Marine Litter in Greenland

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AALBORG UNIVERSITY
STUDENT REPORT

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A Master's thesis on the programme of Environmental Management and Sustainability Science, Aalborg University, Denmark.

In collaboration with Aalborg Zoo.

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PREFACE

This report is a product of a Master's thesis on the programme of Environmental Management and Sustainability Science taken at Aalborg University, Denmark. The thesis was carried out over the period of February-June 2016 and is centred on a fieldtrip taken to Nuuk, Greenland in April. The subject of the thesis is marine litter in Greenland which was developed in collaboration with Aalborg Zoo. In order to obtain the necessary knowledge and data, many people have given me their time and knowledge, and for that I am grateful. In particular I would like to thank:

> The interviewees: Margrethe Rosing Hegelund and Susanne Berglund from the Knowledge Centre for Waste Management in Nuuk, and Bjarne Ellgaard Pedersen from Artic Circle Business for giving me your time and for sharing your knowledge and perspectives.
>
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INDEX

INTRODUCTION

Within the last century, the increase of global consumption has led to a generation of waste that is now influencing the health of marine environments and potentially the health of humans as well. Today, marine litter can be found in every ocean of the world and is seen as the most serious threat to marine environments (Thevenon et al 2014). Not only can it be found near densely populated areas with high waste generations but it is also present in areas far from human activities, which makes marine litter a threat to marine life even in the most remote areas of the world. As the global waste production is not expected to peak before the next century, neither is the generation of marine litter (UNEP 2005; Jambeck et al 2015; Barnes et al 2009). The World Economic Forum published in January 2016 a report which estimates that an amount of plastic equal to one load of a waste truck is being emptied into the ocean every minute. This amount is increasing, and if nothing is done to minimize this development, WEF estimate that in 2050 there will be more plastic than fish by weight in the ocean (WEF 2016).

The presence of marine litter in marine environments is already bringing devastating consequences to many species. 267 different species are currently known to have suffered from either entanglement or ingestion of marine litter (Allsopp et al n.d.; Thevenon et al 2014). Research of fulmars in the North Atlantic Ocean has found plastic litter in the stomachs of 79-99% of examined fulmars (Mallory et al 2006). Other research has shown that smaller pieces of plastic leads to adverse impacts on plankton (Besseling et al 2014), marine worms (Wright et al 2013), oysters (Cressey 2016; Sussarellu 2015), mussels (Li et al 2015) and fish (Pedá et al 2016). Cases of entanglement are more evident to the naked eye and have been observed for a wide range of marine and terrestrial animals e.g. seals, whales, polar bears, sea birds and reindeers (Svalbardposten 2014; UNEP/FAO 2009; Thevenon et al 2014). Besides causing threats to ecosystems, marine litter is also bringing economic, aesthetic and health problems to coastal industries and populations (UNEP 2005).

Until recently it was generally agreed upon that there are five areas in the oceans, where currents circulate and accumulate floating litter. The five areas can be seen in Figure 1. These areas of circulating

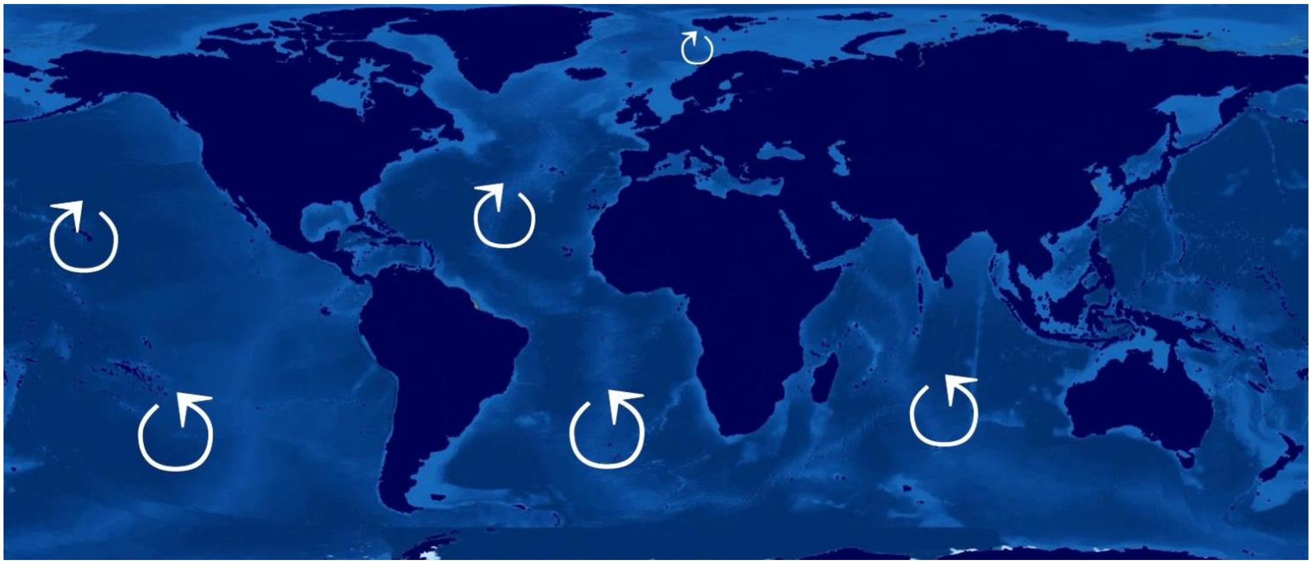


Figure 1: The five gyres where marine litter accumulates plus the newly discovered accumulation zone in the Arctic south of Svalbard. The map is made in ArcMap based on (NOAA 2008) and (van Sebille 2012) with geodata from: Esri, DigitalGlobe, GeoEye, I-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

ocean currents are called gyres, and the accumulation of litter has also been referred to as garbage patches, trash vortexes and plastic soup (van Sebille 2012; Greenpeace 2015). The Pacific Ocean holds the largest amount of marine litter, which is caused by high inputs of waste from coastal nations and because ocean currents bring waste from other regions of the world to the Pacific Ocean, where they converge and create an accumulation of litter. In addition to the five gyres of floating litter, a research by van Sebille et al (2012) indicates that litter is now also accumulating in the Arctic, which has led to a growing concern for Arctic communities and scientists (Bergmann et al 2015, Svalbardposten 2014). The litter is expected to accumulate in the Barents Sea, and this is already being felt in Svalbard where approximately 150 m^3 of litter annually is collected from beaches, and every year animals are being put down because they get entangled in marine litter (Svalbardposten 2014; Devine 2015). Knowledge of marine litter in the Arctic is relatively limited but some research has been carried out in North-eastern Canada, Svalbard, Iceland, Norway and on the Polar cap where Obbard et al (2014) found significant amounts of microplastic in the polar ice at various sites spread across the Arctic Ocean (Bergmann et al 2015; Provencher et al 2010; Mallory 2008; Barnes et al 2009; Humborstad et al 2003). No published research has so far been based in Greenland, where people are very dependent on the wellbeing of the marine ecosystem and where most of the population is living and generating waste along the coast line (Eisted & Christensen 2013; EEA 2012). Several research cruises and projects will however include investigations in Greenland this summer (2016), such as a project by the Danish University of Technology (DTU), the Ocean Research Project and 5gyres (Oceanresearchproject.org 2016; 5gyres 2016).

Initiatives to reduce the amount of marine litter include the international ban to dump plastic waste at sea, which was enacted in 1988 through the international shipping regulation MARPOL Annex V (IMO 2016). Shipping is however still a major source of marine litter and this is generally explained by a lack of enforcement and education (Cole et al 2011). Other initiatives to prevent the generation of marine litter are national bans or taxes on single-use shopping bags, which has been implemented in more than 25 countries on all continents, led by the ban of plastic bags in Bangladesh in 2002, followed by Rwanda and China in 2008 (WEF 2016). Recently a new type of initiatives is occurring, which is technological innovative devices that collect waste from the oceans (Krieger 2016). It is however broadly agreed upon that the most effective initiatives are focused on prevention rather than clean-ups. A minimisation of general waste generation and especially plastic litter will bring benefits related to marine litter, waste management on land as well as the use of resources and energy (Jambeck et al 2015; UNEP/FAO 2009). Initiatives are nevertheless needed for all stages of marine litter, i.e. before, during and after it becomes marine litter, but the suitability of any initiative varies from country to country (UNEP/NOAA 2011).

The following pages present the concept of marine litter, what the potential impacts are for the Greenlandic marine ecosystem and how waste is managed in Greenland. These sections serve as a base for the problem conceptualisation and are followed by a presentation of the general aim and scope of the project.

1.1 MARINE LITTER

Problems of marine litter were first addressed in the 1960s (Bergmann et al 2015). In the 1970s the focus was in particular put on the problem of plastic marine litter, only two decades after plastic was used in consumer products for the first time (Jambeck et al 2015; Provencher et al 2010). In 1980s FAO recognised the problem of abandoned, lost or otherwise discarded fishing gear (ALDFG) in the marine environment (UNEP/FAO 2009) and lately (since the 2000s) the focus is increasingly put on micro plastics (Cole et al 2011). There is a wide variety of marine litter that can be defined based on the material and size. Another characteristic of marine litter is the source and potential impacts (UNEP 2005). Consequently, marine litter is described below in terms of the various materials, applied size-categories, sources and potential impacts of marine litter.

1.1.1 Materials and sizes

Marine litter consists of any material produced or altered by humans that has been lost or discarded and ends up in the marine environment, i.e. coasts and oceans. This includes, but is not limited to, materials of plastics, glass, metals, paper, textiles and timber (UNEP/NOAA 2011). Of these materials, plastics are by far the worse due to its resilience and therefore very slow degradation time which by some scientists is estimated to as high as thousands of years. It is as well generally agreed upon that the degradation time is likely to be longer in cold, polar environments than in warmer environments (Barnes et al 2009; Thevenon et al 2014). Considering that plastics do not biologically decompose and therefore is only subject to a physical degradation, leading to smaller and smaller pieces of plastics, one could discuss the relevance of determining a degradation time (Shah et al 2008). Because of the long degradation time and lack of biodegradation, 60-80% of marine litter is plastic, even though plastics only make up 10% of produced waste by weight (Barnes et al 2009, Potters 2013; European Commission 2014).

When including all applied size divisions, marine litter is assessed within the following sizes: mega (>100mm), macro (20-100mm), meso (5-20mm), micro (<5mm) and recently also nano sized particles (<5µm), although the latter is often included in the micro-category (EPA 2011; Besseling et al 2014; Lee et al 2013; Barnes et al 2009; Thevenon et al 2014; Cole et al 2011). In this report, the term *micro* is used for <5mm and *macro* is used for litter >5mm. Although there are severe environmental consequences connected to any size of marine litter, one size group has recently received increasing focus, i.e. micro plastics, and this is because of its potential to enter the food chain, the difficulty of collecting it from the ocean and the way they are created. Micro plastics can be produced to be microscopic e.g. as plastic pellets or micro beads that are being used in the plastic industry and in personal care products. These are called *primary micro plastics*. The other type of micro plastics is called *secondary micro plastics* and these derive from the larger pieces of marine litter, which slowly degrade into smaller pieces. This means that if marine litter fully or partly made of plastic is not removed from the marine environment, it will eventually degrade into micro plastics (Dubaish & Liebezeit 2013; Obbard et al 2014; Barnes et al 2009; Thevenon, et al 2014; Cole et al 2011). Of the two kinds, secondary micro plastic is the greatest problem because it is most prevalent and will continue to be created for a long time, even if the input of litter to the sea was stopped (Krieger 2016; van Cauwenberghe & Janssen 2014).

1.1.2 Sources

Another way of describing marine litter is by source of which there are often two distinctions; sea-based sources and land-based sources (Mehlhart and Blepp 2012; Tudor and Williams 2004). Approximately 80% of marine litter comes from land, where coastal activities, urban run-offs, wastewater, inadequate waste collection and industrial activities generate a large part of marine litter (Cole et al 2011; Potters 2013; Strand et al 2015). An important source of micro litter is the wastewater from washing machines which carries micro plastics from textiles to the ocean estimated to 20,000 pieces of fibres per litre (Masura et al 2015; Thevenon et al 2014; Watkins et al 2015). Sea-based sources are primarily found within the fishing and shipping industry and these sources can be dominating in areas where there are high concentrations of such activities and where waste productions from communities are small compared with other areas (Potters 2013; Cole et al 2011).

1.1.3 Impacts

The impacts of marine litter are not only related to the wellbeing of marine animals. The fishing and shipping industry are increasingly experiencing economic loss due to marine litter due to e.g. entanglement of propellers (Galgani et al 2000; Thevenon et al 2014). Coastal nations also experience economic costs related to coastal clean ups, which can be essential to some states where tourism is a dominating industry (Thevenon et al 2014; European Commission 2014). At beaches, people are at risk of physical injury from e.g. pieces of glass or metals but human health is at risk in a more opaque way as well. Being part of the food chain, humans are likely to ingest pieces of plastics when consuming seafood, although the physical consequences of this are not yet fully understood (van Cauwenberghe & Janssen 2014; European Commission 2014; IUCN 2016). The focus of this project is set on impacts related to the marine ecosystem and is therefore centred on marine species, which are already experiencing clear negative impacts. There are three overall impacts which can affect marine fauna and marine ecosystems; ingestion, entanglement and the introduction of invasive species.

1.1.3.1 Ingestion

The impacts of ingestion can be both physical and chemical, and they are typically caused by plastic litter. The physical consequences of ingestion can be suffocation, starvation and damage of the interior. Sea birds are especially known to suffer from starvation and reduced growth, because their stomachs fill up with plastics (Provencher et al 2009). Plastics can have various shapes and colours and can resemble natural food. Sea turtles for instance are known to ingest plastic bags due to their similarity with jellyfish, a primary food source of sea turtles (Thevenon et al 2014). The chemical consequences of ingestion derive from the content of the plastic itself and the potential adhesive chemicals in sea water that attach to plastic. Plastics are often found to have adsorbed polychlorinated biphenyls (PCBs), hydrocarbons, pesticides, metals and microbial communities which all can have adverse impacts on the animal such as a change in the hormonal and immune systems (Polar Bears International 2016; Choy & Drazen 2013; Zettler et al 2013; Zarfl & Matthies 2010; Teuten et al 2009). Many chemicals are fat dissolvent, and since the Arctic food web has a high fat level this further enhance the severity of impacts from ingestion of marine litter (Polar Bears International 2016). While the primary content of plastic is polymers, 15% of plastics are additives, which determine the colour and texture of the plastic (WEF 2016). In some cases, plastics also contain contaminants such as biphenol A (BPA) and phthalates, which also raise concerns for the impacts they can have on marine fauna (WEF 2016; Barnes et al 2009; Cole et al 2011).

Ingestion of litter can happen directly by the animal itself, perhaps mistaking it for food, which is called *primary ingestion*. If the litter instead becomes ingested when larger biota eats smaller biota that has ingested litter it is called *secondary ingestion* (Choy & Drazen 2013). The latter type raises concerns for biomagnification of additives and contaminants, for instance when PCB-concentrations in the tissue are magnified through the food chain (Teuten et al 2009).

1.1.3.2 Entanglement

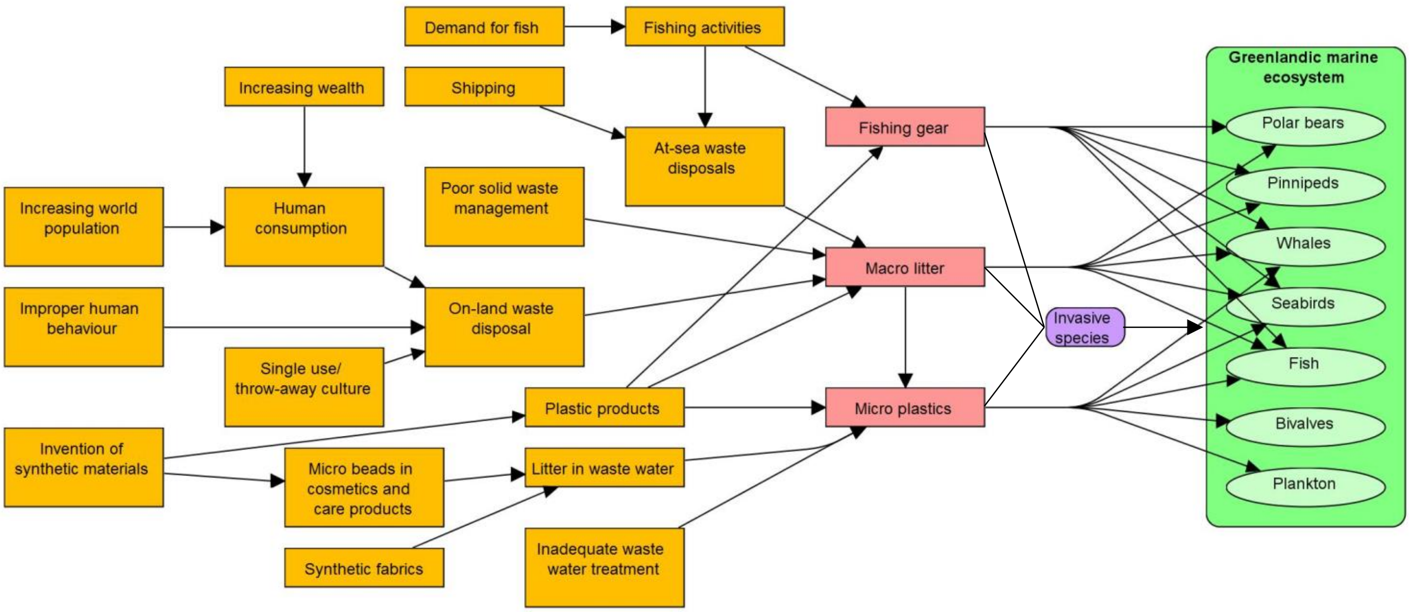
Entanglement is by some experts considered to be worse than ingestion because it is thought more likely to be lethal. As entanglement is more visible to the naked eye than ingested litter, it is however easier to address which enables liberations of entangled animals (Wilcox et al 2015). The dominating marine litter material for entanglements are fishing gear, such as nets and ropes, and plastics, which can cause death by cuts, strangulation and drowning. Even if an animal frees itself from entanglement, it can still suffer from dangerous lacerations and infections, which can hamper the ability to move and feed (Thevenon et al 2014).

1.1.3.3 Invasive species

The impact of invasive species is also mostly connected to plastic litter of which approximately 50% stays floating in the surface when emitted to the ocean (Bergmann et al 2009; EPA 2011). This makes it a dangerous vector of microbial communities and other biological organisms, and in this way it can bring alien species to ecosystems. The invasive species could alter the ecosystem by competing with or otherwise threatening native species (Zettler et al 2013; Barnes & Milner 2005; Barnes et al 2009; Teuten et al 2009; Cole et al 2011; Strand et al 2015).

1.2 POTENTIAL IMPACTS ON THE GREENLANDIC ECOSYSTEM

Although no research on marine litter, known to the author, has taken place in Greenland yet, it is possible by reviewing research of the same or similar species to those in Greenland, to estimate how the ecosystem of Greenland can be impacted by marine litter. In Figure 2, this assessment is depicted through a conceptual model, which presents the impact of micro plastics, fishing gear and macro litter (in this case defined as all litter larger than 5mm). Although the categories of micro plastic and macro litter could cover all marine litter, fishing gear is given separate attention, since it is recognisable as fishing gear and the actors are different from those of general macro litter and micro plastics. Key marine species or biological orders are chosen as representatives for the ecosystem of Greenland.



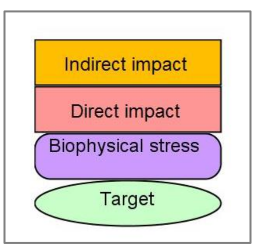


Figure 2: This conceptual model was created using the software Miradi based on the guidelines on conceptual modelling from Foundation of Success (FOS 2009). Based on: Humborstad et al 2003, Bergmann et al 2015, Jambeck et al 2015, Allsopp et al n.d., UNEP/FAO 2009, Choy & Drazen 2013, Rochman et al., 2012, Franeker et al 2011, Dubaish & Liebezeit 2013, Cressey 2016, Svalbardposten 2014, Obbard et al 2014, Sussarellu 2015, Barnes & Milner 2005, Pedá et al 2016, Besseling et al 2014, Wilcox et al 2015, Trevail et al 2015, WEF 2016, Provencher et al 2010, Provencher et al 2009, Mallory et al 2006, Mallory 2008, Lee et al 2013, Barnes et al 2009, Lusher et al 2015, Teuten et al 2009, Bond et al 2013, Li et al 2015, Cole et al 2011, Krieger 2016, van Cauwenberghe & Janssen 2014, Mehlhart and Blepp 2012, Norden 2014, Potters 2013.

Through this model it is possible to see how larger animals mostly are affected by larger marine litter and smaller animals by smaller pieces. The model also depicts however, that larger marine litter (i.e. macro litter and fishing gear) degrades into micro plastics, which when ingested at lower trophic levels poses a threat to the rest of the food chain. Indirect impacts such as trends and norms in human lifestyles lead to the creation of marine litter. These include population growth, increasing wealth, demand for fish, improper human behaviour, single use/throw away culture and the technological evolution that led to the invention of synthetic materials, as depicted in the model. These indirect impacts can lead to severe direct impacts in the Greenlandic ecosystem, no matter the location of the discharge. The impacts that could be affecting marine species in Greenland are elaborated in the sections below.

1.2.1 Polar bears

As the Arctic sea ice diminishes, so does the habitat of polar bears, which means that they are increasingly seen on land near communities. Here they are drawn towards waste sites, often positioned close to shore, due to hunger or simply due to curiosity (WWF 2015). Polar bears on Svalbard are from time to time seen entangled in fishing nets and ropes and these incidences can only be expected to increase as the ice retracts and the amount of marine litter continues to increase (Svalbardposten 2014). Being a top predator in the food chain, polar bears are subject to bio-magnification and therefore known as one of the most polluted species in the world, which is evident in the tissue of the bear, where persistent organic pollutants such as PCBs and pesticides are known to accumulate. Contamination of polar bears has evolved over decades, and it is likely that the increasing impact from marine litter will add negatively to this, again resulting in a cumulative impact, to the accumulation of contaminants in the tissue of polar bears (Sonne et al 2012).

1.2.2 Pinnipeds

Pinnipeds include species of seals, sea lions and walrus, and these are the marine species that are most affected by entanglement with approximately 58% of seal and sea lion species all around the world to have been subject to entanglement (Boland & Donohue 2003). In some populations the number of entangled individuals has been recorded as high as 7,9% (Allsopp et al n.d.). When seals get entangled it increases their energy consumption due to the extra weight and they are therefore forced to eat as much as four times the normal amount (Allsopp et al n.d.). Incidences of ingestion are not as reported as entanglement but research suggest that seals are mostly threatened by secondary ingestion of smaller plastic pieces from fish, which has been observed in seals far from human settlements, between New Zealand and Antarctica (Eriksson & Burton 2003).

The marine environment of Greenland is habitat to five seal species of which the harp seal, the hooded seal and the ringed seal are most abundant. The seals are an important part of Greenlandic hunting culture as well as the economic foundation in many families, and they are an essential food source for polar bears. The harbour seal is the only seal species that breeds on land and is hereby at higher risk of interaction with marine litter along the coastline. Walruses are likewise dependent on so-called haul-out sites along the coast, where there are known to gather. Previously there were many haul-out sites for walruses in western Greenland but today only two sites are known as haul-out sites and both are positioned in the national park of north-eastern Greenland (Greenland Institute of Natural Resources 2003).

1.2.3 Whales

There are approximately 15 different whale species that regularly finds their way through Greenlandic waters. Most of them spend their winter far from Greenland and are therefore likely to come across areas of higher litter concentrations for instance in the North Atlantic Ocean (Greenland Institute of Natural Resources 2003; Potters 2013). A research in Alaska by Neilson et al (2007) assessed the level of entanglement of humpback whales, which also lives in Greenland. They estimated that between 52-78% of the observed humpback whales had scars that derived from entanglement. Lusher et al (2015) have as well expressed a concern that baleen whales in the Arctic could be subject to passive ingestion of microplastic while feeding. New examinations of sperm whales that stranded along the northern German and western Danish coasts in the first months of 2016, showed that the whales' stomachs contained large amounts of marine litter including a 70cm long piece of metal from a car bonnet and a 13 metre long fishing net (JP 2016). Based on the number of species reported, baleen whales are generally more at risk of entanglement rather than ingestion of marine litter, whereas toothed whales to a larger degree have been reported in incidences of ingestion (Allsopp et al n.d.).

1.2.4 Seabirds

Seabirds are to a high degree subject to ingestion of plastics with 36% of the 312 existing seabird species observed with ingested plastics and 16% of seabird species have been subject to entanglement (Allsopp et al n.d.). Greenland has around 65 birds breading in Greenland, of which most are living in the marine environment and depend on marine food sources such as crustaceans and fish. These include northern fulmars, murres, puffins and several gull species (Feilberg 1990; Greenland Institute of Natural Resources 2003). Fulmars are used as ecological indicators by the OSPAR Convention (the Convention for the Protection of the Marine Environment of the North-East Atlantic), which states that acceptable ecological quality is met when less than 10% of fulmars have more than 0.1 g of plastic in their stomachs (OSPAR Commission 2014). Research on Svalbard shows that 25% of their fulmar population exceed the limit of 0.1g, and the fulmars closer to Greenland are as well affected. Three investigations have been carried out along the north-eastern Canadian coast as can be seen on Figure 3.

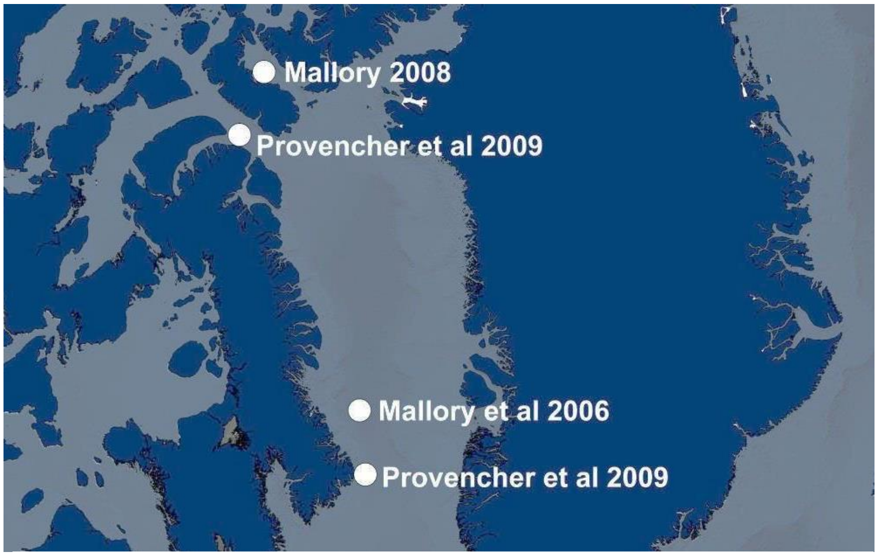


Figure 3: Research on ingested plastic in Northern Fulmars in Canada. The map is constructed in ArcMap using data from Esri, DigitalGlobe, GeoEye, I-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Mallory et al (2006) found pieces of plastic in 36% of 42 examined fulmars that were collected from the by-catch of a Norwegian longliner in Davis Strait. Two years later, further north, Mallory (2008) examined 102 fulmars of which 31% had plastics in their stomachs. The latest of the three fulmar investigations was carried out by Provencher et al (2009), which examined 50 fulmars divided by two colonies of which 84% had ingested plastic. Compared with an investigation from 1976 which showed that there were no plastic pieces in any of the 181 examined fulmars, these more recent findings indicate an increasing trend (Provencher et al 2009). In 2010, Provencher et al (2010) examined the thick billed murre in seven different locations in North-eastern Canada, and found plastic in 11% of the examined birds, which indicate that fulmars are particularly impacted by marine litter but that other marine seabirds are affected as well. The murres spend their winter in Greenland and can therefore have ingested the plastic in Greenland, which could as well be the case with the fulmars (Provencher et al 2010; Mallory 2008).

1.2.5 Fish

Fish are also affected by both entanglement and ingestion of litter although most research on the impacts on fish is focused on entanglement (Moore et al 2001; Allsopp et al n.d.). Lost fishing gear is a big threat to fish species as it can continue to catch fish up to around eight years after it is lost, a process called *ghost fishing*. Investigation along the northern Norwegian coast found that the Greenlandic halibut is particularly subject to this as nets tend to last longer in low waters (below 500m), where halibuts live (Humborstad et al 2003). In 2014, Nielsen et al assessed the distribution and feeding ecology of the Greenlandic shark and found fishing gear and other types of marine litter in 2 of the 24 sharks. Another ingestion research made by Pedá et al (2016) showed that the intestine of a European sea bass was structurally and functionally deteriorated when exposed to a diet containing micro plastics and that the impact was worse if the microplastic had been dipped in sea water in a harbour compared with the effects of clean plastic pellets, which emphasises the potential of marine litter becoming a vector of contaminants in seawater.

1.2.6 Bivalves

Bivalves such as oysters and mussels are filter feeders, which means they can passively ingest micro plastics while feeding, and research has recently focused on the potential impacts on human health, as humans often eat the whole bivalve including the digestive track (Dubaish & Liebezeit 2013; Cressey 2016; van Cauwenberghe & Janssen 2014). Bivalves from a fish market in China have already been found to ingest fibres, plastic fragments and pellets (Li et al 2015) and research by Sussarellu (2015) and Cressey (2016) shows the ingestion of micro plastics reduces the fertility of oysters and the growth rate of their offspring. Van Cauwenberghe & Janssen (2014) have calculated an estimate stating that an average shellfish eater in Europe may consume up to 11,000 pieces of micro plastics annually, which puts further stress on assessing what impacts this could bring for human health.

1.2.7 Plankton

The ecosystem and marine food chain of Greenland are highly dependent on the primary production of phytoplankton and secondary producers of zooplankton, and these are as well in risk of being affected by micro plastics (Greenland Institute of Natural Resources 2003; Besseling et al 2014). Research has examined the ingestion of micro- or nanosized plastics by various plankton species and found that it has a negative effect on body size, fecundity, reproduction and potential negative disturbance on the ecosystem due to an altered density and porosity of faecal pellets (Lee et al 2013; Besseling et al 2014; Cole et al 2015). Research made by Cole et al (2015) and Lee et al (2013) shows how ingestion of micro plastics by copepods can impede the feeding and reduce the fecundity and survival rate, which could have significant consequences in Greenland, where copepods comprise 86% of zooplanktons and are an essential food source for many marine species and thus of great importance to the entire food chain (Greenland Institute of Natural Resources 2003).

1.3 WASTE MANAGEMENT IN GREENLAND

The waste management in Greenland is challenged by a scattered and small population in a country with extreme weather conditions and limited infrastructure (Eisted & Christensen 2011). As a result, the rate of recycling is low, and in settlements where there is no incineration plant, all waste is placed on open dump sites, which are often close to the shore. In some cases, waste is collected by ship for incineration in larger towns, when the generated amount of waste reaches a certain amount (Eisted & Christensen 2013; EEA 2012). Separated and recycled materials include glass, paper, cardboard and bio-waste. Metal waste is collected every fifth to tenth year from towns when a profitable amount is generated for export to Denmark. In smaller settlements, the metal is placed on dump sites (Eisted & Christensen 2011). Hazardous waste an e-waste is as well exported to Denmark in feasible amounts with ships that have come from Denmark with imported products (EEA 2012).

As there is no separation and recycling of plastics in Greenland and incineration is only available in some towns and settlements, there is a risk that waste escape from dump sites and enters the sea or that marine animals such as polar bears and seabirds are drawn by the waste and mistake plastics or other litter of being food or the litter is attached to edible items (Eisted & Christensen 2013; WWF 2016).

Another issue of concern is the dominating input of untreated wastewater to the sea as there are no wastewater treatment in Greenland, which is very expensive to establish due to the distribution of the population and the geology of the country and challenged by a lack of competences and materials (Miljøstyrelsen 2006; Gunnarsdóttir et al 2013; Jastrup et al 2002). The legal notice, made by the home rule of Greenland, no. 10 on latrine and wastewater (Selvstyrets bekendtgørelse nr. 10 af 12. juni 2015 om bortskaffelse af latrin og spildevand) imposes every municipality of Greenland to formulate wastewater plans with a deadline for the first draft in 2018 for towns and 2020 for settlements (Grønlands Selvstyre 2015). The wastewater plans that have already been formulated show however no incentive to improve the level of treatment. Instead they focus on the maintenance of the current sewage system (Hegelund and Berglund 2016). Even if wastewater treatment plants are installed in every town and settlement, micro plastics are still not being caught in the treatment procedure, and it therefore does not prevent the discharge of all litter types, although some reductions in the discharge of larger marine litter would be expected.

AIM AND SCOPE OF THE PROJECT

Due to the lack of research on marine litter in Greenland, the overarching aim of this project was to make a broad assessment of the presence of marine litter in Greenland with the purpose to serve as an opening assessment, hoping many will follow. In addition to assessing the presence of marine litter it was as well an aim of the project to assess what actions could be taken to reduce future discharges and impacts of marine litter, as a way to ignite the incorporation and consideration of marine litter management initiatives into future plans and actions. The broad scope of the project in turn required a broad set of methods compared to other assessments of marine litter.

In order to make the assessment relevant for the Greenlandic community, the project was designed with a point of departure in ways the Greenlandic ecosystem can be affected, as the well-being of the ecosystem is of critical importance for the culture, economy and human health in Greenland. The project was guided by the following research question.

2.1 RESEARCH QUESTION

What types of marine litter are present in the marine environment of Greenland and what initiatives can be implemented in order to minimise future discharges and negative impacts of marine litter?

When assessing the *types* of marine litter it was not only the intent to know the material, size and number but also to estimate the source of the found litter. Parts of the data collection took place in Nuuk, in three areas of the marine environment i.e. the coast, the sea floor and the water surface, and Nuuk is therefore the geographical locus of the quantitative data collected, which was supplemented by qualitative data with a broader geographical scope. The assessment and discussion of potential *initiatives* that can minimise future discharges and impacts of marine litter considers various types of initiatives with different potential actors and with a broad geographical scope was designed with the intent that the results from this report can be applied not only for the area of Nuuk but in other parts of Greenland as well, where the sources of marine litter could be expected to be similar to those of Nuuk.

METHODOLOGY

In order to answer the two folded research question; 1. *What types of marine litter are present in the marine environment of Greenland and 2. …what initiatives can be implemented in order to minimise future discharges and negative impacts of marine litter?,* the project consists of two main surveys; one for the presence of marine litter and one for potential initiatives to minimise future discharges and impacts of marine litter in Greenland. Various methods and theories were applied, as depicted in Figure 4, to cover the broad scope of the project. This chapter includes a presentation of applied methods, the creation of a Marine Litter Management Hierarchy and the use of systems thinking as a theoretical basis of the project design.

The survey of marine litter consists of three main assessments of respectively a coastal survey, seafloor recordings and sampling and analysing of surface litter (See Figure 4). In addition, interviews, both planned and informal, and a questionnaire were carried out to obtain a general insight into marine litter and littering on land in Nuuk and Greenland in general.

Through literature review, the initiative survey first located all proposed initiatives connected to the management of marine litter. These were analysed and categorised according to a hierarchy of marine litter management, developed as part of this project, inspired by the Waste Hierarchy and Mitigation Hierarchy. The categorised initiatives were then related to the context of Greenland with the knowledge obtained through interviews and literature.

The foundation of this project is a theoretical approach of systems thinking, which is applied through the method of conceptual modelling and a system-oriented ecosystem approach (See Figure 4). These concepts are elaborated later in the chapter.

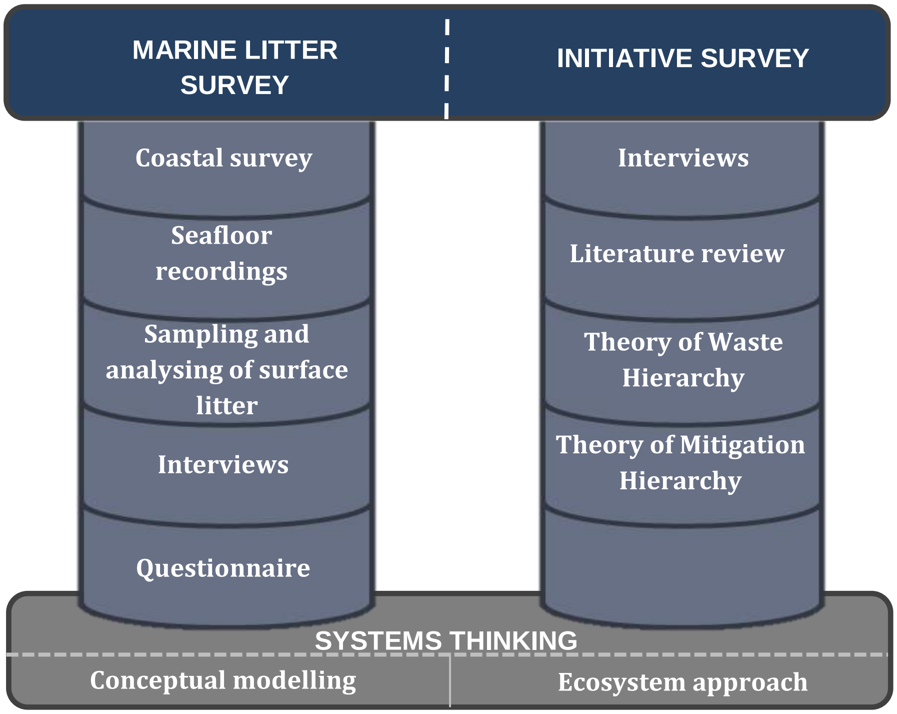


Figure 4: The methodological structure of the project. The two surveys are each built up by a set of methods and theories and are founded in a theoretical approach of systems thinking through conceptual modelling and ecosystem approach.

In the following sections, the applied methods are firstly described followed by a chapter on the development of the Marine Litter Management Hierarchy and the application of systems thinking through conceptual modelling and ecosystem approach.

3.1 METHODS

The methods applied during the project include methods for the generation of quantitative data on marine litter (coastal, seafloor and floating litter) along with interviews, questionnaire and literature review. These methods were chosen in order to cover the broad assessment of marine litter by quantitative as well as qualitative primary data. The presence of marine litter was thus assessed through method triangulation, which enabled a comparison of the findings from qualitative and quantitative methods. This proved beneficent due to limited time and influential factors for the collection of samples and observations, such as season and weather.

3.1.1 Methods for measuring marine litter

Based on an assessment of potential threats, as presented in section 1.2., it was found that all types of litter, if present, has a potential threat towards the marine ecosystem of Greenland. Since marine litter accumulates in various marine environments, it was chosen to make an assessment of marine litter spread across three marine environments (i.e. the water surface, the coastline and the sea floor). The three subsections of this chapter present the methods for generation of quantitative data through collections and observations. The location of the three assessments can be seen in Figure 5.

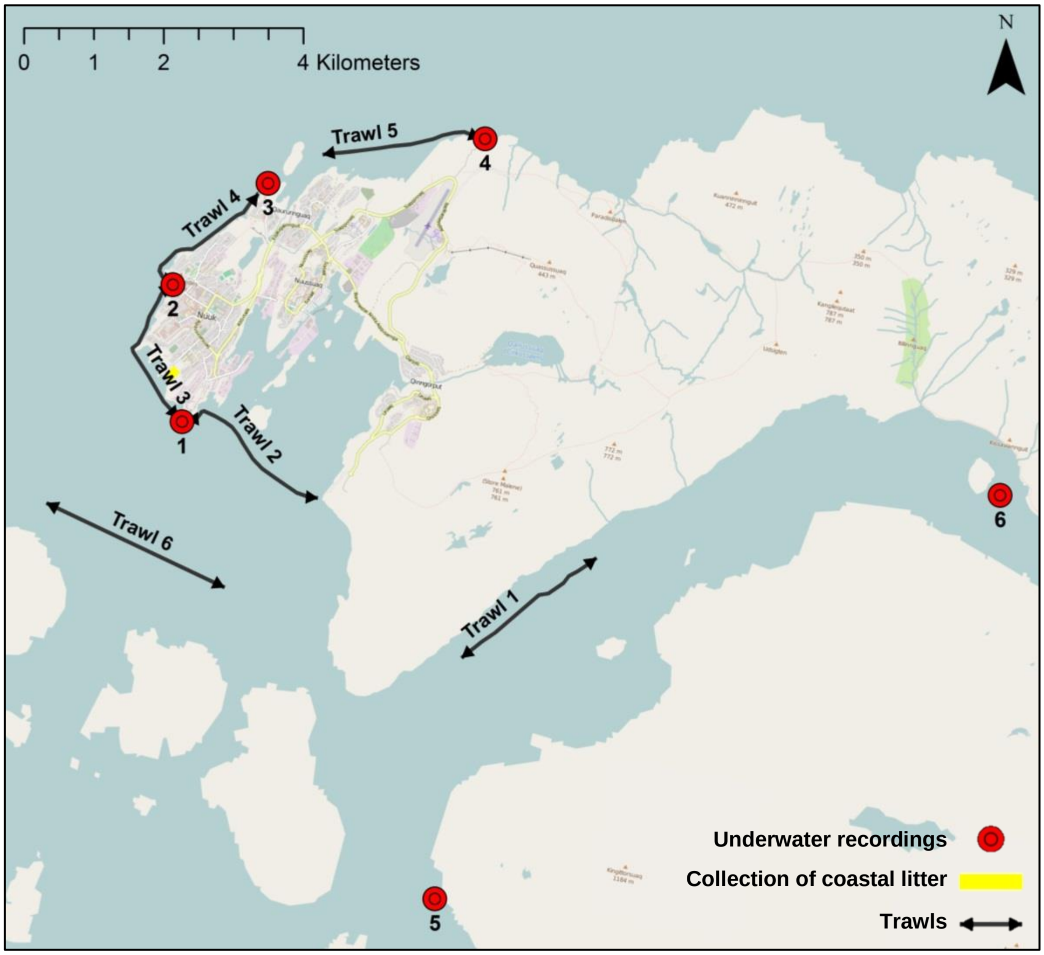


Figure 5: The locations of the six trawls, the six underwater recordings and the site where coastal litter was collected. The site for collection of coastal litter can be seen beneath trawl 3. The map was created in ArcMap by the use of data from OpenStreetMap (and) contributors, CC-BY-SA.

International recommendations for the collection and analysis of marine litter were consulted in the planning of the three assessments. These include the document: Guidance on Monitoring of Marine Litter in European Seas, made by the technical subgroup on marine litter of the EU Marine Strategy Framework Directive (MSFD-2008/56/EC) (EU 2013) as well as recommendations on the analysis of micro plastics from NOAA (Masura et al 2015), the guidelines on survey and monitoring of marine litter by UNEP and ICO (Sheshire et al 2009) and the guidelines for monitoring marine litter on the seabed by UNEP and IMO (NOWPAP MERRAC n.d.).

The following three sections on the coastal survey, seafloor recordings and sampling and analysis of floating litter all begin with a presentation of similar surveys and standard practices, followed by a description of how the assessment was designed for this project.

3.1.1.1 Coastal Survey

Coastal surveys of marine litter were carried out for the first time in the 1980s, mostly by non-governmental organisations, to raise the awareness of the public and to assess the presence of marine litter in a simple way (EU 2013). Through the last three decades, the aim of coastal surveys has broadened and is now increasingly used for scientific research where clean-ups are carried out on the same stretch of beach in a fixed time interval to assess the accumulation rate, the types and potential seasonal variations that may appear. It is also increasingly being used with the main purpose to remove litter from the coast and thereby avoiding any adverse consequences from the collected litter. In most cases the aim of a coastal survey/beach clean-up is a mixture of raising awareness, collecting data and cleaning up (EU 2013; Ocean Conservancy 2015a). The environmental organisation Ocean Conservancy has for 30 years held annually International Coastal Clean-ups, with volunteers cleaning up beaches all around the world and analysing the litter according to type and amount. In 2014, more than 560,000 volunteers were engaged in clean-ups in 91 different countries leading to the collection of 7.3 tons of litter, which shows that coastal surveys have good potential for raising awareness, and that there are people all around the world who are willing to act (Ocean Conservancy 2015a).

For the project at hand, the main purpose of the coastal survey conducted was to assess the magnitude of marine litter in Nuuk. Six beaches were initially chosen through a visual assessment of satellite images as potential survey sites before the field trip to Nuuk. The sites were chosen on criteria of length, slope, material (preferably sand or gravel) and distance to Nuuk. The recommended length of a survey site is 100 m and the slope is recommended to be within 15-45 degrees (EU 2013; EU 2011; OSPAR 2010). The six potential survey sites can be seen in Figure 6. The selected sites were then evaluated one by one in Nuuk, and due to the slope and ice cover on the first two stretches from the east, the third visited site was chosen as the final survey site, where marine litter was collected and later assessed in laboratory. The other five sites were visually assessed with regards to the representability of the chosen site. All six stretches seemed to have approximately similar content and amount of litter.

Figure 6: The six potential survey sites with the chosen site depicted in a cohesive line. Satellite image from Google Earth.

The survey was carried out over a stretch of 140 m, in coverage of the entire coast i.e. from the water line to the back of the beach, which was defined by a significant transition from stone/sand to an elevated grass covered area. The litter was collected by going in a zig-zag pattern between the waterline and the back of the beach slowly moving down the coast, as depicted in Figure 7.

Figure 7: An approximation of the followed track during the survey. Satellite image from Google Earth.

The collected litter was later assessed in a laboratory and sorted according to material and type. The findings are presented later in the report.

3.1.1.2 Seafloor Recordings

The most common way of assessing seafloor litter is by the use of scuba divers (EU 2013; Loakeimidis et al 2015). However, in cold waters or in cases where scuba equipment is not available, as was the case in Nuuk, underwater cameras are as well increasingly being used (EU 2013).

Most methodological guidelines recommend filming a transect of 100m or a matrix of the seafloor and hereby enable the estimation of items/km^2 or items/km (EU 2013; Loakeimidis et al 2015; NOWPAP MERRAC n.d.; Cheshire et al 2009). For the project at hand, it was however chosen to make a point assessment by circling around the same area. This was chosen because the recordings were conducted in connection with the survey of floating litter and the appropriate sailing speed for the trawl was too fast for recordings. Filming a transects and matrices is as well most appropriate in areas that are known to have seafloor litter, and as this was an unknown factor for this project, point recordings worked as a screening of seafloor litter, which covered an overall larger area than if a matrix of 100x100m was recorded. The camera equipment made it possible to follow the recordings from boat and thereby assess the presence of litter instantly and assess whether a recording of a transect or matrix should be prioritised. Six sites were filmed (for locations see Figure 5) leading to a total recording time of 63 min. The recordings were later visually assessed for litter.

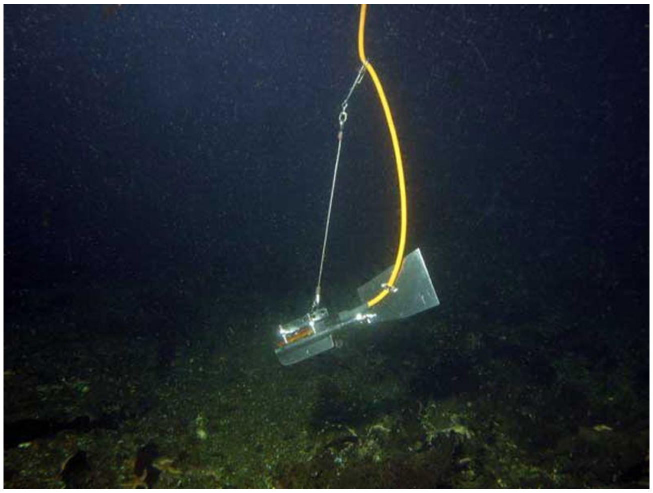


Figure 8: A camera similar to the one used for this project. (LHCamera 2016)

Figure 9: A screenshot from one of the recordings.

3.1.1.3 Sampling and analysing of floating litter

As mentioned earlier, approximately 50% of marine litter floats when it is emitted to the sea. Methods have therefore been developed to assess litter floating in the surface water. Larger items can be visually assessed from ship (Bergmann et al 2015) and smaller litter can be collected by the use of a net that is positioned in the surface water and the samples can then later be analysed in a laboratory (EU 2013; Masura et al 2015). For the project at hand, the latter assessment was chosen i.e. trawling in the surface after smaller pieces of litter.

There are several types of nets that are applicable for the analysis of smaller, floating litter items. The most important characteristic is the mesh size and the positioning of the net in the sea surface. In order to increase the comparability between studies, the MSFD Guidelines (EU 2013) recommend using a net with a mesh size of 333µm which is very similar to NOAA's recommendations of 335 µm (Masura et al 2015). For this study, a bongo net with a mesh size of 335µm was used. The locations of the trawls were chosen so that four trawls were carried out close to the shore of Nuuk and two trawls were carried out further away, respectively in open water and in a fiord. This was done to cover expected high density areas (close to Nuuk) as well as low density areas (open ocean, fiords) as recommended by the MSFD Guidelines (EU 2013). For location of the six trawls see Figure 5 on page 19.

When trawling with the net, high speed can create a bow in front of the opening and it is therefore important to slowly increase the speed while observing the net (EU 2013). This resulted in a steady pace of 3 knots for the present survey. It is recommended by the MSFD Guidelines to begin trawling for no more than 30 min and then assess whether the trawling time could be increased. After one trawl of 30 min it was chosen to continue with this trawling time due to the size of the first sample. The net was mounted on the side of the boat by the use of a boom and with weights attached to the lower side of the frame to keep the net steady and as vertically as possible.

Following the MSFD Guidelines, the net was then taken in and rinsed from the outside to get all particles down into the cod end of the net. The cod end was then inverted over a bowl, rinsed into the bowl, and any

Figure 10: From the left: The Bongo net placed on the side of the boat using a boom. The cod end of the net being rinsed from the outside using a spray bottle. The six samples in blue caps, glass containers.

larger pieces of sea weed and jellyfish were rinsed and let back into the sea. The water sample was then transferred to glass containers (blue caps) and a small amount of preservative was added. The jars were then labelled and the net was reinserted into the water. The samples were later analysed in laboratory as described in Annex 1.

The findings of the three marine litter assessments represent momentarily states of marine litter in Nuuk. Seasonal changes of ice and snow cover, ocean currents and outdoor activities of the population, along with day-to-day variations of wind directions and speed, influence the findings of the three assessments. More assessments would therefore minimise the influence from these variations and increase the reliability of the findings. For this project, the findings of the three assessments are planned as opening assessments that constitute a screening of marine litter, which could form the foundation for future marine litter projects. Although a heightened collection of data would increase reliability, the findings are seen as applicable indications of the presence of marine litter which brings sufficient knowledge in order to discuss future actions to reduce the discharge and impacts of marine litter.

3.1.2 Interviews

Interviews were conducted in order to obtain knowledge that was not available from literature. One purpose was to obtain updated information on the waste management in Greenland for which an interview with two environmental workers in Nuuk was planned. The interviewees are employed at the newly established Knowledge Centre for Waste Management (Danish: Videnscenter for Affaldshånd-tering) in Nuuk, as an environmental technician and centre leader, respectively. The main task of the Knowledge Centre is to spread knowledge on waste management in Greenland, and the interviewees were therefore chosen due to their expertise in giving information and perspectives on the current and future management of waste in Greenland. Besides getting information on the current waste management in Greenland, the interview had the purpose of having a discussion about what initiatives would be possible to implement. The interview took place at the centre and brought information on the current waste management in Greenland and future plans to the project as well as the perspectives of the two interviewees on potential initiatives to reduce discharges and impacts from marine litter (Hegelund and Berglund 2016).

Another interview was carried out with the purpose to increase the understanding of factors that influence the generation of lost fishing gear and with the purpose of getting information on the process of establishing an initiative that acts against the creation of marine litter in Greenland. The interviewee is working on a project that is developing a fishing net recycling company in Sisimiut. The interview was conducted over Skype and was semi-structured as questions were formulated beforehand but the conversation was kept free and led to additional questions that were not planned prior to the interview (Pedersen 2016).

Conversations with locals contributed as well with valuable knowledge on the presence of marine litter around Nuuk and other aspects of the management of litter. These included conversations with local fishermen on where and how they have experienced catching or losing fishing gear.

3.1.3 Questionnaire

A questionnaire was conducted and sent out to Royal Greenland trawlers via the administration at Royal Greenland. The purpose of the questionnaire was to get an insight into what experiences professional fishermen have with marine litter in Greenland. The questionnaire consisted of open and closed questions relating to their observations of marine litter at sea and their experiences of losing fishing gear. Answers were received from three Royal Greenland trawlers.

3.1.4 Literature review

The use of literature review had several purposes. For the contextual part of the project, a literature review was conducted to establish the current status of marine litter research in the Arctic. It was also a key method in creating the conceptual model (Figure 2, page 11), as this requires a contextual analysis of economic, social, biological and other circumstances with influence on the presence of marine litter and thereby the level of impact on the marine ecosystem of Greenland.

Literature review was as well the central methods in the assessment of initiatives to minimise future discharges and impacts of marine litter. For this survey, all types of literature, scientific as well as grey, and media were considered. This was chosen in order to have a broad collection of initiatives for the survey, and since many initiatives are newly created ideas that are not yet found in scientific literature. To consider grey literature allows for more recent discoveries, as grey literature does not require as much time for research and publication as commercial and scientific literature does. Also it allows the inclusion of inventions that might never be addressed in commercial and scientific literature (Pappas and Williams 2011). Initiatives were found in scientific articles, reports, YouTube videos and newspaper articles. All found initiatives were noted down and categorised according to a hierarchy of marine litter management as presented in the following.

3.2 MARINE LITTER MANAGEMENT HIERARCHY

For the assessment of initiatives, a hierarchy of marine litter management was created. This hierarchy was developed with inspiration from the Waste Hierarchy and the Mitigation Hierarchy. Although a few editions of a marine litter management hierarchies have previously been suggested (Watkins et al 2015; CleanSea n.d.), no definition is commonly agreed upon and it is the opinion of the author that a hierarchy of marine litter management would improve the management of marine litter and would clarify that marine litter needs distinct strategies and is usually not fully covered by the general waste management. The Marine Litter Management Hierarchy developed in this project is therefore an input to the discussion of the components and structure of how marine litter is best managed.

The Waste Hierarchy was introduced for the first time in 1975 through the EU Waste Framework Directive (Council Directive 75/442/EEC) and has since then and is today increasingly being applied and requested in waste management and policies (Williams 2015; Apitz 2010). The hierarchy consists of an order of actions prioritised according to their overall environmental performance. Although there are other interpretations of the Waste Hierarchy (e.g. Gharfalkar et al 2015), the Waste Hierarchy include actions of prevention, preparing for re-use, recycling, other recovery, e.g. energy recovery, and disposal (EU 2013) (See Figure 11). It is applicable for managing waste on a short as well as a long term and it can be applied in projects as well as strategies (Apitz 2010).

The moment waste becomes marine litter it becomes a potential impact to marine life. It is therefore not only a question of managing litter in the overall best environmental friendly way, it is also a question of mitigating the impacts that stem from marine litter. The Mitigation Hierarchy presents an order of mitigation actions that focuses on avoiding and minimizing adverse environmental impacts and in cases

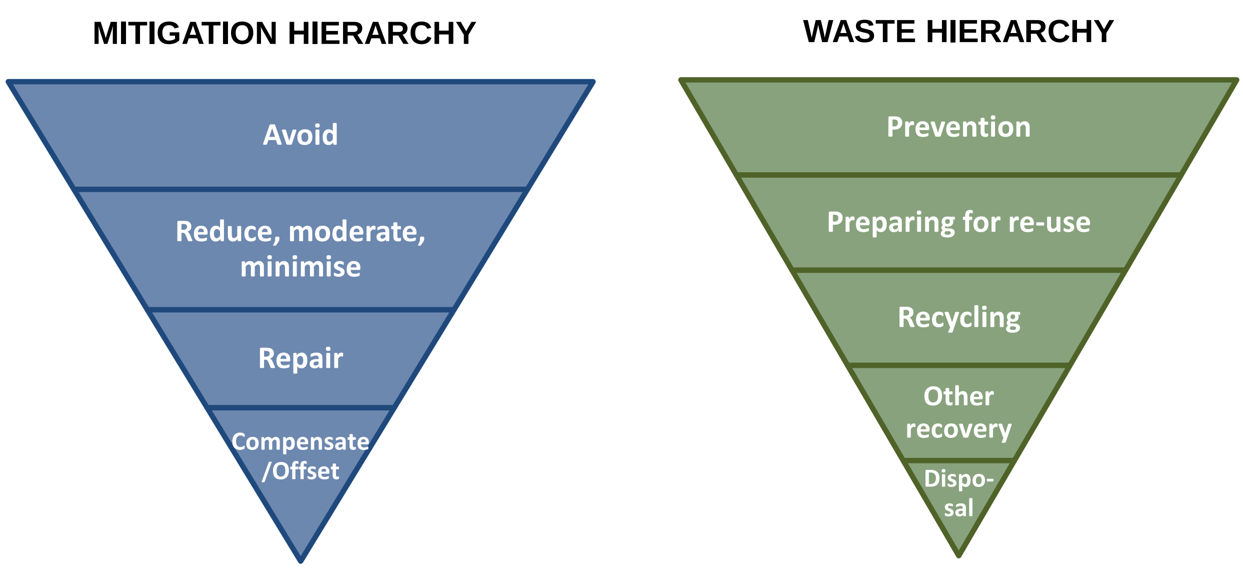


Figure 11: To the left: A combined definition of The Mitigation Hierarchy (Larsen et al 2015; McKenney and Kiesecker 2010; Peste et al 2015; Glasson et al 2005; PriceWaterhouseCoopers 2010). To the right: The Waste Hierarchy as formulated in the Waste Framework Directive (EU 2008).

where the impact is unavoidable, attempt to repair or compensate/offset. It is widely acknowledged and used as an integrated tool in Environmental Impact Assessments. Like the Waste Hierarchy, there are many interpretations of the Mitigation Hierarchy (Larsen et al 2015; McKenney and Kiesecker 2010; Peste et al 2015; Glasson et al 2005; PriceWaterhouseCoopers 2010). A combined edition is depicted in Figure 11 alongside the Waste Hierarchy as formulated by the EU Waste Framework Directive.

When these hierarchies are seen from a marine litter perspective, some elements are highly relevant whereas others are irrelevant in a hierarchy of marine litter management. Central to the definition of marine litter management is that marine litter is created the moment litter enters the marine environment, thus the first step is to *prevent litter from reaching the marine environment*. This step is equivalent to the steps of prevention and avoid from the waste and mitigation hierarchies. Preventing litter from reaching the marine environment includes a wide range of initiatives such as the steps from the Waste Hierarchy assuming the last step of disposal does not lead to any creation of marine litter.

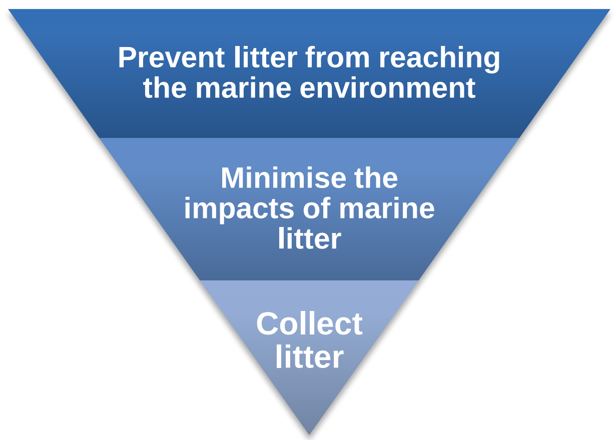


Figure 12: The Marine Litter Management Hierarchy defined for this project.

Certain initiatives can *minimise the impacts of marine litter* once it has entered the marine environment. This type of management was chosen to be the next step of the Marine Litter Management Hierarchy. This step is equivalent to the "Reduce, moderate, minimise" step of the Mitigation Hierarchy. When actions have been taken to prevent litter from reaching the sea and to minimise the potential impacts, the last option of marine litter management are initiatives of *collecting litter*, which in some cases could be compared to the step of repair in the Mitigation Hierarchy. Once marine litter is collected and removed from the marine environment it stops being marine litter. From then on, the waste management should then follow the last three steps of the Waste Hierarchy, i.e. "Recycling", "Other recovery" and "Disposal", granted that the latter option is without any leakage. The combined marine litter and general waste hierarchy can be seen in Figure 13.

The step of compensation/offset of the Mitigation Hierarchy is challenging to incorporate into a setting of marine litter, although one could argue that compensation could be achieved through the development of national parks or coastal zones free from litter sources (e.g. fishing, shipping, population areas). The step

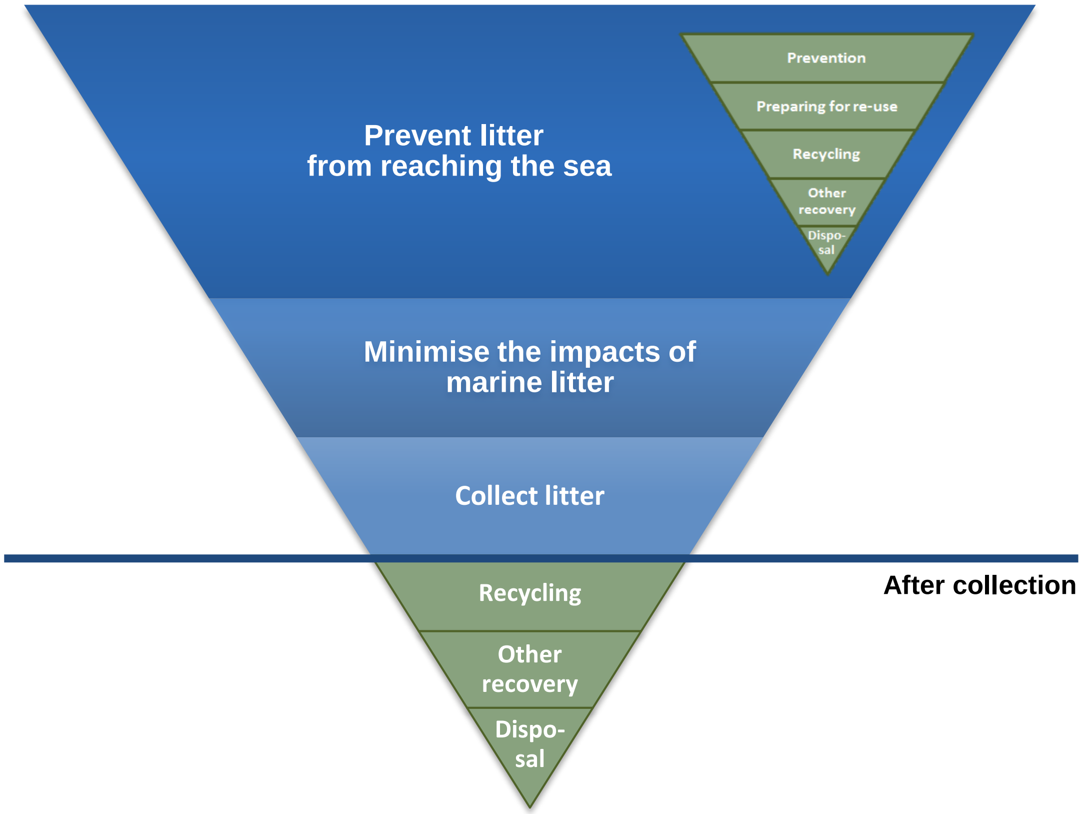


Figure 13: The complete hierarchy of marine litter and general waste management. The first step of preventing litter from reaching the sea i.a. includes the general initiatives of the waste hierarchy, where the overall best option is to prevent litter from being created in the first place. The next level is to implement initiatives that minimise the impacts of marine litter. The least favourable action of marine litter management is to collect litter, after which the collected material should go to recycling, other recovery and as a last option, disposal.

of compensation/offset are however not included into the Marine Litter Management Hierarchy as it should not be considered as options of marine litter management, as marine litter travels with currents and regulated zones are not able to prevent marine litter from having impacts on ecosystems.

3.3 SYSTEMS THINKING

The concept of systems thinking was formulated around the middle of the 20th century and derived from an ancient line of systems theory (Checkland 2000; Yeo 1993; Esmark & Bevir 2011; Ross & Couto 2010; Dekkers 2015). The theory of systems thinking has since then evolved and is now increasingly being used by planners, scientists and politicians. Having started as a hard systems thinking, where the world is seem as a system of endless subsystems, it is now to a higher degree used in an approach of soft systems thinking, which sees the world as a complex set of elements that can be viewed in a systematic way (Davies and Saunders; Yeo 1993; Checkland 2000). Recently, researchers stress the necessity to apply systems thinking due to the increasingly complex world (Kapsali 2011; Russell et al 2014; Yeo 1993; Király et al 2015; Arnold and Wade 2015; Davies and Saunders 1988; Stewart & Fortune 1995).

The problem of marine litter represents this increasing complexity with a vast variety of elements such as the types of litter, types of impacts, sources, actors, recipients, etc., and an approach of systems thinking is therefore an ideal tool. Systems thinking has already been used in the making of The New Plastics Economy report by WEF (2016) to assess the problem of marine plastic litter and propose a new plastic economy centred on recycling, i.e. a circular economy, rather than on disposal. UNEP and NOAA (2011) have as well used systems thinking in the making of the Honolulu Strategy, A Global Framework for Management of Marine Debris, to assess the problems of marine litter and suggest an approach to develop marine litter strategies through systems thinking.

For this project, systems thinking is the theoretical basis of the project design, implemented through an ecosystem approach and the use of conceptual modelling.

3.3.1 Ecosystem Approach

The ecosystem approach can be used when managing human activities that impact the marine environment (HELCOM/OSPAR 2003). The Convention on Biological Diversity defines it as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way." The approach is based on a perception of ecosystems that consist of animals, plant, micro-organisms with humans as an integrated component, as well as the physical, non-living, environment. As formulated in the Helsinki Convention (Convention on the Protection of the Marine Environment of the Baltic Sea Area) "(t)he marine environment is both an ecosystem and an interlocking network of ecosystems", which is in line with the definition of hard systems thinking and emphasises the need to assess any component as a part of the system and not as an isolated element (HELCOM/OSPAR 2003). The ecosystem approach is often contrasted to approaches focused on a single species, single sector or single resource (Currie 2007; Arctic Council 2015).

When an ecosystem approach is applied in management it is often referred to as Ecosystem Based Management (EBM), which is increasingly being implemented by scientists and planners worldwide and has received wide political acknowledgement (Garrelts and Flitner 2011). The increasing implementation of EBM can be explained by the increasing pressure from human activities on ecosystems and that EBM facilitates the implementation of various conservation and environmental management tools, such as conservation of key species or habitats and the establishment of Marine Protected Areas (OSPAR Commission 2015-2016). EBM is also used in the Arctic where it is an important tool in the management of the Arctic ecosystem (Arctic Council 2015; Currie 2007; Bianchi and Skjoldal 2008). According to the Arctic Marine Strategic Plan 2015-2025 (AMSP) "Ecosystem Based Management (EBM) is a cornerstone of the work of the Arctic Council and an important principle to the Arctic States." The focus on EBM led to the foundation of an expert group on Arctic ecosystem-based management in 2011 through the Nuuk Declaration (Arctic Council 2013).

Key elements to the AMSP and the Ecosystem Approach are the *precautionary principle,* and the *polluter pays principle* (OSPAR Commission 2015-2016; Arctic Council 2015). These principles are particularly interesting in a setting of marine litter, where the polluter in many cases is unknown, and where the point for precautionary actions can be difficult to determine, especially if the impacts are not under being surveyed. Further emphasis is put on precautionary approaches as there is often a lack of knowledge in the management of marine ecosystems (OSPAR Commission 2015-2016).

For this project, the Ecosystem Approach was applied by not having a narrow, one-species focus or a focus on one type of litter. Such approaches have been seen lately in the scientific publications on the impacts from micro plastics on one species (e.g. daphnia, oysters, mussels). To understand the total effect of marine litter, these studies are crucial and should continue to be carried out. It is however as well critically important to apply these findings in a systematic assessment through an ecosystem approach. To predict how one species influenced by marine litter can impact the entire ecosystem is highly difficult, which could explain the lack of attempts to do so.

3.3.2 Conceptual modelling

Conceptual modelling is a modelling tool of systems thinking that is increasingly being applied in conservation management, environmental management and international strategies (Davies & Saunders 1988; Yeo 1993; UNEP/NOAA 2011). It allows a systematic assessment of direct and indirect impacts of human activities on ecosystem components (DiGennaro et al 2012; EEAB 2006; Ogden et al 2005; Ping et al 2010; Sanderson et al 2002; Thom 2000; Wilkerson 2013). Following the guidelines of Foundation of Success (FOS 2009), conceptual modelling includes an initial situation analysis that locates the indirect and direct impacts and the links from the impacts to a conservation target (i.e. an ecosystem components). This requires a thorough contextual assessment of all aspects; economic, societal, biological etc. that could have an influence on the direct impacts (CMP 2013). The situation analysis for this project is to a high degree implemented in the introduction of this report.

In addition to the aim of mapping direct and indirect impacts of marine litter on the Greenlandic ecosystem, as seen in Figure 2 (page 11), conceptual modelling was in this project as well used in the assessment of initiatives by depicting the results of proposed strategies through the creation of results chains, as can be seen later in this report. According to FOS (2007) "(…)a results chain represents a team's assumptions about how project or program strategies will contribute to reducing important threats" which is illustrated by a cause-effect chain of the strategy in focus, expected outcomes and the desired impact. In this project, results chains are used to illustrate the assumed effect of proposed strategies in reducing the impact of marine litter based on the assessment of initiatives.

Conceptual modelling has been used on marine ecosystems assessments by environmental organisations such a UNEP, NOAA and WWF (UNEP/NOAA 2011; FOS 2009). Conceptual models and results chains were central tools in the creation of the Honolulu Strategy, *A Global Framework for Management of Marine Debris*, and was seen by the authors of the strategy as "(…)useful tools for civil society, government agencies, intergovernmental organizations, and the private sector to identify marine debris issues." (UNEP/NOAA 2011).

The conceptual model and results chains shown in this report were all made in the Miradi Adaptive Management Software which is a tool for completing the five steps of the Open Standards for the Practice of Conservation, formulated by Conservation Measures Partnership, which includes the creation of conceptual models and results chains (CMP 2013).

FINDINGS

The following two main sections present the findings of the marine litter survey and the initiative survey, respectively. The first section contains the results from the questionnaire, interviews and three marine litter data collections. The second section presents the findings from interviews and literature review of existing initiatives which were analysed by the application of the Marine Litter Management Hierarchy.

4.1 MARINE LITTER SURVEY

The presence of marine litter in Greenland was assessed through the measuring of marine litter in Nuuk along with the knowledge obtained from interviews and questionnaire (see section 3.1). The findings are presented in the following three subsections according to the accumulation area i.e. floating litter, coastal litter and seafloor litter.

4.1.1 Floating litter

The questionnaire that went out to Royal Greenland trawlers gave an idea of what types of litter that can be seen off shore in the sea around Greenland. The respondents had varied experiences but together they have seen litter of plastics, fishing gear (e.g. buoys) and various consumer items floating around in the water surface. One of the trawlers experiences catching plastics, mostly plastic bags, in almost every trawl.

Observations of floating litter were as well done from the shore in Nuuk, which led to observations of various sizes of litter floating close to shore that seemed to have accumulated in these areas due to the motion of the waves. Examples of these are seen in Figure 14 and 15.

Figure 14: Floating litter

Figure 15: Floating litter

The measuring of floating litter by trawl led to 6 trawls of 30 mins and 2.22-2.84km in length each (see Table 1). With an estimated angle of the net opening of 45° and approx. 50% of the frame being below the surface, the total amount of filtered water was 1452m^3. From these trawls, 21 pieces of plastics were found of which 15 were microplastics. The microplastic particles included four balls of polystyrene, four blue fragments which could derive from rope or net, as well as hard plastics, soft plastics and strings of fibres. Examples of the micro plastic findings can be seen to the right in Figure 16. The plastic pieces >5mm included a lemon bottle, fragment of soft blue plastic and strings.

Table 1: The length of amount of filtered water of each of the six trawls.

	Length	Amount of filtered water
Trawl 1	2.84 km	281 m^3
Trawl 2	2.48 km	245 m^3
Trawl 3	2.32 km	230 m^3
Trawl 4	2.22 km	220 m^3
Trawl 5	2.35 km	233 m^3
Trawl 6	2.46 km	243 m^3
TOTAL	**14,67 km**	**1452 m^3**

One type of particles were initially categorised as an un-defined material. This type consisted of 39 pieces of which some of them can be seen to the left in Figure 16. The attempt to determine the material however led to an interesting discussion. Natural scientists with no experience in micro plastic analysis suggested the material could be organic such as skin or scales from zooplankton or fish. When consulting experts of micro plastics analysis they thought that it looked fibrous or textile-like. Consequently a melting test was carried out, which determines whether a material is plastic or non-plastic depending on whether it melts or burns when exposed to extreme heat. As the particles showed no sign of melting, they were not classified as plastics.

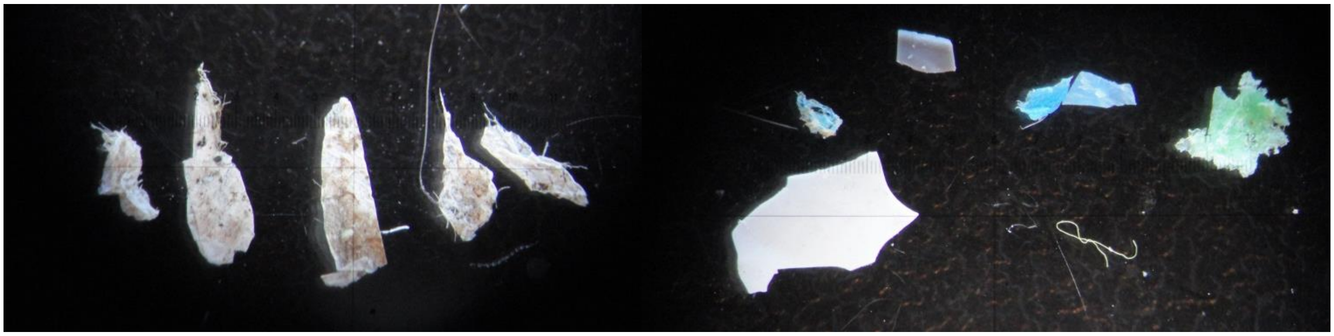


Figure 16: To the left are the particles that were exposed to a melting test. To the right are examples of the microplastic particles. The particles are approximately between 0.5 and 4 mm.

The 15 identified microplastics led to a concentration of 0.01pieces/m^3, which is a relatively low concentration compared to other studies of microplastics, for instance Cole et al (2013) who found 0.27 pieces/m^3 in the English Channel and Lusher et al (2015) who found an average of 0.34 pieces/m^3 in the area south and southwest of Svalbard. The findings of micro plastics in this project are therefore not disturbing when compared to the concentrations found elsewhere in the world.

In conclusion, the findings from the assessment of floating litter showed that in certain areas along the coast there are zones of accumulation in the surface water, which proofs that there are pieces of macro litter present in the water. This consequently also entails a presence of micro plastics. The six trawls for microplastic led to the findings of various types of micro plastics, which could derive from both industry and consumers.

4.1.2 Coastal litter

The assessment of coastal litter was based on a coastal survey, where litter was collected and later analysed, but also included in this assessment are the observations from the other five stretches of coast that were selected as potential survey sites.

All types of litter were observed on the six beaches. Some variations were however possible to see, for instance the most fishing-related litter was seen at the recreational fishing harbour, and some areas were more prone to the accumulation of smaller pieces whereas other beaches had larger items of litter. This variation could be due to wind direction, currents and geomorphology. It was observed that smaller plastic pieces could often be found together with sea weed as can be seen in Figure 17 from the first stretch of coast from the east (location can be seen on Figure 5, page 19).

Figure 17: A pile of sea weed with many smaller pieces of plastics.

The collection of litter was as mentioned carried out over 140m and it let to the collection of 103 pieces of litter i.e. 74 pieces/100m. This is very close to the average findings of the global clean ups arranged by Ocean Conservancy of 71 pieces/100m (Ocean Conservancy 2015a). The number is higher than e.g. Norway (65pieces/100m) and Canada (47pieces/100m) but substantially lower than some Pacific states e.g. the Philippines (610pieces/100m) and Saint Lucia (227pieces/100m) (numbers calculated from Ocean Conservancy 2015a).

The 103 pieces collected along the coast in Nuuk was divided into categories as presented in Table 2. Litter made of plastic constituted 72% of the collected litter, which corresponds to the global estimate that 60-80% of marine litter is plastic (see section 1.1.1). Within the plastic category, some items very easily defined as consumer items, such as hygiene pads and meet trays, whereas other types of plastics, such as lines, rope, strips, are more difficult to categorise as being either consumer or industry related. Most of the collected litter seemed however to derive from consumers. These included plastic bottles, candy wrappers, juice box, duvet cover, gun shells, straw and tobacco packaging. Only the litter of foam, line, rope and strips were seen as potential industry litter in addition to fractions of hard and soft plastics and metal, as these were hard to identify.

Of the top 10 items collected globally in the 2014 clean-ups held by Ocean Conservancy (2015a), some variations are found to the findings of this study. No. 1 item found on beaches globally are cigarette buds, which were not found in this study. This could be explained by the climate that only for a short period invites for long visits to the beach, which could lead to cigarette buds being left on the beach. No. 2 item collected globally is food wrappers and no. 3 is plastic bottles, which were as well collected in this study. No. 4 item is bottle caps, which were not collected but observed on other beaches in Nuuk. No. 6 & 7 items most often found in clean-ups are other plastic bags and grocery bags, which were as well not present on the site of collection (Ocean Conservancy 2015a). This could however be due to a strong, onshore wind on the days leading up to the survey, which could have taken any plastic bags and carried them further ashore. Of the collected items, the plastic gun shells are assumed to be an item that can be found to a higher degree in Greenland than average, due to the prevalent Greenlandic culture of hunting. Another item, sanitary pads, was not expected, but is assumed to derive from the unfiltered wastewater.

Table 2: The collected and sorted coastal litter.

Type	Size	Amount
Metal	5-15cm	**5**
Glass	1-3cm	**2**
Paper	8cm	**1**
Textile		**21**
Cloths	5x15cm	17
Duvet cover	200x90cm	1
Other	20cm	3
Plastics		**74**
Hard plastics	2-30cm	30
Soft plastics	15cm	3
Mixed plastic	10-20cm	3
Plastic bottles	15-22cm	3
Plastic gun shells	7x2 cm	8
Plastic packaging	3-15 cm	7
Foam, polystyrene	7-50 cm	4
Plastic traces	12x20cm	2
Line, rope, strips	<10m	8
Sanitary pads	15x7cm	6

Figure 18: Some of the sorted sections of collected litter.

In conclusion, the coastal survey showed that the examined stretch of coast was just above average in pollution compared to the findings from other coastal collections around the world. That 72% of the collected litter pieces are plastics are a course for concern due to the potential impacts of this material. As it is not possible to determine whether the coastal litter comes from land or from the sea, it is unknown whether the litter has already caused impacts at sea or whether collecting it prevented it from entering the sea.

4.1.3 Seafloor litter

The presence of seafloor litter was assessed by underwater recordings at six locations close to Nuuk as well as through interviews and questionnaire.

The three respondents of the questionnaire have experienced catching various types of litter in their trawling nets e.g. old traps, plastic bags, car tire, dvd, washing machine and bicycles. Since trawling activities takes place along the seafloor, it can be assumed that most of these items were caught on the seafloor. Two of the three trawlers said the item they catch most often is crap traps, where the third, as mentioned above, most often experience catching plastic bags. The variation in amount and type of litter can be explained by the different geographies and trawling depths the trawlers work at. One of the trawlers emphasised an experience where they had received a complaint about a sanitary pad in a box of their industrial shrimps, and shortly after they found as well a sanitary pad stuck in the machinery in one of their factories. The trawlers experience once in a while to have a net ripped on the seabed and sometimes part of the net is ripped loose and therefore lost. One of the trawlers has as well experienced catching fish with fishhooks in their mouths and nets with entangled fish.

Based on the conversations with recreational fishers in Nuuk, it appears to be a common experience to both lose and catch fishing nets. One way of catching fishing nets is when the anchor is taken in and a net or other fishing gear get attached. The loss of fishing net is mostly explained by the vegetation, i.e. in places with a lot of sea weed there is a higher change for a net to get stuck. Another contributing factor when losing gear is if the weather has been windy, which increase the risk of entanglement.

The interviewees also explained how the problem of lost fishing nets earlier on got so big in one particular fiord that fishing activities were banned from that area. The problem of lost fishing gear has previously led to the planning of clean-up activities for seafloor litter (also called fishing for litter), and there is now again talk of the need for similar clean-up events.

The underwater recordings, as mentioned, were carried out in six locations and led to a total recording time of 63 min, with an individual recording time between 6–19 min. The length of a recording depended on the time it took to process the material in the trawl as the recordings were done between trawls. The longest recording of 19 min took place in the water off the shore of the dump site, and this was prioritised as litter was expected to be found and was spotted from the boat before the camera was submerged. From the six recordings it was possible to point out 10 items of litter, one item at site 2, three items at site 3, and six items at site 4 (off the dump site) (see Figure 5, page 19, for location of the sites). The material seemed to be mostly metal, especially the items observed off the shore from the dump site, and otherwise the materials seemed to be plastic. None of the found items seemed however to be related to fishing activities. That no fishing gear was observed could be because fishing activities mostly take place further away from Nuuk. It could as well be influenced by the currents around Nuuk that does not create any zones that would be obvious for accumulation.

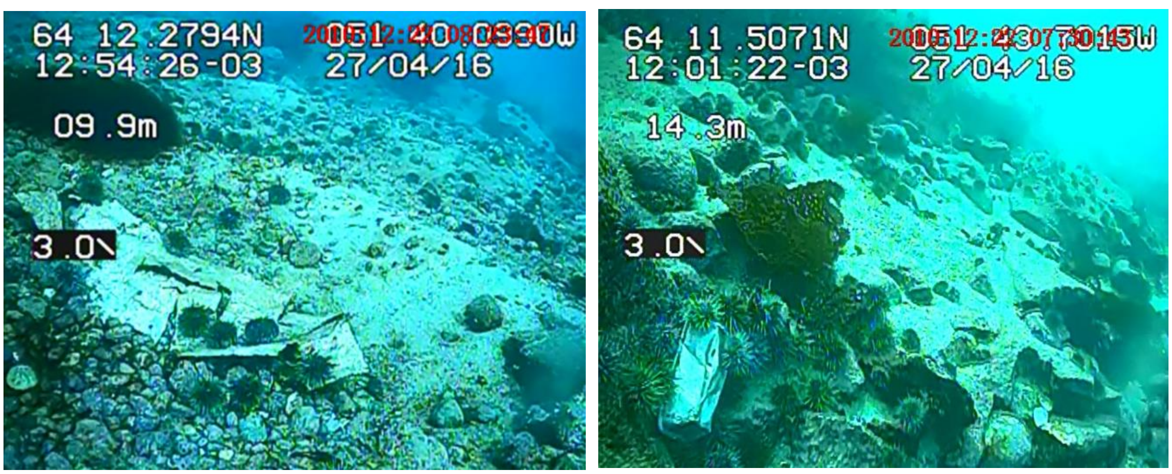


Figure 19: Screenshots of two pieces of located litter on the seafloor recorded by the underwater camera (see section 3.1.1.2.).

In conclusion, although the amount of litter observed on the seafloor in Nuuk was very limited, the findings from the questionnaire and conversations with local fishers could lead to concerns. The experiences of the three Royal Greenland trawlers show how various types of litter can be found far off shore, and if some trawlers experience catching plastic bags in almost every trawl, one could wonder about the impacts of the plastic bags that are not caught and which impacts the caught litter has left behind.

4.2 INITIATIVES

To answer the second part of the research question (p. 16); *... what initiatives can be implemented in order to minimise future discharges and negative impacts of marine litter?,* an assessment of initiatives that either seek to prevent discharges or to minimise the impacts of marine litter was carried out. These include various initiatives such as waste management actions, technological constellations for collection and innovative project ideas for solving problems of marine litter. Of these initiatives, some are well-known and implemented in many countries around the world, whereas others have yet to be fully developed. Initiatives were located in literature and other media (see section 3.1.4 for methodological approach) and then categorised according to the Marine Litter Management Hierarchy (presented in section 3.2). References to where the initiatives were found are given in the figure text of Figure 20. The found initiatives are presented below in three subsections according to the three levels of the hierarchy.

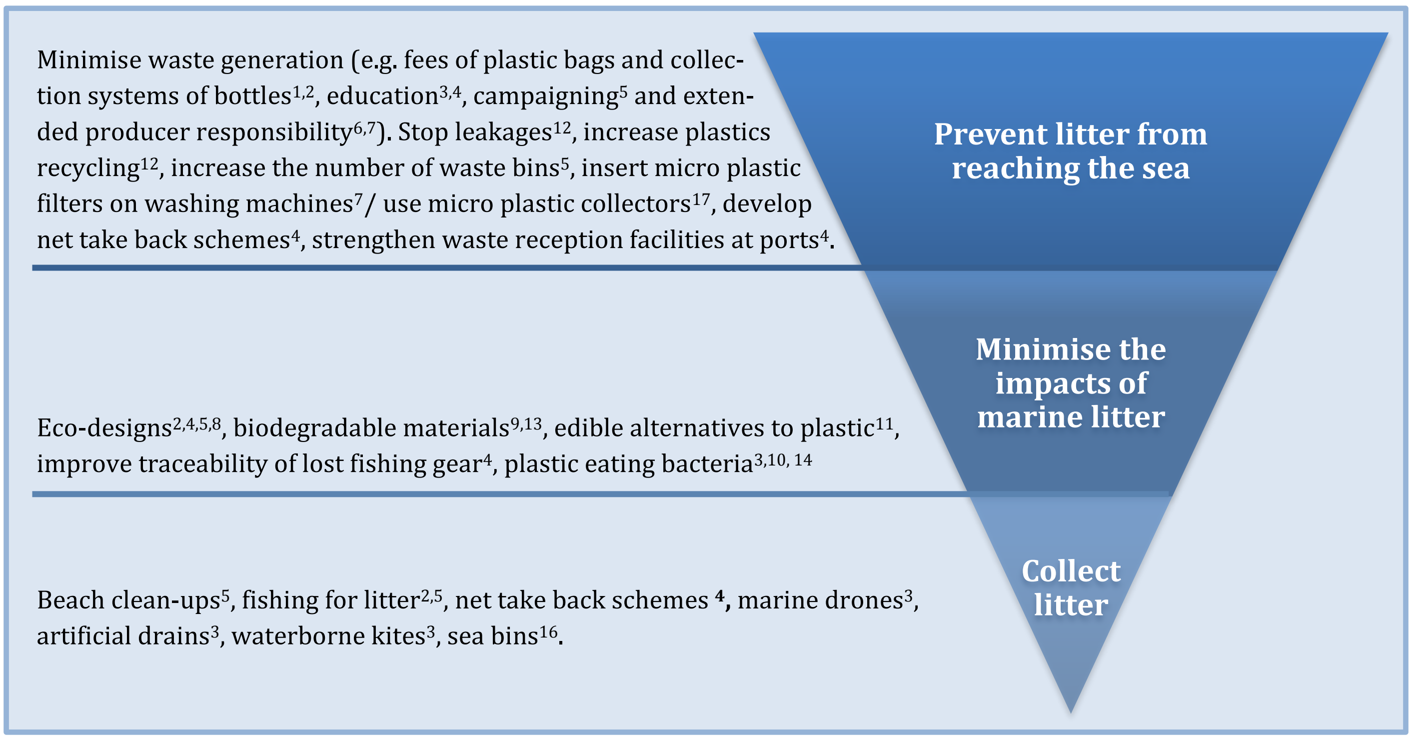


Figure 20: The initiatives located via literature review categorised according to the Marine Litter Management Hierarchy. Sources: 1. WEF 2016 2. Norden 2014 3. Krieger 2016 4. UNEP/FAO 2009 5. Thevenon et al 2014 6. Jambeck et al 2015 7. Watkins et al 2015 8. Wilcox et al 2015 9. Humborstad et al 2003 10. Yoshida et al 2016 11. Saltwater Brewery 2016 12. Ocean Conservancy 2015b, 13. Cooke 2016, 14. UCL 2012, 15. NEA 2015, 16. The Seabin Project 2015, 17. Ducharme 2016.

4.2.1 Prevent litter from reaching the sea

The best way to prevent litter from reaching the sea is to minimise the generation of waste as this can have multiple positive effects in terms of energy and resource savings and with a minimum of environmental impacts. There are many initiatives that seek to minimise waste generation, including putting fees on plastic bags and deposits on bottles. Such initiatives are, as mentioned earlier in this report, already well implemented in many countries all around the world, including Greenland. Other initiatives to reduce the general waste generation are education, raising awareness through campaigning and extended producer responsibility (See Figure 20). The latter one is seen as a good way of addressing marine litter types that are hard to address downstream at consumer level such as microbeads in cosmetics and microfibers from washing machines. Placing the responsibility on the producers could entail a ban on using microbeads such as the ban in the U.S.: "Microbead-Free Waters Act of 2015" signed by the president in December 2015 (The White House 2015). Washing machine producers could likewise be required to implement micro plastic filters into their products. Micro plastic filters for washing machines are relatively easy to retrofit, which means that filters could both be demanded as integrated elements of new machines and as retrofits for older machines.

Prevention initiatives that are specifically focused on marine litter, i.e. preventing litter from reaching the sea, include optimisation of waste management by closing leakage points. Approximately 25% of plastic marine litter from on-land sources derives from leakage points in the collection system, thus resulting in a potential to prevent ca. 20% of the global discharge of marine litter (i.e. 25% of 80% plastic marine litter) by closing leakage points (Ocean Conservancy 2015b). Whether these leakage points are largest at e.g. dump sites or during transportation vary from country to country. It is therefore important to assess the leakage points of the individual country to know where actions should be focused.

Other prevention initiatives include plastic recycling which could be strengthened by an increased use of eco-design that enables a circular economy. Putting up more waste bins in coastal areas is another prevention initiative that can reduce the amount of litter being deliberately left in nature. For sea-based sources, net take back schemes can reduce the economic incentive to dump old nets at sea, as it is currently common practice that fishermen pay when handing in old nets at waste reception facilities at ports. Port reception facilities could as well in general be improved in order to minimise the dumping of litter at sea.

4.2.2 Minimise the impacts of marine litter

Of the assessed initiatives, the number of initiatives focused on minimising the impacts of marine litter is not as high as the number of prevention initiatives (see Figure 20), which could indicate a general trend of prevention initiatives being more numerous than minimisation initiatives. Generally, these initiatives are innovative solutions that depend on new technology and most initiatives in Figure 20 are not yet in production. Through eco-design it is possible to minimise potential impacts in case the product end up as marine litter. One example is the implementation of chips into fishing gear in order to increase the traceability, which then makes it easier to collect the lost fishing gear thereby minimising potential impacts. Minimisation initiatives also include material substitution, where plastics are substituted with more environmentally friendly materials such as bottles of biodegradable plastics (see Figure 20). These should however be viewed as a last option for minimisation and not as a final solution as some biodegradable plastic materials contain additives that are not environmentally friendly. All-natural alternatives to plastic have been developed and these should be prioritised above biodegradable plastics. Material substitution add to the reduction of demand for plastic by substituting plastic items such as six pack rings with another organic material such as cardboard, algae or leftovers from beer productions as invented by Saltwater Brewery (2016).

Initiatives of reducing the impact from marine litter also include the discovery of bacteria that produce a plastic-degrading enzyme and are therefore considered as microplastics eating bacteria (see Figure 20).

These have been suggested to be released in large numbers in areas with high concentrations of marine litter. A project proposed by a group of students from University College London also include the suggested release of bacteria that produce an adhesive enzyme that collects micro plastics into lumps, which can then be used in the formation of artificial islands. It is however critical to thoroughly assess potential impacts before releasing bacteria, that have been modified, into nature or that are not naturally occurring in the specific environment.

4.2.3 Collect Litter

There are initiatives for collecting litter in several marine environments i.e. the coast, the seafloor, the water column and the surface, and some of these initiatives are already well known collection tools whereas others are recent, innovative ideas that have not yet been fully developed. Collection initiatives that have been applied for decades now are beach clean-ups and fishing-for-litter initiatives (see Figure 20). Beach clean-ups require a minimum of equipment, time and money and is an effective way of collecting litter and the same time raise awareness about the problem of marine litter. Fishing-for-litter initiatives have as well been used in some parts of the world, including Greenland, with great success. Of less developed or less widespread initiatives are constellations that collect marine litter either below surface as marine drones, or on the surface in shape of marine kites, artificial drains or seabins. Marine drones, kites and artificial drains have been suggested for the implementation in high concentration areas, such as the Pacific Ocean, whereas seabins are intended for port areas or marinas with high pollution. These collection constellations can be seen in the pictures below.

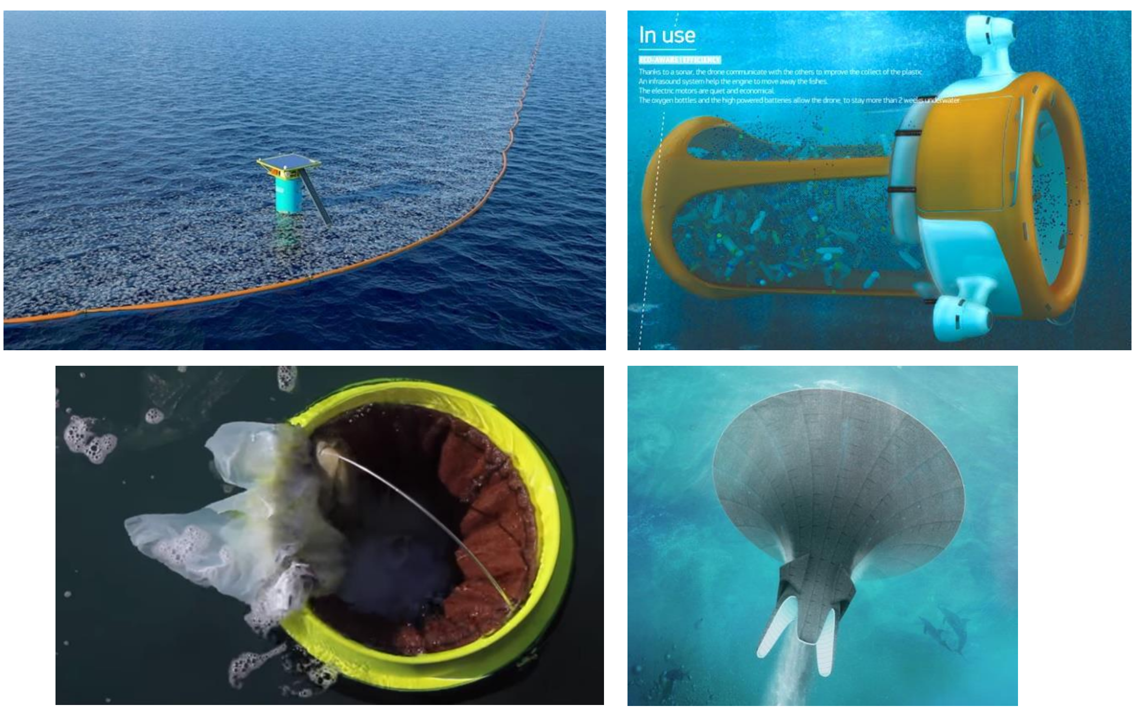


Figure 21: Top left: Waterborn kite-shaped collection system invented by Boyan Slat (Eriksen 2015). Top right: Marine drone for underwater collection (Tuvie 2012). Bottom left: A seabin invented by the Seabin Project (2015). Bottom right: Huge artificial drain proposed to be placed in the Pacific Ocean (Cho 2014).

4.2.4 Initiatives for Greenland

The various initiatives presented in the previous section are effective in different contexts. For instance, in countries where there is very little leakage from the waste management system it might be more effective to focus on other initiatives, such as initiatives that seek to reduce the amount of litter left deliberately in nature. According to the Honolulu Strategy (UNEP/NOAA 2011), the choice of actions and strategies to address marine litter "(…)depend on the social, cultural, environmental and economic context in which they are planned and implemented.". It is therefore necessary to assess these aspects when designing marine litter strategies. Consequently, the initiatives described above are here discussed from a Greenlandic perspective, following the structure of Figure 20. The initiatives have been assessed based on the findings of the marine litter survey, the contextual knowledge acquired through interviews and literature, and the potential effect the initiative is assumed to have, i.e. the amount of litter that can be prevented, minimised or collected.

Prevent litter from reaching the sea

General waste management initiatives for minimising the generation of waste are already employed in Greenland, such as fees on grocery bags and deposits on bottles. One of the aims of the newly established Knowledge Centre for Waste Management in Nuuk is to educate the citizens and its current focus is among others on educating children in kindergartens and schools. It is already possible to see a trend where students are becoming more aware and more interested in the environmental impacts of waste in Greenland (EEA 2011). This could indicate that there is a potential to raise the awareness and knowledge of students by educating them about the impacts of marine litter and how to avoid it. In addition to the initiatives of education focused on children in kindergarten and schools it could as well be beneficial to direct education towards adults or specific target groups. An example could be to inform fishermen about the impacts of lost fishing gear. Campaigns could be used e.g. to focus on women and the impacts of throwing hygiene pads in the toilet. They could be displayed on TV, formulated as posters in the local store or in bus stops. Information on the consequences of lost fishing gear and hygiene pads could as well be given to school children with the potential effect that the children go home and share their newfound knowledge or at least act according to it in their lives.

The influence of extended producer responsibility is limited, as the production of consumer products is very small in Greenland. It would however be possible for the government of Greenland to set up requirements for imported products, such as a ban on micro beads products. The government of Greenland could as well make requirements for households to install micro plastic filters in washing machines.

As described above, when considering waste management improvements it is very dependent on the individual country in terms of where actions should be focused and what the improvement potential is. Based on research of the Greenlandic waste management system (Eisted & Christensen 2001, 2013, Gunnarsdóttir et al 2013), interviews and observations done during the fieldtrip in Nuuk, two issues are seen as key issues if marine litter is to be prevented; waste water and dump sites.

As there is no waste water treatment in Greenland, the potential to improve waste management by establishing waste water treatment facilities is substantial. This would however require extensive economic investments as it would require a restructuration of the entire network of sewers and establishment of new sewers. As this is currently not a priority of the Greenlandic government and due to the expected costs, other initiatives, such as those of education and campaigning as mentioned above, could be applied as an alternative to reduce the amount of litter reaching the sea with the waste water.

Dump sites are key land-based sources of marine litter in Greenland, as many settlements have neither recycling nor incineration facilities and since the dump sites in towns as well as settlements most often are positioned very close to, or on, the coast hereby increasing the risk of leakage to the sea. Ways of minimising this leakage point is to reduce the amount of litter on dump sites by increasing the level of recycling. This is however difficult in Greenland, where waste generation is very scattered and relatively small, which reduce the feasibility of recycling due to transportation expenses. Another aspect that needs to be considered is the environmental impacts that come from collecting waste around Greenland and shipping it to Denmark for recycling. There is already focus on improving the level of recycling by sending more fragments to Denmark for recycling, however other initiatives could be considered to address the amount that inevitably end up on dump sites. These initiatives could focus on the way waste is stored and whether dump sites could be buried or by other means kept from the influence of wind to a greater degree than the current method of occasionally covering the dumped waste with soil. With little vegetation and often strong wind it becomes even more relevant not to leave plastics or other light materials on open dump sites.

Based on the information obtained through interviews and observations, the issue of lost fishing gear, the facilities at port and fees to get rid of waste are seen as an area of big improvement potential. As it currently costs money to get rid of fishing nets at ports, there is an incentive to dump the net at sea, which should be avoided. It is therefore important to assess to what extent this economic incentive leads to deliberate dumping and if so, ideally remove the fee. The project under development in Sisimiut, on which one of the interviewees is working, is addressing this problem by recycling nets, and the fishers can hand in their nets without paying any fee. Initiatives such as this are needed in order to prevent litter from reaching the sea. The recycling process is planned to take place locally and the recycled nets can again be used by locals which leaves a minimum of impacts from transportation compared to the waste fragments that are sent to Denmark for recycling.

Lastly, there is the problem of waste being left in nature either deliberately or as an accident, which can be addressed by putting up more waste bins. It was however the perception of the interviewees from the Knowledge Centre on Waste Management that it is a question of changing the waste culture of the citizens and not the proximity of waste bins. Inappropriate behaviours can be addressed through education and campaigns, which with time could result in a change in culture. It would in addition be good to assess the proximity of waste bins in the coastal areas and to what extent the litter found on the beach derives from consumption in that area or whether it comes from further in-land or from sea. If the waste derives from activities on the beach, waste bins could be placed at the most polluted beaches.

Minimise the impacts of marine litter

The initiatives that can minimise the impacts of marine litter are all founded in the design-phase of product making, which limits the potential initiatives of Greenland, due to the size of production. Nevertheless, creating incentives for product designers and entrepreneurs, as the ones designing the net recycling company in Sisimiut, can encourage the development of e.g. products of plastic-alternatives or

GPS-traceable nets. Already established companies can likewise be encouraged to improve their products if financial support is offered by the state for environmentally friendly initiatives.

Collect litter

Collection of litter is, as mentioned above, an initiative that requires a minimum of financial means and planning compared to other initiatives. Based on the findings from the coastal survey it is considered an initiative of great potential to increase the current level of collection events. There is already a public-private-partnership, Saligaatsoq – Avatangiiserik (CSR 2016), that has a list of activities i.a. focused on reducing the amount of waste in nature and urban areas. They arrange annually a day of waste collection (Saligaatsoq-day) in Nuuk, Illulisiat and Sisimiut, where volunteers spend the day collecting litter in the landscape. This shows that there is already an established structure for collection events, which could be extended with a project focused on marine litter and the collection along the coast. Coastal collection activities could as well be implemented as part of the education in schools, which (in months without snow cover) could include a trip to the local beach to collect litter and assess what can be found.

Another way of collecting litter is the initiative of fishing for litter. This could as well depend on volunteers, or public employees, who fish for lost fishing gear in areas where high concentrations are known to exist. The potential of such initiative would however be greater if the location of lost fishing gear were to be systematically mapped. One way to do this could be to create an online platform where fishers can mark, via an app, if they discover or lose any fishing gear. The GPS-location would then be marked in an interactive map that enables fishing-for-litter volunteers/employees to locate areas with lost fishing gear. Areas with high concentrations of lost fishing gear could as well be located through an extensive assessment based on interviews with recreational and industrial fishers. Another way of getting litter collected is to remove the fee on net disposals and make it easier to dispose of old nets. This could potentially reduce to amount of fishing nets that are currently thrown back into the water after having been caught because the fisherman does not want to spend money on disposing someone else's net.

Technological constellations such as marine drones, waterborne kites, artificial drains and sea bins are not considered appropriate for Greenland due to the financial costs compared to the expected collection potential. The climate of Greenland also problematizes such constellations due to the long period of ice coverage. These initiatives are considered more suitable in warmer, calmer climates where concentrations of litter in the water column are greater than the ones found in this project.

4.2.4.1 Proposed strategies and recommendations

Based on the assessment of initiatives as presented above, three specific strategies are proposed. The strategies were chosen based on the assumed potential compared to the effort and resources they would take to implement. If initiatives are already on their way, such as the net recycling project, these have not been formulated as a strategy. The strategies are presented below as a results chain.

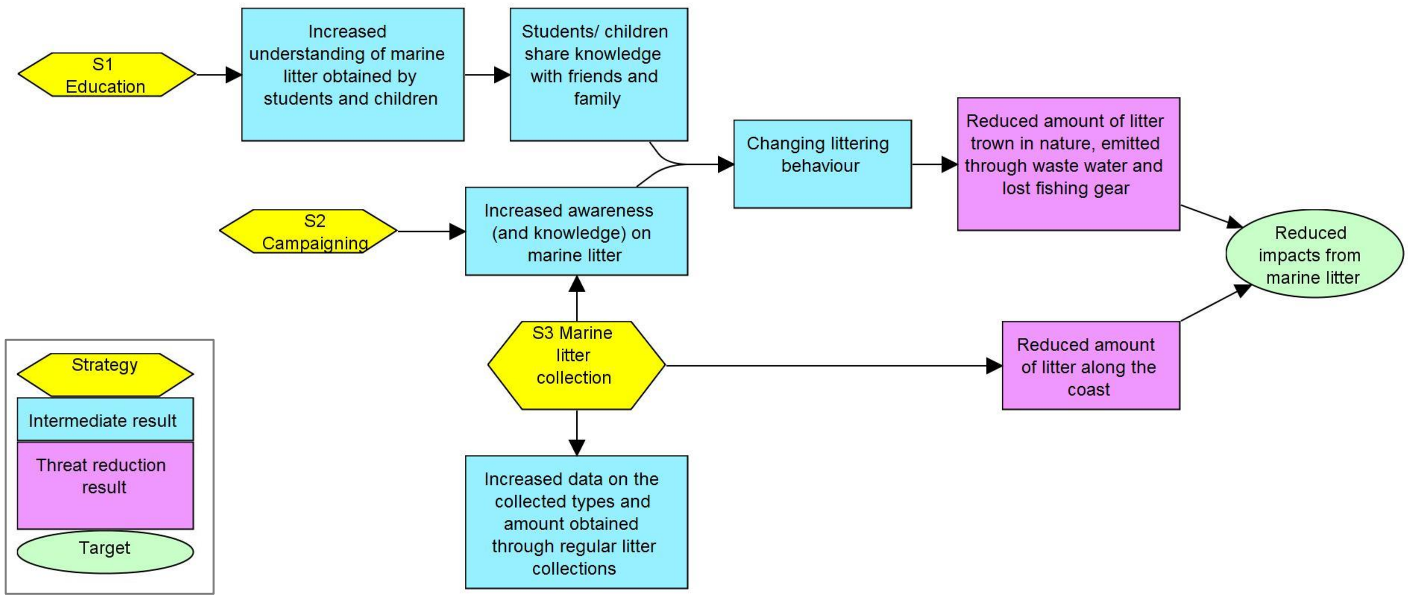


Figure 22: A results chain of the three proposed strategies of 1) Education, 2) Campaigning and 3) Marine litter collection. The model was created in the software Miradi by following the guidelines of FOS (2007). The strategies were formulated based on the findings from the marine litter survey and the knowledge obtained through scientific research on the waste management in Greenland along with interviews, questionnaire and observations.

Strategy 1 (S1) is based on the education initiative focused on schools and kindergartens. The strategy could be combined with the current education activities that focus on general waste management in Greenland. The information shared with the students/children could include 1) Potential impacts of marine litter 2) The sources of marine litter and 3) What they can do to minimise negative impacts. A good way to motivate students and children and make the learning more permanent could be to move part of the education to a beach nearby and conduct a coastal litter survey. The assumed results of this strategy are that it will lead to an increased understanding of marine litter followed by knowledge sharing and a change of behaviour of the students/children and their families (as shown in Figure 22).

Strategy 2 (S2) is focused on changing the behaviour of the citizens through campaigns. These could as mentioned above be TV-campaigns or they could be formulated as posters to put up at bus stops or in stores. The campaigns could address the general behaviour of littering in nature or it could focus on a particular type of litter such as hygiene pads, fishing nets or gun shells. The expected results of this strategy are that campaigns will raise the awareness and potentially also the knowledge, depending on the campaign, on the issue of marine litter, which could lead to a changing littering behaviour. Similar to the strategy of education, this is expected to lead to a reduction of litter left deliberately in nature or emitted with waste water.

Strategy 3 (S3) is, in contrast to S1 and S2, focused on collection. The current collection activities in Greenland focus on urban areas, and there seems to be no collection activities that focus specifically on coastal litter. As the framework of collection activities in urban areas is already in place, it is expected to result in a minimum of implementation difficulties to expand these activities to coastal areas. Collection events should be carried out regularly, at least 2-4 times during the snow-free period depending on how long this is, as it varies greatly from location to location in Greenland. To reach potential volunteers, various media can be used. Facebook has already been used for the planning of collection activities in Greenland and is seen as a good tool to reach volunteers but it could as well be supplemented with posters and advertisements in papers and public places. Collection activities are not only expected to have the direct effect of removing litter from coastal areas (see Figure 22) but is also assumed to result in raised awareness and increased data on the collected litter, which should be systematically assessed according to internationally standards, such as the ones presented by EU (2013). In this way it is possible to track any changes in the amount and types of litter found along the coast.

The three strategies are inserted below into the conceptual model as presented in section 1.2, page 11, to illustrate the assumed coverage of the strategies. This is followed by recommendations on future initiatives.

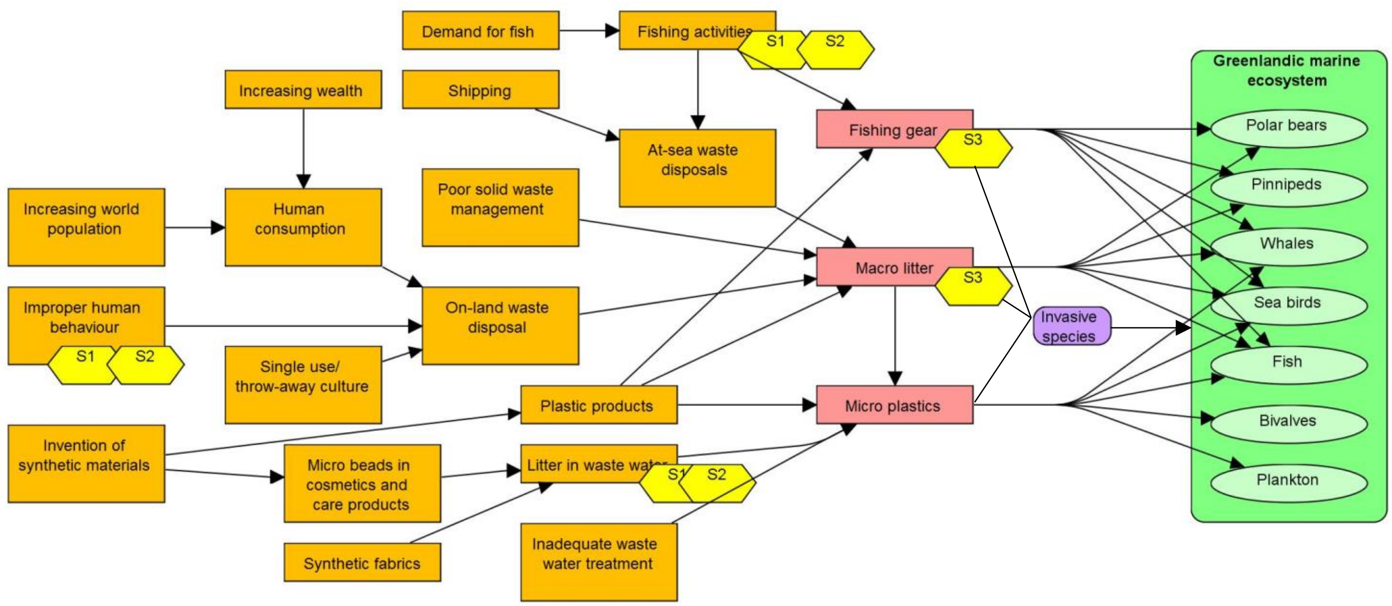


Figure 23: The three strategies are here inserted into the conceptual model, which visualises the coverage of the strategies.

Strategy 1 and 2 (as can be seen in Figure 23) address the indirect impacts of improper human behaviour as well as marine litter from waste water and fishing activities, thereby affecting the direct impacts of all marine litter types, whereas strategy 3 addresses the direct impacts of lost fishing gear and macro litter.

The three strategies are focused on measures of prevention and collection, and are hereby focused on both preventing the creation of marine litter and removing litter that ends up in the marine environment. To focus on prevention and cleaning up is seen as the most suitable strategy for Greenland due to the potentials found at these levels of the Marine Litter Waste Hierarchy. The three strategies are not expected to require much time to plan and implement. Other strategies are more extensive, and recommendations for these potential, future strategies are therefore given.

Recommendations for future initiatives

- With the extent of fishing activities in Greenland, fishing gear is inevitably lost and it is therefore recommended to develop a way to collect lost fishing gear. As suggested above, this could be done through the design of an interactive map, where industrial as well as recreational fishers can mark the location of lost fishing gear. Based on this data, it would then be possible to assess the need to hire fishing-for-litter fishermen or volunteers, such as retired fishermen.
- As the untreated waste water is a key source of marine litter in terms of both micro plastics and macro litter, there is great potential to improve the current level of treatment. Since the restructuration of sewers and installation and construction of treatment plants are considered highly expensive and with long term perspectives, there are other means to minimise the impacts from waste water. The installation of micro plastic filters in washing machines could prevent an estimated 20,000 fibres per litre (see section 1.1.2). This would require political action and willingness to become a first-mover, which would send a global signal of Greenland acting against marine litter.
- Although the incentive to dump nets at sea due to the fee for disposal is addressed by the net recycling project in Sisimiut, other initiatives could as well improve the collection of old nets. It is recommended to improve the reception facilities in ports so that it becomes easier for fishers to get rid of nets and other waste fragments.
- As the dump site in Nuuk is about to be relocated due to an extension of the airport, this opens up possibilities for smart planning of the new dump site. One consideration could be how to avoid leakage to the sea by e.g. closed dump site, burials or storage of light litter in a building.
- In settlements without incineration facilities and where waste rarely is collected by ship, consider establishing closed dump sites/indoor dumps, to avoid the attraction of animals such as polar bears and to avoid leakages to sea.

The recommended initiatives are seen as actions that could be implemented within the near future with a realistic range of economic costs. The implementation is mostly dependent on the Government of Greenland or public institutions at lower levels, such as municipalities. The development of an app for lost fishing gear could however be initiated by interested and skilled citizens/app developers and the implementation of micro plastic filters in washing machine could be done by anyone who wish to reduce their contribution to marine litter.

DICUSSION

As stated in the Arctic Marine Strategic Plan 2015-2025, two principles are of particular importance to the Arctic Council; *the polluter pays principle* and *the precautionary principle*. During the present project, it emerged as a topic for discussion how these principles can be applied in the management of marine litter, considering the differences from pollution of marine litter to pollutions of e.g. hydrocarbon activities, shipping or other human activities in the Arctic, in terms of knowing the source and extent of the pollution. Also discussed in this section is the use of the Waste Hierarchy for waste management in the Arctic, where the distance to recycling facilities is often very long and infrastructure is limited.

The first of the two key principles to the Arctic Council, *the polluter pays principle*, can be particularly challenging to employ in the management of marine litter, as the polluter is often unknown due to the difficulties of locating the source of marine litter both in terms of geography and industry/consumer group. In some cases it is possible to determine the polluting industry/consumer but since it is not possible to link all marine litter to the responsible polluter there is inevitably a cost from marine litter that will spread out in society. As marine litter is a global problem that is dispersed by ocean currents, it is often removed from the polluter and end up causing problems elsewhere. It would therefore be relevant to address the problem of marine litter on regional and global scale and ideally involve all coastal countries around the world. Collaboration would enable actions focused on the largest points of marine litter discharges, thereby reducing the global amount of marine litter, including litter in the Arctic.

From the above perspective it could be stated that the polluter pays principle is without practical meaning and therefore perhaps irrelevant within the scope of marine litter, as the polluter of a specific marine litter item could be anyone close to a coastline or river. As one of the features of marine litter is exactly that the polluter could be living next to you or on the other side of the world, it would perhaps make more sense to set aside the polluter pays principle in the management of marine litter and instead focus on global collaboration while at the same time addressing local sources of marine litter. Experiences could perhaps be drawn from initiatives and actions focused on climate change, as this is a global environmental problem with similar features to those of marine litter i.e. the global scope and spread of impacts and the difficulties of defining the polluter.

The second principle of great importance to the Arctic Council, *the precautionary principle*, is only possible to apply if the current level of impact is known i.e. if the level of impact from marine litter is unknown it is not possible to know when to act in order to be precautious. This makes it critical to keep track of the impacts of marine litter through regular measurements and, in addition, conduct biological assessments focused on e.g. ingestion and entanglement of Greenlandic marine species.

A precautious approach is seen as highly suitable to problems of marine litter due to the irreversibility or lack of compensation opportunities. The last two steps of the mitigation hierarchy, repair and compensate/offset are possible to employ in construction projects but are much more difficult to employ in the case of marine litter, as it can be found in every ocean of the world with no options of isolating the litter or establishing a litter-free area. A precautious approach could therefore be set as the overarching principle in the management of marine litter.

The need for precautious actions could also be related to management of climate change, which in the same way requires precautious actions due to the unknown impacts of a changing climate and feedback mechanisms. This is as well the case of marine litter, where e.g. the effects on human health and the long-term effects of the generation of secondary microplastics are unknown.

One way of having a precautionary approach could involve an optimisation of the general waste management according to the waste hierarchy i.e. reducing the overall waste production and increase the level of recycling as the first two priorities.

When using the waste hierarchy, it is however always important to assess the environmental impacts from each waste management action. This is especially important in Greenland and other Arctic areas, where recycling facilities can be far away and the environmental impacts of shipping needs to be compared to the expected environmental benefits of recycling. There is however no accurate way of comparing the impacts of marine litter to those related to transportation for recycling, and a comparison of impacts should therefore be done with care and should consider long term trends in marine litter and best available technologies within recycling and shipping. Another aspect that should be considered are the multiple benefits that derive from increased recycling e.g. material, energy and land savings. With increasing global population and affluence, technological solutions become equally more important, which in the case of marine litter not only contribute to the collection of marine litter but also in preventing litter from being created in the first place by making transportation of waste and recycling activities more environmentally friendly and less expensive.

Even though marine litter is partly coming from outside the Arctic, and the Arctic contribution to the global presence of marine litter could be minor, the potential impact of arctic mitigation actions should not be underestimated and with the ongoing changes in the Arctic there is even more need for precautious and joint actions.

CONCLUSION

The assessment of marine litter and the initiative survey had the purpose of answering the research question:

What types of marine litter are present in the marine environment of Greenland and what initiatives can be implemented in order to minimise future discharges and negative impacts of marine litter?

The assessment of the presence of marine litter was carried out partly by collecting and analysing marine litter found in, or close to, Nuuk, and partly through the statement of locals and fishers from Royal Greenland. This resulted in an understanding of the presence of marine litter in the area of Nuuk as well as a wider image of what types of marine litter is present in Greenland as a whole.

For the area of Nuuk, the predominant litter type found was coastal litter with 72 % of plastic macro litter and the amount of the collected litter (74 pieces/100m) was just above the global average of 72pieces/100m in 2014. Since Nuuk is far from any ocean accumulation of marine litter or any major ocean current that could bring marine litter to the coast, the relatively high amount of coastal litter could indicate that the primary source is local activities, and that there is a potential to prevent litter from reaching the sea by addressing local sources. Microplastics were as well found in the area around Nuuk, although not in large numbers compared to other places in the world. The found microplastics were mostly connected to industrial activities, which indicate that there is a potential to prevent litter from reaching the sea by increasing the waste management in port areas and at sea. Underwater recordings were as well conducted and these resulted in the observation of 10 items of litter, of which none seemed to be connected to fishing activities. Statements from interviewees and questionnaire respondents however indicated that it is common to lose and catch fishing gear, and that all types of marine litter are caught by activities far off shore, which indicate that there is a presence of seafloor litter that should not be ignored.

The assessments of marine litter are momentarily, albeit useful, indications of the presence of marine litter in Greenland. More assessments should be conducted to raise the reliability and increase the overall knowledge of marine litter in Greenland. Assessments focused on the impacts of marine litter should as well be conducted. These could assess the level of ingestion of macro litter by whales or fish, to what extent plankton is affected by microplastics, or the interaction between polar bears and litter from dump sites.

An assessment of initiatives focused on minimising future discharges and impacts of marine litter was done within the frame of the Marine Litter Management Hierarchy, designed for this project, and the initiatives were then related to the context of Greenland.

Based on the findings of marine litter in Nuuk there appears to be a big potential to prevent marine litter by optimising on-land waste behaviour and management. Statements on the presence of lost fishing gear also indicated a significant potential to reduce the impact of this litter type by collecting already lost fishing gear and reduce the amount of fishing gear lost at sea. To address these potentials to minimise future discharges and impacts from marine litter, three strategies were proposed that focused on initiatives of education, campaigning and collection of litter. The three strategies have the potential to reduce all types of litter from reaching the sea, which is the first step of the Marine Litter Management Hierarchy. The strategy of collection not only removes litter from the marine environment but also has the potential of education and to raise the awareness of marine litter. In addition, recommendations were given for future strategies and actions, including the establishment of an interactive map-app to mark the location of lost fishing gear and then get volunteers or employees to fish for litter in areas of high concentrations. Other recommendations focused on the implementation of microplastic filters in washing machines and how to prevent any leakage from the upcoming new dump site in Nuuk.

The problem of marine litter in the Arctic can only be expected to increase in the coming decades due to the changing Arctic climate, the level of activities and the increase in global waste generation. Thus, in order not to surpass the point where precautious actions are an opportunity, actions should be taken now.

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The analysis of the six samples collected by trawls took place in a laboratory, where each sample was emptied over a 4mm sieve to separate micro particles from larger particles. Ideally the sieve should be 5mm, to adhere to the internationally defined size of micro litter. The particles were therefore later individually measured and divided into groups of <5mm and >5mm. Larger items in the sieve were rinsed in order to let smaller particles pass through the sieve. Any visual larger pieces of litter or potential litter was then removed from the sample and assessed under microscope. The water sample containing the smaller particles was then transferred to glass gars and was poured into a large glass petri dish and then assessed through a microscope. Any micro plastic was removed with a tweezer and placed in a smaller petri dish that was later doubled checked and photographed. If any uncertainty existed regarding the material of a particle, second opinions were obtained from researchers at the Greenland Institute of Natural Resources and later images of the particles were sent to scientists with experience in micro plastic analysis. Later on, a melting test was conducted in order to determine whether a particular type of micro particle were plastic. The material type is determined as plastic depending on whether it melts or burns naturally when heated. All marine litter items were counted, measured and described according to the suggestions in the MSFD Guidelines (EU 2013).

Figure 24: Unfiltered water samples are poured into a metal bowl through a 4mm sieve.

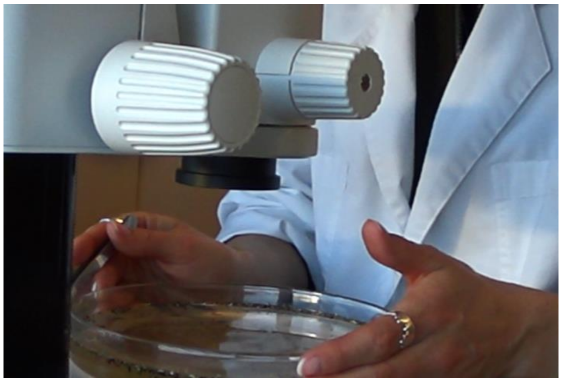

Figure 25: Filtered water sample is assessed through a stereo microscope.