Framsenteret

FRAM– High North Research Centre for Climate and the Environment

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Plastic in the Arctic

by

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0 Preface: Norway's responsibilities and goals in relation to plastic pollution

Clean and healthy oceans are a key priority for the Norwegian Government. Increasing valid concern about the threats posed by plastic waste has triggered ambitious plans for Norway to take a leading role in the international measures and regulations to combat plastic emissions in a global context. At the same time, scientific research is urgently needed to underpin and guide these measures with a sound knowledge base, and to monitor the effects of applied measures. For the Arctic, information on the extent of plastic pollution and its environmental impacts is fragmented and unconsolidated to date. At the same time, Arctic ecosystems are especially vulnerable to environmental perturbations, such as rising temperature, and thus serve as sentinels of global change. Any additional stressor might aggravate climate change effects faster in the Arctic than in more adaptable ecosystems elsewhere. Therefore, the Artic is a very important area to study the environmental and societal effects of anthropogenic changes, including plastic pollution. The new Fram Centre program 'Plastic in the Arctic' aims to promote high quality science to 1) establish the state of plastic pollution in the Arctic, 2) assess potential negative effects on arctic ecosystems in the Arctic, and 3) inform decision making towards measures that minimize negative plastic impacts in the Arctic.

1 Background

Plastic debris is a global environmental concern and has been recognized as one of the world's largest growing problems by the United Nations Environmental Programme (UNEP, 2016). The majority of marine litter is plastic, and is either deliberately discarded or unintentionally lost in the environment. Global estimates show that 335 million tons of plastic are produced per year (PlasticsEurope, 2017), of which 5-12 million tons reach the oceans (Jambeck et al. 2015). In addition, plastic represents a non-negligible use of petroleum and, for this reason, has a climate relevance. Thus, the global contribution of plastic production to petroleum use is of interest, both for the climate and the environment.

Plastics comprise a wide range of organic polymers. The most frequently recorded litter in the environment consists of polyethylene, polypropylene and polystyrene, which are mostly used in packaging (Hidalgo-Ruz et al., 2012), but few measurements include examples from the Arctic. Plastics are semi-persistent, i.e. they break down from macroparticles (defined here as >5 mm in size) to smaller particles, termed microplastics (5 mm - 1 µm) and nanoplastics (<1 µm), through photodegradation, physical abrasion, hydrolysis and biodegradation. Total degradation into basic molecules is, however, slow (Gewert et al., 2015), especially at low temperatures (Booth et al. 2017), except for some so-called 'biodegradable' plastics that are presumed to degrade faster. Due to these fragmentation pathways, microplastics probably represent the majority of plastics in the world's oceans (Cózar et al., 2014; Law & Thompson, 2014).

Wind and currents transport plastic debris toward the Arctic. Although many Arctic regions still seem free of macroplastics, an oceanic 'garbage patch' is predicted for the Barents Sea (van Sebille et al., 2012). In addition to local plastic pollution from fishing and aquaculture industries, shipping, tourism and human settlements, plastic pollution extends into the Arctic region through long-range transport (Zarfl & Matthies, 2010). Transport pathways include the Gulf stream (Cózar et al., 2017) and the high connectivity between the Arctic Ocean and adjacent seas through the Fram and Bering Straits, as well as atmospheric transport in air (NILU, unpublished). Accordingly, large amounts of plastics have been documented in the surface layer of the Greenland and Barents seas (Lusher et al., 2015; Amelineau et al. 2016; Grøsvik et al., 2018), in sub-surface waters of the central Arctic Ocean (La Daana et al., 2017), local waste water (Sundet et al., 2016), the sea bed (Buhl-Mortensen & Buhl-Mortensen, 2017, Bergmann et al., 2017), Arctic sea ice (Obbard et al., 2014; Peeken et al., 2018) and biota (Bråte et al., 2018).

The size distribution of plastic particles, how they are transported (van Sebille et al., 2012, Maximenko et al., 2012, Kukulka et al., 2012), and accumulate in water (e.g. Kai et al., 2009), sea ice (Peeken et al., 2018), sediment and biota, are key parameters for impact assessments. Most arctic terrestrial and freshwater systems, however, that may play an important role for pan-Arctic plastic distributions and impacts, are to date complete data blanks (Eerkes-Medrano et al, 2015; Rillig, 2012), limiting our understanding of the distribution and transport of plastic litter and microplastics into and within Arctic systems. This also applies for the smaller size-fractions of microplastic and nanoplastic, as 80% of environmental studies do not account for particles below the size of 300 µm (Conkle et al., 2018), and distributions of small particles cannot easily be extrapolated from the distributions of large debris (Ter Halle et al., 2017). Technology to measure (and identify) nano-particles in the environment are currently not available, and method development for both sampling and analysis is needed. Plastic reaching the oceans will eventually sink to the ocean floor (94%) (EUNOMIA, 2016), but sinking speeds and horizontal transport processes are understudied (Kowalski et al., 2016). In addition, degradation processes and interactions with biota modify and transform the plastic particles and alter their properties and behavior in the environment. Biofouling, as well as ingestion and egestion by grazers will incorporate plastic particles into food web interactions and the carbon pump (Cole et al., 2016). In the Arctic, some of the particles are entrapped in multi-year sea ice, forming a sink for plastic particles that can be released if the ice melts (Obbard et al., 2014; Peeken et al., 2018).

Although examples for the Arctic are scarce, there is growing evidence that plastic litter and microplastics interact with biota and thus may impact organisms (e.g. Cole et al., 2013; Trevail et al., 2015) and ecosystems at several levels. The consequences of plastic pollution at the ecosystem level is, however, yet to be determined, as well as the environmental risk from marine litter and microplastic pollution. At the organism level, physical impacts by the plastic particles themselves, such as entanglement, ingestion, blockage of intestines and/or hindering limb movements (Gregory, 2009), are distinguished from toxicological effects of plastic-related chemicals (Koelmans et al., 2014). At the food web level, interactions can be indirect and complex. For example, ingestion by one species may not be harmful to the individuals themselves, but their consumers may accumulate large concentrations from contaminated food (Farrell & Nelson, 2013). Ac cumulation processes, such as bioaccumulation and biomagnification have not been studied *in situ*, while first model results predict that less PCB is retained in the arctic food chain when more microplastic is ingested, due to lower biomagnification rates from plastic than from food (Diepens & Koelmans, 2018). In contrast, PAHs biomagnified more when more microplastic was ingested. Verification of such modeling exercises is, however, lacking. The toxic effects of contaminants can either be alleviated or aggravated when combined with microplastics exposure, depending on the dose (Luis et al. 2015). Natural infochemicals, such as dimethyl sulfide (DMS), absorbed to plastic, or microbial biofilms may disguise plastic as palatable food (Savoca et al., 2016; Vroom et al., 2017) and thus increase ingestion rates. Plastic can also serve as transport vehicle for non-native species and thus contribute to invasions and spread of diseases (Kirstein et al., 2016; Viršek et al., 2017). Such complex interactions of physical-chemical and biological processes are not well described and arctic conditions may represent exceptions from patterns established elsewhere.

End consumers of arctic food chains also include humans. Contamination of seafood includes not only the gastrointestinal tract, which is in most cases removed from the final product, but micro- and nanoplastics can enter filet (Karami et al., 2017) and liver (Collard et al., 2017) of fishes, and mussels' feet (Kolandhasamy et al., 2018). Food preparation often adds considerable loads to the plastic contamination (Catarino et al., 2018). There is evidence that smaller particles are even more readily taken up into different organs and types of tissues (Collard et al., 2017; Critchell & Hoogenboom, 2018; Jani et al., 1992), with relevance for similar processes in humans. Medical research with the purpose to shuttle virus or medication into cells provided evidence for plastic nanoparticles crossing tissue borders and causing inflammatory responses (Lusher et al., 2017). Cytotoxic effects seem to be linked to the size of the particles, smaller size classes being more harmful (Hallab et al., 2012). Particle size also plays an essential role in determining how the particles enter the body (Wright & Kelly, 2017). There are, however, uncertainties related to these early studies, as secondary contamination cannot always be ruled out with the methods used (FAO, 2017).

Only on the basis of sound knowledge can the socio-economic dimensions of the plastic problem be addressed. In the Arctic, a number of ecosystem services are impacted by plastic pollution. Safeguarding these ecosystem services and ensuring sustainable use of arctic resources will require clear legislation, effective incentives and efficient control of compliance. Socio-economic aspects include the problems plastic creates for Arctic industries and local communities. The fishing industry is both a source of and affected by marine plastic pollution. The NFR project MARP shows that marine plastic litter is a frequent bycatch, often at the expense of fish yield. Plastic also entangles in fishing gear and vessel propels, which leads to costs of cleaning and repairing. Paradoxically, the fishing industry is at the same time one of the largest marine plastic polluters in the Barents Sea and the Arctic. Litter collected at Svalbard beaches in 2016 contained 90% plastic debris from the fishing industry. A high proportion was deliberately discarded at sea, only a small amount was lost by accident. The tourism industry is also impacted by plastic waste. Tourists go to the Arctic, often on cruise ships, to experience a pristine part of the world. Their experience is often disturbed by marine litter. Some cruise operators implement beach cleanings as a tourist activity. At the same time, rapidly expanding tourism in the Arctic entails an increase in plastic pollution, if no appropriate measures are taken. More knowledge is needed how plastic pollution impacts on tourism, and in turn how much the tourism industry contributes to the generation of plastic waste in the Arctic. The tourism industry can play an important role in raising awareness and supporting solutions in cooperation with management agencies and the research community.

The current state of plastic pollution, especially in marine areas, is a testimony to the challenges of dealing with this material human legacy in ecologically adept ways. Marine plastic pollution can thus be conceptionalized as a form of involuntary heritage, which challenges existing ideals of heritage as something essentially wanted (Pétursdottir, 2017). Heritage practices are traditionally concerned with identifying, collecting, conserving and managing material objects or immaterial heritage (e.g. languages, traditional practices) for the future, as something we can consciously choose to protect or to let go, to remember or to forget, to preserve or to neglect for future generations (Harrison, 2013). Whereas traditional heritage concepts and management strategies emphasize an ideal of deliberate preservation of structures, sites or objects considered valuable, the material accumulation of a largely unwanted and uncontrolled human legacy, such as plastic garbage, makes it necessary to recognize heritage as something beyond human mastering.

Due to the magnitude of the plastic litter problem, it has become one of the key policy issues in environmental politics. Important processes are ongoing in global, regional and subregional institutions and organisations, including the United Nations, the International Maritime Organisation, the European Union and the Arctic Council. This demonstrates that international cooperation is indispensable to address the problem. These actions should be studied in connection with research results and incentives to introduce innovative technologies, the green shift and blue and circular economy principles in the Arctic and beyond. There is a pressing need to understand how to design, develop and implement effective policies and measures to develop adequate management systems that will intersect local, national and international levels.

In summary, it is currently largely unknown how much the Arctic is affected by the global issue of plastic pollution, if the extreme environmental conditions of the Arctic affect plastic transport, degradation and interactions with biota differently from other regions, and if the Arctic acts as a sink of macro- and/or microplastics. How may differ from other regions (Halsband & Herzke, 2018). Emerging knowledge from lower latitudes may not be transferable to the Arctic environment. Arctic studies are therefore crucial to understand potential threats from plastic pollution in this unique environment, where increasing human activity and a changing climate may further exacerbate the issue. We need to address these knowledge gaps urgently, if mitigation measures are to be effective. Human perceptions, attitudes and problem-solving capabilities will play an important role. Tackling these questions will benefit from increased awareness, as well as technological innovation. New methods to detect and quantify plastic debris and to trace the sources may concomitantly promote new technological development that will aid the removal of plastic from the environment, as well as preventive measures.

2 Goals

The new research program in the Fram Centre will establish and disseminate knowledge about the extent, distribution and transport of plastic contamination in the Arctic, and explore how it affects arctic ecosystems on land, sea ice and in the ocean.

Sub-goal 1: Collect data to describe and understand the current distribution of macro-, micro- and nanoplastics in Arctic environmental compartments and their sources, including terrestrial, fresh water, marine and sea ice environments. Identify plastic pollution hot spots and estimate the long-term fate of Arctic plastic pollution.

Approach: Sampling of plastics in different sizes and from a variety of arctic environmental matrices (e.g. soil, beaches, water, sediment, ice); development and implementation of standardized methods for sample collection, treatment and analysis; characterization of plastic types and their abundance and distribution; map plastic litter trends spatially and temporally; enhance and synthesize understanding of plastic litter origin and transport patterns through modeling approaches; …

Subgoal 2: Identify Arctic organisms and food web interactions most sensitive to plastic litter and how pollution levels and particle characteristics determine impacts on ecosystem structure and function.

Study interactions of plastics and ecological processes; describe interactions with and effects on organisms and assess their environmental relevance, analyze trophic relationships, including bioaccumulation and biomagnification, and estimate consequences for food webs and biogeochemical cycling; extrapolate ecological impacts of plastics to arctic ecosystems and plastic pollution hot spots with a view to develop environmental risk assessments for Arctic plastic pollution.

Subgoal 3: Quantify the impacts of plastic pollution on ecosystem services; project the socio-economic costs of arctic plastic pollution and develop cost-benefit scenarios for business as usual versus potential removal and avoidance strategies, including the necessary regulatory measures.

Approach: List and quantify negative effects of macro- and microplastic pollution on ecosystem services, including ecosystem and human health, harvesting of arctic resources, and costs of plastic litter removal.

Subgoal 4: Communicate the findings of the program to relevant stakeholders in management, industry and society to raise awareness, emphasize prevention by encouraging avoidance of future plastic pollution at different levels, and to instigate innovation and technology development that increases the effectivity of mitigation strategies. Demonstrate if the legal framework is apt to deal with plastic pollution in the Arctic, and how laws and regulations are enforced. Highlight gaps in knowledge and deficiencies in action to comply with regulations. Explore effective policy design, study best-practices and develop incentive and management systems.

Approach: Delivery of new knowledge and advice to national and pan-arctic regulatory bodies; integration of research results into educational programs from pre-school to University level; information for the general public through popular science dissemination in various media.

3 Deliverables

The program 'Plastic in the Arctic' will deliver high quality scientific research within and across relevant disciplines that address the variety of plastic pollution issues in the Arctic (Fig. 1). Data from northern Norway, Svalbard and the Barents Sea from field-based collection of samples, experimental laboratory studies, and modeling studies. Within the Fram Centre, the expertise on Arctic knowledge within atmospheric physics, oceanography, ice physics, chemistry, biology, ecotoxicology and social sciences is outstanding, and the Fram Centre framework facilitates direct communication of research to management. **'Plastic in the Arctic' will act as a catalyst for interdisciplinary projects providing a holistic approach to plastic pollution research in the Arctic.** We will develop new perspectives on the plastic pollution problem in the Arctic through novel combinations of knowledge and methodology across multiple disciplines and the natural and social sciences. This will provide an integrated understanding of arctic plastic pollution and serve as basis for targeted science-based management measures. The results and conclusions will be disseminated in national and international written communications, conferences and trade fairs in addition to web-based information.

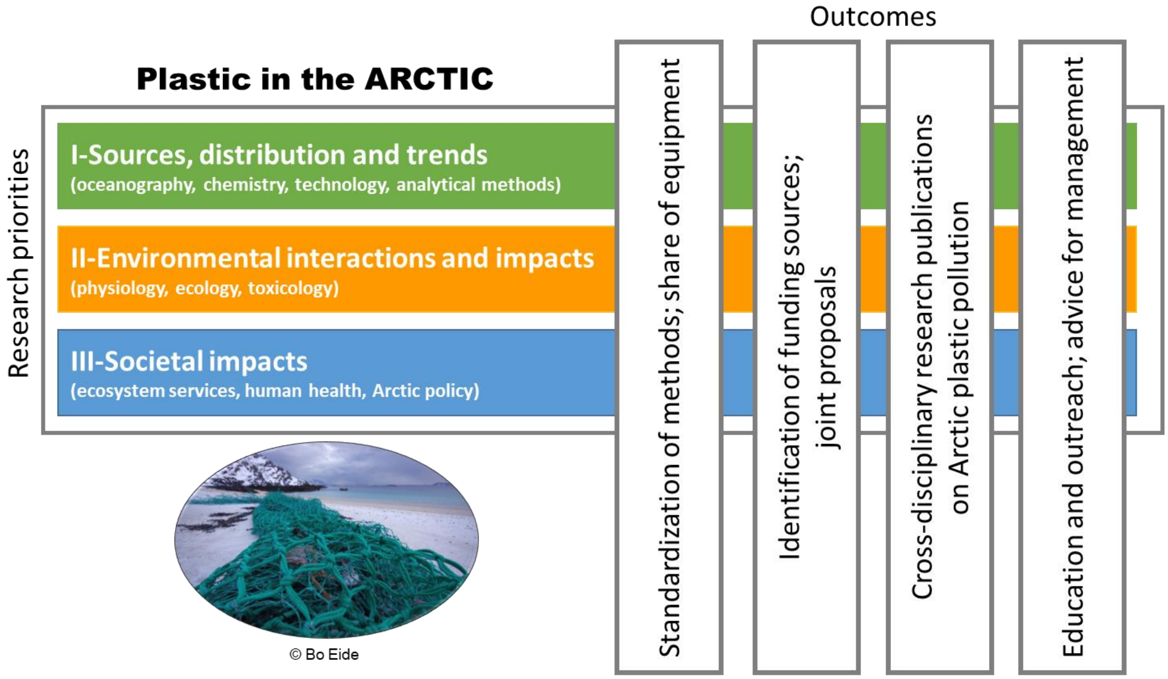

Fig. 1: 'Plastic in the Arctic' program structure and outcomes

4 Research priorities

Three overarching research themes have been identified as priorities to work towards the goals of the program. They address the most urgent questions about plastic pollution in the Arctic: the extent and distribution of plastic litter, interactions and impacts in the environment, and the consequential societal issues following from the presence and effects of plastic debris. To achieve a holistic understanding of the plastic problem in the Arctic, addressing these themes requires research across scientific disciplines, but also across these themes. Although this may create overlap among the research themes, a multidisciplinary approach will create working relationships between the different relevant research fields in the natural and social sciences and enable efficient translation of scientific results into management measures.

Theme 1. Sources, distribution and trends in the environment

Observations on plastic debris in the Arctic remain sparse. Accordingly, mapping of plastic debris and particles in the environment is a key component for building knowledge of horizontal distribution and trends of plastic debris in the Arctic environment. The impact of the temperature on plastic material properties and its transformation (both chemical and fragmentation), especially under polar conditions, remains to be evaluated. Quantification of the accumulation of plastic particles on land, in sea-ice, in surface water and in freshwater and ocean sediments are important for assessing the possible impact on organisms from all parts of the ecosystem in Arctic regions. The size distribution of plastic particles and how they are transported are key parameters for impact evaluations.

Scenario and transport modelling can provide answers for scientific estimates on the origin and fate of plastic debris as of today and predict future changes in the plastic load for the Arctic region. Transport and fate models would provide an important tool for the evaluation and management of plastic particles in the environment. However, models also need to be validated using field data. New tools for assessment of the plastic debris problem and mapping in the environment are urgently needed. To provide validation of such modeling results, development and implementation of standardized sampling and analysis methods is required, and the program endeavors to include method comparisons and/or QA/QC studies across Fram Centre laboratories to achieve the goals of this theme.

There is a parallel between long-range transport of plastic and long-range transport of particles and pollutants to the Arctic. Experiences from pollutant research and policy areas can contribute with knowledge relevant also to plastic transport and provide a basis for the development of decision-making tools.

Theme 2. Environmental interactions and impacts

It is clear that a wide range of arctic organisms interact with plastic litter when encountered in their environment. This spans all trophic levels from microbes to whales, and all sizes, types and shapes of plastic litter from macro- to micro- and nanoplastics (Cole et al., 2011). Scientific efforts to study these interactions have resulted in a large body of experimental and in situ studies (reviewed in Anbumani & Kakkar, 2018), but information for Arctic food webs remains scarce and scattered (Halsband & Herzke, 2017; Hallanger & Gabrielsen, 2018). Macroplastics pose a threat through entanglement (Gregory, 2009) and can be swallowed by marine mammals and fish (Jakobsen, 2018; Ertesvåg, 2017; Andersen, 2018; Silseth, 2018). Microplastics are easily ingested by a variety of organisms, and nanoplastics may even translocate across tissues and organs (von Moos et al., 2012; Walczak et al., 2015). In addition to the plastic particles themselves, additives contained in most plastic products, and/or adhered pollutants may induce toxicological responses, but relevant doses and background contamination levels are crucial prerequisites for realistic assessments (Herzke et al., 2016). The complexity of food web interactions mediates further transformations and transfers of plastics through the arctic ecosystem, e.g. through predator-prey relationships (Farell & Nelson, 2013) and (re-)cycling processes (Cole et al., 2016). Unknown ecosystem effects and environmental risks need to be determined.

This research theme will focus on understanding physical (entanglement, ingestion-egestion, colonization, sinking behavior), and toxicological (leaching additives, adhered contaminants) effects of plastic on Arctic organisms, trophic relationships and food webs. All plastic categories (from macro- to nanoplastics) will be considered. The program will support projects studying how physical and chemical drivers impact important ecosystem components, including low trophic levels (plankton), commercial species, and sentinel species of plastic pollution (e.g. the Northern Fulmar). These projects are by nature multidisciplinary to establish mechanistic understanding of the interactions between plastics, their chemicals and ecological functions, as well as ecosystem level impacts such as bioaccumulation, biotransformation/-degradation, trophic transfer, biomagnification, and vectors to human food chains. The results will serve as the basis for environmental risk assessments and broader socio-ecological studies and investigations into the role of humans as polluters, exposed species and mitigators in theme 3. Despite the need, no stringent quantitative data are currently available on micro- and nanoplastic occurrence in the environment or in food. This is largely due to the complexity of the detection methods necessary to quantify this size class of particles. Nevertheless, in order to answer the pressing question if concentrations of plastics currently present in food items are harmful, this size class cannot be ignored. The need for such data has been pointed out by the FAO (2017) and the European Food Safety Authority Panel on Contaminants in the Food Chain, with particular focus on seafood. They highlighted that toxicity and toxico-kinetic data are lacking for both microplastics and nanoplastics for a human risk assessment. Toxicological data point towards the possibility of adverse long term effects, rather than acute toxicity. Hence long-term experiments with more metabolic/physiological endpoints should be performed.

Theme 3. Societal impacts

This theme will include research on a range of topics, including impacts on ecosystem services and socio-economic costs, legal and geopolitical aspects, cultural aspects, management options and responsibilities, cultural heritage aspects and human perceptions and responses to plastic pollution. Plastic pollution in the north is largely a long-range problem (see theme 1), and a determination of the origin of plastic debris must be integrated with ways in which pollutors and countries have an interest to reduce their emissions.

Marine plastic pollution has gained the attention of the public and several private and public initiatives have been implemented to clean coastlines of plastic waste. Active involvement of the public as well as private initiates will be used in data collections (citizen science) and complement knowledge how engaging the public may bring about change. Studying human engagement with plastic waste will also generate knowledge on how such waste is used and re-used and how Arctic plastic pollution is acted upon and understood. Management strategies for sustainable development and appropriate tools and practices for alleviation of the problem of plastic pollution cannot be developed without taking into account the human dimensions, including understanding the causes and practices leading to plastic pollution and how such pollution affects human use of the environment and ecosystem services.

Societal aspects of marine plastic pollution include legal aspects. How is the legal framework regulating human action in order to prevent the plastic to enter the environment? And once plastic has entered the environment and interferes with the ecosystem, how can it be removed? International conventions and their implementation into national regulations target the problem and pose a responsibility on authorities at different geographical levels to follow through on measures to implement and enforce the regulations. There is a significant mismatch between the possibilities justified in the legal framework, if these possibilities are complied with and how they are enforced. Industrial aspects include impact on the fishing and tourism industries, socio-economic costs, producers' responsibilities, domestic and international reputation of products (for instance seafood), attitude changes both to prevent plastic from entering the environment and for taking responsibility to alleviate the problem. One strategy is to adopt the principles of a circular economy, namely to reconsider and improve the existing value chains in production, use and consumption of plastics. It requires great effort and cooperation from all essential actors, from plastic producers to recyclers, retailers and consumers. Policies incentivising circular economies also need to stimulate innovation and drive investment in the right direction (European Commission, 2018). Change of attitude at management, industrial and individual level is central to enable actions to improve the serious state of the ocean. Including management agencies and industry partners in research and dissemination will thus be an important objective in order to include results as input into short term and long-term planning for easing the plastic pollution problem.

Plastic may pollute cultural heritage sites and affect how such sites are perceived and used by local inhabitants as well as the tourism industry. At the same time, plastic waste is a testament of human material impact on ecosystems and thus challenges existing ideas and ideals of cultural heritage as something essentially chosen. More knowledge is therefore needed on the effect of plastic pollution on cultural heritage for a sustainable and ecologically adept heritage management.

On the consumer side, plastic is the poor's material and a 'luxury', but the aesthetic irritation of the wealthy. This applies globally, but both aspects are relevant in Arctic areas. The distribution effects of measures against plastics in the High North need to be addressed.

5 Organization and leadership

The working group 'Plastic in the Arctic' has been led by Claudia Halsband (Akvaplan-niva) and Göran Broström (the Meteorological Institute) to prepare this science plan and define the first call for proposals for 2019. A leader/co-leader for the program/flagship will be appointed by the ministry of Climate and the Environment (KLD), based on a recommendation by the Fram Sentermøte, upon their decision of the formal implementation of the program into the Fram Centre organizational structure. The program will have annual calls for proposals and support a variety of short- and longer-term activities, including pilot studies, small research projects (1-3 years), workshops, and outreach initiatives. These will be evaluated by external referees, unless a relevant prior evaluation of a directly related project can be supplied. The program leaders and the Fram Centre science coordinator will serve as selection committee and proposals for funding may appoint additional group members to assist with the internal evaluation process. Selection criteria will be published with the call each year.

All participants have competence and/or facilities relevant for plastic pollution research and are embedded in national and international multi-disciplinary research networks working on plastic pollution issues. This will facilitate recruitment of international partners into the program. Collaborating countries in Europe include Germany, the Netherlands, Poland, Italy, France, Ireland, Portugal, Spain, Sweden, Italy, Belgium, Austria, Denmark, Finland and the United Kingdom. Several Fram Centre institutes are involved in the ongoing JPI-Oceans program 'Ecological Aspects of Microplastics'. In addition, close contacts are maintained with researchers in the USA, Canada, China, Japan and Russia, which will benefit the broad scientific scope of the program.

6 Contribution to education

Arctic plastic pollution is a popular topic among students and provides the opportunity to involve students in research projects of the 'Plastic in the Arctic' program. Several participants have had MSc students in the past, who have participated in plastic research. Plastic pollution is also addressed in courses and summer schools at both the bachelor and master/PhD level through ecotoxicology courses at UiT and UNIS (e.g. UiT BIO-2012 and BIO-3009; UNIS Arctic Technology AT-210, AT-331 and AT-330). In collaboration with the Fram Centre institutes, these courses provide opportunities for the program participants to reach out and serve as guest lecturers and sensors, or in turn train students in their labs. Synergies will also be developed through UiT's co-lead of the UArctic thematic network on Arctic plastic pollution. We will also explore the potential for educational activities at large international conferences, such as 'Arctic Frontiers Young' (hosted by Akvaplan-niva) and 'Ocean Outlook' (alternating biannually between IMR Bergen and Woods Hole, MA, USA).

7 Dissemination and outreach

A wide variety of audiences will require information and advice based on the work of the Plastic in the Arctic program. These include environmental managers, the scientific community, different industries operating in the Arctic and the general public. We will establish direct contact to relevant regulating organizations and authorities, including but not limited to the Norwegian Environmental Protection Agency (Miljødirektoratet), the ministries for Climate and the Environment (KLD) and for Trade, Industry and Fisheries (NFD) and others, as well as the Arctic Council and their Working Group AMAP, whose secretariats are co-located in the Fram Centre and thus facilitate direct communication. In addition we will seek cooperation with the Arctic Council Working Group PAME, who plan to propose an outline for an Arctic regional action plan on marine litter in 2019. Through this dialogue, we will actively influence the necessary political processes that work towards national and international conventions to combat plastic litter, similar to initiatives against chemical contaminants such as the Stockholm and Minamata conventions on chemicals, and the Basel convention on the control of transboundary movements of hazardous wastes (Elster, 2018).

We will also reach out to lay audiences through the Fram Centre initiatives such as Fritt Fram and a variety of media outlets (online, print, radio and TV). NPI have experience in producing and publishing books for children and youth, and have in particular issued one on plastic pollution (*Søppelplasten i havet*, Cappelen Damm, 2016). Several events (lectures, seminars and laboratory practicals) directed towards schools have been organized in the past and can be drawn on in the future.

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