gómez P, Anderson E, Box C, Trenholm N. Mitigation strategies to reverse the rising trend of plastics in Polar Regions. Environ Int. 139:105704. (2020). doi:10.1016/j.envint.2020.105704
[24] Haarr ML, Pantalos M, Hartviksen MK, Gressetvold M. Citizen science data indicate a reduction in beach litter in the Lofoten archipelago in the Norwegian Sea. Marine Pollution Bulletin 153:111000. (2020). doi.org/10.1016/j.marpolbul.2020.111000