Sources, fate, effects and consequences for the Seafood Industry of microplastics in the marine environment

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Summary

Microplastics is the term for a wide range of particles made from manmade polymers ranging in size from 10^{-9} m to 5 mm. They can enter the marine environment either as primary particles such as microbeads or micro fibres or as secondary particles from breakdown of marine litter by the action of ultra violet light and mechanical agitation, as would occur at the ocean's surface and along the sea shore. There are uncertainties surrounding the quantity of microplastics in the marine environment and their rate of increase. However, even if environmental inputs of plastics were to cease, the existing marine litter would act as a source of further microplastics, which are likely to be highly persistent in the marine environment. Their fate within marine ecosystems and their potential effects on ecosystems and human health are beginning to be understood. The wide variety of microplastic particles and the differing ways in which they are fragmented means this is a challenging field of study. This information sheet contains a gap analysis, from the seafood industry's perspective, of knowledge concerned with the consequences of microplastic pollution of the marine environment. The most important issues concerning seafood consumption are the consequences for fish and human health of the ingestion of microplastics and the potential pollutant loads attached to the microplastic particles' surfaces. These gaps in knowledge are the subject of ongoing research in European laboratories. Worldwide there is increasing awareness of the microplastics and there are action plans under OSPAR and policy drivers from the EU Marine Strategy Framework Directive which are aimed at monitoring, and in the long term reducing, marine litter and hence controlling inputs of microplastics into the marine environment.

This information sheet has been updated in July 2018; see http://www.seafish.org/media/Publications/FS104_07_18_Microplastics_information_sheet_July_2018.pdf

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Introduction

The sources, fate and effects of microplastic particles on marine ecosystems have been reviewed comprehensively by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) an interagency body of the United Nations, in a report published by the International Maritime Organisation. This Seafish Information sheet abstracts relevant information from the GESAMP report (see Information Sources below) and its summary. It discusses the potential consequences for the Seafood Industry together with a brief gap analysis and further work based on the GESAMP report and discussion with personnel working in the field. All the information is from these sources unless otherwise stated. Readers are referred to these documents for further information.

Sources

Microplastic particles are defined in the GESAMP review as plastic polymer particles of <5 mm down to nano (nm) particles (10^{-9} to 10^{-7} m) in size. They are composed of a huge variety of these synthetic substances, which are derived from industrial processes, both from fossil hydrocarbons and biopolymers. Primary microplastic particles enter the marine environment as particulates, range from particles of around 5 mm used for bulk transport of polymers, to microfiber particles derived from textiles and micro beads as used in cosmetics, to much finer particulates used in industrial abrasives and powders used in moulding. Secondary microplastic particles are particles derived from degraded plastic litter. Although microplastic particles greatly outnumber large (macro) plastic items in the marine environment, they still make up only a small proportion of the total mass of plastics in the ocean. Even if we were to stop future macroplastic litter, weathering of larger particles already in the marine environment would continue to produce microplastic particles for many years. Shapes of microplastic particles range from fibres to spheres with varying levels of surface roughness and sizes include fine particles (~200 nm) down to ultra-fine particles (<200 nm).

Fate and effects

Although there are natural polymers in the ocean such as cellulose and lignin from plant material and chitin from crustaceans, together with starch, protein, DNA and others, these readily degrade in marine ecosystems. However, manmade polymers are very persistent and widespread and ubiquitous in the marine environment including deep sea habitats down to 5,755 m in the Northwest Pacific. There is evidence that plastic litter becomes concentrated in areas of slow circulation in the middle of the 'oceanic gyres' which dominate the hemispheric circulations of the world's oceans. Fragmentation is mediated by ultra violet (UV) light and mechanical agitation as would be experienced at the ocean surface and along the sea shore. Knowledge of the fragmentation rates and mechanisms are needed to reliably infer the rates of microplastic particle generation, their particle size distribution and their impact on different living organisms. This crucial information, especially the fragmentation mechanics, are not known reliably even for common plastics materials. Adding to the challenge is the constant innovation in materials science, producing more polymers whose characteristics are unknown.

Direct effects

Microplastic particles are known to be ingested by species at all levels in the marine food chain from plankton to macro fauna, and are found in the stomachs of fish and birds. There are also interactions with bacterial and algal communities, through the formation of films of micro-organisms on the particles. Uptake via the gills for very fine particles (8-10 µm) has been shown to occur in shore crab. Evidence relating to the presence of microplastics in tissues or body fluid has been obtained from laboratory studies of filter-feeding mussels and sediment deposit feeding lugworms, but there are very few studies of the presence of microplastics in tissues of field collected organisms. Both lugworms and mussels were shown to be able to take particles into their tissues under experimental conditions but it is unknown whether the particles are excreted or transferred to other organs. There is evidence that mussels can accumulate particles in connective tissue but this was at very high concentrations of particles and may not be realistic. However, there remains considerable uncertainty as to the fate of microplastic particles in marine organisms, particularly as it is difficult to emulate the many types of microparticles and the ways in which they are fragmented. There are a number of research projects in progress aimed at improving knowledge in this area; see Further Work. Most of the experimental evidence concerning tissue interactions is from studies on humans and rodents, which indicate that adverse effects may start to emerge due to interactions with cells and tissues by particles of less than a quarter of a millimetre (250 µm).

Indirect effects

Microplastic particles' surfaces are potentially active sites for adsorption of pollutants, and the smaller the particle size the greater the surface area per unit weight of particles will be available for these interactions. The nature of the surfaces of the particles is also important with many of them being characterised as being hydrophobic or water repelling making them attractive to persistent organic pollutants. There are also likely to be additives, monomers and other by-products associated with the plastic particles.

The affinity of persistent organic pollutants, which include polychlorinated biphenyls (PCBs) to the surface of microplastic particulates, has led to investigations into their potential role in mediating transfer of persistent organic pollutants to marine organisms through the gut wall during digestion. Whilst transfer of pollutants mediated by microplastic particles has been demonstrated in experimental studies of lugworms, amphipods, fish and seabirds, the indications are that they are relatively small compared with the natural route via feeding. This was further examined by Koelmans et al, (2016) whose analysis of several studies' results found that at equilibrium, which is the expected condition, the fraction of pollutants attached to plastic particles was very small compared with other media in the ocean. Pollutants ingested from natural prey would overwhelm that from microplastic ingestion.

However, under non-equilibrium conditions, that is where substances such as releasing agents and additives leach off the surface of the plastic there is more potential for uptake. Whilst this is a potential pathway, it should be possible to characterise the leachates' toxicity and their potential effects.

Consequences for the seafood industry

With such a diverse range of possible compounds, particle shapes and sizes and possible interactions it is difficult to make generalisations about potential effects. However, the following issues are likely to be of most consequence;

Human health

So far the surveys of microplastics in fish have concentrated on gut contents rather than muscle tissue. The mobility of tiny plastic particles across the human gut wall has been demonstrated. Clearly human ingestion of microplastics from seafood is potentially of concern. The GESAMP report highlights the possible source from bivalve molluscs and potentially from deposit feeders such as sea cucumbers and other species which are eaten whole. There does not appear to be information on microplastic pathways in fish outside the gut and this would require further research (see Gap Analysis). The GESAMP report makes a number of recommendations which include bringing in expertise from pharmacology and mammalian toxicology to better understand the fate and consequences of nano-sized particles.

The role of microplastics in the transfer of pollutants in marine ecosystems is becoming better understood and at present appears to be less important than transfer of pollutants via the food chain (see above), although the numerous types of particle and pollutant and organism remains a challenge. This is the subject of ongoing work (see below). Public health considerations mean that there are regulations which place limits on the levels of the main pollutants in seafood offered for sale, so the effects should be controllable provided that monitoring and control systems for these pollutants are in place.

Ecosystem health

The widespread distribution of microplastic particles, including inside the bodies of a wide variety of marine organisms has led to concern that there may be an effect on the physiology of these organisms and potentially compromise their fitness and the productivity and biodiversity of marine ecosystems. There are monitoring programs of seabird (Northern fulmar; *Fulmarus glacialis*) stomach contents, designed to index long term trends in particles and this has been adopted as an indicator of environmental quality by OSPAR[1]. Averaged over the whole North Sea 95% of dead fulmars had plastic in their stomach and 62% exceeded the 0.1 gram objective. The average stomach contained 33 particles of plastic, weighing 0.38 g. There are other potential effects in relation to mediation of contaminants (see above) and vectors for invasive species, though the latter probably relate more to macroplastic debris.

Gap analysis

A brief gap analysis, from the seafood industry's perspective has shown the need for:

1. **A risk assessment of microplastic particles, particularly nano-particles and their physiological and ecological pathways in fish and shellfish to assess whether there are any significant risks to humans consuming seafood.**

2. **Better resolution of the role of microplastics in pollutant transfer.** Here the surface characteristics of the microplastics in terms of their ability to adsorb pollutants and the role of substances leaching out of the plastics or off their surfaces are important.

3. **Better information on the ecosystem effects of microplastics with an understanding of the extent to which plastics undermine ecosystem productivity and biodiversity.**

4. **An assessment of microplastic pollution from the seafood industry's own activities.** This would require the investigation of the relative importance of such activities as ghost fishing, litter from vessels or packaging materials production as sources of microplastic pollution and implementation of measures to reduce the effects of those perceived to be the highest risk.

5. **Ultimately there is a need to understand the way in which human attitudes and behaviour can be influenced to reduce the sources of macroplastic and microplastic litter.** The GESAMP report discusses these social aspects at some length mostly concerned with macroplastic litter since there is not much information on social aspects of microplastic pollution. One aspect that stands out is the increasing public interest, with increasing articles in broadsheet newspapers in recent years.

Further work

Worldwide the GESAMP report should be seen as an important step in the assessment of the effects of microplastic pollution and it makes a number of action orientated recommendations to address marine microplastics. Within OSPAR there is an agreed action plan designed to reduce litter in the Northeast Atlantic. These actions include quality status indicators (see section Ecosystem health for

[1] OSPAR is the short name for the Convention for the Protection of the Marine Environment of the North-East Atlantic derived from the predecessor organisations the Olso and Paris Commissions (www.ospar.org)

details) and the Fishing for Litter scheme, which involves fishers in collection of marine litter and developing schemes to evolve best practice in relation to inputs of plastics from fishing gears, including cod end chafer or 'dolly rope' into the marine environment. This will help to fill gap four above.

In Europe, the Marine Strategy Framework Directive (2008/56/EC) sets out 'Good Environmental Status' in relation to marine litter under Descriptor 10 headed as 'Properties and quantities of marine litter do not cause harm to the coastal and marine environment'. In this Descriptor (2010/477/EU) there is a requirement for a monitoring programme for marine litter including an investigation of the activity to which it is linked and where possible its origin, which should help to contribute to gap 4 above. The Descriptor recognises the need for further development of indicators relating to the biological impacts of litter, notably in relation to micro-particles as well as enhanced assessment of their potential toxicity.

Research work is being undertaken by European Institutions, mainly under the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans www.jpi-oceans.eu). This is a coordinating and integrating platform, open to all EU Member States and Associated Countries, which focuses on making better and more efficient use of national research budgets. There are several research projects being initiated under the JPI Oceans Ecological aspects of microplastics, which are described at www.jpi-oceans.eu/ecological-aspects-microplastics and which are likely to be able to progress knowledge in gaps 1-3 above.

These are described below;

Project **BASEMAN; '**Defining the baselines and standards for microplastics analyses in European waters' will cover validation and harmonisation of analytical methods aimed at improving identification and quantification of microplastics in the environment. http://jpi-oceans.eu/sites/jpioceans.eu/files/public/Press%20release/Short%20description%20BASEMAN.pdf

WEATHERMIC; 'How microplastic weathering changes its transport, fate and toxicity in the marine environment'. This will include understanding the changes they undergo as a result of various environmental weathering processes, like UV exposure, biofilm growth and physical stress. http://jpi-oceans.eu/sites/jpi-oceans.eu/files/public/Press%20release/Short%20description%20WEATHER-MIC.pdf

The project 'Ecotoxicological effects of microplastics in marine ecosystems (**EPHEMARE**)' will investigate; uptake, tissue distribution and final fate and effects of microplastics in benthic and pelagic ecosystems and their potential role as vectors of persistent pollutants such as (see Indirect effects above) that readily adsorb onto their surfaces. More details at http://jpi-oceans.eu/sites/jpi-oceans.eu/files/public/Press%20release/Short%20description%20EPHEMARE.pdf

PLASTOX 'Direct and indirect ecotoxicological impacts of microplastics on marine organisms'; this project will investigate the ingestion, foodweb transfer, and ecotoxicological impact of microplastics, together with persistent organic pollutants (POPs), metals and plastic additive chemicals associated with them, on key European marine species and ecosystems. http://jpi-oceans.eu/sites/jpi-oceans.eu/files/public/Press%20release/Short%20description%20PLASTOX.pdf

There is also a project being carried out by the Norwegian organisation **NOFIMA** which is investigating the interactions between microplastics and cod http://nofima.no/en/nyhet/2016/02/research-into-microplastic-and-cod/

Information sources

GESAMP (2015). “Sources, fate and effects of microplastics in the marine environment: a global assessment” (Kershaw, P. J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p.

http://www.gesamp.org/data/gesamp/files/media/Publications/Reports_and_studies_90/gallery_2230/object_2500_large.pdf

GESAMP (2015) Microplastics in the oceans; a global assessment; Layman’s summary of the above report

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Koelmans, A A, Bakir, A G, Burton, A, and Janssen C R, (2016) Microplastic as a Vector for Chemicals in the Aquatic Environment: Critical Review and Model-Supported Reinterpretation of Empirical Studies Environ. Sci. Technol. 50 (7), pp 3315–3326

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