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THE ROYAL SWEDISH ACADEMY OF SCIENCES

Solutions to Plastics in the Ocean – the Baltic and Beyond

Abstracts

13 June – Day 1

Distribution of micro-plastics in the marine environment

Martin Hassellöv, Department of Marine Sciences, University of Gothenburg

Plastic pollution of the oceans has recently become a highly recognized global challenge, since polymeric solid debris is the dominating form of marine litter, and often ubiquitous, in a variety of forms, objects and sizes, from megaplastics (e.g. lost fishing gear), to minute worn, fragmented plastic pieces, in the micrometer scale (microplastics), and plausibly even smaller (nanoplastics). Early reports from manta trawl (>300µm) samples of high microplastics abundances from the subtropical gyres created wide spread narratives of ocean garbage islands, which have sparked research interests, public opinions and policy drive to high-level forums.

The presentation will start the journey at these ocean gyres, discuss global measurements and modelling, to what is known from large scale sources and pathways, and the state of knowledge on fate processes and sources. Plastics in the environment are influenced by oxidative weathering and biofouling, and weathering cause flexible plastics to become brittle and prone to fragmentation under ambient mechanical shear forces and wear. Biofilm coated plastics can be ballasted, but weathered fragmented microplastics can also interact with natural organic matter and take part in the vertical flux, so called marine snow. These processes will sort microplastics from source to sea and distribute particles between sea surface, semi buoyant pelagic, and the sediments. While the bulk of studies have focused on the sea surface, emphasis on sediments and vertical processes are increasing.

Microplastics require a comprehensive characterization and the field has evolved from simple visual sorting to state of the art vibration microscopy techniques (e.g. FTIR and Raman) and scanning electron microscopy, and associated multivariate image analysis techniques. Examples from studies of sediment microplastics abundance, characterization and distribution from the Swedish coastal waters will be discussed together with the dominating sources identified.

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"Balticus Plasticus": Micro-plastics in the Baltic: Outcomes of IUCN report on micro-plastic pathways, country footprints and impacts on biodiversity

Joao Matos de Sousa, the International Union for Conservation of Nature (IUCN) GMPP (Global Marine and Polar Programme)

IUCN is finalizing a project that seeks to advance our understanding of the causes of, consequences from, and collective action in response to plastic pollution in the Baltic Sea. Aiming to offer decision-makers a sound basis for taking measured action, the project was composed by 5 different initiatives/research:

The first is the The Marine Plastic Footprint, an ambitious effort by four researchers to develop science-based metrics that measure plastic leakage in order to increase what they describe as both the materiality and circularity of plastic.

The second watches what happens when that footprint falls on frozen seas. More specifically, it explores the effect of microplastics on sea ice, the results of which could have implications for the northern, and to a lesser extent, Southern polar ice caps.

Melted from, floating below, or sinking to the bottom depths under the frozen surface, a third area of research examines how microplastics that enter the marine biodiversity, might then affect the extent to which they harm a range of important species, from invertebrates at the bottom of the food chain, to predators at the top.

From laboratory research to industrial production to retail consumption, private sector decision-makers hold the power to, slow, stop or reverse the flow of plastic to the sea. Our fourth area of research conducted a survey of businesses in the relevant industries to better understand the levels of awareness, activism, responses, and incentives at work. Marine plastic pollution management often boils down to people management, and one of the most effective way to change course is through voluntary measures driven by the need to reduce exposure to brand, finance, or regulatory risk.

As a public sector baseline, or backstop, what would an effective regulatory framework look like? Our final report examines the body of government policy mandates, with a gap analysis of what may be missing from the equation, and recommendations on how to improve them.

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What do we know about the toxicity of micro-plastics in the marine environment?

Bethanie Carney Almroth, Department of Biological and Environmental Sciences, University of Gothenburg

Microplastics have infiltrated virtually every environment on the planet. These particles have presented a challenge to ecotoxicologists studying impacts, as 'microplastics' includes a wide variety of materials in a broad ranges of sizes. They can exert effects via physical interactions with organisms and/or via sorbing or leaching toxic chemicals. Current research has greatly increased our understanding of the mechanisms of effects associated with exposure to microplastics, addressing both particle and chemical effects. We have gained a more nuanced and detailed picture of mechanisms of effects, exposure pathways, environmental levels and risks.

Laboratory exposure studies provide evidence that microplastics are ingested, and smaller size particles may cross biological barrier and be taken up. Trophic transfer between species can occur. Analyses of chemical composition of microplastics in marine environments show that they sorb and accumulate pollutants, but research into vector effects remains ambiguous. Some studies indicate that microplastics may release certain chemical substances upon ingestions, eliciting toxic effects, while other studies indicate that these vector effects are limited and of negligible importance. There is, however, consensus concerning the problematic use of toxic chemicals in plastic products.

Assimilating this knowledge from many levels of biological organization allows us to conclude that current levels of microplastics may not be highly problematic in the environment at present, save for a number of local hot spots. However, predictions of exponential increases in the use of plastic materials, together with concomitant increases in microplastics in the marine environment, foresee increased risks in the near future. Plastic pollution should be avoided, and mitigation efforts need to be addressed at the source.

14 June – Day 2

Formation of micro-plastics by degradation and their fate in the marine environment

Ignacy Jakubowicz, RISE Research Institutes of Sweden

In the context of marine protection research, the term "microplastic" is "loosely" used in the literature to include a very broad range of polymer based materials. These materials have many different chemical and physical forms, such as cross-linked vs thermoplastic, crystalline vs amorphous and rubbery vs glassy. Pure polymers are rarely used as commercial products but often contain different additives in small quantities or, in larger quantities plasticizers and fillers. Quantity and type of additives in the formulation can significantly alter physical end chemical properties of the finished material, its durability and ability to form micro-particles. Polymeric materials can degrade by a variety of mechanisms such as photo- and thermo-oxidation, hydrolysis, chemical and biological degradation and a combination of these. Degradation alters many physical and chemical properties e.g. surface functional groups, size, shape, surface charge etc. which affects important properties such as buoyancy, hydrophobicity, biofouling, adsorption of chemicals from the environment and consequently influences MP uptake.

Oxidative degradation is an important process that affects the distribution and fate of plastics in the marine environment. The durability of the material can vary greatly depending on the environmental conditions and the usage of different additives. For instance, some commercial PE products are design for a long service life while others for a rapid disintegration. Oxidative degradation of PE leads to formation of degradation products such as ketones, aldehydes, alcohols, carboxylic acids and low molecular mass hydrocarbon waxes. Once the molecular weight of the polymer is sufficiently reduced, the degradation products can be utilized by microorganisms as nutrients to produce CO_2, water and biomass. Degradation creates also a much more attractive surface for biofouling and the formation of biofilm which causes the material to sink.

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Microbes and micro-plastics in aquatic systems, is there a link?

Stefan Bertilsson, Department of Ecology and Genetics, Uppsala University

Microplastic particles are ubiquitous in the oceans and present surfaces and microscale habitats for bacterial attachment and growth. Understanding such biofouling mechanisms in the new marine ”plastisphere” is central for predicting the fate of plastics in marine environments and the ecological impacts. Plastic pollution is an area of growing concern because of the widespread use and dispersal of plastics and the slow degradation in the environment. Over time, physical processes fragment plastics into microparticles barely visible to the naked eye, and these are subsequently trasported from coastal waters to ocean gyres where currents may concentrate them. The accumulation of such suspended particles present a gradual and largely invisible change in the ocean biome and may not only cause an accumulation and restribution of different pollutants and other chemicals, but also surfaces and refugia for different groups of marine microorganisms. Recent studies based on cultivation-independent molecular methods have shown that such plastisphere microorganisms differ in taxonomic community composition relative organisms living in the surrouding waters. In this presentation I will review the currently available information on the microbiome of marine microplastics and discuss potential implications for the microbial ecology of marine waters, pathogen dispersal and long-term persistence of the microplastic particles. I will identify gaps in our current knowledge and provide some ideas for research that may help us predict and manage the potential problem of microplastics.

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Enzymes and degradation of micro-plastics

Verena Reiser, Novozymes A/S

Petroleum-based plastics have replaced many natural materials in technical applications. With their desired properties such as low weight durability and low production cost), they have been employed in a wide range of applications like the packaging industries, agriculture, household practices, etc. However, many of these products are remarkably persistent to degradation in the environment which leads to environmental problems. Approximately 311 million tons of plastic was produced worldwide in 2014. The synthetic plastics that constitute about 80% of total global plastic usage are polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyurethane (PU) and polyethylene terephthalate (PET).

Recently, enzymes capable of modifying or degrading plastic polymers have been identified. Mostly these are enzymes are secreted by microorganism to degrade plant polymers. The most prominent enzyme classes are cutinases, lipases and proteases. Some of these enzymes have been discussed to be candidates for biocatalytic recycling processes, by which the valuable monomers can be recovered and re-used. For a successful industrial recycling application, though, the slow turnover number and the low thermal stability of these enzymes must be addressed. Recent protein engineering efforts working on thermo-stability and kinetic parameters show promising results.

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Risk assessment and regulation of micro-plastics

Kristian Syberg, Department of Science and Environment, Roskilde University

Plastic pollution is currently one of the most important environmental problems due to a widespread use of plastic products across the globe and insufficient handling of plastic waste. The pollution of plastic is now ubiquitous in all environmental compartments and especially microplastic is found in all geographical locations across the globe. At the same time, the scientific understanding of microplastic environmental impact is still relatively unknown. This pose a dilemma since our regulatory system is highly based on our capability to quantify risk and subsequently use such risk assessments to inform policy decisions.

This presentation will address this dilemma by presenting work conducted by a group of experts under SAPEA in the fall 2018. The expert group was tasked to write a report with the title: "A scientific perspective on microplastics in nature and society". The part concerning risk assessment and European regulation will form the foundation for this presentation.

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