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MARINE PLASTIC LITTER - A MASSIVE WASTE PROBLEM

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ABSTRACT

The pollution of the oceans with anthropogenic and especially plastic litter is acknowledged as one of the major environmental stressors. Life cycle assessments of plastic products carried out to date have failed to take into account the fact that the oceans represent a final sink for plastics. At present, around 800 species have been shown to have negative interactions with marine litter, the majority relating to entanglement in and ingestion of plastic items. Additionally, marine litter causes socio-economic costs and may impact the wellbeing of society at large. The causes and sources are manifold and include insufficient producer responsibility, lack of awareness of the consequences of littering as well as poor sewage and waste management. Beside large items such as bags and bottles, the presence of microplastic particles sized 5 millimeter and smaller has also been verified in water bodies, sediments and marine organisms throughout the oceans of the world. Large garbage patches, where litter accumulates due to prevailing flow regimes have been verified in all large ocean currents. Plastics degrade very slowly in the marine environment due to physical, chemical and biological processes, and when they settle in sediments they may persist for centuries. The presence of marine litter is largely based on society´s prevailing production and consumption patterns. Meanwhile, this issue has gained increasing recognition in international and regional fora, as exemplified by the European Strategy for Plastics in a Circular Economy, various resolutions by the United Nations and Action Plans adopted inter alia by Regional Seas Conventions and the G7/G20. The challenge remains to take advantage of the current political momentum to effectively implement these Action Plans and further develop tailor-made solutions. Change can only be triggered by compiling solutions together with experts of important sectors such as from waste prevention and management and by spreading the knowledge through education at all levels and age groups.

1. INTRODUCTION

In addition to other key issues such as climate change, the pollution of the environment, and particularly oceans, with anthropogenic litter, is acknowledged as one of the major environmental stressors, causing detrimental impacts on marine biodiversity as reported over the last four decades (Sutherland et al., 2010). The term marine litter comprises any solid material which has been deliberately discarded, or unintentionally lost on beaches, on shores or at sea, including materials transported into the marine environment from land by means of rivers, drainage or sewage systems or winds. It includes any persistent, manufactured or processed solid material and originates from a series of sea- and land-based sources (UNEP, 2005).

Although marine litter consists of a wide range of materials including metal, wood, rubber, glass and paper, there is clear evidence that plastic litter is by far the most abundant type of material. On average, 75% of marine litter collected from European beaches is represented by various forms of plastics, with a similar predominance of plastics being reported from sampling on the seabed and in biota (Barnes et al., 2009). Due to the light weight of these products, plastics can be transported by ocean currents over long distances and are pervasive throughout our oceans from the poles to the equator, from the sea surface to the deep sea and from rivers to lakes and coastal areas.

The mass production of plastics started in the middle of the twentieth century, and traces confirming this advent are present in the Earth sediments (Zalasiewicz et al., 2016).

In addition to large items such as plastic bags or bottles, the presence of microplastic particles has also been verified in water bodies, sediments and marine organisms throughout the oceans of the world.

2. WHERE DOES THE LITTER COME FROM?

Plastics production increased rapidly from the 1950s, with global production reaching approx. 311 million tons in

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2014. Plastics have replaced the use of traditional materials in numerous sectors, including construction, transportation, household goods and packaging, and are also used for a series of novel applications, including in the medical field. Many different varieties of polymer are produced, although in terms of volume the market is dominated by several major types: polyethylene (PE, high and low density), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS, including expanded EPS) and polyurethane (PUR) (UNEP, 2016).

Due to insufficient producer responsibility, lack of awareness over the consequences of littering, the short life cycle of many products and high consumption rates, the durability of plastics, poor sewage and waste management (see Figure 1) including badly operated and illegal landfills and untreated stormwater as well as and maritime use, particularly in the shipping and fishing sectors, a significant portion of the plastics produced worldwide enters into and persists in marine ecosystems (Lebreton et al., 2017 and Werner et al., 2017). For the year 2010 a modelling exercise was carried out for 192 coastal countries, which led to an estimated 3.5 billion metric tons of solid waste being produced, of which 275 million tons were plastics. Mismanagement of plastic litter in these countries alone led to an estimated input of eight million metric tons plastic waste entering the bordering seas, including the Mediterranean and the Black Sea in 2010 (Jambeck et al., 2015). Another study indicated that between 1.15 and 2.41 million tons of plastic waste currently enters the ocean every year from rivers, with over 74% of emissions occurring between May and October (Lebreton et al., 2017).

3. MICROPLASTICS

Plastic particles sized 5 millimeter and smaller are defined as microplastics. Primary microplastics are those originally manufactured with small dimensions; secondary microplastics are those resulting from the breakdown and use of larger items. An assessment of the land-based sources and emissions of microplastics released into the marine environment, has recently been carried out in the North-East Atlantic, showing that the major sources are preproduction pellets, cosmetics, abrasive cleaning agents, rubber infill from artificial sports fields, road runoff from car tyre wear, laundry fibres, and paints (Verschoor et al., 2017). The assessment also focused on the emission of larger land-based litter such as bottles and packaging, which subsequently break down in the sea to microplastic particles. The estimated source emissions are shown in Figure 2.

FIGURE 1: Plastic input from municipal solid waste and wastewater (source: GRID-Arendal and Maphoto/Riccardo Pravettoni: https://www.grida.no/resources/6931).

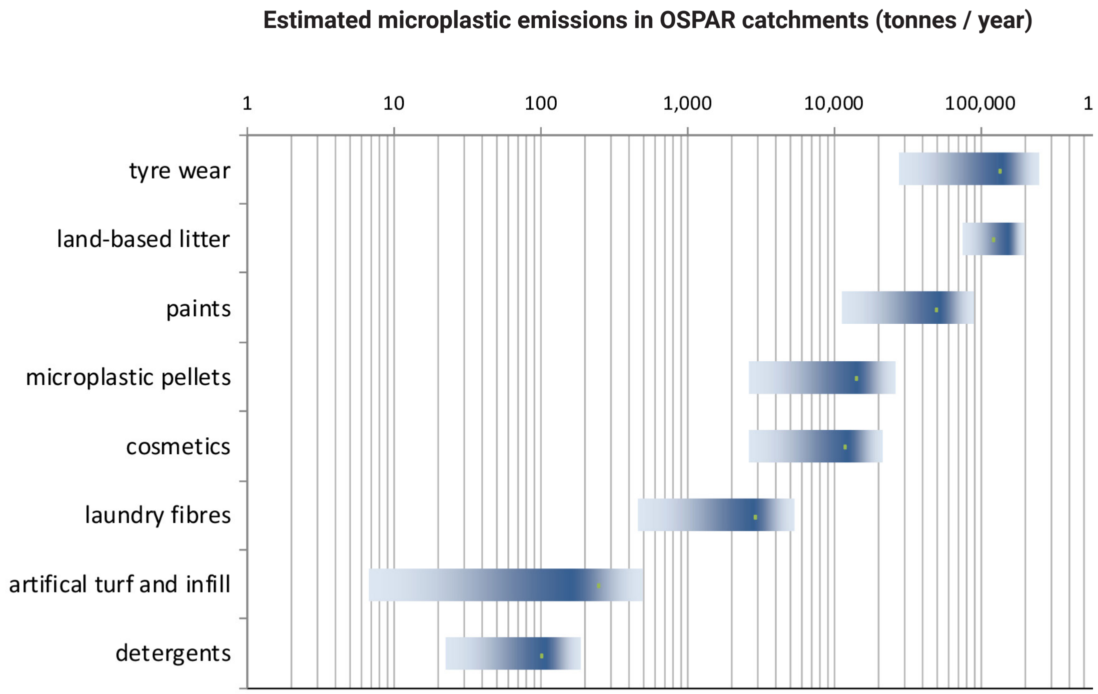

FIGURE 2: Estimated emissions in OSPAR catchment area (source: Verschoor et al., 2017).

4. TRASH GYRES IN MANY PLACES

Large garbage patches where litter accumulates due to prevailing flow regimes have raised particular concern. Although the exact size, content, and location is difficult to accurately predict, the so-called Great Pacific Garbage Patch is known to be the biggest, as it spans waters from the West Coast of North America to Japan (NOAA, 2017). Meanwhile these kinds of patches have been verified in all large ocean currents. According to a global estimation, 5.25 trillion particles with a total weight of circa 270.000 tons are floating on the surface of the oceans (Eriksen et al., 2014 - see also Figure 3). Compared to the inputs these numbers appear low, although it should be kept in mind that litter washed ashore, ingested by biota and that has sunk to the seafloor is not included here. Available data hypothesize that 70 percent of marine litter sinks to the seafloor. As an example, a time series of litter caught in fishing nets in the North Atlantic identified plastics in 62% of the trawls conducted, with densities of litter on the seabed calculated to be up to 580,000 particles per square kilometer.

The Northern fulmar, a small relative of the albatross, feeds exclusively on the open sea and regularly confuses litter particles with food. Data from approx. 1,000 dead fulmars concluded that this sea bird species ingests and egests circa six tons of plastic litter per year in the North Sea region alone. On a global scale, marine species process and redistribute hundreds of tons of plastics in a similar vein every year (Van Franeker, 2011). Data quantifying the biological degradation of synthetic polymers by microorganisms are currently still lacking.

5. BEST-BEFORE DATE: 2618

Tourists mainly perceive litter pollution at holiday destinations as an aesthetic disturbance alone, but for many marine species this pressure is a serious threat to their health and often even to survival. Plastics degrade very slowly in the oceans due to physical, chemical and biological processes. Given that plastic items are often buoyant, an increasing load of plastic litter is being dispersed over long distances, and when they settle in sediments they may persist for centuries (Derraik, 2002). Macroplastics fragment into millions of meso- (2.5 cm down to 5 mm) and microplastic particles (smaller than 5 mm), making them accessible to a wide range of marine biota, from primary producers to higher trophic-level organisms potentially infiltrating the entire marine food web. For example, the WWF determined for the Baltic Sea in the year 2011 that 5,000 – 10,000 gill nets were lost or discarded (WWF Po-

FIGURE 3: Floating marine litter in Cretan waters (source: Stefanie Werner, 2016).

land, 2011). According to scientific research the remaining fishing capacity of so-called ghost nets varies from 6-20% of their initial fishing capacity. Gill nets are made of nylon, which takes up to 600 years to degrade (Ten Brink et al., 2009). Whereas abandoned fishing nets may initially cause entanglement and strangulation of marine species for substantial timeframes, they sooner or later degrade to increasingly smaller particles. The smaller they get the wider the range of species that might ingest them.

6. MARINE LIFE SUFFERS

A recent literature review updated the total number of marine species known to be negatively affected by marine litter to 817 (CBD, 2016). In more than half of these studies entanglement in and ingestion of marine litter items have been documented. Circa 17% of these species are red-listed by the International Union for Conservation of Nature (IUCN) or classified as threatened or endangered. Although the interactions pose a threat to the entire population in only a few cases, it is inevitable that the known impacts will cause a deterioration of the physical condition of affected individuals, with a far greater number of organisms being affected by as yet undocumented sublethal effects. Each year, millions of animals that live in the oceans are debilitated, mutilated and killed by marine litter. In particular, packaging such as strings and sheets, as well as litter related to fishing activities, constitute a high risk for marine life. Rope and netting account for 57% of encounters of marine organisms with litter worldwide, followed by fragments (11%), packaging (10%), other fishing related litter (8%) and microplastics (6%).

An example is the Northern gannet, a seabird which collects litter items at sea for use in nest building. The breeding colony on the uninhabited island of Grassholm (Wales, United Kingdom) is the third largest worldwide with around 40,000 breeding pairs. A study investigated the use of plastics as nesting material. On average, the gannet nests contained 470 grams of plastics, which equates for the entire colony to 18.6 tons (Votiera et al., 2010). Remains of nests, ropes, strings and packaging were particularly abundant, and were also observed in the gannet colony on the German island of Helgoland, where 97% of nests contain plastics (see Figure 4). As a result, mortality due to entanglement and strangulation in litter items is two to five times higher than normally in this population (Dürselen et al., in publication).

Impacts of the ingestion of marine litter include starvation from a full stomach due to a continuous feeling of saturation, low storage of body fat, as well as injuries and blockages of the gastrointestinal tract. In addition, plastics often contain toxic or hormonal effective chemicals or absorb persistant organic pollutants from the seawater. Therefore, the ingestion of plastic particles may provide a pathway facilitating the transport of harmful chemicals to organisms. Deposit- and filter feeding fauna are particularly susceptible to the uptake or ingestion of microplastics, as well as planktonic invertebrates in oceanic gyre regions where microplastic concentrations are high. A study revealed an average ratio between microplastics and mesozooplancton weights of 0.5 in the North Western Mediterranean Sea, which might induce a potential confusion for zooplankton feeders (Collignon et al., 2012).

FIGURE 4: Entangled Northern Gannet on the island of Helgoland (source: Peter Hübner).

In addition, marine litter is known to act as a vector for the transport of biota, including invasive species, and to damage habitats by altering the assemblage of species, e.g. by providing artificial habitats or through smothering. As an underlying ethical aspect of the above-mentioned biological impacts, the issue of animal welfare should not be neglected. The major types of litter affecting marine animals may cause problems for a wide range of species. Impacts may result in poor animal welfare over a range of timeframes; acute impacts may produce suffering and distress for minutes, while chronic impacts may be cumulative, causing increasing suffering over periods as long as years.

Expanding on the socioeconomic perspective, the impacts are manifold. Amongst other things, marine litter may spoil the beauty of the sea and the coastal zone, interfere with fishing and damage fishing boats and gear, block cooling water intakes in power stations, contaminate beaches, commercial harbors and marinas, injure livestock and coastal grazing land, interfere with ships, causing accidents at sea, be a serious hazard to human health, particularly when composed of medical and sanitary waste, damage local economies by contaminating fish catches, driving away tourists and cost a significant amount to clean up. For example, the annual beach cleaning costs in European countries range from around 3,000 to up to 65,000 Euros per kilometer. A frequently raised concern relates to the issue of potential health threats due to the presence of microplastics and associated contaminants in seafood. However, on the basis of current evidence, the risk appears to be no more significant than via other routes of exposure (Werner et al., 2016).

7. TO COMBAT MARINE LITTER

The existance of marine litter is largely based on society's prevailing production and consumption patterns (OSPAR, 2014). The removal of litter from the marine environment may only succeed in capturing marginal amounts, is time- and cost-consuming, and implies additional ecological risks such as the by-catch of marine organisms and damage of habitats. Useful removal activities include passive Fishing-for-litter initiatives, where fishermen are provided with the required logistics to store litter they catch on board of their vessels and to dispose it free of costs in harbors.

However, general prevention programs should represent the major focus of our efforts to combat marine litter. The saving of resources, improving the life-cycle of products, implementing extended producer responsibility schemes, establishing adequate waste, sewage and storm water management, modifying and substituting products and raising awareness should be at the heart of resolute action to prevent further inputs of marine litter. In times of global markets, producers should pay attention to the availability of appropriate waste disposal structures at the point of destination of their goods, which includes a need to set up these structures when not available. The use of plastics should become more sustainable by applying smart product design and revising policies hampering the achievement of a reduced application of plastics. Other key issues relate to an extended durability and long service life of products, strong specifications to prevent technical obsolescence and the avoidance of single-use applications wherever possible. A fundamental aspect relates to the current widespread and non-transparent utilization of additives, which should be thoroughly revised if a true circular economy is to become a feasible possibility. A multiplicity of added substances such as softeners and flame retardants impede eco-effective recycling. Plastics turn to waste or cannot be reused in high-quality products, with only downcycling representing a possible option rather than recycling. Biodegradable polymers do not yet represent a viable option for the replacement of conventional plastics, as they only degrade faster under determined industrial conditions (e.g. constant high temperature), but not in the marine environment, and standards underlying certification of the latter are still lacking.

With regard to sea-based sources of marine litter, a 100 percent integration of waste disposal fees in the regular harbour fees is required to prevent illegal discharging from ships at sea. This No-Special-Fee system has already been widely introduced in Baltic Sea harbors. Inspections at sea and related sanctions should be intensified and the retrieval and recovery of ghost nets e.g. through gear marking should be supported on both an economic and organizational level. Last but not least, with the aim of raising awareness and preventing littering, the topic of marine litter should be comprised in all academic and professional curriculums and become a subject for general education.

Action Plans on Marine Litter focusing on a comprehensive set of actions aimed at targeting the major sea-based and land-based sources, together with the implementation of suitable removal and education activities, exist on an international (G7/G20, UNEP), regional (Regional Seas Conventions) and national (in Europe especially under the EU Marine Strategy Framework Directive) level. These instruments strive to obtain an efficient and effective horizontal multi stakeholder involvement. By considering the implications for the marine environment as an ultimate sink for litter they add weight to existing sectoral approaches of other regimes and legal frameworks.

In a European context, Regional Action Plans on Marine Litter exist for the North-East-Atlantic (OSPAR), the Mediterranean (MEDPOL) and the Baltic Sea (HELCOM). Actions related to waste management in these plans aim at identifying loopholes that result in the evolution of waste into marine litter, at raising awareness of the link between waste management and marine litter in the public opinion, the commercial sector and politics; clarifying the role of the waste management sector in preventing and reducing marine litter; identifying concrete examples for Best Practise in waste management to be promoted via the Regional Seas Conventions, and developing the latter on the basis of measures to be applied in the context of their implementation.

Close cooperation with waste management experts to achieve these goals is currently ongoing. Indeed, the author fervently hopes that events such as Sardinia 2017 will lead to a deeper connection and understanding between the "Waste" and "Marine litter" communities to achieve the vision of plastic-free seas for future generations.

8. CONCLUSIONS

Marine litter is regarded as one of the most threatening types of pollution to marine ecosystems. Life cycle assessments of plastic products carried out to date have failed to take into account the fact that the environment and especially oceans represent a final sink for plastics. A range of problems associated with marine litter render this a highly complex issue. Being bioavailable to many species, micro-plastic particles smaller than 5 millimeters in size, which originate from the breakdown and use of bigger items, as well as from their direct application in plastic products, are of particular concern. Plastics are highly persistent and often contain toxic or hormone-based chemicals or absorb persistent organic pollutants from seawater. At present, approx. 800 species have been found to have detrimental interactions with marine litter, the majority relating to entanglement in and ingestion of plastic litter items. Additionally, marine litter bears a high socio-economic burden and may impact the wellbeing of society at large.

Recently, this issue has gained increasing recognition in international and regional fora, as exemplified by the European Strategy for Plastics in a Circular Economy, various resolutions by the United Nations and Action Plans adopted inter alia by Regional Seas Conventions and the G7/G20. The challenge remains to take advantage of the current political momentum to effectively implement these Action Plans and further develop tailor-made solutions. Change can only be triggered by compiling solutions together with experts of important sectors such as from waste prevention and management and by spreading the knowledge through education at all levels and age groups.

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