Integrating Activities for Advanced Communities

D2.11- INTERACT Pocket guide on how to reduce plastic consumption and pollution

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Author: Marie Frost Arndal[1], Cornelya Klutsch [2] and Elmer Topp-Jørgensen[1]

[1]Arctic Center, Department of Ecoscience, Aarhus University, [2]Nibio Svanhovd Research Station, Norway.

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The Arctic and alpine environments are unique and vulnerable ecosystems that is undergoing dramatic changes. Temperatures are increasing 3-4 times faster in the Arctic than elsewhere on the globe, alpine glaciers are disappearing at an alarming rate, species distributions are changing, environmental pollutants accumulate, sea ice is disappearing, etc. Plastic pollution and climate change share the same fossil origin, oil and gas. Plastic impacts climate change through the extraction of oil and gas for plastic, energy used in the transport, production and waste handling phases (recycling and disposal), and plastic is a source of pollution impacting ecosystems through often unintended littering of e.g. macro- and microplastics. Plastics account for 3.4% of global greenhouse gas emissions.

Plastics are now found in all environments all over the world, including in the Arctic and alpine environments; e.g. on land, in water, in the seabed, in glaciers, and in the marine and terrestrial food chains.

Plastics are used for many purposes at research stations, i.e. research instruments, laboratories, containers, packaging, clothing, vehicles, etc. and have many useful properties, e.g. lightweight, durable, easily cleaned/sterilised and cheap. However, some plastic products are made for single use (or short-term use) and some easily degrade or shed microfibres wherever they are used. So while plastic can be sturdy and have long durability, large amounts of plastic end up in the environment as litter (macro to nanoscale) or as waste that needs proper treatment or disposal.

Research stations have an obligation to ensure a clean environment, both for ethical and scientific reasons. Stations should therefore continuously work to reduce problematic plastic use and waste. This guidebook was made by and for managers of research stations to increase awareness of the problem and provide guidelines for how stations, scientists and local communities can reduce negative impacts of plastic use and pollution.

2. About this guide book

The Arctic and alpine environments are unique and vulnerable ecosystems that are undergoing dramatic changes. Temperatures are increasing 3-4 times faster in the Arctic than elsewhere on the globe, alpine glaciers are disappearing at an alarming rate, species distributions are changing, environmental pollutants accumulate, sea ice is disappearing, etc. Plastic pollution and climate change share the same fossil origin, oil and gas. Plastic impacts climate change through the extraction of oil and gas for plastic, energy used in the transport, production and waste handling phases (recycling and disposal), and plastic is a source of pollution impacting ecosystems through often unintended littering of e.g. macro and microplastics. Plastics account for 3.4% of global greenhouse gas emissions.

Plastics are now found in all environments all over the world, including in the Arctic and alpine environments; e.g. on land, in water, in the seabed, in glaciers, and in the marine and terrestrial food chains.

We all have a share in the plastic pollution that is generated by all of us, and once it degrades into micro or nano particles, they are virtually impossible to remove from the natural environment and could stay there for centuries to come.

This guidebook was made by and for managers of research stations to increase awareness of the problem and provide guidelines for how stations, scientists and local communities can reduce negative impacts of plastic use and pollution.

The aim of this guide is to:

- Increase awareness of the impacts of plastic use on climate and the natural environment.
- Provide guidelines for how to manage plastic use at research stations.
- Provide guidelines for reducing negative impacts of plastics at the station and during fieldwork.
- Describe tools for engaging local communities in addressing the issue of plastic use and pollution.

3. Introduction to Plastic

It is impossible for most people on the globe to go through a day without encountering plastics. What used to be made of wood, metal, paper, cotton, or leather are now often made of or contain plastics. The discovery of plastic was revolutionary and at that time human manufacturing was not constrained by limited natural resources and few were aware of the potential climate effects of fossil fuel use. The production of new materials was a huge benefit for many and today remains a vital resource in modern day society, e.g. health care, production industries, transport, agriculture and fisheries, telecommunications, clothing, packaging and storage, everyday utensils, etc. It was also regarded as being good for the natural environment as plastics could substitute natural and limited resources such as ivory, wood, metal, and horn.

It was not until after World War II that plastic became more widely used. Polyester was introduced in the 1950s, and polypropylene, which is now one of the most used polymers in the world, was not available until 1954. Plastic began to replace the more expensive paper, glass, and metal materials, and today there are thousands of types of plastics serving different purposes.
It is now difficult to imagine a life without plastic. It is used for so many purposes and all around the globe, and we all have a share in the impacts it has on human health, the natural environment and climate.

3.1.What is plastic

Plastic polymers can be synthesised by using carbon atoms from petroleum and fossil fuels. Different plastic types, that are made from plastic polymers, have different characteristics. Most polymers are used in common consumer products in the form of polypropylene (PP), polyethylene (PE) and polystyrene (PS). Shopping bags are made from polyethylene, food containers from polystyrene, and drink bottles made by PET (polyethylene terephthalate, a form of polyester) (see Figure 1, plastic types and usage). A number of chemicals or additives, such as softeners (phthalates), fire-retardants, dyes, and sun filters, are added to make the plastic very sturdy or flexible – i.e., to make it *plastic*. There are more than 10,000 different chemicals known to be used as plastic additives throughout the manufacturing process (Hamilton *et al.,* 2022).


Plastics are used for many purposes at research stations; personal care, kitchen, buildings and interior, laboratories, workshops, cleaning products, etc. (Photos: Reynir Sveinsson and Josefine Lenz/Svenja Holste).

Renewable plastics, also known as bioplastics, exist, although they account for a next-to-nothing fraction of the total plastic production. These are made from plant sources such as castor beans, soy, corn, potatoes, tapioca and wood fibres. Through processing, the plant material is broken down into sugars that are changed through fermentation or chemical processes to form polymers. By adding resins to the polymers, manufacturers can create the type of plastic they need for a given project - these resins may be derived from plant sources or from petroleum products. Hence bio-based plastics are not, by default, more sustainable than fossil-based plastics, and many bioplastics are not biodegradable, it may simply mean that it breaks down into smaller particles faster - it doesn't disappear.

Plastic	Packaging types	Recycling number and examples
Polyethylene terephthalate: PET	Water and soft drink bottles, salad domes, biscuit trays, salad dressing and peanut butter containers	
High-density polyethylene: HDPE	Milk bottles, freezer bags, dip tubs, crinkly shopping bags, ice cream containers, juice bottles, shampoo, Chemical and detergent bottles	
Polyvinyl chloride: PVC	Cosmetic containers, commercial cling wrap	
Low-density polyethylene: LDPE	Squeeze bottles, cling wrap, shrink wrap, rubbish bags	
Polypropylene: PP	Microwave dishes, ice cream tubs, potato chip bags, and dip tubs	
Polystyrene: PS	Cd cases, water station cups, plastic cutlery, imitation 'crystal glassware', video cases	
Expanded polystyrene: EPS	Foamed polystyrene hot drink cups, hamburger take-away clamshells, foamed meat trays, protective packaging for fragile items	
Mixed	Water cooler bottles, flexible films, multi-material packaging	

Figure 1. Main plastic types and their usage, recycling number and examples of recycled products (World Economic Forum 2016).

3.2. History of plastic production and waste generation

The total amount of plastic produced since its invention is estimated to 8,300 million metric tons (Mt). (Geyer *et al.,* 2017). The global plastics production has recently doubled from 2000 to 2019 to 460 million tons (OECD, 2023).

The unconcerned glory days of plastic are long gone and the environmental concerns are building up; climate impacts (of extraction, production, transport, recycling and disposal), chemical components of certain plastics have known environmental effects and health concerns, and the durability that have made plastic a success also means that it will stay in the environment for hundreds of years if not disposed of in the right way.

Single use plastics
Many plastic products are only designed for single use – or in other words, designed to be waste. As an example, the single use plastics, such as cotton bud sticks, cutlery, plates, straws, stirrers, balloon sticks, as well as cups, food and beverage containers made of expanded polystyrene. Recent examples include the COVID-19 pandemic which generated 1,600,000 tons/day of plastic waste globally (more than all people living in Norway, Sweden and Finland combined or 11.428 blue whales) mainly due to the increased production of disposable personal protective equipment and testing kits. To sustain this demand for personal protective equipment, many single-use plastic legislations were withdrawn or postponed. In addition, lockdowns and restrictions on public gathering all increased the dependency for online shopping and hence an increase in plastic packaging material.

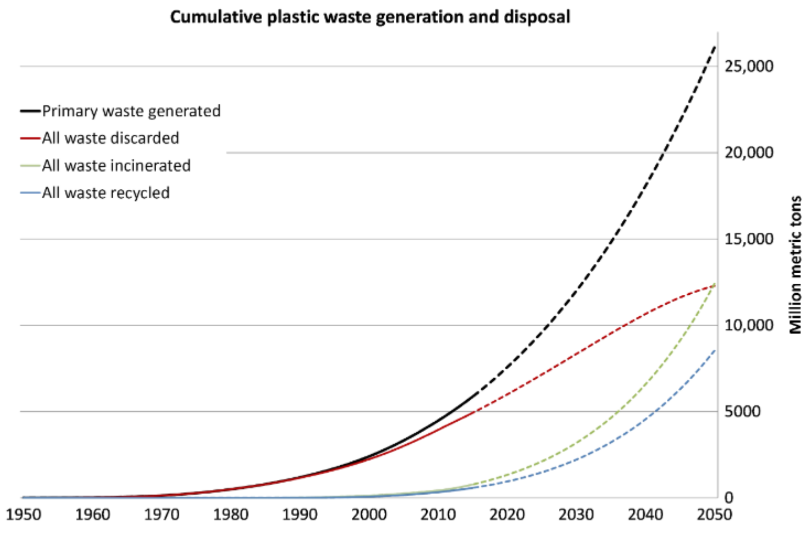


Figure 2. Cumulative plastic waste generation and disposal (in million metric tons). Solid lines show historical data from 1950 to 2015, dashed lines show projections of historical trends to 2050 (Geyer *et al.,* 2017).

There has been a steady increase in plastic production since the 1950'ies and global plastic waste generation more than doubled between 2000-2019 to 353 million tons (OECD, 2023) (Figure 2).

There are some uncertainties about numbers, but OECD (2023) estimate that globally, only about 9% of plastic waste is recycled, 69% is incinerated, while 22% end up in the environment or in landfills (See also Figure 3). If current production and waste management trends continue, Geyer *et al.* (2017) estimate roughly 12,000 million tons of plastic waste will be in landfills or in the natural environment by 2050.

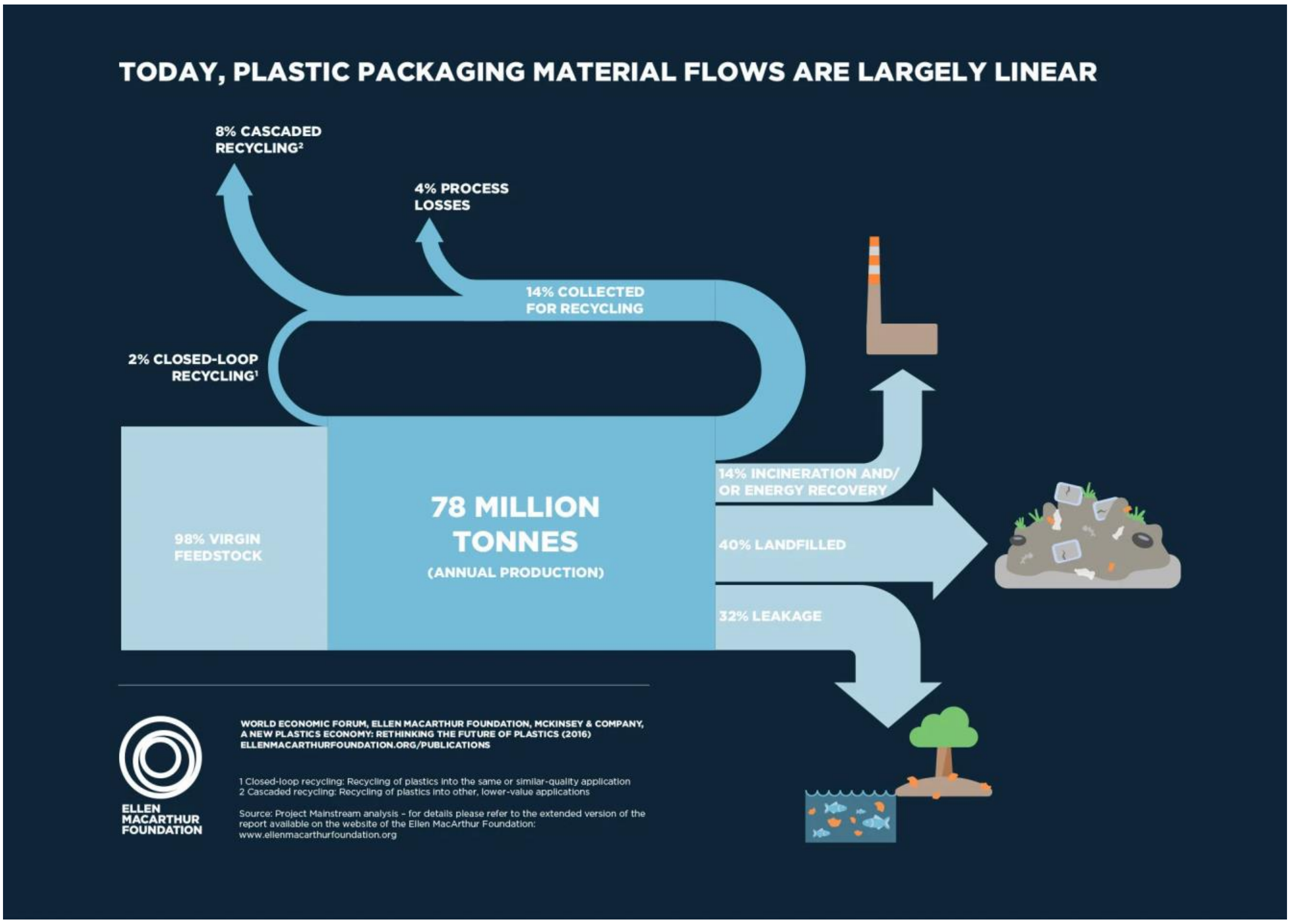


Figure 3. The current life of plastics: production - recycling - waste (https://ellenmacarthurfoundation.org/plastics-and-the-circular-economy-deep-dive).

With these huge numbers, billions of metric tons of material will accumulate across all major terrestrial and aquatic ecosystems on the planet, unless we develop a global management strategy for plastic very soon. The solutions require laws, regulations, management practices and technology setting global standards for industrial production and design that maximises recycling, proper sorting, collection, recycling, and proper disposal practices at a global scale, and awareness raising enabling people to make the right choices when buying, using, sorting and disposing plastic products. By developing such standards and practices we can ensure that products and materials are designed to be durable, reused, repaired, recycled or easily degradable (ellenmacarthurfoundation.org).

Current price of plastic products does not reflect the true cost of disposal and the cost of recycling or disposal. The 'polluter pays' principle hence needs to be included in the regulation of the plastic industry and products until the value of plastic waste as a resource becomes more viable in a circular economy.

3.3.Breakdown of plastics and degradation processes

Most plastic types do not decompose. Instead plastic items will break down over time into smaller and smaller particles through mechanical abrasion, hydrolysis, or photodegradation through UV from sunlight. Fragmentation and weathering may proceed until the nanoscale (i.e. 0.000001 mm). Degradation rates are slow and especially so under cold arctic or alpine temperatures. Also at the bottom of the sea, the breakdown of plastic can happen more slowly due to cold temperatures and lack of sunlight. Half- lives range e.g. from 58 years for bottles to 1,200 years for tubes (Koelmans *et al.,* 2022), meaning that it often takes hundreds to thousands of years for the plastic pieces to reach nanoscale (Figure 4).

This means that there is an accumulation of plastic pollution as more and more ends up in the environment.

Plastic degradation processes
Mechanical abrasion: is a tactile process of scuffing, scratching, wearing down, marring, or rubbing.
Hydrolysis: is any chemical reaction in which a molecule of water breaks one or more chemical bonds.
Photodegradation: is degradation of a photodegradable molecule caused by the absorption of photons, particularly those wavelengths found in sunlight, such as infrared radiation, visible light, and ultraviolet light.
Biodegradation: is the process by which microorganisms break down organic matter.

Kind of Plastic	Decomposition Time	Same Time Since
Fishing line	±600 years	Christopher Columbus discovered America (1492)
Plastic bottles	±500 years	Miguel de Cervantes was born (1547)
Plastic cutlery	±400 years	Galileo Galilei said the earth is round (1630)
Lighter	±100 years	The Titanic ship sank (1912)
Plastic glass	70-80 years	World War II ended (1945)
Plastic bag	±60 years	Men traveled to the Moon (1969)
Shoe sole	10-20 years	First cell phone with color screen (2000)
Cigar butt	5-10 years	Fukushima nuclear accident (2011)
Balloon	±2 years	Paris Climate Agreement (2015)

Figure 4. Decomposition time of selected plastic products (Aguilar 2018).

3.4. Size classes of plastic

Plastic pollution comes in many different sizes, and each size class has different environmental effects. Plastics in the environment come in at least five size classes although these classes have not been formally adopted by the international research community (see Figure 5). For simplicity, we describe commonly used particles of macro-, micro-, and nano-sizes.

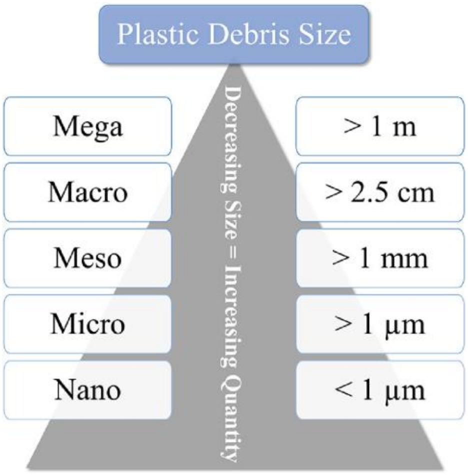


Figure 5. Five size classes of plastics defined by Müller (2021). Here we only describe three for simplicity). Reproduced from Müller (2021).

Macroplastic is generally defined as plastic items larger than 5mm, e.g. bottles, bags, straws, string/fishing net, shotgun shells, buckets or pieces thereof. It can impact individual animals through e.g. entanglement, ingestion (blocking or accumulating in stomach), suffocation (blocking airways). Many of us have seen plastic waste washed ashore on beaches and many have seen photos of wildlife entangled in or suffocated by plastic, and stomachs full of plastic.


Macroplastics can be found on remote beaches and in the stomachs of animals living far from densely populated areas (Photos: Maria Granberg).

Macroplastic waste also has a significant economic implication for a range of marine industries, e.g. aquaculture, fisheries, harbours, industrial seawater users, marinas, municipalities, power stations, rescue services, shipping, and water authorities. These include costs related to e.g. cleaning, blockages, entanglement, and contamination. Marine litter can also be a possible vector for the transfer of alien species, such as bryozoans, barnacles, polychaete worms, etc. Litter also impacts people’s quality of life by loss of aesthetic value and reduced recreational opportunities.

Microplastics are generally defined as less than 5mm and come in different shapes, e.g. spheres, fragments, granules, pellets, flakes, beads, filaments, or fibres. Microplastics are primarily a concern due to their small size, which means easy ingestion in marine life and in food chains (see physiological effects below).

Primary microplastics are plastic pieces produced in that size, e.g. nurdles (building blocks of most plastic products), cosmetic microbeads (used in crème, hair products, toothpaste, etc.), etc., while secondary microplastics come from the degradation of larger plastic objects. The vast majority of microplastics come from the breakdown of larger plastic waste.

Nanoplastics are generally defined as < 1 µm but the identification of nanoplastic particles is still challenged by technical detection capabilities (AMAP guidelines). Under laboratory conditions, a plastic particle of 1 mm in diameter would require about 320 years to reach a nanoscale diameter of 100 nm, but in the environment, degradation can be assumed to be faster (Koelmans *et al*., 2022). The actual amounts and characteristics of nanoplastic particles in the environment remain largely unknown (Koelmans *et al.*,2022 and references herein).

3.5.Handling of plastic waste

Ideally, plastics should never be waste, but be part of a circular economy where plastics are reused or recycled (Davidson *et al*., 2021). Currently, however, around 40 percent of plastic products are garbage after less than a month and it is estimated that only 9% of plastic waste has been recycled since 2015 (Geyer *et al.,* 2017). The majority of the waste has been disposed of in landfills.

There are essentially three different fates for plastic waste (Geyer *et al.,* 2017):

1. It can be recycled or reprocessed into a secondary material. Contamination and the mixing of polymer types generate secondary plastics of lower technical and economic value.
2. Plastics can be incinerated.
3. Plastics can be discarded and either contained in a managed system, such as sanitary landfills, or left uncontained in open dumps or in the natural environment.

The most used waste disposal mechanism is landfills (50%), followed by incineration (19%) (burning plastic trash to create energy), and 22% evades waste management systems and goes into uncontrolled dumpsites, is burned in open pits or ends up in terrestrial or aquatic environments, especially in poorer countries (OECD, 2023).

A landfill can, in theory, act as a carbon sink if there are no leakages. This will require that CO_2 and other greenhouse gases emitted from decomposition processes are captured. However, landfills do often leak and spread to the environment. Plastic in the landfill is lost from the value chain in a circular economy and a continued demand for plastic necessitates additional extraction of fossil fuels for the production.

Landfills are widely used for disposal of plastic waste and receive close to half of all global plastic waste (Photo: Maria Granberg).

When burning plastic, you also remove plastic from the value chain and the burning of plastic waste produces other harmful pollutants, such as dioxins, metal compounds and greenhouse gases. Thus, incineration should take place in proper treatment plants that remove harmful substances from emissions.

One of the biggest barriers to plastic recycling is separation: when different polymers are mixed, the resulting material does not usually have useful properties. It is possible to recycle plastic back into oil and then to other useful products like fuel (or other types of plastic). The main problem is that it requires a lot of energy. It should not take more energy to recycle plastic than you're saving by recycling it.

Biodegradable/bio-based plastics are considered to be plastic under the EU's Single Use Plastic Directive. Currently, there are no widely agreed technical standards available to certify that a specific plastic product is properly biodegradable and not harmful to the environment.

3.6.Plastic waste in the natural environment (sources and sinks)

Plastic pollution can be transported to the Arctic and alpine environments from far away via wet (ocean currents, rivers, rain) or dry (air) deposition, or waste emissions by industry and humans (tourists, researchers, locals).

Surface circulation models and field data showed that the poleward branch of the Thermohaline Circulation transfers floating debris from the North Atlantic to the Greenland and Barents seas, which would be a dead end for the plastic waste. Given the limited surface transport of the plastic that accumulated here and the mechanisms acting for the downward transport, the seafloor beneath this Arctic sector is hypothesised as an important sink of plastic debris (Cózar *et al., 2017*). Scientists believe that 80% of the plastic in the aquatic environment ends on the ocean floor. In the Arctic deep sea, microplastic concentrations range between 0 and 16,041 particles kg^{-1} sediment and rank amongst the highest measured concentrations globally (Bergmann *et al*., 2022).

Plastic pollution of the terrestrial soils can be between 4 and 23 times higher than in the seas, depending on the environment. Especially sewage (domestic waste water) is an important factor in the distribution of microplastics where sewage sludge is applied to fields as fertiliser on agricultural fields.

Wastewater treatment is often lacking in the Arctic and other remote locations. In some communities, traditional waste management solutions are direct emission to the sea/water ways, and landfills, sometimes next to the sea. This means that plastic litter and microplastics more easily reach the environment and enter the ocean.

When we wash synthetic fabrics and clothing, like polyester, fleece or jackets in washing machines, the clothing sheds tiny plastic fibres. It is shown that microfibre fleeces are the most commonly detected type of fragments in various water bodies (Mishra *et al., 2017*).

The majority of the losses of primary microplastics (98%) are generated from land based activities. Textile fibres and particles from car tire abrasion are the two main sources of primary microplastic in the ocean. The main pathways of these plastics into the ocean are through road runoff (66%), wastewater treatment systems (25%) and wind transfer (7%) (iucn.org). The International Union for Conservation of Nature (IUCN) (Boucher and Friot, 2017) divides the global contribution of different primary sources of microplastics into the marine environment into seven categories:

1. Synthetic textiles.
2. Vehicle tyres.
3. Road markings.
4. Personal care products and cosmetics.
5. Plastic pellets.
6. Marine coatings.
7. City dust.

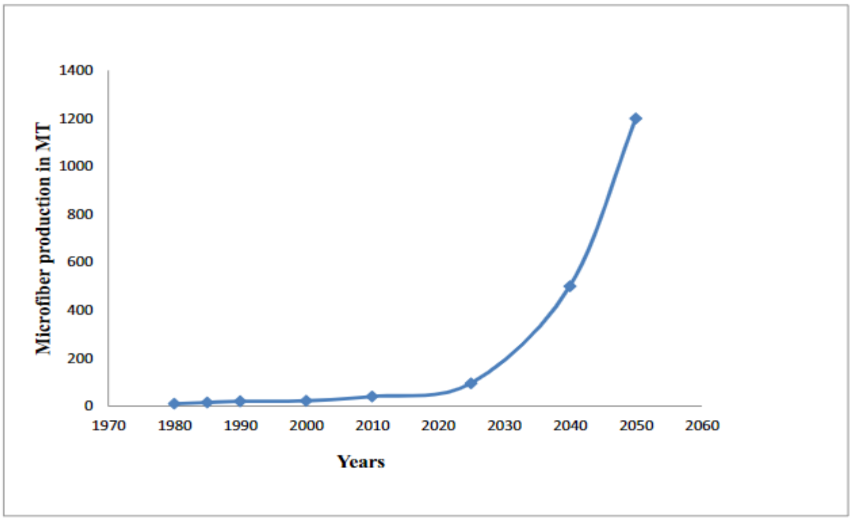


Figure 6. Historical and projected rate of microfibre production (Mishra *et al.,* 2017).

4. Environmental impacts of plastics

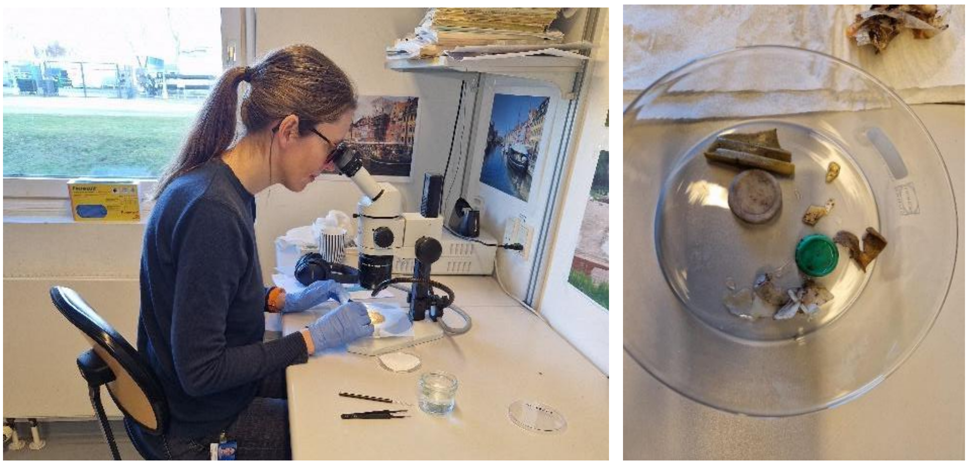
Plastic is present all around the globe in all size classes. Micro- and nanoplastics are present in air, water and ice. It is ingested by animals, including commercially important species of fish and shellfish eaten by humans. There is also evidence that micro and nanoplastics can be found in internal organs of humans (e.g. lungs, livers, spleens and kidneys). However, the environmental impact and health risk associated with human consumption are not yet well known (Koelmans et al., 2022). There is, however, substantial evidence that plastics-associated chemicals, such as methyl mercury, plasticisers and flame retardants, can enter the body and are linked to health concerns (https://www.unep.org/interactives/beat-plastic-pollution/). Therefore, there is a clear need for improved understanding of the effects of plastic pollution and vector borne chemicals on ecosystems, species and human health.

4.1.Physical effects

Some effects of plastic waste in the environment are obvious to see, while others are less visible. For macroplastic, wildlife and fish can get entangled in plastic (get stuck or suffocate), eat plastic that fills up or block their digestive systems, or have their airways blocked or gills destroyed by plastic pieces. The visible impact caused by macroplastic to larger animals, is well documented (AMAP Plastic Monitoring Plan recommend Northern fulmar (bird) as one of 11 plastic monitoring components).

On the other hand, very little is known about what micro- and nanoplastics can do to the ocean's smallest organisms such as zooplankton, fish larvae, and clams. It has been suggested that smaller particles are potentially more hazardous if ingested but it may also be that very small particles in the nano size range may pass into and out of organisms with relative ease (Sapea 2019). Microplastics often pass through the digestive systems of living organisms, and as with many chemicals 'the poison is in the dose' – meaning that it is the number (and size) of particles that pose a threat and the possible chemicals attached to it (Sapea, 2019). Microplastic may also adhere to smaller organisms restricting their movements and hence their ability to find food (https://www.unep.org/interactives/beat-plastic-pollution/).

The microscopic sizes mean that it is almost impossible to filtrate for micro- and nanoplastics without impacting smaller ocean organisms and animals in the ocean. More work is needed to understand the differential retention and effects of particle size.



Plastic debris from the stomach of a Northern fulmar (Photos: Jannie F. Linnebjerg).

4.2.Chemical effects

The role of chemical adherence to or release from plastic particles is of particular concern in the Arctic because of the dependency on subsistence harvesting of natural resources. Monitoring of chemical contaminants in the Arctic has been conducted for several decades through the Arctic Monitoring and Assessment Programme (AMAP), an Arctic Council Working Group.

It has been hypothesised that release of chemicals from microplastic after particle ingestion increase exposure to these chemicals, and subsequently lead to chemical risks to biota (the 'microplastic vector effect'). Newer studies suggest that this effect is unlikely to play a major role (Koelmans *et al.,* 2022), also as concentrations of toxins at sea remain very low (Flint *et al.,* 2012). There may however be a need to evaluate the behaviour of plastic additives under Arctic and alpine conditions as the migration of chemicals (e.g. leaching, adsorption/desorption) is slower in colder regions (Hamilton 2022).

The effects of nanoplastics are even more uncertain than microplastic, due to absence of studies on their behaviour in the environment. Currently limited or no data is available for nanoplastics in food, and toxicity data are lacking for both microplastics and nanoplastics (EFSA, 2016). As the distribution and concentrations of nanoplastics in the environment remains largely unknown, we do not know enough about the role of nanoplastics for the total chemical risks posed by fragmenting microplastic (Koelmans *et al.,* 2015).

Neither do we know much about the effects of small plastic particles can have on humans. What we do know, however, is that there are chemicals in plastic, such as Bisphenol A and phthalates, which can have harmful effects on humans.

The plasticizers phthalates can easily leach out or evaporate as they are not chemically bound in the materials they are added to. People are exposed to phthalates by handling or coming into contact with items stored in such plastic types (e.g. eating and drinking foods that have contacted products containing phthalates). Phthalates are frequently used in raincoats, sports clothing and even children's toys. It is tested that it has harmful effects on the human body, which includes early onset of puberty, reduced male reproductive system development, impaired hormone system function, reproductive and genital defects, etc. (Mishra *et al.,* 2019).

Bisphenol A (BPA) is used primarily in the production of polycarbonate plastics and can damage female reproductive hormones. The BPA in food packaging materials are now regulated more strictly in many countries, especially in infant feeding bottles. The general 'background exposure' to Bisphenol A through, for example, other foods and food packaging is 40 million times higher than from eating blue mussels that may contain microplastics (Rist *et al.,* 2018). This means that the number of blue mussels one eats with associated microplastics is completely insignificant compared to one's exposure to Bisphenol A through other sources. What should be in focus is our total exposure to plastics and microplastics in our everyday lives.

To fully understand the chemical effects of micro- and nanoplastics, we need an improved understanding of chemical properties of different plastic types, and their distribution and concentration in the natural environment, to the volatility of chemical compounds and their effect on ecosystems, species and humans (including their role in cumulative effects).

AMAP provides recommendations for monitoring of plastic and chemical additives including persistent organic pollutants (POPs), and are currently developing monitoring recommendations for emerging pollutants (newer chemical compounds used by the industry). Further standardisation of sampling and detection methods, health effect studies, etc. is key to fully understand the scale of impact of chemicals associated with micro- and nanoplastics.

4.3.Climate change contributions (production, transport, degradation, recycling)

Since the modern plastics industry relies on fossil fuels for its raw material, transport, manufacturing processes, recycling or treatment of plastic waste (incineration), the production of plastic has an impact on climate change, contributing to global CO_2 production. Currently a total of 6% of the global raw oil extraction is used for plastic production (World Economic Forum 2016) . This number does not include the oil that is used afterwards in transportation, processing, handling, etc. or the CO_2 emitted when the plastic is degraded. Furthermore, greenhouse gases such as methane, ethylene, ethane, and propylene are released during degradation of some common plastic polymers throughout their lifetime (Royer *et al.,* 2018).

When the darker particles are deposited on snow and ice (can be emitted on site or smaller particles transported by air), they affect the ice-albedo feedback, by reducing the ability of snow and ice to reflect the sunlight resulting in increasing melting of snow and ice (Geilfus *et al.,* 2019). In the atmosphere, microplastic particles can serve as condensation nuclei for water vapour, producing effects on cloud formation and hence the climate.

5. International agreements and legislation

Legislation addressing plastic pollution can mainly be grouped into measures that aim to protect the environment and those that are focused on waste (Sapea report 2019). There is a broad range of international, national, regional and local policies and legislation concerning plastic production and waste handling, but policies are implemented inconsistently across regions. To reduce plastic pollution, international collaboration is needed to implement standardised policies (legislation and management practices) and long-term monitoring programs (Linnebjerg *et al.,* 2021).

The AMAP Regional Action Plan on Marine Litter (2021) will enable the Arctic Council to take targeted and collective action to address problems with marine litter in the Arctic. The overall objective of the Regional Action Plan is to "*support Arctic States' efforts to reduce marine litter in the Arctic marine environment, prevent the potential negative impacts and mitigate the risks it may pose, and to improve cooperation on and awareness of this shared objective*". The plan is not legally binding and relies on national implementation of its actions that addresses both activities in the sea and on land, and outlines strategic actions within eight thematic areas. Until the completion of the Arctic Council Regional Action Plan on Marine Litter, there is no pan-Arctic framework to address plastic pollution (Linnebjerg *et al.,*2021).

The EU adopted a European strategy for plastics in January 2018, that aims to reduce marine litter. It is now part of the EU's circular economy action plan (CEAP 2020), which builds on existing measures to reduce plastic waste. The "Directive on the reduction of the impact of certain plastic products on the environment" (commonly referred to as the Single-Use Plastics (SUP) Directive) entered into force in 2019. It aims to tackle pollution from single-use plastics (and fishing gear), as the items most commonly found on European beaches. From 2022, Member States will be obliged to report on fishing gear containing plastic placed on the market and fishing gear recovered at sea.

The European Commission adopted the new circular economy action plan in March 2020. The new action plan aims to e.g. make sustainable products the norm in the EU and ensure less waste. A central initiative is to improve the science on the risks and occurrence of microplastics in the environment, tap water and food, and reduce environmental pollution and potential health risks. In 2022, UN Member States endorsed a resolution to End Plastic Pollution and forge an international legally binding agreement by 2024; *End plastic pollution: towards an international legally binding instrument.* The resolution addresses the full lifecycle of plastic, including its production, design and disposal.

Some business sectors also work to reduce their use and disposal of plastics. The tourist industry is contributing to the large amount of plastic waste in our environment. The Global Tourism Plastics Initiative aims to reduce plastic pollution through an agreement to be developed by 2025. Their commitments include elimination of unnecessary single-use plastics, transition to reuse models and use of reusable, recyclable, or compostable plastic packaging and items. The Association of Arctic Expedition Cruise Operators (AECO) is working to combat marine plastic pollution by sharing of best practices and lists of alternative products (which AECO is currently developing) with its operators.

The scale, distribution and amounts, and effect of plastic waste ending up in the environment necessitates continued development and implementation of international standards for plastic production governance and waste handling practices to ensure a circular economy for plastics and prevent negative climate, environmental, and health impacts.

6. A future outlook

6.1.No easy way of removing micro and nano plastics from the environment

Due to their size and ubiquity, there are currently no cost-efficient mechanisms to collect microplastics from the environment at scale once they have been introduced to it. Therefore, the most efficient way to mitigate microplastic pollution is to prevent microplastics from entering the environment in the first place and by targeting actions to reduce emissions at the source.
The market today offers an array of alternative plastic-free products and the options are increasing. From lipsticks free of micro-plastic or brushes made of wood to t-shirts made of natural fabrics.

6.2.A sea of unknown health and environmental effects

Some plastic types contain chemicals with known negative effects on the natural environment and human health, and there is also mounting evidence of the physical effects on wildlife. Our knowledge of the long term effects of plastic particles found in the environment is less well understood and more research into sources, sinks and effects of different types of plastic is needed.

6.3.Alternatives to plastics

There is potential for the microspheres and microfibres in building paint to be replaced with either glass beads or cellulose-based microspheres; or for the microplastics used in industrial abrasives to be replaced with coconut shell, dry ice, silicon, or glass beads. There are also examples of materials based on plants and fungi.

When considering alternatives to plastics, it is important to consider climate and environmental impacts of the entire lifecycle of the materials: extraction, production, transport, use, reuse, recycling, treatment, emissions to the natural environment and it's impacts on society, landscape, environment and species.

6.4.Circular economy and waste as a resource

Eliminating plastic waste relies, in part, on changing behaviour. To eliminate plastic waste requires wide-scale system changes and a shift from a linear to a circular plastics economy (Figure 5), where plastic is flowing around in a 'closed loop' system and where products are re-used, re-purposed, recycled, and recovered (Allison *et al.,* 2022).

In a circular economy, materials are designed to be used, reused, and recycled, not to end up in landfills or the environment. No materials are lost, no toxins are leaked. All the plastic items we use should be circulated to keep them in the economy and we should avoid losing any of it to the environment. A shift from a linear to a circular plastics economy means a system that keeps plastics in a 'closed loop' system where products are re-used, re-purposed, and recycled (Figure 7).

Ultimately, preventing plastic waste in the first place is the key to a cleaner, healthier environment.

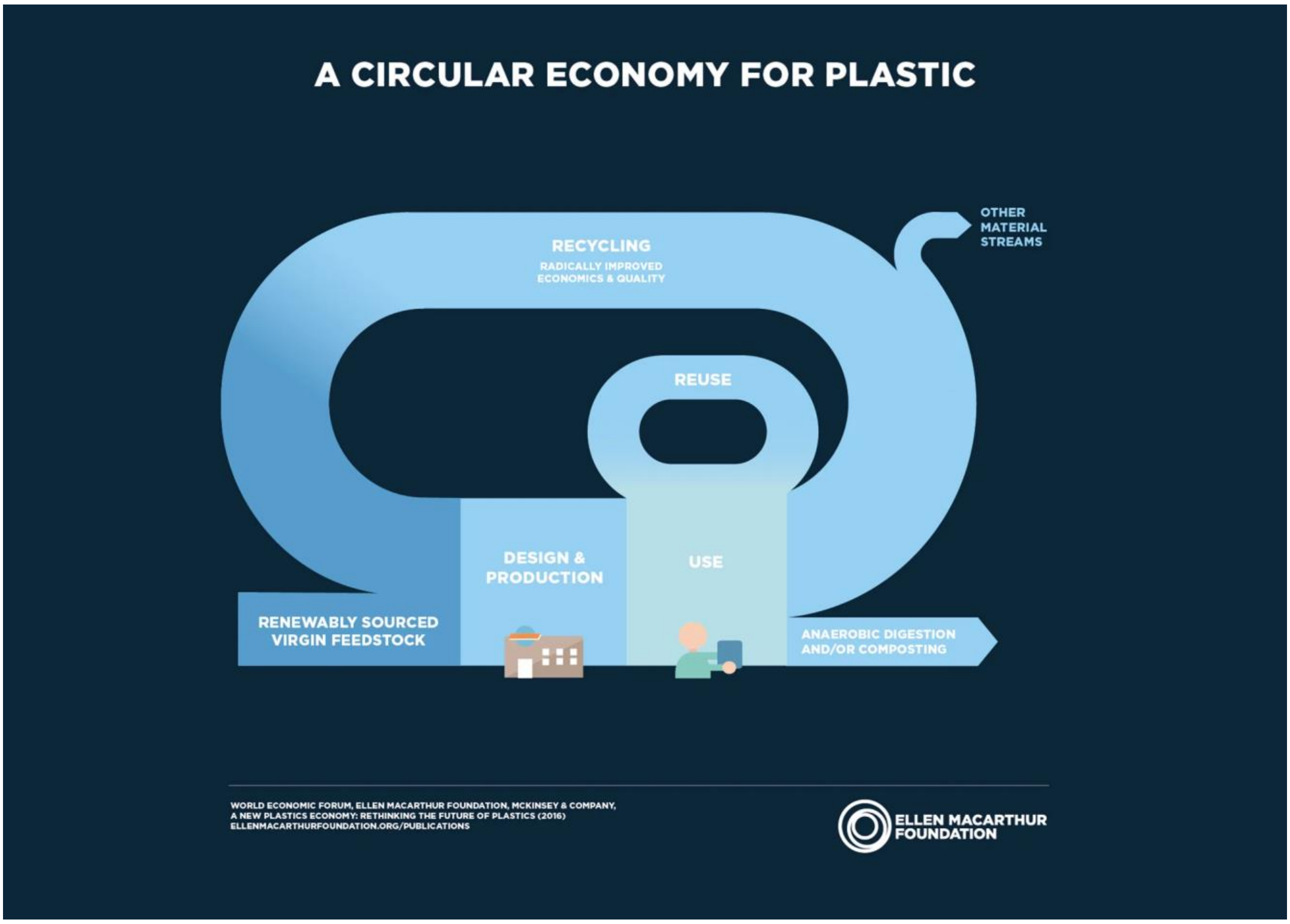


Figure 7. Envisaged circular economy for plastics (https://ellenmacarthurfoundation.org/plastics-and-the-circular-economy-deep-dive)

7. Guidelines for research station managers

Plastics are used for many purposes at research stations, i.e. research instruments, laboratories, containers, packaging, clothing, vehicles, etc. and have many useful properties, e.g. lightweight, durable, easily cleaned/sterilised and cheap. However, some plastic products are made for single use (or short term use) and some easily degrade or shed microfibres wherever they are used. So while plastic can be sturdy and have long durability, large amounts of plastic end up in the environment as litter (macro to nano scale) or as waste that needs proper treatment or disposal.

Reducing the use of plastic is a first step towards reducing plastic waste generation and pollution (Figure 8). For this, research stations need to consider durability of plastic products, reuse and recycling potentials and alternative products in purchase policies. Secondly, research stations should develop use policies, and implement proper waste management systems to limit emission to the environment, incl. sorting procedures and proper disposal mechanisms with minimal impacts on the natural environment and human health. Furthermore, research stations can also play a role in monitoring plastic pollution and guiding behaviour of staff, visiting scientists and local communities.

Research stations can and should therefore work with plastics on several levels, e.g. internal policies, scientific monitoring of local environmental problems associated with plastics and influencing human behaviour.

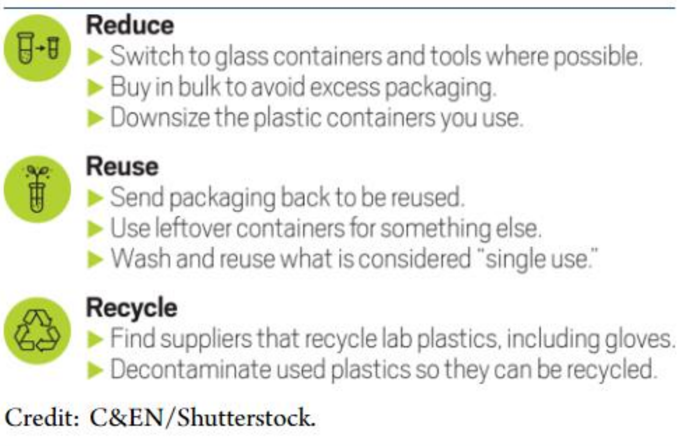


Figure 8. The principles for minimising environmental impacts of plastics, Urbina *et al.,* (2015).

7.1. Reduce use through purchase policy

An efficient way of minimising plastic use at a research station is to develop a purchase policy that can guide station management and staff in relation to buying plastic products or products containing plastics.

A purchase policy can prioritise:

- Sturdy and durable plastic products.
- Products with no harmful chemicals.
- Reusable or repurposed plastic products.
- Recyclable plastic products.
- Alternative products with no plastic where possible.

7.2.Re-use products for same or other purposes

- Use plastic containers used for transport (e.g. food, paint) for other purposes.
- Reuse packaging materials (or return to supplier).

7.3.Implement proper waste handling system at station

- Collect, sort and store plastic waste in relevant fractions for reuse, recycling or disposal.
- Submit recyclable and disposable plastic to municipal treatment system (if these follow good environmental practices) or transport to proper treatment facility.
- Treatment on site should only be done if you have proper treatment equipment (e.g. incinerator that burns at required high temperatures).
- Put filters on outlets to rivers, oceans, etc. to collect microplastic.

7.4. Influence staff and user behaviour

7.4.1.At station

Research stations can develop rules and guidelines to restrict the use of plastic products or products containing plastics, and minimise emissions to the natural environment.

Recommendations:

- Develop rules and guidelines for staff and visitors related to:
    - Allowed/prohibited use of certain products, e.g. easily degradable plastics and products containing microplastics.
    - Expected behaviour, incl. collection, sorting and disposing of plastic products.
- Offer certified environmental cleaning agents, toothpaste, etc. that do not contain plastics or environmental pollutants. In this way, stations can ensure that no harmful substances are emitted.

7.4.2.In field

Make sure not to contribute to the plastic pollution in the environment by using only sturdy, durable and recyclable plastic for your fieldwork. Plastic markers can easily be broken down or destroyed by the harsh weather in the Arctic or by curious animals. Plastic pollution left behind from researchers will stay in the ecosystems for many years.

Recommendations

- Do not litter.

- Bring a refill water bottle to avoid single use bottles.
- Bring a lunch box and *food paper/beeswax cloth*, instead of packing food in plastic bags, foil or food wrap/cling wrap.
- If needing to use plastic, prioritise sturdy, durable, and environmentally friendly plastic that does not deteriorate and spread to the environment.
- Consider alternatives to plastic when possible, e.g. using metal or wood sticks and pegs for plot identification.
- Duct tape – will not last in the field during the arctic winter! Do not leave it in the field for longer periods and bring it back for proper sorting.
- When using plastic in the field (plastic chambers or tents), make sure that it does not blow away during a storm or spread to the environment.


Plastic tent used for field manipulation studies (Photo: Marie Frost Arndal).

7.5. Monitor plastic use, waste generation and pollution

7.5.1. Plastic use and waste monitoring at station

Research stations have an obligation to ensure a clean environment, both for ethical and scientific reasons. Stations should therefore continuously work to reduce problematic plastic use and waste. Conducting an environmental impact assessment can help develop policies, rules and guidelines to mitigate negative effects of plastic, and monitoring of volumes of different plastic types used at the station, waste generation and emissions to the natural environment is essential for improving station procedures for handling plastics at the station.

7.5.2. Monitoring plastic pollution

An Arctic Regional Action Plan to address plastic pollution should draw from the harmonised approach for marine litter monitoring modelled by OSPAR. Focus should be on science that can establish a baseline of current plastic pollution, and a foundation for collaborative science to enable effective plastic pollution monitoring and intervention assessment.

Much can still be done to standardise/harmonise data collection and improve our knowledge on distribution and effects on the natural environment. According to Brittany *et al.,* (2020) the scientific community should focus on:

- Development of harmonised protocols and standardisation of data to measure trends over time in a consistent way that is conducive to data sharing.
- Consistent monitoring throughout the year to account for seasonal fluctuations.
- Establishment of baselines from which to measure progress.
- Better data collection from certain parts of the Arctic Ocean region, particularly the Central Arctic Ocean and coastal areas in Siberia, Arctic Alaska, and Canada.
- Increased sampling of snow on ice floes to improve estimates of atmospheric transport of litter.
- Seafloor sediment monitoring, since plastics of all sizes accumulate there.
- Identification of "hot spots"—areas of acute contamination with greatest risk to wildlife and the marine ecosystem.
- Improved use of satellite imagery to assess where ice forms and how it moves, thereby providing information about where ice picks up microplastics.
- Further initiatives to develop remote sensing for detecting large debris at sea, as well as sensors to detect plastics in the water column that could be installed opportunistically on vessels.
- Increased collaboration between Arctic communities and scientists in community monitoring of plastic pollution.

The Arctic Monitoring and Assessment Programme (AMAP, Provencher *et al.,* 2022) has published an ecosystem-scale litter and microplastics monitoring plan. In it, litter and microplastics monitoring is prioritized in four compartments; water, aquatic sediments, shorelines, and seabirds. Implementation of the monitoring activities should include community-based local components where possible.

A Sustainable Development Goal (SDG) indicator (SDG 14.1.1.b) on plastic debris density, and monitoring parameters (Level2: Beach Litter), including beach litter and microplastics data collection by citizen scientists, was developed by the UN (United Nations, 2022; (sdgs.un.org/partnerships/collect-citizen-observation-local-litter-coastal-ecosystems).

7.5.3. The role of citizen science and community-based environmental monitoring (CBEM) in plastic pollution research and monitoring

Effective management of plastic pollution requires actions targeting individual behavioural and societal changes - citizen science and community-based monitoring may have important roles in the reduction of plastic pollution, from organising clean-up initiatives to reduce local plastic pollution to connecting the general public with the government (Popa *et al.,* 2022).

Citizen science, the involvement of the general public in research processes, has recently been explored as one way of engaging non-experts in plastic litter research while at the same time, raising awareness and nurturing behavioural changes towards sustainability (Pierini *et al.,* 2021, Popa *et al.,* 2022). Citizen science projects in the context of plastic pollution have spanned from marine plastic litter research (Zettler *et al.,* 2017), plastic pollution in rivers and on streets (e.g. Forrest *et al.,* 2019, Kiessling *et al.,* 2019, 2021, Lynch *et al.,* 2018, Rech *et al.,* 2015), evaluation of household waste and recycling (e.g. Kala *et al.,* 2021, Pierini *et al.,* 2021, Popa *et al.,* 2022 and references therein), and littering (e.g. Nelms *et al.,* 2022).

In a recent literature review, it became apparent that there are three major plastic research areas in which citizen scientists have collaborated with researchers: i) litter distribution, including density and types, ii) recycling of litter, and iii) plastic management practices (Popa *et al.,* 2022). However, there is a clear lack of standardisation regarding data collection for quantification of plastic pollution among studies (Nelms *et al.,* 2022).

The most common citizen science projects that deal with plastic pollution are connected to clean-up initiatives (Nelms *et al.,* 2022). Because of the nature of public involvement in clean-up operations, participants may not necessarily be interested in more detailed assessments, like noting types of plastics or density estimates.

Other challenges (and some solutions) for citizen science projects targeting plastic pollution include:

1. Data quality: A common concern is the accuracy of data collected by non-experts, particularly younger participants like school children. However, studies have shown that school children conducted tasks with similar accuracy as untrained professionals (Castagneyrol *et al.,* 2019). Hence, data collected by school children can be valuable as long as researchers are involved in quality checks and thorough training of citizen scientists (Popa *et al.,* 2022).
2. Ease of data collection: Volunteers will be overwhelmed if data collection is clunky and complex. Recent technical advancements, like mobile phone apps, may further accelerate

data collection and have the advantage that data can be directly submitted to a database. This reduces the messiness of hard copies and their transcription to a database, which can introduce additional transcriptional errors as well as errors based on readability of original notes. In addition, mobile phones allow for photographs taken at the same time to be submitted alongside data points for additional verification. However, a disadvantage is lack of internet connections in remote regions like the Arctic. Hence, careful consideration of what the best approach may be, is crucial to ensure robust data collection.

3. Temporal consistency/loss of interest over time: Motivation of volunteers may decrease over time and this may lead to discontinued data collection. Therefore, a strategy for continued communication and engagement needs to be developed. These may include newsletters to the community, lotteries to distribute prices, or similar things. Follow-up meetings in communities to update on the progress of the project is also an important part of these efforts.

The European Union has produced a report on best practices in citizen Science for environmental monitoring: https://data.consilium.europa.eu/doc/document/ST-9973-2020-INIT/en/pdf.

7.5.4.Community-based environmental monitoring (CBEM) of plastic pollution

Community-based environmental monitoring (CBEM, Siderova and Virla, 2022, Provencher *et al.,* 2022) can be defined as "*a process whereby non-government organisations, community groups, or individuals participate in long-term monitoring of selected species, habitats, or ecosystem processes with the ultimate goal of improving management of ecosystems and natural resources*" (Yarnell and Gayton, 2003). In the context of the Arctic, these community-based monitoring projects will often include or be initiated by indigenous communities that live in the respective areas and have valuable local knowledge and traditional ecological knowledge.

Funding is a crucial aspect for these efforts to succeed. For example, the Government of Canada has established a dedicated funding scheme, the Indigenous fund for community-based environmental monitoring (https://www.canada.ca/en/environment-climate-change/services/oil-sands-monitoring/community-based-monitoring.html).

7.6.Influence local communities

A lot of the abovementioned reduce, reuse, and recycle principles can be applied to the reduction of plastic waste in local communities. This may be particularly relevant in Arctic local communities because these are usually rural and isolated with less waste management infrastructure than more southern communities. Therefore, information campaigns in the local communities may be one way to inform, motivate, and provide opportunities for the public.

Previous studies have found three main problems with the awareness of citizens when it comes to plastic pollution:

1. Litter blindness (De Veer *et al.,* 2022, Kerber and Kramm 2022): In several studies, it has been found that people tend to ignore plastic pollution, except if it poses a direct threat to

them or is perceived as a nuisance. This leads to an underestimation of the risks linked to plastic pollution. Connected to this is that many rural regions lack proper plastic waste disposal facilities and thus, plastic is burned privately.

2. Lack of knowledge (Popa *et al.,* 2022): Unawareness on how to recycle different types of plastic or recycling symbols, and how to avoid plastic pollution and reuse of plastics (to which this guide may form the basis of awareness campaigns).

3. Underestimation of own contribution to plastic pollution: It has been shown that citizens miscalculate the amount of plastic waste they generate and dispose of (Zikali *et al.,* 2022).

7.6.1.Ways to increase awareness in local communities

1. Use of social media: Use and analyses of Twitter posts have found that social media can be an effective way to reach global audiences (Abreo *et al.,* 2021, Otero *et al.,* 2021).

2. Story-telling (Praet *et al.,* 2023): Story-telling has been used to increase awareness about marine debris in school children.

3. Citizen science projects and clean-up programs: Direct involvement in research-based projects can increase awareness and knowledge on plastic pollution (Locritani *et al.,* 2019, Wichmann *et al.,* 2022). Dedicated clean-up programs with a limited time effort may be suitable for many rural communities. Ideally, local authorities should be involved in these efforts to connect citizens to the government and facilitate the development of plastic pollution management that is accepted by the community (which will likely result in higher adherence rates). Finally, collaborative development of easy-to-understand guidelines for the wider community and developing campaigns (see also below) to reach the wider community to bridge this knowledge-implementation gap. This may lead to behavioural changes, but is not always enough to do so.

4. Information campaigns on plastic pollution in community centres, malls, museums, churches, etc.: These initiatives can reinforce lessons learned or prepare citizens for clean-up days, for example. In addition, they may reach other audiences not reached by other initiatives.

7.7.Green transition funding and institutional change

Some of the above recommendations come with an extra cost. The costs of using glass dishes to replace plastic petri dishes for cell culture are for example around 30 times higher (Urbina *et al.,* 2015). However, other developments, for example, lighter and more compact petri dishes that save plastic waste, may offer alternatives where the switch to glass petri dishes is not feasible (Reu *et al.,* 2019).

To fund the sustainable lab expenses, external funding may be required. Grant agencies should also be encouraged to introduce incentives to reduce plastic waste. This could for example, include funding new lab washing-up and recycling facilities in applications, and support higher lab costs to fund the transition to sustainable lab equipment instead of the current single use plastic. This transition will also require the support and information of employees at the station and the larger research institute. A good overview of how scientific workplaces can become more sustainable is given by (Durgan *et al.,* 2023).

3D printing and energy generation from plastic waste

Another recent development is to recycle lab plastics for 3D printing or energy generation (https://experiment.com/projects/reducing-scientific-research-waste-production-can-we-recycle-lab-plastics-for-3d-printing). In the case of 3D printing, the idea is to collect plastic waste in the lab and then use 3D printers to generate new plasticware that can be used in the laboratory or elsewhere in the organisation.

Sahu *et al.,* (2021) proposed a system to use laboratory plastic waste for energy harvesting by generation of stable and cost-effective triboelectric nanogenerator (TENG) mechanisms for sustainable powering of low-power electronics. It has been also proposed to use 3D printing with marine plastic waste to build products for the marine industry in a circular economy framework (Cañado *et al.,* 2022, Maldonado-García *et al.,* 2021). To conclude, it appears that different scalable solution related to 3D printing are being developed and these may reduce plastic waste in the future at scientific stations and maybe, local communities alike.

8. Inspiration for how to manage plastic

8.1.Housing, interiors and kitchen utensils

Building materials, interiors and utensils may all include plastics. This is not necessarily a problem, it all depends on the types of plastic and the degradation processes it is subjected to (see Chapter 6). The important thing is that it is durable, sturdy, free of harmful chemicals, reusable and recyclable.

8.1.1.Building materials and interiors

- Exposed building materials prone to degradation (e.g. from weather and sun light) should where possible be durable and long lasting non-plastic (end environmentally friendly) based materials.
- If using plastic products in the interior building design, prioritise plastic products and types that can be reused or recycled.
- Furniture and carpets, etc. should preferably be made from natural fabrics (e.g. wool, textiles, sisal) to avoid accumulation of plastic particles in indoor air and house dust).
- Use plastic free interior and exterior building paints.

8.1.2.Kitchen utensils

- Use environmentally friendly alternatives to plastic where possible, e.g.:
  - Store food in glass, metal or sturdy reusable and recyclable plastic containers.
  - Glass containers to microwave food.
  - Drink tap water out of a glass (where safe to do so).
  - Use matches instead of disposable plastic lighters or invest in a refillable metal lighter.
- Avoid single use plastics, e.g.:
  - Reduce takeaway cups of plastic or with plastic coating.
  - Avoid plastic cutlery – use metal or wooden cutlery.
  - Avoid using plastic bags.
  - Do not use plastic straws.
  - Avoid excessive food packaging in plastic.
  - Use reusable bags for shopping. Have some non-plastic bags or bag packs at the station that visitors can use to do their shopping.
- Buy loose tea and use a tea egg or a teapot filter, as many tea bags contain plastic (many tea brands and supermarkets use a plastic called polypropylene to seal their teabags).

Cigarette butts and vape pens

According to the WHO, a minimum of 4.5 cigarette filters, made mostly out of cellulose acetate – a plastic- are discarded every year and therefore, they represent the most littered items (WHO, 2022). In addition, packaging waste from cigarette boxes account for 2 million tonnes of packaging waste (WHO, 2022). Cigarette filters contain microplastics and are the second-highest form of plastic pollution worldwide and one of the top polluting items found in marine environments.
https://www.who.int/publications/i/item/9789240051287

There should be strict policies at research stations to discourage littering of cigarette butts and although it may be unrealistic to expect people to stop smoking, it may be worthwhile to have campaigns to advertise biodegradable filters.
https://www.biofuelsdigest.com/bdigest/2022/07/18/biodegradable-cigarette-filters-achieve-key-patent/

8.2.Clothes and washing

In the Arctic, much of our modern winter clothes are made from artificial fibres, like fleece. Fleece is commonly made of polyester, and polyester is a synthetic fabric, which means fleece releases microplastics. These synthetic fabrics provide numerous benefits: they are lightweight, quick drying, highly insulating, and remarkably resistant to wear. But those benefits come at a cost to the natural environment.

The most likely origin of this released polyester is laundry. More than one-third of the microplastics in the ocean come from synthetic clothing. A recent study (Ross *et al.,* 2021) found that 73% of synthetic fibres found in the Arctic were polyester. The powerful currents and winds out on the open sea make it difficult for even advanced technology to clean it, once it is the aquatic environment. Clothes pollute more the first few times we wash them, so consider buying less new clothing and keep your old for as long as possible. Never buy very cheap fleece products, as the fibres of these are extra vulnerable. Garments of a higher quality shed less in the wash than low-quality synthetic products, illustrating the importance for manufacturers and consumers alike to invest in gear built to last.

Studies show synthetic jackets laundered in top-load washing machines shed approximately seven times as many microfibres as the same jacket in front-load washers. Putting your synthetic clothing into a filter bag before washing by hand or machine can significantly reduce the flow of microfibres into your drain. Several types of laundry filter devices have been developed, including those that are built into the washing machine, those that can be retrofitted into older machines, and devices that are placed in the drum of the machine during the laundry cycle.

Recommendations on clothes and washing

- Buy natural fabrics (wool, cotton, silk, linen, cashmere), or environmentally certified clothing (https://alwaystheadventure.com/sustainability/sustainable-outdoor-clothing-brands).
- Remove single stains on the fleece by hand, instead of using the washing machine
- Use a front loaded washing machine equipped with filters or use a microplastic washing bag when washing synthetic materials (e.g. Acrylic, nylon, and polyester).
- Fill up your washing machine – a full load results in less friction between the clothes and less fibres will be released.
- Use washing liquid instead of powder – the powder will, through the 'scrub' function, loosen the fibres of the clothes.
- Wash at lower temperatures – some fabrics will be damaged in high temperatures and result in looser fibres.
- Avoid long washings that will cause more friction of the clothes and more fibres released
- Dry spin at low to decrease the friction of clothes.
- Air dry clothes where possible (which also saves energy) and use wooden clothespins.
- Consider donating old fleece, as well as other old clothing. If you donate your old fleece, you prevent other people from buying new ones.

8.3.Cleaning

Cleaning tools, cloths and detergents may be made of or contain plastics. While sturdy reusable tools may not degrade easily, the use of synthetic cloths and sponges, and detergent containing plastics will add microplastic to the wastewater.

Recommendations:

- Buy durable plastic cleaning equipment that can be reused and recycled.
- Use reusable natural scrubbers instead of plastic scrubbers and synthetic sponges (e.g. Loofah scrubbers).
- Consider cleaning tablets instead of liquid soap, shampoo, bodywash, and cleaning detergents – this reduces transported volumes and reduces CO_2 emissions.
- Use detergents without plastic components.
- Use natural, reusable and washable cotton cloths or flannels for washing up and cleaning rather than disposable cleaning cloths or microfibre cloths.

8.4.Personal care products

Losses from Personal Care Products are the only losses that can be considered as intentional losses, where the product containing microplastics is poured into wastewater on purpose. This could be in products like facial and body scrubs, sunscreen, lotion or toothpaste. An IUCN report (Boucher and Friot, 2017) estimates that personal care products make up 2% of total primary microplastics entering the global marine environment. Unfortunately, there do not appear to be widely accepted, naturally occurring alternatives for the polymers in PCPs and cosmetics performing functions beyond exfoliation.

Several apps can help you scan products for plastic, e.g. 'Beat the microbead', where you can find out if your personal care products contain microplastic.

Furthermore, female hygiene products, like tampons, tampon applicators, and pads, are the fifth largest contributor to plastic pollution along the coastline of Europe (European Parliament, 2021, Snekkevik *et al.,* 2023). It is estimated that up to 45 billion disposable menstrual hygiene products are used and disposed of each year (Barth 2021). The production of these products is estimated to account for approximately 245,000 tonnes of CO_2 emissions/year (Cabrera and Garcia, 2019). An additional problem is that these products are not properly discarded, and this may lead to problems in Norwegian treatment plants in 2021 (Norsk Vann, 2021), including economical costs.

Based on a meta-analysis from the United Nations Environment Program (UNEP, 2021), it was concluded that reusable menstrual cups had a significantly lower environmental impact than a disposable option. Other options include menstruation underwear, and reusable/washable pads (Snekkevik *et al.,* 2023). Since one of the problems is incorrect disposal of these and other products, posters about proper disposal with a bit of background information on why this is important, is advised.

Recommendations for researchers visiting a research station

- Avoid using personal care products that contain microplastics.
- Don't throw plastic of any kind in toilets.
- Choose plastic-free chewing gum.
- Plastic-free toothpaste/toothpaste tablets.
- Use a razor with replaceable blades instead of a disposable razor.
- Bring paper bags or sustainable shopping bags instead of plastic bags.
- Pick up the trash that you find in the environment.

8.5.Laboratories

Laboratories are high consumers of plastics (as well as energy and water). As responsible researchers working with some of the most vulnerable ecosystems on earth, we should cut back on disposable plastics as much as possible.

In 2015, a team at the University of Exeter did a back-of-the-envelope calculation to estimate how much plastic waste scientific labs generate in a year. The answer was over 5.5 million metric tons (Urbina *et al.,*, 2015). Plastic lab products are diverse, including pipet tips, used gloves, weighing boats, tubes, flasks, reagent bottles, cuvettes, and more.

There are many ways to make laboratories more sustainable, to save resources and to certify them (Durgan *et al.,* 2023). Several standards for environmental good practice for Laboratories exist with guidelines and certification (e.g. ISO 14001). LEAF, Laboratory Efficiency Assessment Framework, is a new, independent standard for good environmental practice in labs. The standard recommends ways that lab users can reduce waste, save plastics, water, energy, and other resources.

Recommendations for laboratories (adapted from Kilcoyne *et al.,* 2022)

- Where contamination is less of an issue, consider reusing items, e.g. weighing boats, petri dishes, dispensers and gloves.
    - Reuse plastic tubes following chemical decontamination and autoclaving.
- Use alternatives to plastic where possible or prioritise recyclable plastics.
    - Replace plastic pots with compostable paperboard pots where possible.
    - Use natural rubber gloves.
    - Use pipette tips that can be washed before reuse.
    - Use glass centrifuge tubes instead of plastic.
    - Use glass syringes instead of plastic versions.
    - replace plastic petri dishes for cell culture with glass ones.
- Use sustainable materials, such as reusable wooden sticks for patch plating and metal loops for inoculation.
- Store and reuse packaging material like Styrofoam boxes (good for shipping of material that needs to be cooled) and packaging material like Styrofoam chips, bubble wrap, and air cushions.

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