Multilevel assessment of microplastics and associated pollutants in the Baltic Sea

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with the support from all project partners

In recent years the scientific, public, and political awareness of the plastic accumulation in our global oceans has increased. At the same time, the scientific data on microplastic sources and sinks, on its impact on the ecosystem and on mitigation strategies is limited, in particular regarding small-sized microplastics.

Due to its highly populated drainage area and severe marine traffic, the Baltic Sea holds a high potential for microplastic contamination, but few data are available. BONUS MICROPOLL wanted to close this knowledge gap further and succeeded in providing a better understanding of microplastic sources, sinks, fate, and impact in the Baltic Sea ecosystem.

Significant amounts of large microplastics found on Baltic beaches

In a unique and extensive field sampling campaign the microplastic content was analysed in 190 sandy beach samples from 35 Baltic Sea regions, covering all nine boarding states of the Baltic Sea. In total, 9,345 plastic particles were counted and characterised. The most common litter were industrial pellets (19.8 per cent), non-identifiable plastic pieces 2–25mm (17.3 per cent) and cigarette butts (15.3 per cent). Overall, Baltic beaches are significantly polluted with large micro- and meso-litter (2–25mm).

Monitoring techniques for beaches at the Baltic Sea were tested, advanced, and compared. The sand rake method for micro- (2–5mm), and meso (5–25mm)-litter, developed in this project, was found to be most applicable on all sandy beaches. It allows for providing a full spatial pollution pattern and pleases the requirements of the Marine Strategy Framework Directive (MSFD). When applied over several years, it was evaluated as a solid basis for assessing the effectiveness of marine litter mitigation measures.

Overcoming the challenge of analysing small microplastics

One of the biggest challenges in microplastic research is an efficient extraction of microplastic particles from environmental samples without contaminating the sample or the loss of microplastic particles, especially with regard to small microplastic fractions. In the course of this project, several methods were successfully tested and evaluated to prepare water, sediment, and biota samples for microplastic analysis. A detailed protocol was developed, applicable for multiple environmental matrices. With the help of a decision tree, future microplastic researchers can pick the most convenient procedure for their specific sample.

Further, optimisations in the automatisation of the elaborate spectrometric analysis to detect polymer types and numbers were achieved. Up to 40,000 particles in an environmental microplastic sample can now be analysed by a combination of optical microscopy with FTIR- and Raman microscopy. The open source software package GEPARD (Gepard-Enabled PARticle Detection) was developed with which commercial and specialised self-acquired spectral polymer databases are automatically addressed. In a marine plastic database (MPDB), programmed and developed in the project, all project results on microplastic types, shapes, colours and amounts were stored and can be requested by public authorities. The MPDB allows general import of data also from other microplastic projects, and it allows exchange with other marine litter databases. The database structure has already been used in other projects and institutes across Europe.

Harbours and wastewater, including sanitary sewer overflows, are major sources for smaller microplastic in the Baltic Sea

As an example area, the Warnow estuary, Germany, was investigated concerning microplastic (>500µm) concentrations and sources. Microplastic abundances of 46–379 particles kg^{-1} sediment dry weight were detected, with lower abundances (2 MP kg^{-1} dry weight) in the opening to the Baltic Sea. The most frequently found polymers were those that are also produced in highest quantities: polypropylene and polyethylene, but also paint particles containing a polymeric portion. Marinas and wastewater treatment plants (WWTPs) were identified as important point sources, responsible for a significant amount of microplastic input.

Image 1: Microplastic particles and fibers found in the Vistula river, Poland. Photo © B.Urban-Malinga and M. Białowąs/NMFRI.

Municipal wastewater and its transport pathways to the aquatic environment via WWTPs or sanitary sewer overflow (SSO) have been investigated across the whole Baltic Sea. The compilation of facility data and microplastic emission calculations indicate that WWTPs still contribute with considerable discharge of microplastic to the Baltic Sea despite relatively good removal efficiencies. However, SSOs are likely a significant source for microplastic to the Baltic Sea, too. It was estimated that among these sources, stormwater runoff including sewer overflow contributes 62 per cent of the annual microplastic input to the Baltic Sea, WWTPs with 25 per cent, and untreated wastewater with 13 per cent.

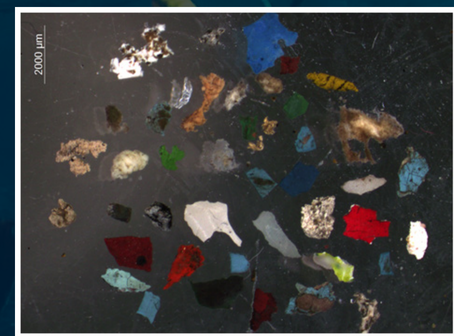

Image 2: Paint particles containing a polymeric component, detected in sediments in the Warnow River, Germany. Photo © N. Stollberg/IOW.

Microplastic emission and fate in the Baltic Sea

Microplastic emission data for the Baltic Sea region for several input pathways were collected and emission scenarios for certain polymer types developed. These scenarios allowed us to estimate transport, behaviour and deposition of microplastic in the Baltic Sea environment. Our model results showed that under the assumption that beach accumulation efficiently removes microplastics from sea-water close to the coast, the average residence time of high and low-density polymers in the water body is relatively short, with about 14 days.

Environmental conditions, as storm events, play an important role for microplastic transport, especially for the remobilisation of settled microplastics from the sediments. At the same time, it is difficult to reconstruct these conditions for the past and provide reliable model forcing. Therefore modelling microplastic transport must show large uncertainties. These errors cannot be eliminated even if the transport model was exact, that is, even if the model perfectly captured how

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the particles' vertical motion, settling and resuspension behaviour depend on wave and current conditions. However, models can still help to estimate microplastic transport when used in combination with empirical methods. They can point towards microplastic hot-spots where field campaigns can afterwards provide quantitative estimates.

All model results were uploaded on a THREDDS Server (Thematic Real-time Environmental Distributed Data Services) to allow data analysis in the field of geoscientific modelling by the scientific community. Major outcomes of the transport simulations will also be published in journals targeting a broader audience and may help stakeholders to develop regionally targeted monitoring or emission avoidance strategies.

Bacteria in the marine environment will not help us solve the plastic issue

Through in situ and laboratory experiments, field sampling, and literature reviews the potential of microplastic to carry specific microorganisms and pollutants was intensely investigated. It was found that the microbial colonisation of microplastics is strongly influenced by environmental parameters such as salinity and nutrients, rather than by polymer properties of the plastic material. Further, a specific accumulation of pathogenic bacteria associated with biofilm development on plastic particles compared to natural particles could not be detected. Physicochemical properties of plastic materials were found to change when exposed to microorganisms, indicating a possible biodeterioration of the material. However, an experimental laboratory study, as well as a broad literature review indicate that, e.g., residual monomer degradation is being carried out by microorganisms, but that no full microbial plastic degradation has taken nor will take place in the marine environment in time scales relevant to human society. While marine bacteria probably do not metabolise plastic polymers, polycyclic aromatic hydrocarbons (PAHs) associated with plastics are much more susceptible to bacterial degradation. In line with this, it was found in this project that certain PAHs specifically accumulate on polyethylene or polystyrene compared with the natural particle control.

Mostly indifferent effects of microplastics on Baltic biota

The ecotoxicological impacts of microplastics on Baltic Sea organisms were examined in laboratory, field studies, and meta-analysis. Mostly indifferent, but also some adverse effects of microplastic exposure were observed. The meta-analysis revealed no inhibitory effects on algal growth, whereas laboratory studies showed no effects on planktonic grazers and development of the early life stages of the sea trout. However, some behavioural alterations were found in benthic fauna (bivalves and lugworms) exposed to microplastics. Also, the frequencies of nuclear abnormalities and chromosomal damage increased in the sea trout larvae after exposure to microplastics, indicating possible genotoxic effects.

Using field data, we found neither an affection of fish body condition nor embryo aberrations in benthic amphipods related to microplastic uptake. Moreover, there was no association between the body burden of hydrophobic organic contaminants and microplastic uptake in herring.

The results of the project show rather low impacts of microplastics on Baltic biota, especially when environmentally relevant concentrations are considered. In part, the lack of observable microplastic effects can be related to our limited analytical capacity for particles <50µm and other environmental contaminants that mask the responses related to the microplastic exposure. To address these and other methodological challenges in ecotoxicological testing with microplastic, we developed a novel method that improves the hazard assessment. Further, research targeting effect mechanisms of microplastic exposure is necessary for a holistic assessment of the ecological consequences of this pollution.

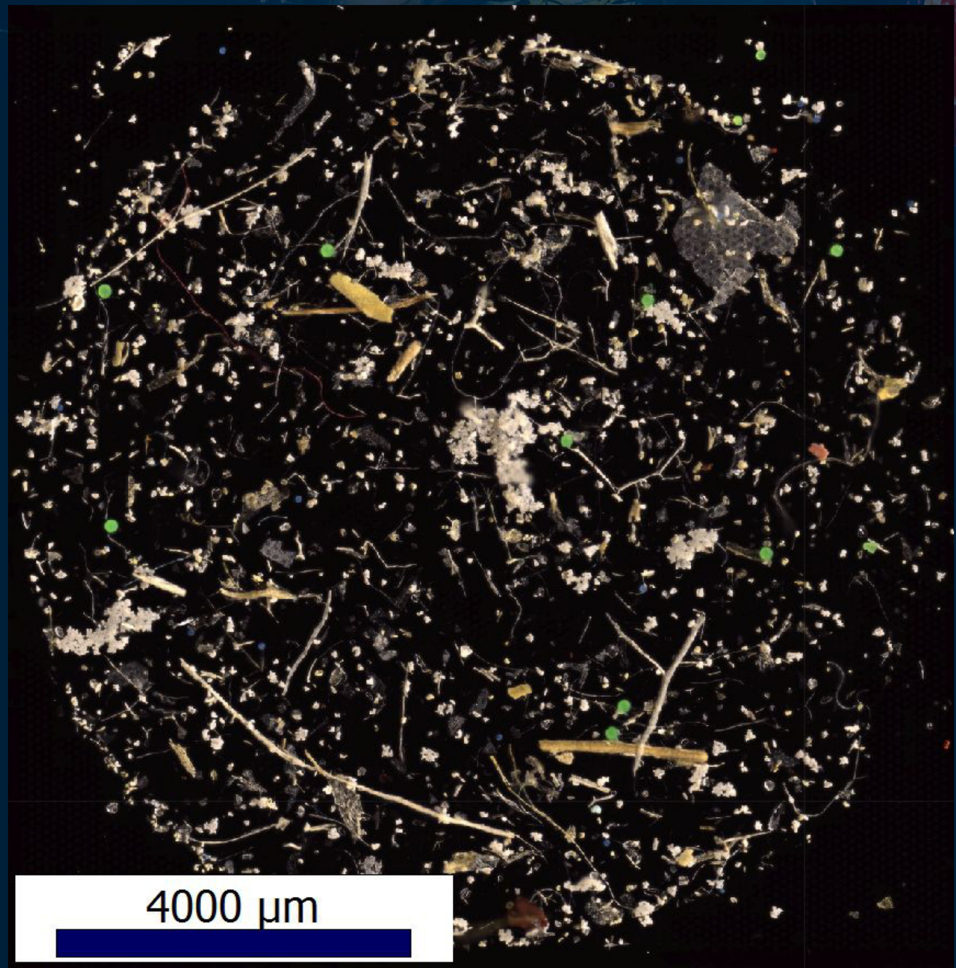

Image 3: Image of a Baltic Sea beach sample. Green spherical dots are model plastic particles for recovery measurements. Photo © Program GEPARD/IPF.

Image 4: Separating funnels to perform a density separation of microplastics from sediments. Photo © K.Beck/IOW.

Successful mitigation of microplastic input

In the South Baltic region, the perception of beach pollution with a focus on discarded cigarette butts was investigated. Results of the surveys showed that beachgoers do not see cigarette butts as marine litter or a litter item at all. This reveals a need for environmental education.

Measures to increase the personal responsibility of a beachgoer (e.g. ballot bin or pocket ashtray), revealed to be ineffective as a pollution reduction measure but served well as a public awareness tool. It was concluded that fines or a smoking ban combined with mechanical cleaning on the beach are the only management option to prevent pollution.

With regard to municipal wastewater, certain mitigation measures, including technical solutions, a significant reduction of microplastic-emissions from WWTPs and SSO events can be achieved. Even so, complete removal of microplastic at WWTPs may not be realistic; an average removal efficiency of 97 per cent at WWTPs in the Baltic Sea basin is considered a reasonable target compared to 93 per cent estimated by the project at present. Further, the reduction of sewer overflows from the present 1.5 per cent to 0.3 per cent of the annual wastewater loads would reduce the total emissions to the Baltic Sea by 50 per cent.

Overall statement

The results of BONUS MICROPOLL have significantly increased the knowledge about microplastic in the Baltic Sea ecosystem. Via end-user workshops, public relations work, so far 24 scientific publications, and presentations at conferences we assured to spread the knowledge to a broad audience. While some experiments on the impact of microplastics on Baltic biota showed no or minor effects, genotoxicity increased via exposure to microplastics. It became clear that the problem is not solved by the marine system itself, for example through microbial biodegradation. The only way to prevent further pollution is through public education, the implementation of management measures and technical improvement to reduce identified microplastic input pathways.

PROJECT SUMMARY

BONUS MICROPOLL focuses on the multilevel impacts of microplastics themselves, and of associated pollutants and attached biofilms on the Baltic Sea ecosystem. The project aims at the assessment of the current status of microplastic input and distribution in the Baltic Sea, emanating risks originating from microplastics, and the suggestion of cost-effective monitoring and mitigation strategies regarding microplastics and associated pollutants.

PROJECT LEAD PROFILE

Dr Sonja Oberbeckmann is a marine microbiologist at the IOW, focussing on anthropogenic effects on microbial communities. After completing her PhD in 2011 at the Alfred-Wegener-Institute, she worked with microplastic biofilms in the UK, USA, and Germany.

PROJECT PARTNERS

Leibniz Institute for Baltic Sea Research Warnemuende (IOW), Germany (lead); Leibniz Institute of Polymer Research Dresden, Germany; Stockholm University, Sweden; Klaipeda University, Lithuania; IVL Swedish Environmental Research Institute, Sweden; Tallinn University of Technology, Estonia; and the National Marine Fisheries Research Institute, Poland.

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