

Marine Litter and Micro-plastics: Why Are They of Concern and What Can We Do?

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Marine litter is defined as any persistent manufactured or processed solid material discarded, disposed of or abandoned in marine and coastal environments (UNEP, 2005). It affects coastlines, the water column and the sea bed and poses a risk to a wide variety of marine organisms.

When people think of marine litter, they tend to think of the litter that ends up on our beaches. It is a global problem, with ocean currents carrying litter across national boundaries. Around 20% comes from sea related activities and 80% is land-based. Most monitoring to date has been on beach litter and it estimated that over 40% of beach litter can be attributed to litter discarded by the public.

Marine litter is found everywhere in the world's oceans, close to densely populated areas but also in remote areas, far from obvious sources (UNEP, 2005). A large proportion of marine litter is comprised of material that degrades very slowly, if at all. Plastics and polystyrene may take hundreds or thousands of years to degrade.

Litter can cause harm:

- to wildlife through entanglement or ingestion
- to habitats through smothering of the seabed
- by acting as a platform to invasive species by helping them to be transported around the globe.

Sewage related debris can also be a health hazard. Lastly, there is an economic cost – cleaning beaches, freeing fouled propellers, cleaning power station intakes to name but a few.

The lifetime of a piece of plastic litter can range from hundreds to thousands of years. Plastic floats and therefore it can travel long distances in the ocean and is easily washed onto beaches. It's very possible that much of the plastic in our seas may not have originated from a Scottish source. The other side of the coin is that the plastic in someone else's

seas may have come from Scotland! On average approximately 80% of beach litter is made up of plastics compared to around 32% on the seabed. Plastics are resistant to being degraded by chemicals but can be susceptible to photo-degradation in sunlight and to being mechanically degraded by wave action. Micro-plastic litter (<5 mm in size and usually much smaller) is on the increase due to this fragmentation of larger plastics and micro-plastics have the capacity to absorb, transport and release pollutants. In addition micro-plastics are used in cosmetics and as abrasives for 'sand' blasting.

There are many local, regional, national, European and global initiatives to reduce the litter in the world's seas. For example the European Marine Strategy Framework Directive requires Member States to ensure that 'Properties and quantities of marine litter do not cause harm to the coastal and marine environments'. Marine Scotland is working towards this, with the development of Scotland's Marine Litter Strategy and monitoring of marine litter using Marine Scotland vessels and other initiatives.

Ultimately litter is a preventable problem and we all have our part to play in reducing the amount of litter entering our seas and disfiguring our coastlines.

References

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Microplastics in the Scottish Aquatic Environment: An overview of sample collection, processing, identification & biological effects

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This presentation shall provide an overview of the research currently being undertaken by the Centre for Environmental Research (CER) in UWS investigating the area of microplastics in the aquatic environment. The issue of microplastics (small particles of plastic <5 mm diameter) in the environment is receiving increasing attention in both the scientific literature and popular media. Here we describe the collection, processing and identification of microplastics in sediments from the Clyde river, estuary and firth and their potential biological effects.

Sample collection sites ranged from the inshore freshwater site along the river Clyde at Daldowie, into the tidal areas at Erskine out into the Firth, as far south as Irvine. A collection protocol was developed using a 0.5m quadrat, randomly placed (in triplicate) on the high water mark along the bank/beach. Roughly 1 Kg of sample was collected and taken back to lab in aluminum containers.

Samples were dried in the oven (70°C for 24h), thoroughly mixed and a sub-sample taken for microplastics analysis. The microplastic particles were separated out from sediment and detritus material primarily using density separation techniques based on flotation, similar to those used in forensic sciences. In this technique the sediment sample is added to saturated brine solutions of different densities to find the optimum combination for different types of plastic. Brine solutions tested were sodium chloride (NaCl), Sodium bromide (NaBr), Sodium Iodide (NaI) and Zinc Bromide (ZnBr). Using spiked samples NaCl gave average recoveries of 97% for high density polyethylene, 71% for polyethylene terephthalate (PET), 94% for polypropylene, 97% for polyethylene (180 µm) and 65% for polyethylene (53-75 µm). Particle size was found to have a large influence on separation. Although excellent recoveries were obtained for the lighter plastics (e.g. polyethylene), NaCl was not suitable to separate out the heavier plastics such as PET. In further spiking experiments percentage

recovery of PET increased from 71.01%, using NaCl solution, to 89.76% and 93.7%, using NaBr solution and NaI solution respectively, giving a 22.69% increase in PET retrieval. These results are similar to those published by Claessens et al., (2013).

Following separation microplastics were identified using attenuated total reflectance (ATR) Fourier transform infrared spectroscopy (FT-IR). This technique produces an IR spectrum with a distinctive molecular fingerprint allowing sample identification. When these separation and identification techniques were tested on sediment samples taken from the environment, using NaCl brine solution the main plastics found were polyethylene (46.88%), polystyrene (25%) and polypropylene (15.63%). Samples of cellophane (6.25%), polyvinyl chloride (3.13%) and PET (3.13%) were also found.

The potential biological impact of microplastic was initially investigated by the development of a feeding bioassay using the cnidarian *Hydra attenuata*. The acute toxicity of the commonly used plasticiser Di(2-ethylhexyl) phthalate (DEHP) was also investigated on the *Hydra attenuata* and the beadlet anemone (*Actinia equina*). Although acute toxicity was not observed at concentration up to 100 ppm chronic effects on feeding (*Hydra* and anemone) and regeneration (*Hydra* only) were observed. Future work to be undertaken in this area shall also be discussed.

Acknowledgements

The authors acknowledge the provision of fish samples from Marine Scotland Science.

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Microplastics in the marine environment: Assessing the composition of micro-plastics in the Firth of Clyde.

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The increasing amount of plastic debris in marine and coastal environments has become more evident over time, mostly explained by the growth in the use of plastic materials and the high demand for single-use plastic products¹. A large percentage of the global plastic production ends up in the marine environment, where their long persistence means not only an aesthetic problem in coastal areas, but also a hazard for marine life, being responsible of death by choking and entanglement of a wide range of species, including birds, fish, marine turtles and marine mammals.

Once plastics are discarded into the environment, they are susceptible to several degradation processes, with photo-degradation by exposure to UV light being the most efficient process leading to plastic fragmentation. These plastic fragments bring a new hazard to the environment, since they become bio-available to a new array of species, including planktonic animals or filter feeders. The fact that they have been reported to absorb persistent organic pollutants (POPs) as well as leach chemicals added in industrial manufacturing (i.e. heat stabilisers or flame retardants), only increases the risk to the whole ecosystem, since these hydrophobic contaminants bio-accumulate in tissues and hence may biomagnify throughout marine food webs.

The chosen area of study, the Firth of Clyde, is one of the most industrialised coastal environments in Scotland, with heavy industry, large coastal populations, power stations and the sewage sludge dump site at Garroch Head (dumping ceased in 1998) making the region an area of interest for a study of micro-plastics in marine sediments. Surface sediment samples from Hunterston, Holy Loch and Garroch Head were studied for the presence of micro-plastics using a hyper-saturated saline solution to separate micro-debris (including plastics) by flotation. The study then focussed on Garroch

Head where sediment samples from a core were also studied.

Once the micro-plastics were collected and sorted by size and colour, transmission mode Fourier Transform Infrared Spectroscopy (FT-IR) was employed to identify the polymers of the micro-plastic fibres and fragments. This permitted a qualitative analysis of the composition of the micro-plastic debris in selected areas of the Firth of Clyde.

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Investigating the presence of microplastics in waste water treatment plants and fish located around Scotland

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Microplastics generally refer to small pieces of plastic <5mm in size. They are formed from the degradation of larger pieces of plastics, are designed to be of a microscopic size for industrial use, or are made for use in personal care products. Waste packaging and fishing gear are thought to be major sources of microplastic pollution in the marine and freshwater environment ([Andrady, 2011](#)). Waste water may also be a significant contributor of microplastics to the environment as many face wash products can contain plastic microbeads ([Fendall and Sewell, 2009](#)), also the simple act of washing clothes made of synthetic fabric is capable of releasing thousands of fibers into the waste water ([Browne et al., 2011](#)). The ability of waste water treatment plants (WWTP) to remove these microplastics is therefore incredibly important as this will prevent the receiving water from becoming loaded with this pollutant preventing any potential negative effects. The river Clyde may represent a major source of these microplastics in the Firth of Clyde through the input of WWTP's.

Here we examine three WWTP (Dalmuir, Shieldhall, & Daldowie) located along the River Clyde. These three WWTP releasing effluent into the River Clyde were sampled at various stages of the treatment process, representing the combined waste of over a million people. These samples will be filtered and any potential microplastics will be identified using Fourier transform infrared (FT-IR) spectroscopy. Initial filtering of just 100ml of influent has resulted in 22 potential microplastics being found.

The uptake of microplastics has been investigated in *Nephrops* with 83% examined in the Clyde Sea having been found to contain microplastics ([Murray and Cowie, 2011](#)), however the extent to which fish are affected by microplastics has not been investigated in Scotland. Here we examined two demersal fish species (*Platichthys flesus* & *Pleuronectes platessa*) collected from areas around Scotland (Outer Forth, Bowling, St Andrews

Bay, Holy Loch, Garroch head & Hunterston) for microplastics. Preliminary results show that 76% of the fish stomach and gut contents sampled contain potential microplastics. Initial identification of these potential microplastics has shown Nylon and polyethylene to be the most abundant polymers present.

The results of this study will provide information on the efficacy of WWTP in the removal of microplastics from waste water and the extent to which WWTP are contributing to microplastic pollution in the river Clyde. The study will also help determine the extent to which two demersal fish species are ingesting microplastics in Scotland.

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Determination of the Partition Coefficient of PAHs and PCBs between LDPE and Sea Water, in order to evaluate the efficiency of biological uptake of PAHs and PCBs by *Mytilus edulis*

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Plastics are synthetic polymers manufactured from petroleum based feed stocks and are used in every sector of society including agriculture, industry, medical and domestic¹. There has been a global increase in the use of plastic, particularly single use items such as plastic bags. In 2011 alone it was estimated that 280 million tonnes of plastic were manufactured globally².

Plastic litter was identified as a potential environmental concern in the early 1970's, however it was not until the late 1990's that the issue came to the forefront of the scientific community as a result of increasing ecological concern.

Around 60% to 80% of marine litter (by mass) is attributed to plastic. The presence of discarded plastic in the marine environment can cause a number of problems for marine biota. Micro-plastics (330 µm – 5 mm) are thought to be responsible for causing the death of organisms either through obstruction or tearing of the gastro-intestinal tract (GIT) and/or by providing a means of transporting and concentrating organic pollutants³.

The three main sources of primary micro-plastics are pre-production beads, "sand" blasting debris and "scrubbers" or abrasive particles included in cosmetic and cleaning products. Micro-plastics have been proven to act as vectors for persistent organic pollutants (POPs) and are often referred to as pollutant "sinks"¹. The highly hydrophobic nature of POPs such as PAHs and PCBs, leads to preferential adsorption of these compounds onto hydrophobic particles such as micro-plastics. If the POP coated micro-plastics are ingested by marine organisms this establishes a pathway for the introduction of harmful compounds into the GIT of the organism. Once inside the GIT, POPs can desorb from plastics and enter the biological system of an organism. These harmful compounds can be bioaccumulated in the

tissues of an organism and thus there is potential to biomagnify up the marine food web.

The aim of this study is to calculate the partition coefficient for a series of PAH and PCB compounds between sea water and LDPE (low density polyethylene) in order to identify a range of compounds which are most likely to become adsorbed on to micro-plastics. Following this investigation a series of micro-plastic LDPE samples will be doped with PAH and PCB compounds. Blue mussels (*Mytilus edulis*) will be exposed to these doped micro-plastics in order to evaluate the bioavailability and uptake efficiency of the adsorbed persistent organic pollutants.

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Towards a baseline database of microplastics contamination in Scottish Marine Environments

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Microplastics are defined as fibrous or particulate pieces of plastic smaller than 5mm and are commonly found in seawater, intertidal sediments, and other coastal environments. The generation and potential impacts of microplastics have been extensively discussed by authors such as Derraik (2011) and Andrady (2002). These plastics can enter the marine environment from the breakdown of macroplastics discarded at sea or onland as well as from consumer products containing microbead technologies. They have recently become an area of interest because of potential health risks they may pose to marine organisms. Microplastics have been shown to absorb toxic and persistent bioaccumulative compounds from seawater, including metals and persistent organic pollutants (POPs), which can be taken up and biomagnified up the food chain.

In recent years the UK has taken a stronger stance on reducing plastic pollution around the coast with more focus put on recycling plastics. Microplastics need to be monitored in order to evaluate the effectiveness of the Scottish Government's initiatives to reduce plastic debris in the environment. The aim of the present study, therefore, was to initiate the development of a hitherto lacking quantitative marine baseline microplastic database, for Scotland, starting with the Firth of Forth.

This was done by taking intertidal sediment samples around the Forth, from Musselburgh on the South shore around to Burntisland on the North shore. Fragments were examined through the process of precipitation/floatation in a supersaturated sodium chloride solution and filtering the supernatant. The material retained on the filter was examined and sorted using a high powered dissecting microscope. Plastic particles or fibres were counted and representative particles removed

for polymer identification using Raman microscopy. Using GIS to create a distribution map, the initial data suggest that sites with muddier sediment had less microplastic debris compared to sites with sandy sediment, and show that the majority of plastics found were fibrous, mainly polypropylene, with a range of different colours and sizes. Furthermore, on several sites along the North shore there was a substantial number of larger plastic nurdles scattered along the shore.

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