MEETING REPORT

Plastic in the Polar Environment: sources, impacts and solutions

28-29 October 2019 at the Energy and Environment Institute (EEI) at the University of Hull, HU6 7RX

Compiled and edited by the SCAR Plastic AG steering committee: Claire Waluda, Elisa Bergami, Cath Waller, Clara Manno and Ilaria Corsi. We are grateful to the following scientists who actively contributed to this report: Kirstie Jones-Williams, Jack Buckingham, Clare Collins, Rachel Coppock, Emily Rowlands, Vicky Dewar Fowler and Anatolii Chernov.

INTRODUCTION

The 2-day Workshop "Plastic in the Polar Environment: sources, impacts and solutions" was held on 28-29 October 2019 at the University of Hull (UK), organized by the SCAR PLASTIC Action Group Steering Committee and sponsored by the Energy and Environment Institute at the University of Hull.

The focus of the workshop was to examine the occurrence and distribution of plastic debris in Polar Regions, discuss how best to address their potential impacts and investigate potential mitigation strategies for plastic pollution both in Arctic and Antarctic environments.

The Workshop programme included eight plenary talks covering the state of knowledge and critical gaps in our knowledge of plastic at high latitudes, working group sessions and a panel discussion, with the active participation of academic experts, early career scientists and representatives of citizen science projects, tourism operators and policy makers.

The workshop was very well received and involved 45 participants from 14 countries. Travel fellowships were awarded to eight early career scientists to enable them to attend the event. We thank Hurtigruten and Airbnb for sponsoring the travel fellowships and APECS for managing the applications process.

DAY 1 Monday 28th October 2019

1.1 Welcome and Introductions

Prof Daniel Parsons, University of Hull
Welcome to the Energy and Environment Institute, University of Hull

Plastics, and their derived products, are now pervasive within all earth surface systems; they are present in the air that we breathe, in soils, throughout aquatic biota and have even been found in the most remote polar oceans. Despite this global distribution, there is a fundamental lack of understanding concerning the sources, pathways, and interactions of plastics with a range of environmental processes and a limited understanding of the hazards and risks associated with the presence of plastics within these systems. I am proud and delighted to host the SCAR meeting at the Energy and Environment Institute (University of Hull): we have a fantastic range of science to present and discuss. I believe the SCAR group is already making, and will continue to make, a real difference to one of our most treasured environments on Earth.

Dr Clara Manno, Plastic Action Group Steering Committee
Overview and Outlines of the workshop

We've only had access to 'plastic' for the last 70 years, but we are programmed to use it and throw it away! There has been much recent interest in plastic in pristine regions and the time is now to act together and collaborate on our research. We launched the SCAR Plastic Action Group at POLAR2018 in Davos, Switzerland which was attended by 78 participants from 20 different countries. In this meeting (and the AG as a whole) we aim to: (1) establish a network of scientist interested in plastic in Polar Regions, (2) assess the occurrence, distribution, source and fate of plastics, (3) evaluate the impact on ecosystems, (4) propose mitigation to limit plastic pollution and (5) generate best practice protocols. One of our main outputs from this meeting will be an opinion paper for presentation at the SCAR Open Science Conference taking place in Hobart, Australia in August 2020.

1.2 Plenary Talks

Dr Cath Waller, University of Hull
Plastics in the Southern Ocean: what do we know?

It is estimated that there are as many as 5 trillion pieces of plastic in the oceans. Microplastic pollution (particles <5mm) is recognised as a major problem in the world ocean. Antarctica is generally thought to be a pristine and isolated wilderness, free of most of the anthropogenic stressors found in populated regions of the world. However, recent studies in the Southern Ocean have reported microplastics in deep-sea sediments and surface waters. This presentation details our predictions of microplastic contamination in the Southern Ocean, based on quantifiable data from research stations, cruise ships and fishing effort. Implications for benthic foodwebs are also considered.

Q&A:
Q) How do we investigate the effects of increasing tourist numbers?
A) Tourism is not slowing down: 40,000 tourists plus associated staff. We need to engage with bodies such as the International Association of Antarctica Tour Operators (IAATO) and produce recommendations to SCAR to reduce our science footprint. We are also engaging with the Antarctic Treaty Consultative Meeting (ATCM) and Committee for Environmental Protection (CEP) and are making steps to feed our science into policy. E.g. Resolution 5 (2019)
https://www.ats.aq/devAS/Meetings/Past/87

Q) Is one of the aims of the workshop is to facilitate knowledge exchange between Antarctic and Arctic regions?
A) Yes, absolutely. The Arctic is far more connected, particularly in terms of governance. We can learn lessons from the Arctic Council, and it is very important to collaborate.

Dr Stefano Aliani, Marine Science Institute – National Research Council
Debris in polar oceans: Antarctic Circumpolar Expedition and Arctic PolarQuest

The widespread occurrence of plastic contamination has been commonly reported in studies all over the world. In Polar Regions, records of plastic pollution in the Arctic date back to 1960s, with some of the first observations of plastics at sea and its consequences for marine life from Alaska. Records of plastics in Antarctica date back to the same period, but since then has not received comparable attention in the literature and so far, we have only scant knowledge. Here, we summarise information from papers arising from the Antarctic Circumnavigation Expedition (ACE), a circumpolar survey in 2016/17, and some information from PolarQuest, a citizen science cruise in Svalbard in 2018. Polarquest data are still preliminary but micro and macroplastics were recorded on Svalbard beaches and floating at sea up to 81°N.Very low concentrations of floating macro- and microplastics have been found around Antarctica with mean densities of 0.03 macrolitter items·km^{-2} and 188 microplastics·km^{-2} found. These densities are one order of magnitude lower than in adjacent temperate waters. Microfibres have been largely ignored by traditional sampling methods which use mesh nets that are too coarse to sample most fibres. In Antarctica a novel method was used to sample microfibers in oceanic surface waters and microfibers were discovered to be widespread in surface waters around Antarctica as well as in King Penguin *Aptenodytes patagonicus* faecal samples. Microfibres were found in 77% of King Penguin faecal samples collected at South Georgia, with concentrations more than twice as high in incubating penguins than in penguins rearing chicks. However, only 9.6% of these microfibres were synthetic, which mirrors samples collected at sea in the region. The wider implications of these emerging pollutants for Antarctic ecosystems are still largely unknown.

Q&A:
Q) Are drones/new technologies helpful in identifying plastics?
A) Presently we can only spot large items, but it is something for future work.

Q) Where do you think the fibres are coming from?
A) Through the water column (vertical movements), atmospheric deposition, biotic pathways. Fibres seem to be all pervasive.

Q) How do we delineate between natural and synthetic fibres?
A) We don't know if the biota can distinguish between natural and synthetic. They will have defences against natural items but not against synthetic. We need to define mitigation and identify risk.

Dr Ilka Peeken, Alfred Wegener Institut
Microplastic pollution in the Marine Realms of the Arctic

Marine plastic pollution has been a study subject for several years in the Arctic (https://www.pame.is/). Contamination can enter the Arctic though the inflow gateways of the Atlantic and Pacific Ocean, but also terrestrial input and river discharge have been identified as potential sources. A synthesis of the current microplastic (MP) concentration data reveals relatively high contamination levels in the inflow of the North-eastern Atlantic Arctic sector but also in the Beaufort Sea. MP have been reported for all Arctic marine environmental compartments from snow to the deep-sea floor with extremely high concentrations of very small particles found both in sea ice and deep-sea sediments. Within sea ice, the plastic contamination is very variable and suggests unique oceanic footprints for various oceanographic currents. The drifting sea ice allows the redistribution of MP which will eventually be released in the Marginal Sea ice zone. Contamination with plastic in marine birds was recognized early on but recent studies also report MP contamination in fish and benthic fauna. The studied polymer composition suggest that mainly fabrics & single use products dominate the MP particles found in the Arctic realm.

Q&A:
Q) There are maps of plastic in the Southern Ocean e.g. SOOS – is there anything similar for the Arctic?
A) Yes – LITTERBASE (https://litterbase.awi.de/) – though it is not very specific for microplastics.

Dr Erik van Sebille, University of Utrecht
How did it get there? How do ocean currents transport plastic towards Antarctica?

The surface flow in the ocean is such that most floating material is accumulated in the centres of the five subtropical gyres, in the so-called 'garbage patches' there. Especially in the Southern Ocean, where the westerly winds cause a northward Ekman transport, floating plastic is expected not to be transported southward. However, plastic has now been found floating near Antarctica. While local sources from tourism, fisheries and science cannot be excluded, it could also be that some of the plastic does arrive on Antarctica from more Equatorward regions, where concentrations of floating plastic are orders of magnitude higher. Evidence for the southward, against-Ekman-flow transport comes from genetic analysis of a piece of kelp found on Antarctica. This kelp came from a population

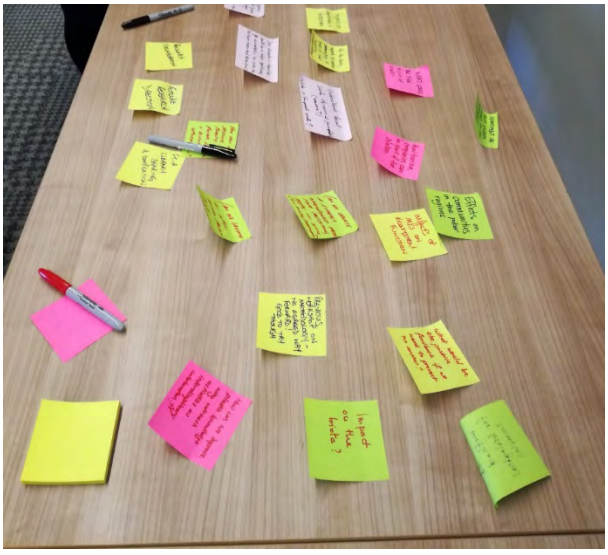
in South Georgia or Kerguelen, and most likely travelled to the Antarctic Peninsula against the Ekman transport by wave-driven Stokes drift. The piece of kelp is hence evidence that Antarctica is not as isolated as long thought.

Q&A:
Q) How much of the origin can you map? A lot of the simulations you did started with an even distribution of plastic in the ocean.
A) Ocean-scale garbage patches will form regardless of where plastic enters the ocean. For local/short term models it does depend where the plastics start, and this is the next step in our analyses.

Q) Why are there more microfibers than anything else?
A) We are looking at model simulations to examine this.
Q) Are you considering the vertical movement of biota in your models?
A) Yes – we have the capacity to look for biota driven microplastic transport - for example we can simulate schools of tuna in the Pacific.

1.3 Brainstorming topics for working groups

Workshop participants got together to brainstorm the topics to be addressed in the working groups. Ideas were organised using post-it notes and these were fed into the three working group sessions later in the day.



1.4 Working groups

i. Methodologies and transport prediction

Key Discussion Points:

What are the key problems with current in-situ plastic sampling methodologies? There is a lack of standardisation both in terms of methodologies for sample collection and the ways in which findings are reported.

Would it be beneficial to have a 'best practice' protocol and what would this look like? A protocol could propose 'best practice' for sample collection based on defined circumstances and could be set out as a flow chart to follow. This could be beneficial for developing a method that is globally comparable but should be used in conjunction with new methodologies and technologies to ensure innovation is not stifled. There is certainly potential to produce a MP environmental sampling protocol that could be used at every base and on every ship, however it would need to adopt a simplistic approach. To develop a best practice protocol, proper experimental design is critical.

What about local sources of plastic pollution in Antarctica? We need to determine the mass, type of polymer, density, colour and source (ship/field/ocean) of plastics used in research. Artificial tagging is a potential option that could use artificial DNA to tag a few key potential sources e.g. field clothing or fishing equipment to aid with tracking plastic input.

What about collaborative action to improve standardisation? Coordinated action could be used; bases and cruises can collaborate and sample at the same time with the same people utilising a standard toolkit. For this, putting pressure on national agencies may be key, giving for example a set list of what and where to sample. This could be used for varying plastic sizes.

Do we need to decide a recommended unit of measure? Whilst it may be beneficial in some cases to decide a 'best practice' unit of measure, it must also be considered that from a modelling point of view, it can be beneficial to have differing units, for example, mass is better for budget whilst count is better for impact. Perhaps it would be more advantageous to focus on ensuring that all relevant metadata is available to enable conversions. Certainly, from a modelling point of view, unit variability is manageable provided the correct metadata are available.

For metadata standardisation, position, time, depth etc. can be arranged in a common way as inputs. Everybody collecting the same metadata for plastics is important, as is preparing datasets in the same format, ready for the big datasets expected in the future.

Recommendations:

- The development of an open access data portal which can be utilised to log all sampling in the region, detailing sample locations/methodologies/metadata/intended use etc. or at least a communication as to what is being collected and where as a starting point, with the aim of open data in the future is advised. This is particularly important to maximise the use of samples collected and encourage collaboration, as well as to avoid unnecessary replication of sample collection and to minimise required research vessels/cruises and subsequent pollution. The use of similar open access data portals has proven successful in other research areas.
- In addition, a standard plastics sampling protocol and toolkit should be developed. This would need to remain simplistic to ensure standardised methods are adhered to and are therefore comparable. The sampling protocol should address both efficiencies, i.e. what is the best way to sample based on defined circumstances, but also address efficacy, ensuring we are measuring with the proper tools.

ii. Impacts on biota, pathways

Key Discussion Points:

What are the impacts of plastics on biota? Biological impacts of plastic pollution (from macroplastics to micro- down to nanoplastics) are a major issue to be addressed, but the research in Polar Regions is still at an embryonic stage, with few reports on plastic ingestion and studies evaluating potential negative effects upon acute exposure.

Why should we study plastic pollution in Polar Regions? Since there is increasing evidence of plastic occurrence in Polar Regions and plastic ingestion in some polar species, we urgently need to acquire knowledge on plastic impacts, considering the unique characteristics of Polar ecosystems (e.g. short food webs, fragile ecosystems, both terrestrial and marine). In this view, it is important to address the ability of Polar organisms to cope with changes (e.g. increasing temperature, presence of pollutants) and consider plastics as an additional stressor for them. The bioavailability and impacts of plastic-related chemicals (adsorbed/leached) must also be considered.

Which polar species might be most sensitive to this threat? Since sea ice has been identified as a major sink with high plastic loads, keystone species strictly interacting with sea ice, such as amphipods (Arctic) and krill (Antarctic), may be particularly vulnerable to plastics. Considering the short trophic foodwebs present at the poles, other Polar organisms sensitive to plastic pollution may include: fish (including the impact of fisheries at high latitudes), benthos (bivalves as filter-feeders and sea urchins as grazers), air-breathing predators (marine mammals and seabirds).

Which plastics might be more dangerous? Nanoplastics could be particularly harmful due to their size and high surface reactivity. Based on the latest reports, microfibres constitute a large part of the plastics present in Polar Regions, and the potential impacts of natural/synthetic fibres are almost unknown.

What are the major limitations? Difficulties related to working in remote locations, which can limit the sampling and number of organisms collected for plastic ingestion analysis/selected for laboratory assays.

Some knowledge gaps in methodologies need to be fulfilled to support further research on biological impacts; these include:

- Determining the behaviour of plastic, in terms of weathering and fragmentation, under remote environmental conditions peculiar to Polar Regions (i.e. in presence of sea ice).
- Defining the unique interactions between plastics and polar organisms, also in terms of the microbial colonization on plastic surfaces.
- The detection limit of 10 µm for the identification of plastic particles poses constraints for setting the concentrations/doses in exposure studies.

Recommendations:

- From an environmental risk assessment (ERA) perspective, future research studies need to determine the actual exposure to address the risk associated with plastic pollution in Polar

Regions. Data on plastic weathering and fragmentation processes under appropriate Polar environmental-relevant conditions are needed, together with the optimization of methods to detect sub-micron and nanoplastics as well as fibers, discriminating between natural cellulose/rayon vs synthetic (e.g. nylon).

- Active cooperation with experts in methodologies will allow us to define metrics for dose-responses studies and set the concentrations/doses based on real exposure. The development of traceable materials (metal-doped or fluorescent dyes embedded in the polymer) to test will ensure the acquisition of data at environmentally relevant conditions, with the identification of suitable endpoints (e.g. alteration in behaviour, feeding, developmental effects). Data acquired on biological impacts on key polar species will be used for modelling in order to predict the effects at communities and ecosystem level.
- Multi-stressor studies are encouraged, since it is not only a matter of quantifying the plastics but also addressing the ability of polar organisms to cope with plastics combined with other pollutants or under different climate change scenarios.
- Biomonitoring should be conducted through non-destructive samples (feathers, faeces) when possible and for marine mammals and seabirds in order to determine plastic ingestion, referring to keystone species at lower trophic levels. Changes in microbial communities on plastics compared to the surrounding environment must be investigated.
- Need to provide indications for quality control measures to mitigate contamination during sampling and sample processing.

iii. Remediation, solutions and policy

How can the use of plastics in Polar logistics and scientific operations be reduced? The research community which seeks to understand the extent of plastic pollution in the Polar Regions must also reduce their own impact. The inextricable link between behaviours related to plastic consumption and overall attitude to resource usage presents an opportunity to examine the research community's wider resource demand and determine short- and long-term sustainable solutions. Knowledge sharing of challenges and successes for sustainable practices between research institutes, bases and ships would be beneficial. The European Polar Board has devised an "Action Group on Environmental Impacts of Polar Research and Logistics" to provide an overview report on current practices.

What are the opportunities to collaborate with other industries to investigate plastic pollution in the Polar Regions? There is a sense of urgency to rapidly improve our spatial and temporal dataset of plastic pollution at high latitudes on land and at sea. The tourism and fishing industries presents two very diverse opportunities for both data collection and improved public engagement. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Marine Debris Programme has implemented measures to monitor and reduce the amount of debris entering Antarctic waters. One major initiative has been to work with fishers and fishing vessel operators to educate and inform about the potential impacts of marine debris to seabirds and mammal by displaying a marine debris poster and producing a document *"Overboard is not forgotten"* outlining

environmentally conscious protocols for the handling, storing and discarding of different types of refuse.

There are also opportunities to develop the social sciences discussion around marine health in the Polar Regions, particularly in the Arctic, to understand perceptions of pollution and how indigenous communities are affected by plastics.

How can the tourism industry be part of the solution? The tourism industry has a history of successful citizen science programmes which serve to educate on environmental issues whilst also providing benefits to the locations they visit. For example, some ship-based tourism operators have been successfully running beach clean-ups on Svalbard for the last fifteen years, and others have useable laboratory facilities on board which would enable experiential learning opportunities and effective in-situ sample processing. These are not only opportunities for data collection, but potentially also to educate on plastic pollution beyond the macro scale and inform on micro and nanoplastics pollution.

We do not advocate and cannot promote any activities which may cause more disturbance than good, for example by employing similar programmes in the Antarctic – this is strictly managed by CCAMLR and qualified scientists and must be maintained this way. However, there are opportunities to work more closely with the International Association for Antarctica Tourism Operators (IAATO) and the Association of Arctic Expedition Cruise Operators (AECO) to collect data and educate. A programme for educating about sea-surface microplastics pollution and potentially data collection from the ships using underway pumps would be the most feasible option. A set of protocols to standardise this data repository would be required and an online live resource which provided information on upcoming cruises and potential opportunities for collaboration would be beneficial.

What are the major barriers for collaboration with the tourism industry? There are several major barriers which currently limit knowledge of and access to collaborative research with the tourism industry.

- There lacks an easily accessible, and simple online resource to identify upcoming cruises or expeditions which may be able to collect data for scientists.
- A standardised protocol for microplastics collection and identification does not yet exist.
- Permitting processes are prohibitively complicated for citizen science – Protocols developed by scientists require permits for the allocated scientist, however the data cannot be collected in the absence of the permitted scientist and so the full benefit of using citizen scientists to expand the spatial and temporal and breadth of data collection is not being achieved.

Recommendations:

- There is a sense of urgency within the Polar research community to work more collaboratively in investigating the impacts of plastics in the Polar Regions. Collaboration promotes knowledge sharing, resource pooling and therefore reduces the combined overall environmental impact. Communicating our efforts and findings to the wider public and utilising the resources available to improve our spatial and temporal datasets of plastic pollution can be done by fostering stronger relationships with the tourism

industry. Currently, a lack of communication between scientists and other industries exists and IAATO and AECO are one of the major conduits for improving this.

- We therefore recommend developing a basic online database of resources to communicate available cruises, laboratory facilities and citizen science opportunities which could be utilised by the scientific community to collect both natural and social sciences data on plastic pollution. Likewise, the scientific community need to provide standardised simple methodologies for plastic data collection. It should also be noted that databases for Antarctic marine debris are less visible than those for the Arctic, which are currently facilitated by LITTERBASE and the Arctic Data Center (https://arcticdata.io). We recommend hosting similar databases for the Antarctic via the SCAR platform.

1.5 PANEL DISCUSSION:

Ilka Peeken, Stefano Aliani, Erik van Sebille, Jack Buckingham, Elisa Bergami, Kirstie Jones-WIlliams

Q) Is long term monitoring as being done in the Arctic, possible in the Antarctic?

- Certain areas are covered in the Arctic but every other year/every 3 years. It is difficult to forward plan and sample the same areas each year as cruising schedules may not allow repeat visits, the same issues will present themselves in the Antarctic.
- Marine protected areas could be expanded.
- Antarctic Circumpolar Expedition (ACE) cruises sample in a different way, can sample directly from the water into the lab without contact from the air. This work also highlighted that experimental design needs to be improved.

Q) Should we be sampling at different depths?

- Yes - for modelling purposes. Not so much if you care about the impact of plastic on marine life, in this instance you need to focus on where there is marine life first. In terms of transport it is important to take the whole ocean into a consideration, but it is also important to have a priority list.
- It is important to look at different plastic sizes. In the polar environments macroplastic is likely a significant source of the micro- and nanoplastic.
- There needs to be a separation between data collected on scientific cruises and bases and general protocols for citizen science. We do not need the same level of precision for citizen science as we do in the laboratory – we can look at something less rigorously in order build up a wider database quickly. We need reports of not just plastic presence but also a lack of plastic – this is reported less often. Another way to increase the dataset is to decide on key plastic parameters – it can become part of a standard methodologies taken on ships etc.
- There appears to be an increase in smaller items of plastic in some areas e.g. Bird Island (South Georgia), degradation is a likely source but what about atmospheric sources?
- With microfibres categories are broad – it is important to build up a library together and this can help with identifying plastic sources.

- Remote sensing of plastic in Polar Regions is not taking place at present (although Plymouth Marine Laboratory have started to look at large plastic sheets from space to see if these can be detected and possibly work down from this). Some groups (European Space Agency, Norway and Greece) are also beginning to look at this. However, the satellites operating over Antarctica are not able to detect plastics at present.

Q) What is the most important thing to do as a group to move the science/policy forward?

- To speak with a single voice in every country to deliver the message that the Antarctic/Arctic science community has identified what is crucial.
- Now we know plastic is there, it is important to determine what the effect is on the organisms and the ecosystem.
- This is particularly important for sea ice organisms in the Antarctic.
- Data sharing and information sharing to combine results from different research. FTIR library sharing for example.
- A multidisciplinary approach is needed to agree what is the best approach to test ecotoxicological effects
- Collaboration and Citizen Science is key to give us more usable data
- From a modelling point of view, a better handle on what plastic enters the ocean and from where around Antarctica, DNA tagging could be key.

DAY 2 Tuesday 29th October 2019

2.1 Plenary Talks

Dr Ilaria Corsi and Elisa Bergami, University of Siena

From macroplastics to nanodimensions: how to assess the risks to Antarctic species

Although plastic debris has been recently reported in Antarctic coastal and open waters, the potential impacts of micro- (< 1 mm) and sub-micron plastics (< 1 µm), as a result of the continuous fragmentation of plastics in the marine environment, is still overlooked. With the experience gathered in nano-ecotoxicology research, the first studies conducted to assess the effects of charged polystyrene nanoparticles (PS NPs), as model nanoplastics (< 100 nm), on Antarctic aquatic organisms are presented. We investigated the effects of carboxylated (PS-COOH) and amino-modified (PS-NH_2), over short-term exposures (up to 48 h). Antarctic fairy shrimp (*Branchinecta gaini*), Antarctic sea urchin (*Sterechinus neumayeri*) and Antarctic krill (*Euphausia superba*) juveniles were chosen as key species for Antarctic Peninsula lakes, marine benthic and pelagic ecosystems, respectively. PS NPs have been found associated with direct sub-lethal effects beyond the standard ecotoxicological end-points (i.e. mortality), leading to immunotoxicity, physiological alterations and modulation of stress responses at the molecular level, suggesting specific mechanisms of toxicity related to NP surface charge. Our results indicate that nanoplastics may impair an organism's energy budget and survival under continuous exposure. Nanoplastics may also disclose large-scale potential detrimental effects on Southern Ocean and Antarctic food webs and biogeochemical cycles.

Q&A:

Q) Can you comment on the change in diatom chain length and possible ecosystem effects?

A) The particles get into the polysaccharides which form the chains, interacting either at a mechanical or chemical level. Whilst this is not a toxic consequence as an endpoint, there is still a very strong ecological function disruption related to the change in formation and sinking of algal aggregates. Phytoplankton productivity and carbon flux will be impacted.

Joseph Nolan, European Polar Board
Minimising the environmental impact of polar research and logistics - a focus on plastic

The European Polar Board (EPB) began an initiative to minimise plastic use and waste in Polar research and logistics with a workshop during the POLAR2018 conference in Davos. This workshop, for researchers, programme managers and infrastructure operators, led to several practical recommendations to reduce plastic use and waste in fieldwork. An Action Group within the EPB was implemented to develop the initiative, which was expanded to focus on all environmental impacts relating to Polar research in the field. The EPB Action Group on Environmental Impacts of Polar Research and Logistics is working in cooperation with other entities, including the SCAR Plastics in Polar Environments Action Group, INTERACT, FARO and others, to develop practical guidelines to minimise the negative impacts of research and related activities in the Arctic and Antarctic.

Further information is available at:

http://www.europeanpolarboard.org/activities/action-groups/action-group-on-environmental-impacts-of-polar-research-and-logistics/

Q&A:
Q) How do you enforce a reduction in plastic use?
A) We can't police this, but we can provide guidelines and advice on best practices.

Tania Gibéryen, Script/MENJE, sila.lu Zero Waste Lëtzebuerg, Polar.lu
Zero Waste and plastics polar research: from a citizen science project to polar expedition!

With the support of the national funding agency *FNR.lu*, the Luxembourgish zero waste initiative *Sila.lu – Zero Waste Lëtzebuerg* set up a science outreach program on plastics and waste. This project was implemented during the *Regatta.lu Sailing Schools*, a large sailing event hosting about 200 participants, most of them high school students. The focus of the event was on two major outreach strategies : (1) : minimizing the overall production of waste during the week-long regatta event and (2) : having the students organize a scientific beach clean-up, in collaboration with the British Antarctic Survey and the University of Hull. This talk will showcase the different steps and pragmatic solutions developed during the different phases of the project, as well as discuss their feasibilities and challenges encountered. The discussion will open the way to which of these elements could be used towards the design of an Arctic sailing expedition, whose research and outreach (and participatory) activities will focus on sustainability, i.e. climate change, waste and plastics.

Q&A: No time for Q&A

Dr Verena Meraldi, Hurtigruten Ltd.
Hurtigruten, the war on plastic and making a difference

Hurtigruten, a Norwegian company with high sustainable goals, owns 16 ships and hotels. In addition to the 11 ships operating along the Norwegian coast, our 5 expedition vessels sail the worlds' oceans. To celebrate the company's 125th anniversary, single use plastics were banned. The two new additions to the fleet are hybrid ships that allow a reduction in fuel use of up to 20% as well as reduced carbon emissions with efficient engines and heat recovery systems. The ships operating along the coast are being transformed to the same technology or running on Liquid biogas with shore power when alongside. In addition to reducing food waste, Hurtigruten has partnered with the EAT foundation to offer plant-based menus on board, reducing carbon emission from meat derived products. Hurtigruten has been conducting beach clean-ups for many years, particularly in Svalbard, involving our guests and increasing their awareness of the global plastic problem, and contributing to the SALT and MALINOR projects.

Scientific data collection in the Polar Regions is challenging due to its remoteness, the harsh environment and high operational costs. For the last couple of years, we have supported the scientific community by transporting researchers and their equipment to and from their study areas in Polar Regions, we have also established collaborations with scientific institutions that use our ships as platforms for data collection, or public outreach. For one such collaboration, the Norwegian Institute for Water Research (NIVA) has installed a FerryBox on board MS Roald Amundsen, in addition to the typical sensors to monitor water temperature, salinity, Chlorophyll concentration, etc., a microplastic collection unit allows sampling anywhere in the world. The data from the FerryBox is publicly available, and MS Roald Amundsen will sail to both polar areas, where data on microplastic litter is required, making it the perfect platform to fill in the gaps in the plastic marine litter knowledge.

Q&A
Q) How do you involve scientists on board your ships?
A) Scientists are generally expected to engage and increase awareness via e.g. lectures

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2.2 Travel fellowships – presentations.

Each recipient gave a brief overview of their work on polar plastics:

Anatolii Chernov (Taras Shevchenko National University of Kyiv/National Antarctic Scientific Center of Ukraine) - *GPR investigation of glaciers and first steps in identification of plastic particles in the ice*

Jennifer Cocking (Scottish Association for Marine Science, UK) - *Aerial detection of plastic pollution in the marine environment*

Solene Giraudeau-Potel (Scottish Association for Marine Science, UK) - *Investigation of toner material as a potential source of microplastic*

Gregory Merrill (Duke University, USA) - *Assessing the impacts of plastic pollution on the energy mobilization and thermoregulatory capacities of blubber in marine mammals*

Letícia Palmeira Pinto (Universidade de São Paulo, Brazil) - *Evaluation of morphological and molecular changes induced by titanium dioxide nanoparticles in embryos of the tropical sea urchin* Lytechinus variegatus

Becky Peel (University of Bristol, UK) - *Quantifying polymer contamination of the terrestrial environment*

Gabriel Stefanelli Silva (Universidade de São Paulo, Brazil) - *Microplastic in the cold deep: how can biological collections tell us a story of pollution?*

Deniz Vural (Istanbul Technical University, Turkey) - *Using carbon dating techniques to study permafrost synthesis*

L-R: Jen, Gabriel, Letícia, Deniz, Solene, Becky, Greg, Anatolii

2.3 Working groups

i. Databases

Key discussion points

How are data on polar plastics currently being databased? There are a lot of different groups collecting data on plastics (from the macro to nano scale) and it is important to consolidate methodologies, protocols and current practices.

How do we align Arctic and Antarctic data? Current operational databases such as those operated by SCAR, SOOS and LITTERBASE are a good starting point.

How do we ensure consistency in data collection? There is potential to develop field and experimental data collection sheets to ensure consistent variables and associated metadata are collected by as many people as possible.

How do we view existing data? Currently the distribution of macro- and microplastic in the Southern Ocean can be viewed via the Southern Ocean Observing System map (soosmap.aq). LITTERBASE has global distribution data based on the published literature.

How good is the coverage of Polar Regions? There is reasonable coverage at both Poles, but it is important to identify currently existing gaps.

Recommendations

- Identify gaps in the data.
- Populate SOOS data maps with additional data from fieldwork and the literature.
- Develop field and experimental data collection sheets (standard data to record).

ii. Calibration/toolkit/monitoring

Key discussion points

What is the best way to standardise methodology for sampling? We need to separate these into different methods and guidelines for each. AMAP (Arctic Monitoring and Assessment Programme; https://www.amap.no/) has devised guidelines for sampling and standardisation for: water, sediment, atmosphere, ice, snow, and biological samples. We need to understand how we can best transfer this to the Antarctic environment.

What are the unique considerations for working in Polar Regions? We have lower allowances for contamination, than what can be achieved in areas of high pollution. Additionally, permits are

required to collect samples in Polar Regions which may be from multiple regions and have a limited time window for application.

How can we develop a tool kit for monitoring in Polar Regions? We should establish a group discussion to exchange up-to-date results and ideas. This can be done via the PLASTICS-AG network (mailing list/website).

How do we ensure consistency in monitoring between sites and operators? We should establish a sequence of actions required to investigate different compartments: land, water, snow, ice, air. Determine methods and "tool kit" for analysis and establish protocols for laboratory analysis and format of the final data and metadata.

Recommendations

- Develop a platform for utilising archived samples (e.g. similar to OTLET).
- Develop best practice guidelines (focussing on the unique requirements for working in the Polar regions).
- Develop standard protocols for collecting macro plastics, plastics in water samples/snow.
- Engage and develop citizen science programmes with IAATO and AECO.
- Produce recommendations to SCAR for investigating toxicity of plastics.
- Develop an early career researcher (ECR) network for Polar Plastics.

2.4 Summary & Outcomes of the meeting

Assessing the impact of plastic pollution on the Polar Regions is still at an early stage. Understanding the sources of plastics and quantifying the scale of the problem are necessary in order to minimize the environmental risks and impacts. Little has been done to date to effectively assess the amount of plastic entering the Antarctic environment (both terrestrial and marine). However, the increasing number of publications showing their occurrence in all environmental compartments clearly show that prevention and mitigation actions need to be urgently undertaken. There is a need to develop common actions and strategies among the main actors involved in research and policy. Data and samples from Polar Regions can be limited by their remoteness and difficulty of access. There is an urgent need to improve spatial and temporal data coverage and to improve our understanding of the fate and behavior of plastic in such climate scenarios and their interaction and potential negative effects on Polar species. In addition, the research community investigating plastic pollution in the Polar Regions must also aim to reduce their own impact and agree at the international level to limit the use of plastics during the activities in the fields and on research bases.

Acknowledgements

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Career Scientists (APECS) for the help in the administration of travel fellowship application and Hurtigruten and Airbnb for their generous sponsorship of early career scientists.

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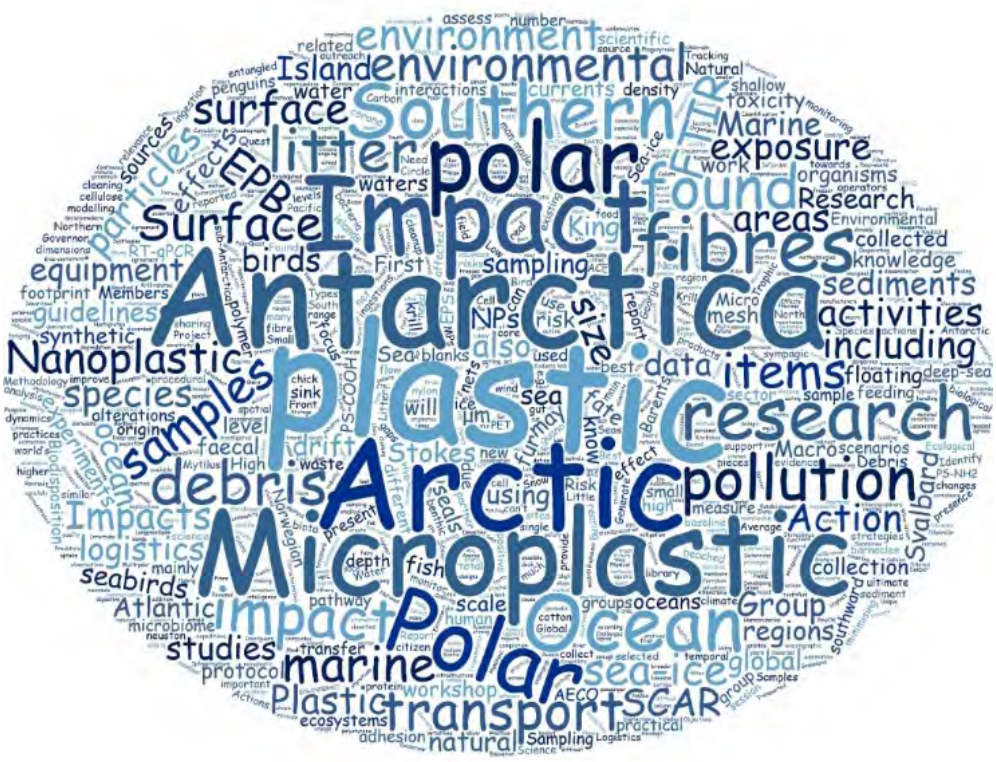
Travel fellowships were supported by:



Appendices

1. Agenda
2. List of delegates

Plastic in the Polar Environment: sources, impacts and solutions

AGENDA 28-29 October 2019

Energy and Environment Institute (EEI) at the University of Hull, HU6 7RX

Monday 28th October

from 08:30	*Registration and refreshments*
	Morning session (*Chaired by Dr Claire Waluda, British Antarctic Survey*)
09:15-09:20	Welcome to the Energy and Environment Institute, University of Hull *(Prof Daniel Parsons, Hull University)*
09:20-09:30	Overview and Outlines of the workshop by AG steering committee (*Drs Cath Waller, Claire Waluda, Clara Manno, Elisa Bergami, Ilaria Corsi*)
09:30-10:00	Plastics in the Southern Ocean: what do we know? (*Dr Cath Waller, Hull University*)
10:00-10:30	Debris in polar oceans: Antarctic Circumpolar Expedition and Arctic PolarQuest (*Dr Stefano Aliani, Marine Science Institute – National Research Council*)
10:30-11:00	*Coffee break and networking*
11:00-11:30	Microplastic pollution in the Marine Realms of the Arctic (*Dr Ilka Peeken, Alfred Wegener Institut*)
11:30-12:00	How did it get there? How do ocean currents transport plastic towards Antarctica? (*Dr Erik van Sebille, Utrecht University*)
12:00-12:15	Introduction to working groups and guidelines

12:15-13:30 *Lunch buffet*

Afternoon session (*Chaired by Dr Cath Waller, Hull University*)

13:30-15:30 Working Groups Discussion Session 1: (1) Methodologies, (2) Impacts, (3) Solutions

15:30-16:00 *Coffee break and networking*

16:00-17:00 Panel Discussion (*Drs Ilka Peeken, Stefano Aliani, Erik van Sebille, Elisa Bergami, Jack Buckingham, Kirstie Jones-Williams*)

17:00-17:05 Conclusions of the first day (*AG steering committee*)

Tuesday 29 October

Morning session (*Chaired by Dr Clara Manno, British Antarctic Survey*)

09:20-09:30 Welcome and summary of the previous day

09:30-10:00 From macroplastics to nanodimensions: how to assess the risks to Antarctic species (*Dr Ilaria Corsi and Elisa Bergami, Siena University*)

10:00-10:15 Minimising the environmental impact of polar research and logistics - a focus on plastic (*Joseph Nolan, European Polar Board*)

10:15-10:30 Zero Waste and plastics polar research: from a citizen science project to polar expedition! (*Tania Gibéryen, Script/MENJE, sila.lu Zero Waste Lëtzebuerg, Polar.lu*)

10:30-10:45 Hurtigruten, the war on plastic and making a difference (*Dr Verena Meraldi, Hurtigruten Ltd.*)

10:45-11:15 SCAR PLASTIC-AG travel fellowship ceremony (*Chaired by AG steering committee and APECS representative*)

11:15-12:30 Working Groups Discussion Session 2: (1) Methodologies, (2) Impacts, (3) Solutions

12:30-14:00 *Lunch buffet*

Afternoon session (*Chaired by Drs Ilaria Corsi and Elisa Bergami, Siena University*)

14:00-15:30 Plenary session to discuss the recommendations of the working groups

15:30-16:00 *Coffee break and networking*

16:00-16:30 Final remarks and end of workshop (*AG Group steering committee members: Bergami, Corsi, Manno, Waller, Waluda*)

List of delegates

Surname	First name	Affiliation
Aliani	Stefano	Marine Science Institute – National Research Council
Alvarez	Lucrecia	University of Hull
Balbi	Teresa	University of Genoa
Beard	Dylan	University of Plymouth
Bergami	Elisa	University of Siena
Blumenroeder	Julian	University of Hull
Buckingham	Jack	University of Hull
Chernov	Anatolii	Taras Shevchenko National University of Kyiv
Cocking	Jennifer	Scottish Association for Marine Science
Collins	Clare	University of Hull, UK
Coppock	Rachel	Plymouth Marine Laboratory
Corsi	Ilaria	University of Siena
Day	Thalia	A Plastic Planet
Dewar-Fowler	Vicky	British Antarctic Survey
Gibéryen	Tania	Script/MENJE, sila.lu Zero Waste Lëtzebuerg, Polar.lu
Giraudeau-Potel	Solene	Scottish Association for Marine Science
Hurley	Jessica	University of Hull
Jones-Williams	Kirstie	University of Exeter
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Lewis	Lyndsey	Quark Expeditions
Manno	Clara	British Antarctic Survey
McQuilkin	Alison	University of York
Mendrik	Freija	University of Hull
Meraldi	Verena	Hurtigruten Ltd.
Merrill	Greg	Duke University
Nawrot	Adam	Fundacja forScience, Poland
Nolan	Joseph	European Polar Board
Palmeira Pinto	Letícia	Universidade de São Paulo, Brazil
Paradinas	Lola	Scottish Association for Marine Science
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Peel	Becky	University of Bristol
Rowlands	Emily	University of Exeter
Scott	Victoria	University of Hull
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ten Brink	Felicitas	University of Hull
Thapa	Kaustubh	University of Utrecht
Thorpe	Sally	British Antarctic Survey
Valero	Kat	University of Hull

Surname	First name	Affiliation
van Sebille	Erik	University of Utrecht
Vural	Deniz	Istanbul Technical University
Waller	Cath	University of Hull
Waluda	Claire	British Antarctic Survey
Wilson	Daniel	University of Exeter
Yansaneh	Osman	University of Hull

Infographic showing connections established with stakeholders during SCAR PLASTIC-AG Workshop (28-29 October 2019, Hull UK).