Written evidence submitted by Defra

Questions posed by the committee:

1. How do microplastics impact on marine plants and animals? What economic consequences could result from increased microplastic pollution in the ocean?
2. How do the main sources of microplastics differ in (a) scale of output and (b) the importance of their environmental impacts? How should these relative impacts direct policy priorities?
3. What impact could microplastics have on human health? Are there knock-on impacts for Government policies, on e.g. food standards?
4. Other countries, including the USA, have taken action against microbeads in personal care products. What kind of impact would a similar ban in the UK have on the environmental situation around microplastics?
5. To what extent do larger pieces of plastic in the ocean contribute to microplastic pollution, and how can this be dealt with?
6. How comprehensive and certain is our knowledge about the scale of microplastics and their effects on the natural environment? What should research priorities be, and who should fund this research?
7. How effective is international cooperation around these issues, and what more can be done?

1. How do microplastics impact on marine plants and animals? What economic consequences could result from increased microplastic pollution in the ocean?

a. How do microplastics impact on marine plants and animals?

The evidence base on the effects of micro-plastics in the marine environment is limited. However, they do not biodegrade, they accumulate in the marine environment, they can absorb toxic chemicals and pathogens, and their small size means they have the potential to be ingested by marine organisms.

Microplastics have been found in a wide variety of species including zooplankton,[i] mussels,[ii,iii] oysters,[iii] shrimp,[iv] marine worms,[ii,v] fish,[vi,vii,viii,ix] seals,[x] and whales.[xi,xii] Several of these species are of commercial importance. For example, a 2009 survey in the Clyde Sea found 83% of Norwegian lobster contained plastic, mainly in the form of fibres.[xiii] Similarly, trawls in the English Channel found microplastics in 36.5% of fish caught[vi].

Impacts could potentially be caused by the plastic polymer itself, by the additives it contains, or by other chemicals which are known to associate with microplastics once they are in the ocean. However, there are a variety of polymers in use and thousands of different additives used in products, which hampers predictions of how they would behave if they were ingested. The same plastic polymer can also behave differently according to its size and shape.[xiv] There is very little known about the rate at which plastic additives leak into their surrounding environment (whether this be the ocean or biological tissues), as well as the potential levels of exposure for humans and wildlife.

Chemicals on microplastics ingested by an organism can dissociate from plastic particles and enter body tissues. This has been demonstrated in lugworms and seabirds.[xv] In the latter case, contaminants were passed to the birds as a result of eating polyethylene resin pellets as well as eating fish that were exposed to contaminants in water. This suggests that these chemicals have the potential to travel through the food chain. Natural sediments can also attract these chemicals, although there is some evidence that certain chemicals preferentially attach to plastic.[xvi,xvii] There is uncertainty over the extent to which chemicals dissociate from plastic and migrate into tissues in different environmental conditions, and their ability to move up and accumulate in the food chain.

Microbeads are small plastic particles used in a variety of cosmetic and personal care products such as scrubs, soaps and toothpaste. The United Nations advisory body, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution (GESAMP) reviewed the evidence on microplastics, such as microbeads, in 2015[xviii]. It found that research on the potential ecological risks of microplastics was relatively new and that there was “a large degree of uncertainty surrounding this issue”. Field studies in this area face several difficulties. Wildlife in the ocean environment is exposed to a wide range of other pressures, including rising temperatures, ocean acidification, and other types of pollutants such as mercury. Disentangling the effects of microplastics from the effects of these other factors is unlikely to be possible in the marine environment.

However, GESAMP found with high confidence that “the ingestion of microplastics may have an effect on the feeding, movement, growth and breeding success of the host organism”. It listed the main potential impacts of microplastics on marine organisms:

- physical effects (physical obstruction or damage of feeding appendages or digestive tract or other physical harm);
- chemical effects (microplastics can transport chemicals into marine organisms, which may lead to toxicity);
- impaired health;
- impacts on the population of different organisms, and the wider ecosystem;
- dispersal of damaging invasive species and pathogens.

Wildlife

Laboratory experiments have shown that plastic ingestion can have detrimental effects in a range of species, though some of these experiments expose animals to higher concentrations of microplastics than those that have been reported in sediments and the water column.

Defra has funded a project, undertaken by the University of Plymouth, to assess the potential for detrimental physical and toxicological effects to occur as a consequence of organisms ingesting microplastics. Laboratory experiments showed:

- Microplastics do accumulate pollutants from seawater but this is dependent on the plastic involved and the pollutant. These pollutants can desorb (be released) from microplastics into the guts of marine organisms. This was faster in gut conditions representative of warm blooded organisms. However this is unlikely to make an important contribution to the overall burden of the pollutant compared to the amount of chemical transferred to the organism via normal ingestion of contaminated food or directly from contaminated seawater.

- Chemical additives in plastic may be of greater harm than the pollutants from seawater that stick to microplastics.

- Microplastics can transfer along a simple food chain from a mussel to a crab. The crabs then defecate the microplastics back into the environment.

- Microplastics can cause physical harm to marine worms, but only at concentrations comparable to heavily contaminated shorelines. They remain in the gut and are subjected to extensive digestion with no nutritional benefit, resulting in energetic cost.

The magnitude of effects varies between species, and some animals appear only to be affected at certain stages of their lifecycle. For example, laboratory studies showed:

- Polystyrene microparticles can reduce the number and size of eggs produced by oysters,[xix] but a separate study found no measurable effects on the development or feeding capacity of oyster larvae.[xx]

- Blue mussels exposed to high concentrations of high density polyethylene (HDPE) grains[xxi] and polystyrene microbeads[xxii] can absorb them into tissues through their gills and feeding apparatus. Plastics inside tissues in the polystryrene study caused no measurable harm, but the HDPE study found evidence of an inflammatory response. It is unknown whether these effects were caused by mechanical abrasion or a toxic effect of the plastic's chemistry.

- Energy reserves in lugworms (a key food source for fish and wading birds and an important animal for maintaining the ecology of the seabed) exposed to PVC were 50% lower than worms which were not exposed to microplastic.[xxiii] This was probably as a result of reduced feeding activity, inflammation, and plastic particles being retained in the gut for long periods of time.

- Copepods (a type of zooplankton eaten by several commercially important fish larvae), exposed to polystyrene microbeads can produce smaller eggs with reduced hatching success.[xxiv] They have also been shown to produce microbead-laden pellets[xxv] that can transfer up the food chain.[xxvi] These have been shown to sink at different rates to normal pellets,[xxiv] raising the possibility of an effect on carbon cycling, a key oceanic process that can affect the rate of climate change.[xxvii]

- Exposure to polystyrene can disrupt hormone production in female Japanese medaka (a type of fish).[xxviii] Hormone production was also disrupted in males, but in this case the effects were considered to be more likely a result of chemicals that had become associated with the microplastic particles in the ocean rather than the microplastic itself.

Environmental Effects

There are also potential environmental effects of microplastics that are not related to the ingestion of these particles by animals or algae. For example:

- The colonisation of microplastics by microorganisms could provide a means for invasive non-indigenous species to spread to new areas.

- Pieces of microplastic can provide a surface on which marine organisms can lay their eggs. The population and egg density of the marine pond skaters have been shown to correlate with increasing amounts of microplastics in the North Pacific.[xxix]

- Communities of microbes associated with plastic fragments are different to those normally found in seawater.[xxx] A study looking at the microbial communities on pieces of polyethylene (the most commonly produced plastic worldwide) and polypropylene (commonly used in packaging) found that of a total of 3,484 species of microbe, 799 were unique to polypropylene, 413 were unique to polyethylene, and only 53 were shared by polypropylene, polyethylene and seawater. The ecological consequences of this are also unknown.

- The presence of high concentrations of microplastics in beach sediments can change their permeability and heat absorbance[xxxi]. This could affect species where gender is determined by temperature (e.g. sea turtles) and sediment-dwelling species that might be at a higher risk of desiccation (e.g. worms, crustaceans, and molluscs).

b. What economic consequences could result from increased microplastic pollution in the ocean?

There has been little assessment of the potential economic consequences of increased microplastics in the ocean. However an economic analysis demonstrated that there are potential costs associated with microplastics to the aquaculture sector in the UK[xxxii]. Removal of microplastics from the marine environment is currently considered to be prohibitively expensive and technically infeasible.

2. How do the main sources of microplastics differ in (a) scale of output and (b) the importance of their environmental impacts? How should these relative impacts direct policy priorities?

a. How do the main sources of microplastics differ in (a) scale of output and (b) the importance of their environmental impacts?

Microplastics may be primary or secondary. Primary microplastics are those which were produced in microplastic form, as pre-production pellets for the production of plastic articles or as microbeads for exfoliation, for example. Secondary microplastics are those which started as larger plastic items and were subsequently degraded into smaller and smaller particles until they became microplastics.

Sources of microplastics include fibres from textiles, microbeads from cosmetics, large pieces of plastic debris which become microplastics as they fragment and degrade, normal wear and tear of plastic products such as tyres, fishing nets, rope and carpets, as well as plastics in paints and varnishes.

For larger items, it is frequently possible to identify what type of plastic (eg polyethylene, polypropylene) a particular piece of ocean debris is made of. However, when pieces become small and fragmented they are almost impossible to trace to their original source. It is generally agreed that a significant proportion of marine litter was originally lost or disposed of on land before being blown or washed into the marine environment. Estimates are as high as 80%[xxxiii]. However a recent MCS report on beach litter showed the source of 44% of litter items could not be categorised[xxxiv]. For these reasons there is uncertainty over the identity of the major sources of microplastic pollution.

A recent report by Eunomia for the European Commission reported that annual inputs across Europe from tyre dust, pellet spills and building paints were high (>10,000-50,000+ tonnes per year)[xxxiii]. Estimates for other sources such as marine paint and personal care and cosmetic products were lower (<10,000 tonnes per year). Indeed, microplastics from cosmetic products are believed to make up a very small percentage of the total of micro-plastics entering the marine environment, with estimates ranging from 0.01% to 4.1%.

The movement, storage and elimination of microplastics by marine organisms will depend on the size of the particle[xviii]. Particles at the smaller end of the size spectrum (nano scales) have been shown to cross membranes into cells, in controlled laboratory experiments. When microplastics cross cell membranes, some tissues have been shown, in vitro, to exhibit a response to the presence of particles; i.e. causing inflammation and cell damage, followed by healing responses and fibrous encapsulation of particles. The risk of associated effects following exposure to microplastics will depend on: i) the number of particles; ii) the size distribution, shape, surface properties, polymer composition and density of the particles; iii) the duration of exposure; iv) the kinetics of absorption and desorption of contaminants, with respect to the plastic and the organism; and, v) the biology of the organism.

b. How should these relative impacts direct policy priorities?

There is still a limited understanding of the sources, types, and distribution of microplastics in the marine environment, and on the relative impacts of the main sources and further work is need to improve our understanding of this issue.

There is widespread agreement that the most effective way to reduce microplastic pollution is to focus on preventing plastic from entering the marine environment in the first place (both microplastics and larger pieces of debris that will eventually fragment into microplastics).

The UK's Marine Strategy[xxxv] sets out what the UK is doing to address marine litter, including microplastics. In addition it recognises that further work is needed to better understand marine litter and its impacts because of the limited understanding of current levels, properties, and impacts of marine litter on the seabed and in the water column. The monitoring programmes that the UK is putting place will further contribute to our understanding of the issues. Once the extent of the problem is better understood we will be able to assess the need for any additional measures.

3. What impact could microplastics have on human health? Are there knock-on impacts for Government policies, on e.g. food standards?

United Nations advisory body, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution (GESAMP) reviewed the evidence on microplastics, such as microbeads, in 2015[xviii]. It found that research on the potential human health risks of microplastics was relatively new and that there was "a large degree of uncertainty surrounding this issue".

There is overlap between the areas where relatively high concentrations of microplastics are present (i.e. coastal areas) and areas in which aquaculture is conducted, indicating a potential hazard of microplastics for this sector. Several studies show that microplastics are present in sea food sold for human consumption,[xxxvi,vi,ii,iii,xxxvii] including mussels in North Sea mussel farms and oysters from the Atlantic.

Microplastics can potentially accumulate in the human food chain[xviii]. Microplastics have been recovered from the soft tissues of both commercially mussels (Mytilus edulis) and oysters (Crassostrea gigas). The presence of marine microplastics in seafood could pose a threat to food safety, however, due to the complexity of estimating microplastic toxicity, estimations of the potential risks for human health posed by microplastics in foodstuffs is not yet possible.

No studies have investigated whether microplastics can be unintentionally ingested by humans and subsequently transported into tissues.[xxxviii] Although the gut may be an important barrier,[xxx] there is a possibility that very small particles such as nanoplastics could penetrate gut tissues. Experiments in rats have showed that polystyrene microspheres of 50-100nm (1nm = 1 millionth of a mm) can be absorbed into the body through the gut and transported to the liver and spleen.[xxxix] The ability of plastics to enter tissues is likely to depend on their size and chemical properties.

Even for high level consumers of seafoods that are most likely to be relatively highly contaminated with marine microplastics, such as mussels or crab, dietary exposure to microplastic particles is likely to be relatively low compared with inhalation of microplastics (Personal communication, Food Standards Agency 2016).

4. **Other countries, including the USA, have taken action against microbeads in personal care products. What kind of impact would a similar ban in the UK have on the environmental situation around microplastics?**

Microbeads from personal care products are believed to make up a very small percentage of the total of micro-plastics entering the marine environment, with estimates ranging from 0.01% to 4.1%[xxxiii]. A ban in the UK would therefore be expected to have only a small impact on the environmental situation around microplastics. However microbeads, like other microplastics do not biodegrade and therefore accumulate in the marine environment. There are also suitable less harmful alternatives. Defra therefore supports voluntary action by industry to phase out microbeads from personal care products. Defra is also supporting other EU Member States in calling for the European Commission to come up with proposals to ban micro-beads in cosmetics and detergents.

5. **To what extent do larger pieces of plastic in the ocean contribute to microplastic pollution, and how can this be dealt with?**

Microplastics make up only a small proportion of the total mass of plastic in the seas[xl]. All larger pieces of plastic in the ocean have the potential to break down and become microplastics, therefore the future contribution of larger plastic pieces to microplastic pollution is expected to be considerable. This issue should be addressed by tackling both land-based and sea-based sources of litter, by removing litter that has already reached the marine environment, and by increasing education and awareness of the issue to promote behaviour change across individuals, businesses and communities. The UK's Marine Strategy Part Three[xxxv] sets out a comprehensive list of the actions we are taking to address these points. In addition we are developing a National Litter Strategy which will complement existing work including actions to address litter in the marine environment. It will promote concerted, co-ordinated and effective actions to reduce litter and littering on land, which in turn could lead to a reduction in the amount of litter reaching the marine environment.

6. **How comprehensive and certain is our knowledge about the scale of microplastics and their effects on the natural environment? What should research priorities be, and who should fund this research?**

As mentioned earlier, there is still a limited understanding of the sources, types, distribution and trends of micro-plastics in the marine environment, and of the relative impacts of the main sources. However there is evidence that microplastics could cause harm to marine plants and animals, and there are concerns as to the potential human health impacts.

Our research priorities are to develop our understanding, focusing on the evidence which will support policy making. We are seeking to establish a baseline and trends for marine litter, and to better understand harm caused by marine litter, to allow quantitative targets to be set in the future as appropriate. The monitoring programmes we are putting in place will further contribute to improving our understanding of these issues. Research is also needed to identify how best to address key issues related to marine litter. Methods to address marine litter include reducing land-based and sea-based sources of marine litter, removing litter that has already reached the marine environment and raising public understanding of the risks of marine litter and the role they can play in preventing it. Our priorities are set out in the OSPAR Regional Action Plan on Marine Litter.

The UK plays an active role in marine litter and micro-plastics science, through which Defra advises and influences micro-plastics research. There are numerous Natural Environment Research Council-funded activities in this area, such as RealRiskNano which distinguishes the realistic environmental risks of nano-plastics by investigating fate and toxicology in real-world scenarios. In addition, the UK has participated in all the recent Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans)-funded micro-plastics projects through representation on project advisory panels and chairing of the JPI Oceans Management Board. There are also some unfunded UK academics involved in the winning consortia, with whom we regularly work on marine evidence and R&D issues.

The UK also plays an active role in both the EU's Technical Group (TG-ML) on the marine litter aspects of the MSFD and the OSPAR marine litter expert group (ICG-ML). Both groups address a wide range of policy, evidence, monitoring and R&D issues relating to marine litter and micro-plastics, and have both developed a common approach to monitoring and evidence/data gathering, which the UK has assisted in developing and adopted for MSFD purposes. The UK would expect any wider standard procedures to reflect this work.

Research councils, academic institutions, government and businesses should work together to fund and support research.

7. How effective is international cooperation around these issues, and what more can be done?

The UK works in partnership with other countries across Europe and the world to identify sources, distribution and impact of marine litter and to develop methods to address the issue. The UK has internationally-recognised experts on marine litter and is actively involved in developing and implementing international approaches to addressing the issue.

International cooperation on tackling marine litter is managed through a range of groups, conventions and legal instruments. The main ones include:

- **The EU Marine Strategy Framework Directive (MSFD):** This is the overarching policy framework for addressing marine litter. A Technical Group on Marine Litter (TG-ML) provides guidance on targets, monitoring and measures.

- **MARPOL (the International Convention for the Prevention of Pollution from Ships**): Annex 5 of the convention specifically deals with marine litter and prohibits the disposal at sea of all forms of plastic.

- **The Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR):** A regional seas convention facilitating cooperation between contracting parties. An Intersessional Correspondence Group on Marine Litter (ICG-ML) made of scientific, technical and policy experts aims to coordinate the activities of MS with regard to marine litter in order to collaborate and share best practice.

- **The Food and Agriculture Organization's Code of Conduct for Responsible Fisheries:** This includes guidance on waste management. In the UK, the Seafish Authority introduced the Responsible Fishing Scheme in 2006 (re-launched in 2015) to complement the FAO Code.

- **United Nations Environment Programme's global partnership on marine litter.**

- **The G7 group:** The UK also works with the other G7 countries to address marine litter.

To date, the effectiveness of international cooperation on marine litter has been demonstrated by the achievement of significant advances in addressing marine litter at a regional seas and global level:

- In January 2014, the European Parliament passed a resolution on plastic waste in the environment calling for single use plastics that cannot be recycled (including microbeads) to be phased out or banned outright.

- In June 2014, OSPAR contracting parties agreed a regional action plan (RAP) on marine litter. This plan fulfils requirements of the MSFD for EU Member States to work together to address marine litter, and contributes to United Nations Environment Programme's global partnership on marine litter. Implementation of this plan is in progress.

- In October 2015, following efforts by OSPAR to push for the voluntary phase out of microbeads in cosmetics, the trade association Cosmetics Europe recommend that their use be discontinued by 2020. The British Plastics Federation also issued a statement that microbeads should not be used in cosmetics. At the time of writing, 25 UK companies have pledged to phase out microbeads from their products or to continue to be microbead-free, as well as large multinationals including Unilever, Colgate/Palmolive and Procter & Gamble.

- In 2015 the G7 agreed an action plan to address litter in the marine environment. The G7 Science Ministers are developing improved data collection and monitoring approaches, in order to enable a better understanding of sources, composition and deposition of litter entering the marine environment.

- A written declaration on the reduction of microplastic pollution, led by British MEP Catherine Bearder, is currently circulating.

In the coming years we will maintain and strengthen international coordination to tackle marine litter including micro-plastics:

- **implement European Directives including the MSFD:** This includes participating in EU level reviews of existing legislation, eg packaging and port reception facilities directives.

- **implement OSPAR RAP and G7 action plan:** These include actions specifically aimed at microplastics, but all the actions have the potential to address primary or secondary microplastics.

- **explore the potential to implement either a national or an EU-level ban on the use of microbeads in cosmetics:** particularly if the voluntary approach is deemed inadequate.

- **develop a microplastic indicator:** The system of monitoring plastic debris is currently based on three indicators: beach litter, seabed litter and plastic found in the stomachs of fulmars (a seabird species). Under OSPAR, further indicators, including an indicator for microplastics, are under development. These will help develop our understanding of the sources, quantities and distribution of marine litter.

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