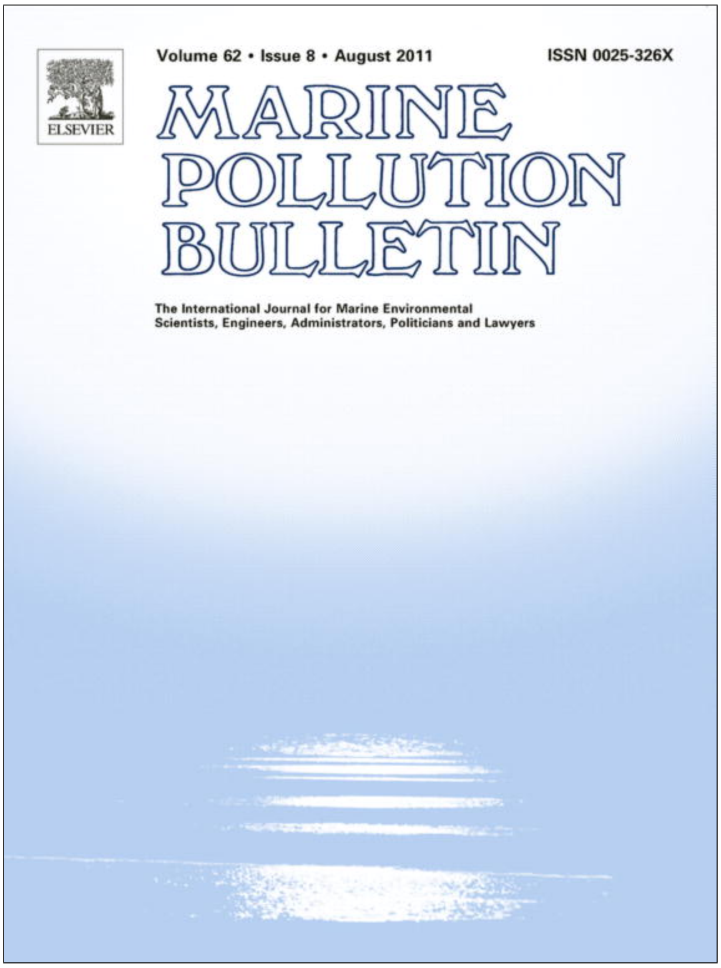
Volume 62 • Issue 8 • August 2011
ISSN 0025-326X
ELSEVIER
MARINE POLLUTION BULLETIN
The International Journal for Marine Environmental
Scientists, Engineers, Administrators, Politicians and Lawyers

Marine Pollution Bulletin 62 (2011) 1589–1591

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Editorial

Microplastics in oceans

Since the Marine Strategy Framework Directive (MSFD) was adopted in 2008, EU member states must develop activities to achieve "good environmental status" (GES) in the European marine environment by the year 2020 (established in the Commission Decision 2010/477/EU of the 1st of September 2010). As well as many other tasks such as the conservation of biodiversity and the fight against oil pollution, the problem of marine litter, particularly plastics, has been recognized at the European level by a specific task group. Although monitoring programs of plastic pollution have long been implemented, and impacts on fish and seabirds have been reported, for example those induced by swallowing or entanglement in plastic items or ropes, more research is needed to support appropriate activities against other negative impacts of plastics on marine ecosystems.

Adverse effects on marine organisms, particularly of microplastics (<5 mm) are investigated occasionally only. Based on analyses with mussels, there is some early evidence that microplastics are transferred to the circulatory system (Browne et al., 2008) and induce an increased immune response at a molecular level. We need to clarify whether further kinds of physical effects may be observed, especially when transferred to organisms other than mussels. As far as the microplastics' size is concerned, filter feeders and other organisms near the bottom of the marine food chain may be primarily affected (Thompson et al., 2004; Moore, 2008). This still needs to be validated, also by clarifying which levels of the food chain are most affected. Investigations on marine mammals also showed that plastic particles are transferred along the food chain by feeding on plastic-contaminated fish (Eriksson and Burton, 2003). It will be essential to elucidate the underlying mechanisms in order to find out whether enrichment or depletion occurs within the food chain and if microplastics can finally be found in marine top predators and in humans. Moreover, microplastics may serve as transport vectors for invasive micro-organisms to remote regions (Barnes, 2002; Gregory, 2009). However, it is still unknown to which extent they contribute to changes in species assemblages and how they influence endemic species and ecosystems.

Since plastics contain additives like plasticizers or organic pollutants, which have sorbed out of the marine environment into the plastic matrix (Carpenter et al., 1972; Hale et al., 2010), physical effects may be enhanced by chemical and toxic effects. In seabirds a positive relationship between pollutant concentration and plastic burden has already been observed (Ryan et al., 1988). First investigations, especially on plastics as passive samplers, reveal that equilibrium sorption of organic pollutants is about two orders of magnitude higher than to natural sediments and soils (Mato et al., 2001). Again, detailed knowledge on mechanisms is missing. It is neither investigated how pollutants sorb onto or into microplastics in comparison to natural particles like suspended matter, detritus or phytoplankton, nor can we describe how material properties, additives or weathering influence the sorption behaviour. In order to decide whether uptake of microplastics and associated pollutants increase bioaccumulation of the pollutants in marine organisms, mechanisms like substance leaching out of the plastic matrix need to be quantified. Since plastic particles may settle from the water body to the sediment it also has to be clarified whether sediment represents a sink and, thus, a long-term source for microplastics and associated chemicals.

Accumulation of larger plastic has been observed in ocean gyres (Moore et al., 2001), on beaches, and in sediments worldwide (Barnes et al., 2009). Emissions resulting from dumping of plastic waste (although forbidden by the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78) which came into force in 1983) and from riverine input is a well-established research field, as is input of microplastics from the use in cleaning products (Fendall and Sewell, 2009) and from weathering of macroplastics. Nevertheless, knowledge on mechanisms and quantities is still scarce. The most significant emission pathways of microplastics into the oceans have to be elucidated to devise effective options for a reduction of plastics input into the marine environment. Identifying the interrelation between source and sink regions will help to bring accumulation "hotspots" to light. In this context, mechanisms like weathering and sedimentation need to be investigated since these processes influence transport behaviour in the ocean compartment and, in addition, affect the potential of the particles to endanger organisms of different sizes and in different habitats. Therefore, emission and transport pathways in oceans, in particular to remote regions like the Arctic (Zarfl and Matthies, 2010) have to be clarified, physical effects on organisms of different levels of the marine food chain have to be identified, and chemical effects, which are induced by pollutants contained on or in plastic particles, have to be elucidated.

Several hints and pieces of scattered information are available on fate and effects of plastics in the marine environment. In most cases, however, systematic knowledge on underlying processes is missing. Thus, we need to collate the available information and to fill knowledge gaps in order to support policy and responsible organisations to build up a strategy for the achievement of GES in 2020. Knowledge of sources, sinks, abundance and trends of microplastics in the oceans are as important as the development of metrics and monitoring tools and strategies, definition of effect endpoints and agreement on thresholds.

European experts met on the 29th October 2010 at the University of Osnabrück, Institute of Environmental Systems Research, to discuss the various issues of plastics in the oceans and identify scientific research tasks to gain more knowledge on emission, transport, fate and effects of plastics in the oceans. They agreed on the following list of open questions which should be investigated in the near future:

doi:10.1016/j.marpolbul.2011.02.040

Emission, transport and fate (Descriptor 10 of the MSFD)

→ Which are the most significant emission pathways of microplastics into the oceans (direct emission as shredded plastic waste, direct emission resulting from the use in cleaning products, weathering of macroplastics)?
→ Which transport pathways and velocities do microplastics underlie? How fast do microplastics weather? What are the trends in microplastic abundance? Which time scales need to be taken into account?
→ How are source and target regions interrelated?
→ How do emission, transport, weathering, etc. depend on plastic properties (polymer, additives, size, specific weight, shape, etc.)?
→ Where do microplastics accumulate (beaches, sediment)?
→ What are effective tools and monitoring strategies for the specification of GES as far as microplastics in the marine environment are concerned to monitor trends of abundance, distribution and composition?

2. Physical effects (Descriptors 2 and 10 of the MSFD)

→ What kinds of physical effects are induced within marine organisms by microplastics (Descriptor 10)?
→ Which organisms are especially concerned? Which level of the food chain is the lowest affected?
→ How does the transfer along the food chain proceed? Is there enrichment/depletion within the food chain? Can microplastics finally be found in the top predator?
→ What are adequate endpoints reflecting physical effects of microplastics in organisms?
→ Which amount of microplastics in organisms would be tolerable? What thresholds should be established?
→ What is the abundance of invasive species carried by microplastics? Which trends can be observed (Descriptor 2)?
→ Which impact do these invasive species have on endemic species and ecosystems?
→ How can the amount of plastic-induced invasion be measured?

3. Chemical effects (Descriptor 8 of the MSFD)

→ How strongly do organic pollutants sorb onto or into microplastics? How does weathering of the surface influence the sorption behaviour?
→ How do pollutants sorb onto or into microplastics in comparison to (natural) particles (suspended matter, detritus, phytoplankton)?
→ Do absorbed pollutants leach significantly out of the plastic matrix?
→ Does the sediment represent a sink for microplastics and, in addition, for the associated pollutants?
→ Does uptake of microplastics and associated pollutants increase the bioaccumulation of pollutants?
→ Will established thresholds of organic pollutants be exceeded by an additional uptake via "polluted" microplastics?

Acknowledgements

The following were participants in the workshop: Ulrich Callies, Helmholtz-Zentrum Geesthacht, Zentrum für Material und Küstenforschung (D); Kim Detloff, Nature and Biodiversity Conservation Union Germany e.V., Berlin (D); David Fleet, Schleswig-Holstein Agency for Coastal Defense, National Park and Marine Conservation, Tönning (D); Elke Fries, Institute of Environmental Systems Research, University of Osnabrück (D); François Galgani, Institut français de recherche pour l'exploitation de la mer (Ifremer), Corse (F); Gunnar Gerdts, Alfred Wegener Institute for Polar- and Marine Research, Helgoland (D); Georg Hanke, Joint Research Centre, European Commission, Ispra (I); Maximilian Hempel, Deutsche Bundesstiftung Umwelt, Osnabrück (D); Angela Köhler, Alfred Wegener Institute for Polar- and Marine Research, Bremerhaven (D); Michael Matthies, Institute of Environmental Systems Research, University of Osnabrück (D); Michael Neumann, German Federal Environmental Agency, Dessau (D); Carolin Rettig, Institute of Environmental Systems Research, University of Osnabrück (D); Martin Scheringer, Institute for Chemical- and Bioengineering, ETH Zurich (CH); Peter Seifert, BMBF Project Management, Jülich, Rostock-Warnemünde (D); Renate Sturm, Helmholtz-Zentrum Geesthacht, Zentrum für Material und Küstenforschung (D); Nadia von Moos, Alfred Wegener Institute for Polar- and Marine Research, Bremerhaven (D); Stefanie Werner, German Federal Environmental Agency, Dessau (D); Christiane Zarfl, Institute of Environmental Systems Research, University of Osnabrück (D).

References

Barnes, D.K.A., 2002. Invasions by marine life on plastic debris. Nature 416, 808–809.
Barnes, D.K.A., Galgani, G., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society of London Series B 364, 1985–1998.
Browne, M.A., Dissayanake, A., Galloway, T.S., Lowe, D.M., Thompson, R.C., 2008. Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). Environmental Science and Technology 42, 5026–5031.
Carpenter, E.J., Anderson, S.J., Harvey, G.R., Miklas, H.P., Peck, B.B., 1972. Polystyrene spherules in coastal waters. Science 178, 749–750.
Eriksson, C., Burton, H., 2003. Origins and biological accumulation of small plastic particles in fur seals from Macquarie Island. Ambio 32, 380–384.
Fendall, L.S., Sewell, M.A., 2009. Contributing to marine pollution by washing your face: microplastics in facial cleansers. Marine Pollution Bulletin 58, 1225–1228.
Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasion. Philosophical Transactions of the Royal Society of London Series B 364, 2013–2025.
Hale, S.E., Martin, T.J., Goss, K.-U., Arp, H.P.H., Werner, D., 2010. Partitioning of organochlorine pesticides from water to polyethylene passive samplers. Environmental Pollution 158, 2511–2518.
Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., Kaminuma, T., 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environmental Science and Technology 35, 318–324.
Moore, C.J., 2008. Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. Environmental Research 108, 131–139.
Moore, C.J., Moore, S.L., Leecaster, M.K., Weisberg, S.B., 2001. A comparison of plastic and plankton in the North Pacific Central Gyre. Marine Pollution Bulletin 42, 1297–1300.
Ryan, P.G., Connell, A.D., Gardner, B.D., 1988. Plastic ingestion and PCBs in seabirds: is there a relationship? Marine Pollution Bulletin 19, 174–176.
Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonicle, D., Russell, A.E., 2004. Lost at sea: where is all the plastic? Science 304, 838.
Zarfl, C., Matthies, M., 2010. Are marine plastic particles transport vectors for organic pollutants to the Arctic? Marine Pollution Bulletin 60, 1810–1814.

Christiane Zarfl
Institute of Environmental Systems Research, University of Osnabrück, Barbarastr. 12, 49076 Osnabrück, Germany

David Fleet
Schleswig-Holstein Agency for Coastal Defense, National Park and Marine Conservation, Schlossgarten 1, 25832 Tönning, Germany

Elke Fries
Institute of Environmental Systems Research, University of Osnabrück, Barbarastr. 12, 49076 Osnabrück, Germany

François Galgani
Institut français de recherche pour l'exploitation de la mer (Ifremer), 83507 La Seyne-sur-Mer Cedex, Corse, France

Gunnar Gerdts
Alfred Wegener Institute for Polar- and Marine Research, Kurpromenade, 27498 Helgoland, Germany

Georg Hanke
Joint Research Centre, European Commission, via Enrico Fermi 2749, 21027 Ispra, Italy

Michael Matthies
Institute of Environmental Systems Research, University of Osnabrück, Barbarastr. 12, 49076 Osnabrück, Germany
Tel.: +49 541 969 2576; fax: +49 541 969 2599.
E-mail address: matthies@uos.de