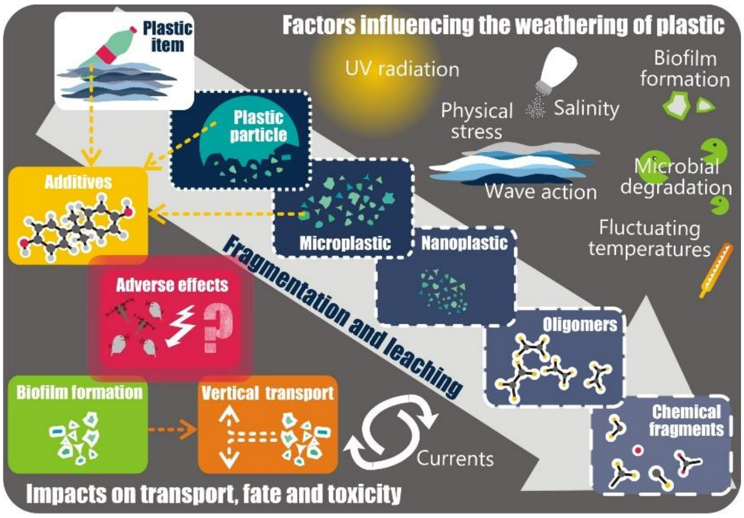
PROJECT Final REPORT

WEATHER-MIC –

HOW MICROPLASTIC WEATHERING CHANGES ITS TRANSPORT, FATE AND TOXICITY IN THE MARINE ENVIRONMENT



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PUBLISHABLE SUMMARY

The overall aim of the WEATHER-MIC project is to assess how microplastic weathering changes its transport, fate and toxicity in the marine environment. Microplastic in the ocean is exposed to UV light, wave action, biofilm growth and other weathering factors. These factors lead to fragmentation, degradation, and surface modifications, changing the density and particle size distribution of microplastic, which ultimately impacts their environmental fate and transfer in food webs. Despite the importance of these aging processes and their related impacts, the hazards associated with weathered microplastic were not well understood when WEATHER-MIC started. To achieve better knowledge about how weathering influences the physicochemical properties, environmental fate and toxicity of microplastic, we carried out research activities divided into seven scientific work packages (WPs).

Research activities in WP1 were focused on experiments and data interpretation related to artificial weathering of plastic in the SU “weathering wheel”. This work was published in a paper in Environmental Science & Technology Letters (Gewert et al., 2018) that described the identification of free chemicals in water that were liberated under artificial weathering as chain scission products of plastic. This paper provided a major building block for further experiments aiming at development of a “fingerprinting” method for plastic leachates based on their mass spectroscopic signals. Method development has been completed using idealized samples that consist of one of six different known plastic types. Analysis of these idealized samples indicated that unique mass spectroscopic fingerprints of each plastic polymer could be identified following artificial weathering. However, unknown mixtures of plastic materials did not show the same chemical fingerprints.

The main tasks in WP2 at NGI focused on developing the 1DV settling model for irregular microplastic shapes, in coordination with KUL (WP4), and to integrate the recent data on weathered microplastic from IKTS as part of developing ways to account for weathering effects on settling behavior. In addition, much activity was done in WP5 to (i) generate field-weathered material, (ii) quantify microplastic in sediment cores from the Oslo Fjord, and (iii) quantify microplastic in sediment and water samples taken off the coast of Havana as part of a collaboration with Race for Water.

Different methods for physical characterization of plastic materials were established and applied at IKTS. Changes in particle size distribution and shape were identified as key parameters that changed with weathering, together with surface charge and crystallinity of the polymer. IKTS focused further on the characterization of weathered low-density polyethylene (LDPE) and polyethylene terephthalate (PET) samples. Existing methods were optimized, and new methods were developed and standardized. The carbonyl index is a parameter that is very suitable for evaluating the influence of UV

light on plastic during weathering, which is determined by means of Fourier Transform Infrared Spectroscopy (FTIR) analyses. For LDPE, an ultraviolet (UV) light-induced tendency to embed oxygen in the chemical structure was shown. In addition to the chemical properties, changes in the surface properties also occurred as a result of weathering. Streaming potential measurements on PET sheets confirmed that growth of biofilm leads to changes in surface charges. These new methods can also be applied to naturally aged samples. Important data concerning the ratio of biofilm volume to polymer volume are determined by computed tomography. Together with the results of the density analyses, based on a flotation method, taking into account the influence of the biofilm, the final biofilm density can be calculated. The data are of particular interest for sedimentation and distribution models of microplastic in the aquatic environment (WP4).

Our partners at SU focused also on the aggregation and sedimentation of microplastic in the Baltic Sea as part of the so-called marine snow (WP3). Mesocosm experiments revealed that bacterial communities on plastic material differed substantially from the communities on natural material. Protocols for stable-isotope labeling of biofilm and quantitative analysis of biofilm communities on microplastic particles were established and are in preparation for publication. These methods are instrumental to measure transfer of the bacterial biomass in the system, including sediment-living microorganisms and animals consuming particles that carry biofilms.

In WP4, two 3D models have been set up for two model areas, but their field validation has largely been hampered by lack of field data. Furthermore, using data generated by WP2, KUL analyzed settling rate data for various types and shapes of microplastic particles. They showed that particle settling follows the expected trend for similarly shaped particles, known from fluid mechanics, and confirms that the settling behavior is entirely governed by the dimension and shape (characterized by the 3 principle length scales) of a particle, relative particle density and the fluid viscosity. Weathering may be reflected in changes of density and as a consequence leads to a shift on the trend line. Changes in surface properties do not seem to play an important role, relative to the uncertainty band around the mean trend. Microplastic particles seem to be easily captured in aggregates, and the settling behaviour of these aggregates follows the same trend curve.

At UFZ, particles of different size classes and particle-free leachates after UV-weathering were tested (WP6) by applying a high-throughput algal assay using several biological endpoints of synchronized cultures of the chlorophyte *S. vacuolatus*. While in the fraction <1.2 µm the amount of PET particles doubled after weathering, LPDE did not show any differences. Furthermore, no effects of the different size classes on algal performance were found. Similar results were obtained in the *D. magna* assay. Concentrated leachates of PE, polypropylene (PP), polystyrene (PS) and PET were tested against positive controls (e-waste and a new keyboard) in cell-based bioassays and in the algae test. E-waste leachates had strong effects, while the preproduction polymers showed only slight or no effects. In some cases, we observed stronger effects of the leachates generated under UV light irradiation compared to the dark controls, indicating a UV-induced leaching of compounds that enhances effects. In general, the cell-based reporter gene bioassays indicated low effects caused by the pure polymers, whereas positive controls elicited clear effects. Hence, all experiments indicated that the polymers themselves showed limited, if any, effects. For higher-tier assessment, biofilm communities were used and revealed that characteristics of different plastic materials showed an effect on the early colonization processes of bacteria. However, these differences became less evident during further succession processes.

The main aims of WP7 were to provide estimations of the environmental risk posed by the weathering process. Fragmentation of plastic items as well as the leaching of degradation products and additives need to be considered in this regard. Experimental data generated within WEATHER-MIC were complemented by relevant data from the scientific literature. The literature research focused on leaching processes and the impact of leachates on biota. Literature data indicate that weathering increased the release rates of additives, but not the total amount that is being liberated. Leaching studies focus mostly on additives, whereas little data exist on polymer degradation products. For risk assessment, the ongoing degradation of substances in the leachates needs to be taken into account. Finally, a number of future research needs were identified and discussed.

As part of WP8, the outcomes of the project were presented at several scientific conferences and meetings, amongst others the JPI Oceans Final Conference on Lanzarote on November 20, 2018. WEATHER-MIC scientists contributed to a range of meetings and expert workshops, such as "Thresholds for Marine Litter" organized by the MSFD technical group on marine litter and a related panel discussion on Lanzarote. Several partners participated in the interdisciplinary Berlin University of the Arts & Technical University Berlin project "Microplastics and Medusae". WEATHER-MIC also collaborated with Race for Water for various dissemination activities. Furthermore, WEATHER-MIC scientists participated in a range of interviews for the press, internet, radio and television, launched several videos from the field and lab on their YouTube channel, and were present at the press conference for the opening of the Ocean Plastics Lab in Berlin. WEATHER-MIC scientists were also active in many other seminars and conferences. For examples, please see: http://www.jpi-oceans.eu/weather-mic/about

PART A - SCIENTIFIC REPORT

This part summarizes the progress and major scientific achievements made in WEATHER-MIC.

INTRODUCTION

Plastic in the environment is exposed to weathering forces such as UV light, wave action and colonization by biota which can have a substantial impact on the fragmentation, polymer degradation and particle surface modification. These altered properties have the potential to change the plastic's density, size distribution and environmental fate, but at the time when WEATHER-MIC started, their impact was poorly understood. The vast majority of existing studies was conducted with spherical, non-biofouled particles that had little to do with a large fraction of the real-world weathered, irregular plastic in the environment, and the results hence had limited environmental relevance.

Therefore, WEATHER-MIC focused on weathering effects on microplastic transport, fate and hazard potential in the marine environment, primarily using lab experiments and models. The laboratory experiments allowed us to study the isolated impact of single weathering factors (e.g., UV irradiation only), and to better understand their particular importance in the interplay with other factors. Furthermore, the WEATHER-MIC consortium put a major focus on preproduction plastic, low in additives. This study material enabled investigations of the chemicals that are liberated from the polymer backbone during weathering and studies of the effects of the polymer itself on biofilm formation and cell- as well as organism-based bioassays. In addition, some complementary studies were conducted within WEATHER-MIC with field-weathered preproduction plastic and with native material collected in the environment.

AIMS OF THE PROJECT

The overall goal of WEATHER-MIC was to assess how weathering processes impact the transport, fate and toxicity of microplastic particles and their leachates in the marine environment.

Core innovations of WEATHER-MIC were the development and validation of several tools to identify and quantify the effects of weathering, model their influence on horizontal and vertical transportation, and address the implications for trophic transfer and toxicity. The core deliverable of WEATHER-MIC was a *robust set of innovative experiment- and model-based exposure and effect assessment tools to* *enable the necessary incorporation of microplastic weathering into risk assessment of marine microplastic pollution.* The aims and approaches for WEATHER-MIC are presented below:

(1) WEATHER-MIC used artificial weathering in laboratory experiments combined with non-target chemical analysis and particle imaging to "fingerprint" weathered plastic particles. (WP1)

Weathered microplastic generation and quantification. We developed laboratory-based methods to artificially weather microplastic (mainly by strong UV irradiation, but also using physical stress such as turbulence and biofilm formation), and studied the impacts with microplastic fingerprinting tools that exploited novel liquic chromatography/high resolution mass spectrometry (LC/HRMS)-based non-target analysis of plastic leachates (WP1). Non-target screening methods were developed to study chemicals that were liberated from the plastic for microplastic fingerprinting. In non-target screening, peaks in a sample detected using MS are identified using exact masses, isotope and adduct patterns, retention time and recorded fragmentation. We applied an advanced HR-Orbitrap-MS instrument to conduct non-target analysis of leachates from plastic. As part of this fingerprinting, we employed particle size, particle imaging and surface charge analyses to study the effects of artificial weathering on plastic particles using Dynamic Imaging Analysis, Scattered Electron Microscopy, and Electrokinetic Analysis, amongst other techniques. Field samples were used to test the novel fingerprinting approach.

(2) WEATHER-MIC investigated how weathering processes of microplastic affecting their size distribution, surface morphology, density, aggregation-flocculation behaviour and microbial biofilm communities influence the vertical distribution, trophic transfer and toxicity of microplastic. (WP1, WP2, WP3, WP6)

Fate of weathered microplastic. No known aggregation, sedimentation or flow models existed for microplastic as a function of weathering and biofilm formation, neither at the laboratory nor at the field scale. In WP2, a selection of the weathered materials and weathering test protocols from WP1 were used to study how weathering affects the vertical distribution of microplastic with time in controlled column sinking experiments mimicking different marine environments (e.g. varying in salinity, turbidity, biofilm growth conditions, clay content) representative of the Oslo Harbor and the Baltic Sea. The changes in microplastic content (e.g. surface morphology, fragmentation-aggregation) at different depths in the columns was monitored with selected non-target and imaging techniques developed in WP1. The influence of microplastic-associated biofilm and effects on its intake by consumers was characterized as part of WP3 and WP6 (SU, UFZ).

(3) WEATHER-MIC investigated if the spatial distribution of microplastic pollution from laboratory-scale column tests on microplastic exposed to different weathering regimes can be extrapolated to monitoring data from the Stockholm Archipelago and Oslo Harbor using sediment transport models parameterized for microplastic. (WP2, WP4, WP5)

Weathered microplastic transport modeling. From the systematic identification of influential weathering-related parameters (WP2), we developed a microplastic "particle-population"-balance model including weathering effects (e.g., break-up and aggregation) and settling that can describe the time dependence of microplastic distribution in the water column. In a second step, this column model was incorporated into a 3D hydrodynamic code to model the combined effects of weathering, settling, turbulent dispersion and advection by currents in the highly complex marine environment (WP4). These are, to our knowledge, the first models that consider plastic as dynamic entity that will change properties over time, can separate and aggregate, and are based on earlier models developed for cohesive clays. KUL developed this novel incorporation using the TELEMAC system (www.opentelemac.org) to generate microplastic transport models specifically optimized for the Oslo

Harbor and a selected area of the Baltic Sea, Himmerfjärden Bay. We expected the evolution of the size distribution of the weathered material to be influenced strongly by wind- and wave-induced turbulence. The problem of turbulence modeling at the free surface of oceans itself is a substantial challenge, requiring the development of new source terms for the turbulence model. The final microplastic transport model is based on an existing model for cohesive sediment flocs. The validity of the hydrodynamic model was tested in the field (WP5), by sampling near microplastic source outlets (e.g. the Norwegian Bekkelaget Wastewater Treatment Plant).

(4) WEATHER-MIC tested if toxic effects of weathered microplastic can be reproducibly assessed by a combination of toxicity tests using adapted OECD guidelines for ecotoxicological testing of chemicals to microplastic particles and of weathered plastic leachates using cell-based bioassays. (WP6)

Ecotoxicity of weathered MPs. The assessment of the toxic effects of microplastic has to date been done in a non-standardized way. We assessed whether well-established OECD guidelines (TG201 and TG202) for the ecotoxicological testing of chemicals present in the environment can be adapted to microplastic particles, using *Daphnia magna*, *Nitocra spinipes, Corophium volutator* and marine algae (*Skeletonema costatum* and *Tetraselmis suecica*). To improve the existing test procedures, we developed and validated a novel method for hazard assessment of particulate materials, such as microplastic. In addition, we tested the sum effects of the unknown fraction of chemicals that leach from plastic debris using cell-based bioassays, an algal assay and *Daphnia magna*. The cell-based bioassays address relevant modes of toxic action related to endocrine disruption and also a suite of adaptive stress responses, to ensure that no relevant effects are overlooked. Different weathering experiments conducted within WP1 led to mixtures with different compositions of additives, oligomers and sorbed environmental pollutants being liberated from the polymers.

Core deliverable:

A robust set of innovative exposure and effect assessment tools to enable the necessary incorporation of microplastic weathering into risk assessment of marine microplastic pollution. (WP1-7)

RESULTS AND DISCUSSION

This section describes the progress and achievements made in each work package.

WORK PACKAGE 1: ARTIFICIAL AGING AND FINGERPRINTING OF MICROPLASTIC DEBRIS (LEAD: PROF. M. MACLEOD, SU)

Objectives

- To develop laboratory protocols that simulate the weathering of primary and secondary plastic debris in the marine environment and provide samples of weathered polymers for further experiments in WP2 and WP6
- To develop non-target screening methods based on liquid chromatography/mass spectrometry to identify free chemicals liberated from plastic under simulated weathering conditions, with a focus on degradation products of plastic polymers
- To develop methods to identify and characterize plastic debris based on the "chemical fingerprint" liberated under simulated weathering conditions, and to trace likely sources of plastic debris to the marine environment
- To develop and validate methods for enhanced characterization of microplastic behavior by physical parameters and particle imaging.

Two protocols for weathering plastic under UV light were developed. At SU, we designed and constructed a rotating mixer to artificially age plastic material (Figure 1). This "weathering wheel" is built out of aluminum-covered particle board and holds up to six 350 mL quartz glass tubes horizontally. An electric motor rotates the tubes around the centrally mounted UV lamp, which ensures constant mixing and equal UV exposure of the plastic sample in each tube. A strong airflow is used to maintain a constant temperature of the lamp and samples at around 35 °C.

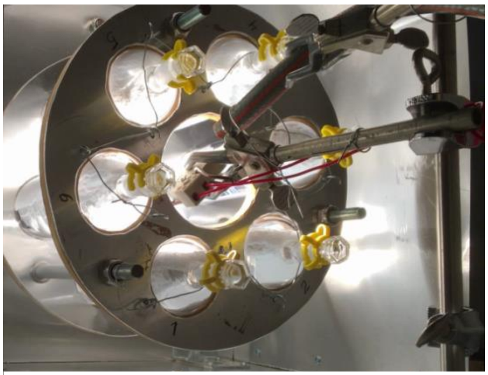

Figure 1. Weathering wheel at SU.

At IKTS a separate UV weathering protocol was developed to weather plastic in sea water (Figure 2). Above each sample, a UV lamp with enhanced UVB irradiation is mounted. The UV intensities are comparable to those occurring in the environment. In addition to UV irradiation, the samples can be subjected to mechanical stress on an orbital shaker. Weathered plastic material and leachates from both systems were exchanged amongst the WEATHER-MIC partners in WP2 and WP6.

Gewert et al. (2018) showed that plastic floating in the ocean could be a constant source of chemical pollutants that are slowly cleaved from the polymer backbone under UV light irradiation. Plastic material was weathered on the "weathering wheel" under UV exposure equivalent to the effects of more than a year of exposure to the sun in just five days. After the simulated solar exposure, water from the quartz tubes was analyzed for unknown chemical pollutants using an ultra-high resolution Orbitrap mass spectrometer linked to a liquid chromatography system. Twenty-two specific chemicals in the water that are oxidized fragments of the plastic polymers were positively identified, which confirms that the plastic polymers are degrading and producing chemicals that enter the surrounding water. The 22 chemicals identified in the study are carboxylic acids and dicarboxylic acids. In addition 500 different mass signatures of chemicals were detected that could to date not be positively identified.

Figure 2. Weathering setup at IKTS.

Using the weathering wheel protocol and high-resolution mass spectroscopy analysis, SU researchers successfully demonstrated that distinct "fingerprints" of chemical substances were released to water from pure samples of six different polymers. These fingerprints were reproducible for the pure plastic in triplicate analysis. However, analysis of leachates from single plastic weathered at IKTS were not identical to the SU fingerprints. And, mixtures of plastic materials that were weathered and analyzed at SU did not show the same chemical fingerprints as the pure plastic. One possible explanation is that radical reactions in the water produce cross-products of the different plastic materials.

Finally, we tackled the physical characterization of polymer samples and the related method development. IKTS established various measurement methods in order to determine polymer properties which can change due to weathering in the environment. In addition to particle size and shape, the surface charge and crystallinity of the samples are of particular interest. The particle size and shape distribution for granules and powders was determined by dynamic image analysis. The results showed that mechanical stress in the form of shaking in particular can lead to agglomeration of powdery samples. The particle shape, to the contrary, does not seem to be influenced by artificial weathering in the laboratory. The surface charge of polymer sheets can be quantified by streaming potential measurements. The results showed that an accumulation of biological material on the surface leads to a change in the surface charge compared to the pristine, unweathered material. The crystallinity also changes due to the artificial weathering of the samples in the laboratory. The analyses using dynamic differential calorimetry showed that the crystallinity of PET and PE samples increased as a result of irradiation with UV light.

WORK PACKAGE 2: THE INFLUENCE OF WEATHERING ON MICROPLASTIC AGGREGATION AND SETTLING (LEAD: PROF. H.P.A. ARP, NGI)

Objectives

- To develop a series of column experiments simulating weathering of diverse plastic materials in waters representative of the Baltic Sea (low salinity) and Oslo Harbor (mid to high salinity) under diverse conditions;
- To characterize the changes in microplastic-aggregates using diverse measurements (visualization, particle size distribution, density), that can be used to better account for field observations (WP5);
- To provide a model to account for the influence of weathering and sedimentation that can be implemented in a large-scale estuarine model (WP4).

Three different column setups (see Figure 3 for an example) were used to measure the sinking velocities of both microplastic granules and fibers, weathered and non-weathered, over a wide variety of temperatures and salinities, using water directly sampled from the Oslo Harbor at different locations and depths. Furthermore, aggregates of microplastic PET-powder and algae were grown at SU, and their sinking velocities were measured there. The data obtained from all the column experiments was compared with theoretical expectations for the sinking behavior of spherical particles under still conditions. One theoretical model that has been shown to work extremely well, particularly for weathered spherical particles, was the Schiller-Naumann model (eq. 1):

$$c_D\,(Re_p) = 24\,(1+0.150\,Re_p^{0.687})\,/\,Re_p \qquad (1)$$

where c_D is the drag coefficient and is dependent on the Reynold's number of the microplastic particles (Re_p). The practical value of using a model like the Schiller-Naumann model is that both fluid properties and properties of microplastic are incorporated into the values of Re_p and c_D (Re_p). Therefore, changes to the microplastic properties, including weathering-induced changes, can in principle be modeled by accounting for how they change Re_p. Preliminary results of the model are shown in the Figure below, and a related manuscript is in development (Toorman et al., in prep.).

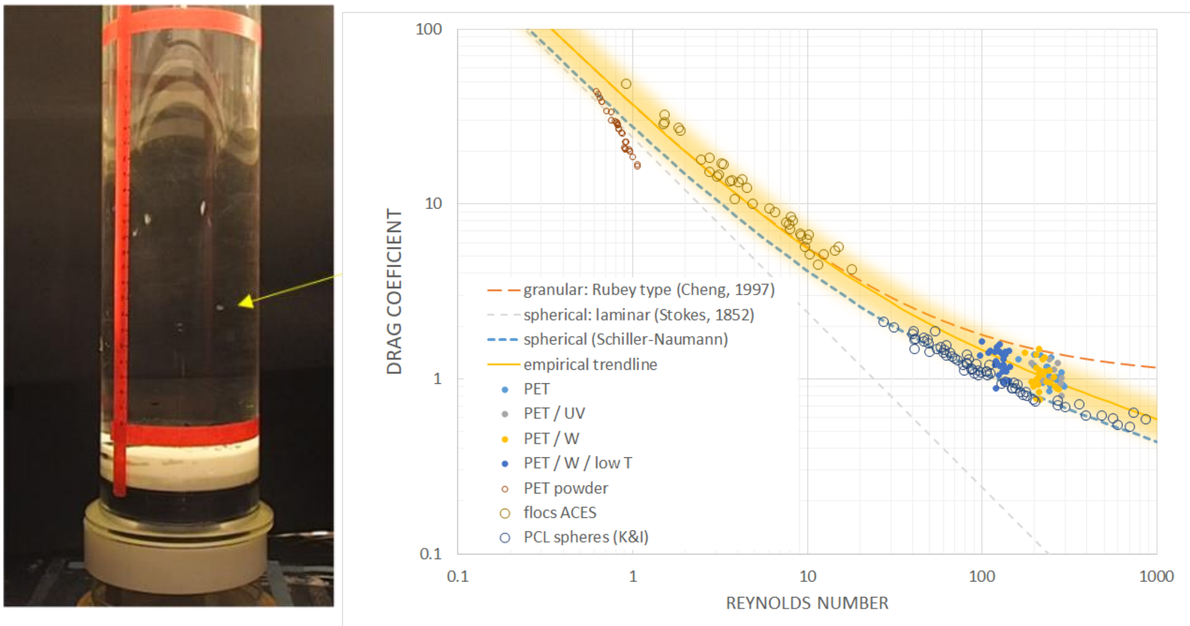

Figure 3. Left: a photo of the column experiment; Right: Experimental data for PET particles ("W" = weathered, "UV" = UV light exposed), PS in algae flocs (SU ACES) and Polycaprolactone (PCL) spheres.

Furthermore, IKTS developed additional techniques to characterize how weathering changes microplastic (see WP1). Key information for the modeling would include changes to size and density, as these affect the Reynold's number, and also particle size distribution. Dynamic image analysis has been used to visualize microplastic particles of various size and shape and to determine their particle size and shape distribution. The density of dry polymer samples of different polymer type, size and shape without biological coatings was measured by helium pycnometry and floating tests in different density solutions. Weathering was found to have a measurable influence on the density of granules, but it was not substantial enough to impact the sinking velocities. Weathering effects on particle size distribution can have a substantial impact. For instance, biofilm aggregation of microplastic was found to fall on the same line as theoretical expectations and errors based on Reynold's number and drag coefficient, as observed with other particles (Figure 3). If a biofilm is present on weathered samples, it can be visualized by computed tomography (CT, Figure 4).

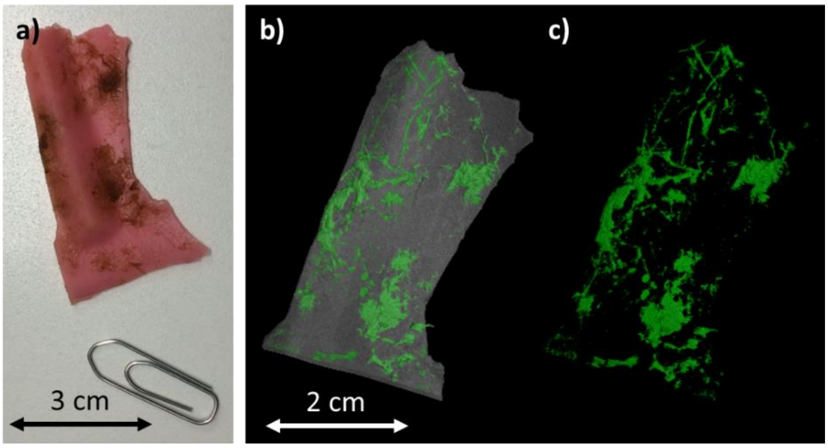

Figure 4. Imaging of field microplastic using CT, including the visualization of algae. a) field-weathered polymer item, b) 3D-image of the item with biological attachment, c) 3D-image of the biological coating of the item

Both the volume of the polymer fragment and the volume of the biofilm can be calculated using imaging software. The density of biologically weathered samples was determined by flotation tests in different salt solutions or ethanol-water mixtures with varying densities. The results in general revealed an increase in density due to the attachment of biofilm on the polymer surface; though not enough to affect sinking velocities unless it led to aggregation.

WORK PACKAGE 3: EFFECTS OF BIOFILM FORMATION ON THE VERTICAL DISTRIBUTION OF MICROPLASTIC IN SITU AND TROPHIC TRANSFER (LEAD: PROF. E. GOROKHOVA, SU)

Objectives

- To evaluate natural loads of biofilm on microplastic along a vertical profile of the water column and along the inshore-offshore gradient in the northern Baltic proper;
- To assess effects of microplastic on bacteria production in sediment and overlaying water using microcosm experiments;
- To evaluate fitness-related consequences (growth, recruitment success and population growth) for grazers (benthic and pelagic copepods) exposed to microplastic with varying biofilm load.

As observed in WP2, in the water column, the downward flux of microplastic is primarily driven by the aggregation with microorganisms and other particulates, the so-called marine snow. To predict the occurrence of microplastic, we need to understand ecological forces, such as phytoplankton blooms, behind the aggregation and degradation of plastic material. To address the first objective, we conducted field sampling of particulate material in pelagia of the northern Baltic proper. Using a Marine Snow Catcher, a special device for collecting intact marine snow aggregates (Figure 5), we collected material with a 10-m depth resolution. The FTIR-based analysis of the extracted particles and screening of the associated bacterial communities using 16S rRNA gene profiling are being finalized.

Furthermore, a mesocosm experiment revealed that bacterial communities colonizing microplastic were significantly different from those on natural substrates (Ogonowski et al., 2018). Moreover, to evaluate the settling rate of the aggregates as a function of the biofilm composition, an experimental study has been conducted and is being prepared for publication (McGivney et al., in prep.). These experimental results on biofilms were complemented by evaluation of behavioral and growth effects of microplastic and the associated biofilms on the grazers (Gorokhova et al., 2018). Moreover, protocols for biofilm stable-isotope labeling and quantitative analysis of biofilm communities on microplastic particles were established and are in preparation for publication. These methods are instrumental to measure transfer of the bacterial biomass in the system, including sediment-living microorganisms and animals consuming biofilm-covered particles.

Furthermore, for evaluating fitness-related consequences for consumers, a novel concept of a standard testing procedure for establishing effect concentrations of microplastic has been developed (Gerdes et al., 2019). Based on the results of WP3, funding for a project “Towards quantifying impacts of microplastics on environmental and human health” (2019-2021; Swedish Environmental Protection Agency) has been secured.

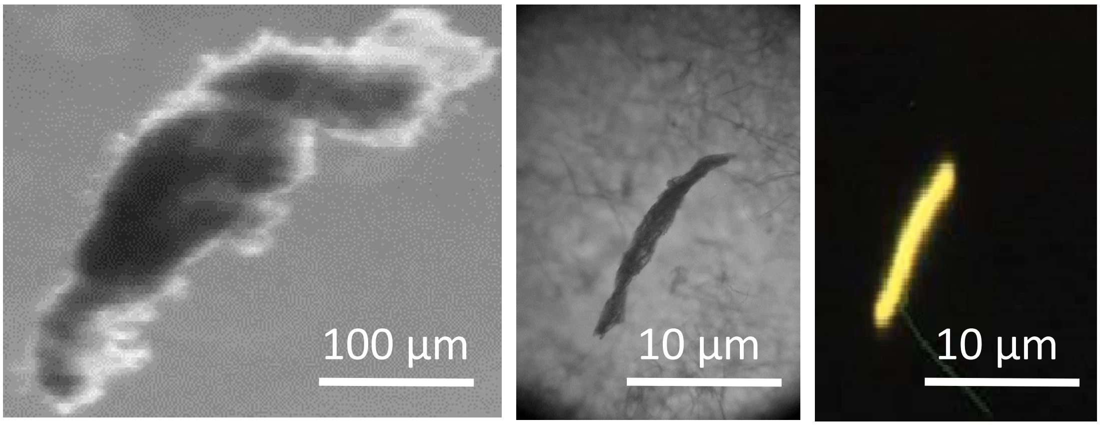

Figure 5. Marine snow aggregate collected at 100 m depth (Landsort Deep; northern Baltic proper; August 2018) before (left panel) and after enzymatic digestion leaving only a few undigestible particles (middle panel). Staining with Nile Red (right panel) suggest that at least some of these particles are synthetic polymers.

WORK PACKAGE 4: MODELING EXTENSION TO REAL WORLD ENVIRONMENTS (LEAD: PROF. E. TOORMAN, KUL)

Objective

- To develop a modeling framework for the 3D dispersal of microplastic particles in a coastal environment

Two 3D models have been set up, one for the Oslo Fjord (NO) and one for the Himmerfjärden Bay (SE). Open sea boundary conditions were generated with a depth-averaged (2DH) Baltic Sea & Skagerrak model (starting from the North Sea). The 2-Class Population Balance Equation (2CPBE) flocculation of Lee et al. (2011), implemented by Ernst (2016) in the TELEMAC3D code, has been tested in these two models.

No actual validation of the model could be performed due to the intensive field data requirements compared to the available data; this validation would require a more extensive sampling campaign than the ones currently performed. Only one approximately realistic scenario has been simulated, i.e. the dispersal of a flux of microplastic particles from the sewer treatment plant in Oslo Harbor over a period of 4 weeks (Figure 6, left panel). The outcome was that the material disperses very slowly because in that corner of the Fjord there is hardly any current to transport the particles. A similar simulation for the Himmerfjärden case is shown in Figure 6 (right panel). Longer term simulations have not been performed yet because of the long computational time and problems with the necessary turbulence model.

A major bottleneck for the advancement of the model was the observation that the preferred turbulence model, i.e. k-epsilon, did perform poorly to very bad near the bottom. The analysis of this problem led to the identification of the source and the proposal of an entirely new treatment of the near-bottom boundary conditions (Toorman et al., in prep.). Once this new method has been positively evaluated and implemented into the TELEMAC source code, longer term simulations are still planned to be carried out using the HPC facilities of KUL. Furthermore, with co-funding by the BELSPO BRAIN.be project INDI67, the flocculation modeling work has been extended to include an additional population of particles aggregating with algae (Shen et al., 2018a; Shen et al., 2018b; Shen et al., 2019a; Shen et al., 2019b). This approach seems promising for the future application to plastic particles as well, and is planned to be applied in follow-up projects.

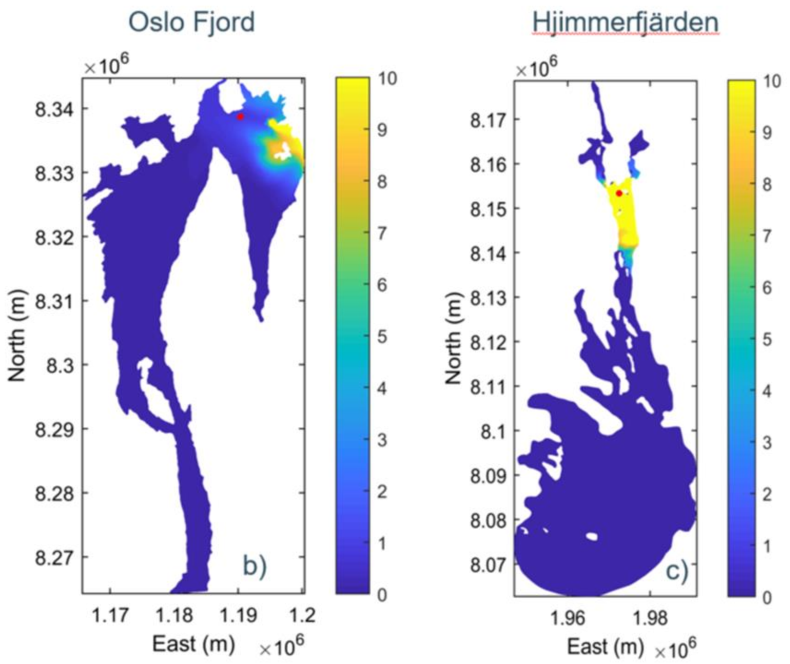

Figure 6: Microplastic concentration at the surface [mg/l] after 28 simulated days released from a source point (red dots) situated at the location of the waste water treatment plants.

This WP has resulted in much better understanding of the actual practical and numerical problems that at this moment hamper the development of a detailed model which accounts for all relevant processes. The final scientific report of this WP therefore mainly focuses on the lessons learned, the identification of knowledge and (very importantly!) data gaps and recommendations for future steps in model development.

WORK PACKAGE 5: MODEL VALIDATION AND FIELD EVALUATION (LEAD: PROF. H.P. ARP, NGI)

Objectives

- To collect sediment cores and water column samples in Oslo Harbor and the Baltic Sea;
- To analyze the microplastic content in the sediment cores and the water column and compare the observations with our predictions based on WP2 tests;
- To match predictions in size distribution and profiles of microplastic particles with WP4 model predictions.

Sampling in the Oslo Harbor and Himmerfjärden Bay in the Baltic Sea was carried out during the project or using samples collected during the last few years before the start of the project. The resulting samples are continuously being processed to obtain more information about the presence and properties of microplastic in this area. One example is presented in Figure 7, related to a MSc thesis (S. Mahat), quantifying microplastic along the Oslo Harbor shore line. Microplastic in sediment cores was also sampled, though this data is still being processed as part of another MSc thesis (C. Singdahl Larsson). As part of the work, an effective and fast two-step digestion protocol was developed for the removal of organic matter from field samples. A method paper is currently in preparation, describing the original methods developed in this Oslo Harbor study. As a spin-off to WEATHER-MIC, NGI has also started receiving sediment samples for microplastic analysis on a commercial basis.

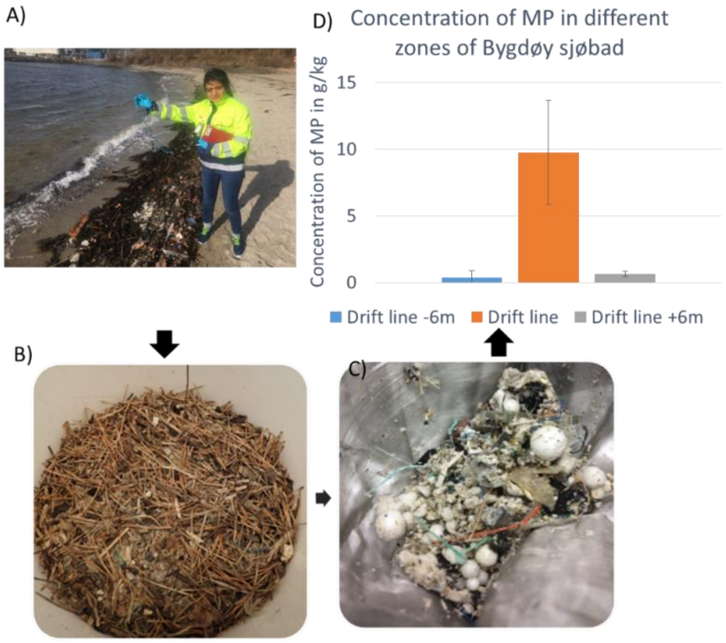

Figure 7 A. Sabnam Mahat showing macrolitter pollution within the drift debris of Oslo Harbor, B) an example of organic matter and top 2 cm of sand at the drift line, C) the same organic matter after application of the digestion protocol (NGI) resulting in an upconcentration of MPs, and D) the relative concentration along the coastal study area of the driftline.

To generate aggregates, a "mesocosm exposure" system was set up directly in the Oslo Harbor, at a Marina in the town of Drøback (Figure 8). The purpose of this mesocosm exposure setup was to age the reference microplastic used by the WEATHER-MIC consortium in a real-world environment. The mesocosm was established in February 2017, and the exposed microplastic materials were harvested at several time points until October 2017. The aged samples were distributed to IKTS for particle imaging and property analysis, and to SU for analysis of algae communities and feeding studies. Much more particles than needed for WEATHER-MIC were generated for future analysis.

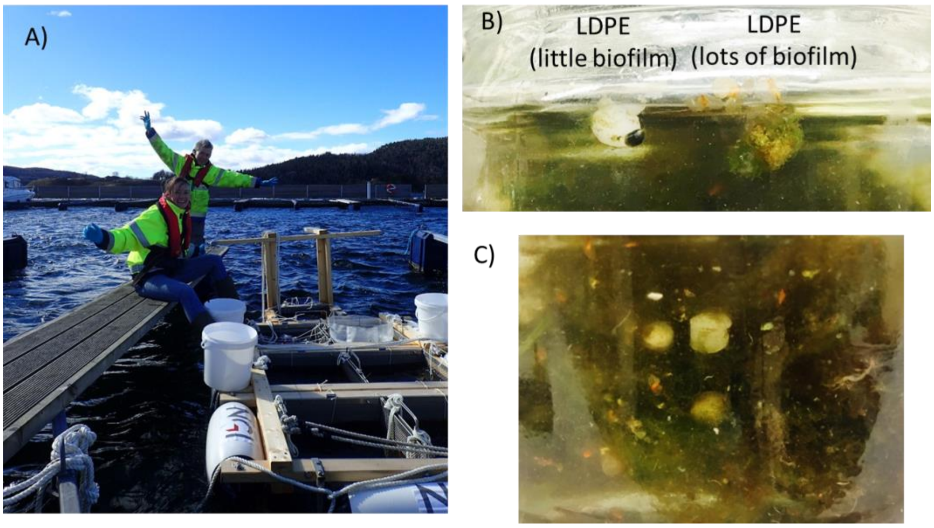

Figure 8 A. the Oslofjord mesocosm exposure raft, for aging known microplastic particles in a real-world environment, B) examples of harvested particles, showing biofilm (algae) growth on some of the floating PE particles; C) an agglomerate of algae and several microplastic particles, indicative of how algae blooms could cause sinking of microplastic (so-called "marine snow").

It does remain a central challenge to obtain enough field data to validate the modeling work (for WP4, amongst others). Particular needs include: a high density of microplastic concentration data along with particle size distribution and degree of biofilm colonization at the surface and throughout the water column; fluxes in the study areas with high time resolution; emission rates from sources; and measured sedimentation rates. Recent research showed that microplastic can be found in all depths of the water column in Oslo Harbor and Himmerfjärden Bay. In Oslo Harbor, more microplastic is seen near the main river (Akerselva) than emitted from the main wastewater treatment plant (Bekkelaget). A general expectation is, however, that most microplastic is found in the top layer of the sediment than anywhere else in the water column.

The research of WEATHER-MIC partner IKTS focused on the analysis of field-weathered materials, covering some material provided by NGI. The weathered granules are currently being characterized by computed tomography (Figure 9). Methods to calculate the volume and to determine the density of the biofilm-containing granules are being developed (see WP2). The obtained data are important input parameters for modeling of the materials' sedimentation behaviour.

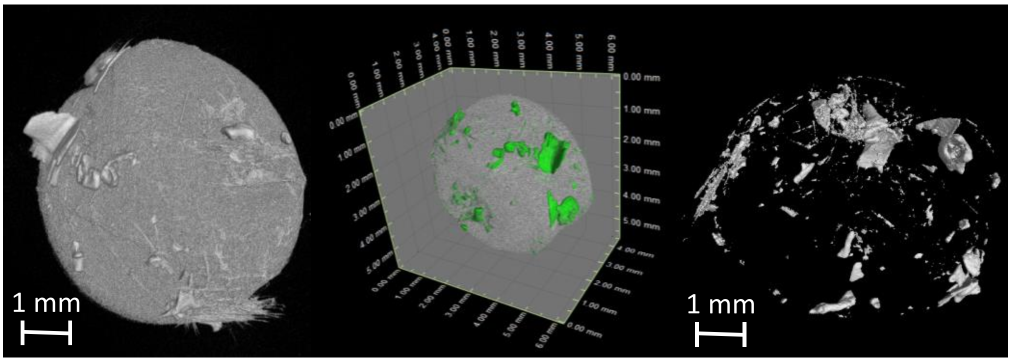

Figure 9: Computed tomography of an environmentally weathered PE particle. Left: PE particle with biofilm; center: dimensions of the particle including the colored biofilm; right: biofilm without particle.

WORK PACKAGE 6: TOXICOLOGICAL ASSESSMENT OF MICROPLASTIC PARTICLES AND THEIR LEACHATES (LEAD: DR. SCHMITT-JANSEN, UFZ)

Objectives

- To screen toxicological effects of virgin and weathered microplastic and its leachates in environmental organisms according to OECD guidelines;
- To evaluate toxicological effects of microplastic particles and their leachates on biofilm communities by applying the concept of pollution-induced community tolerance (PICT);
- To provide mechanistic information on the impact of plastic leachates using cell-based reporter gene bioassays.

Two types of samples were tested in organism biotests: (i) virgin, dark-weathered and UV-weathered polymer particles as well as different size fractions; and (ii) chemical leachates that are liberated from the polymer during artificial weathering (see Table 1 for an overview).

Table 1. Overview on sample generation for biological testing (for details, see WP1).

	Fractionation of polymer particle samples	**Leachates containing chemicals liberated from polymers**
Polymers tested	PET, LDPE; Keyboard	PP, PS, PET, PE; Keyboard, E-waste
Generated at	IKTS (WP1)	SU (WP1)
Weathering set up and parameters	Covered beakers, illumination with UV lamps from above 28 days, shaking In MilliQ water Dark control, t0 control 	Quartz glass tubes rotating around UV lamp (weathering wheel), seawater 5 days 
Characteristics	By wet sieving, the following size fractions were generated: <140 µm, <60 µm, <40 µm, <20 µm, <1.2 µm ("particle-free leachate")	Chemicals in the seawater leachates were enriched by solid-phase extraction, extracts were dosed into bioassays
Bioassays	*Daphnia magna* 48 h Immobilisation assay in miniaturized format (24 well, 5 neonates / 1.5 ml of medium) *Scenedesmus vacuolatus* 24 h growth inhibition assay in miniaturized format (96 well plates)	*Daphnia magna* 48 h Immobilisation assay in miniaturized format (24 well, 5 neonates / 1.5 ml of medium) *Scenedesmus vacuolatus* 24 h growth inhibition assay in miniaturized format (96 well plates) Cell-based reporter gene bioassays
Hypothesis	Different size fractions of particles generated during weathering affect organisms differently	Substances (or mixtures thereof) deliberated from the polymer backbone exert toxic effects in organisms
Remark	PP and PS were not tested because the fractionation protocol was not applicable to these materials.	Polymers low in additive content were used to account for degradation products

In general, particles and their size fractions showed no or little effects in the biotests. However, for all types of tested polymers, an uptake into the gut tract of *Daphnia magna* was observed (Figure 10).

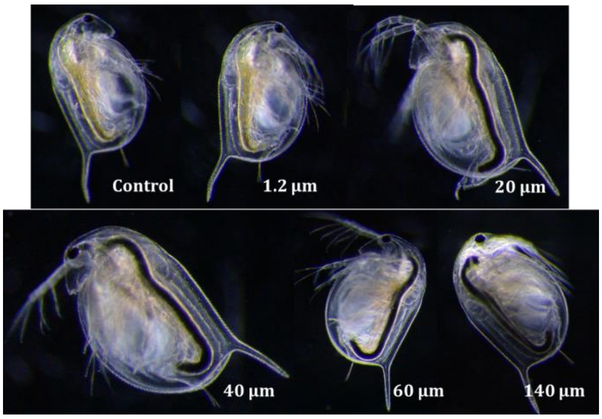

Figure 10. Weathered particles from keyboard sample. Neither of the size fractions affected the mobility of daphnids, but particles from all size fractions were internalized. In contrast, control daphnids and those exposed to the <1.2 µm fraction (considered as particle-free leachate), showed a green coloration of the gut from the feed, green algae.

E-waste plastic leachates had strong effects on algal growth and photosynthesis, while PE showed a slight and PS and PET no inhibition. In addition, the leachates of UV-weathered PE showed a slight trend to affect algal growth more than non-weathered leachates (Figure 11).

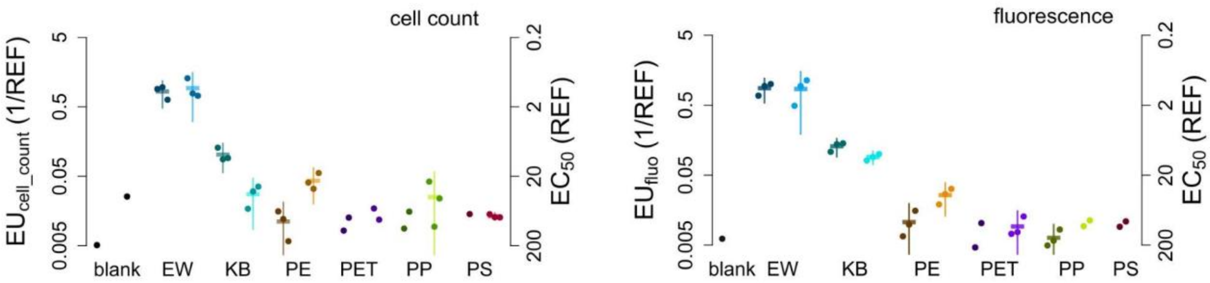

Figure 11. Effect units (EU = 1/EC$_{50}$) and effect concentrations (EC$_{50}$) (dark symbols – dark control, DC; light symbols – UV-exosure) tested in a high-throughput algal assay with two endpoints (cell count / fluorescence.).

We summarized the current knowledge on plastic-biofilm interactions and their implications for the fate of microplastic in the environment in a review article (Rummel et al., 2017). Three main topics were addressed in consecutive experimental work:

To identify the effect of weathering of plastic on biofilm succession, a microcosm experiment was performed using UV-aged and pristine plastic sheets (PET, PS, glass control). The early biofilm stages between 1-3 days seemed to be driven by highly variable attachment processes when analyzing the community composition based in 16S rDNA. Interestingly, the community composition became more similar with prolonged duration of the experiment. After 32 days of incubation no differences between the different polymeric materials (PET and PS) and the control glass material, as well as between UV-weathering and dark weathering treatments could be observed (Figure 12). Furthermore, the relevance of partitioning processes between the plastic, water and the biofilm was addressed since plastic may potentially act as a source or sink of hydrophobic organic contaminants. The sorption of a model herbicide (terbuthylazin) to PE sheets was recorded as a kinetic uptake in the PE and depletion in the water phase using solvent extractions followed by LC-MS analysis (Figure 13). The PE/water partition constant of terbuthylazine was determined to be log $K_{\mathrm{PE/water}}$ = 1.9 $\mathrm{L_w/kg_{PE}}$.

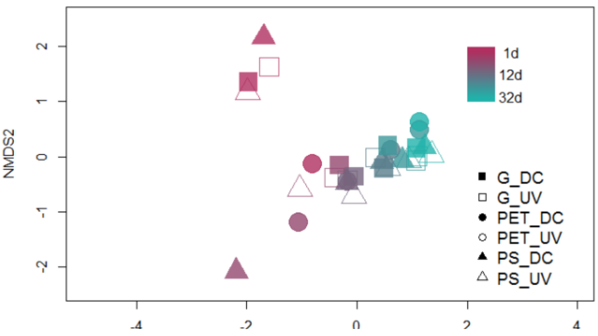

Figure 12: Nonmetric multidimensional scaling plot (NMDS) of the 16S Amplicon sequencing data for biofilms grown on dark control (DC) and UV-weathered (UV) Glass (G), PET and PS sheets.

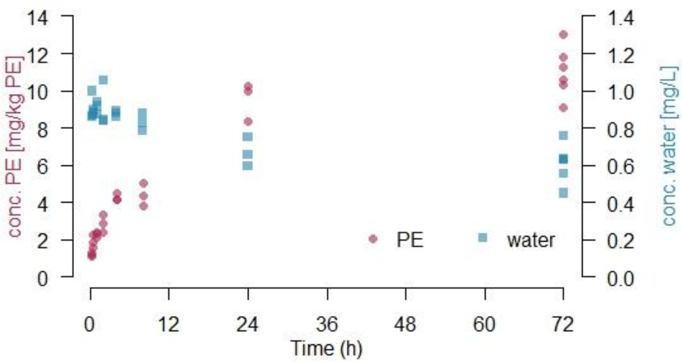

Figure 13. Kinetic uptake of terbuthylazine into PE sheets (red) determined by LC-MS. Concurrently the depletion in the water phase (blue) can be observed over time.

In a last step, we investigated if PE acted as a source of terbuthylazine to biofilms of different pre-adaptations to the toxicant by applying the concept of pollution-induced community tolerance (PICT). Our hypotheses were 1) that pre-adapted biofilms show higher tolerance to settle on a PE surface that leaches terbuthylazine and 2) that leaching of terbuthylazine from PE may affect the photosynthetic activity of the pre-adapted communities less compared to control biofilms grown without stressor. Our results showed that PE can act as a source of terbuthylazine to the water and can cause negative effects in biofilms. Control biofilms showed an effect concentration (EC_{50}) of 41.4 µg/L while the pre-adapted PICT biofilms showed a slightly higher EC_{50} of 81.5 µg/L indicating a small but non-significant PICT response.

Cell-based reporter gene bioassays

Leachates of UV-weathered microplastic and dark controls in artificial seawater were generated at SU. They included PE, PET, PS and PP as well as two positive controls: a sample of e-waste (EW, known to contain a large variety of pollutants) and a new keyboard (KB, expected to contain additives such as flame retardants). In addition, a variety of different blanks was prepared. The extracts were dosed into a range of cell-based reporter gene bioassays, covering different endpoints: cytotoxicity, activation of metabolic enzymes (arylhydrocarbon receptor, AhR, and peroxisome proliferator activated receptor gamma, PPARγ) and adaptive stress responses (oxidative stress, AREc32). The effects that the samples elicited were assessed relative to a specific potent reference chemical (Rummel et al, 2019). The dosed amounts are given as relative enrichment factors (REFs) on the basis of the enrichment factor of the extraction and the bioassay dilution factor. From the data we derived effect concentrations at 10 % of the maximum effect of the reference compound (EC_{10}) which can be transformed into bioanalytical effect units ($EU_{bio} = 1/EC_{10}$).

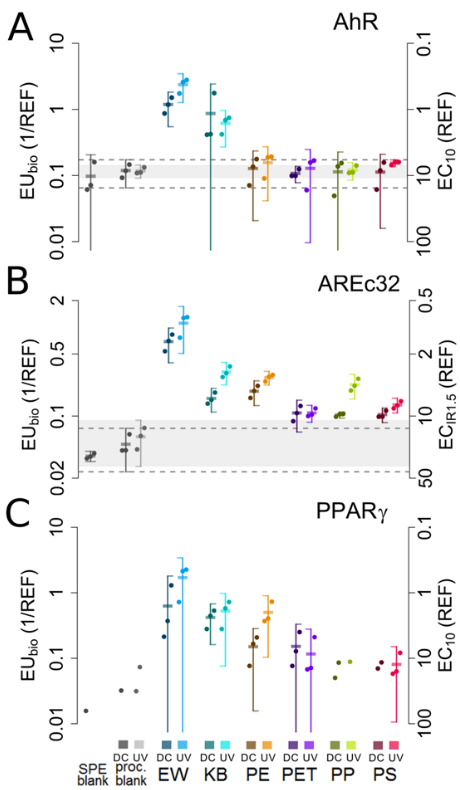

Figure 14. Bioanalytical effect units (EU_{bio}) defined as the inverse EC_{10} (1/REF on left y-axis, REF on right y-axis), measured for SPE blanks, procedural blanks, two positive controls (EW and KB) and the four test polymers PE, PET, PP and PS in the cell-based bioassays AhR (A), AREc32 (B) and PPARγ (C). Dark controls (DC) and UV-treated (UV) samples are presented in darker and lighter shades of the different colors.

The results are given in Rummel et al. (2019). They indicated that the "pure" polymers often did not elicit effects distinguishable from the blanks, whereas the positive controls showed clear effects and hence provided proof-of-concept of the approach. However, high enrichment factors were needed to observe any effects. These data suggest that the polymers themselves may be less problematic than additives or pollutants being sorbed during field exposure, but further testing is necessary.

WORK PACKAGE 7: ESTIMATION OF ENVIRONMENTAL RISK POSED BY VIRGIN AND WEATHERED MICROPLASTIC AND THEIR LEACHATES (LEAD: DR. D. KÜHNEL, UFZ)

Objectives

- To combine data on microplastic exposure and fate from WP1-5 with effect data obtained in WP6;
- To provide estimations on environmental risk posed by weathered microplastic;
- To provide knowledge on the most critical properties of microplastic particles after the weathering process (such as shape, roughness, most toxic fraction).

The main aims of WP7 were to provide estimations on the environmental risk posed by microplastic affected by weathering processes. Upon release into the environment, plastic items change constantly due to external influences (UV light, turbulence, abrasion, ingestion by organisms), and particle properties are modified in an ongoing process (e.g. size, brittleness, hydrophobicity). To estimate the environmental risk posed by microplastic hence requires taking into account these constantly ongoing modifications of plastic particles, acquire knowledge on the relevant processes and finally characterize effects in environmental organisms by weathered microplastic and other degradation products (Jahnke et al., 2017). Hence, results from the WEATHER-MIC project on the different aspects of weathering are brought together and related to current data from the growing body of scientific literature (that, however, mostly deals with studies on pristine, unweathered particles). A white paper is in preparation, which will give a synopsis of the impact of weathering on microplastic exposure, fate and hazard; for a summary, see Table 2.

Table 2. Summary of the aspects that were specifically considered:

Exposure / Fate	• Parameters leading to particle fragmentation and polymer degradation (physical, chemical, biological) • Leaching of additives and polymer degradation products • Adsorption of contaminants during residence time in the environment • Time scales of weathering in the environment: when does relevant transformation occur? • Methods of exposure assessment: bias in sampling and subsequent preparation for analysis
Hazard	• Biological effects of plastic fragments, polymer degradation products and absorbed contaminants in different species • Triple role of biofilms: protection of polymers from weathering / change in community composition due to polymers / change in particle size distribution, bulk density and settling (e.g., as marine snow) • Role of microplastic internalization • Particle size fractions and biofilm coatings: relevance of prey size for internalization
Challenges for risk assessment	• Impact of weathering on exposure estimation (dosimetry): how to deal with shift to higher particle numbers the smaller the size gets • No-effect studies • Dosimetry: different dose metrics (mass-based, number-based)

The most prominent findings from the WEATHER-MIC project are described in the WP1-6 reports. As not all experiments are finalized and data evaluation is ongoing, final conclusions on the impact of weathering on microplastic risk are under development. However, several future research needs regarding microplastic weathering have already been identified. One of the most important research needs concerns the time scales of weathering in different marine environments (e.g. coastal regions, surface water, deep sea), as our laboratory experiments showed a slow rate of fragmentation. With regard to polymer degradation products, so far identification of compounds was in the focus of investigation, but for risk assessment also quantification is needed. Concerning the leaching of additives from the polymer matrix, literature data indicate that weathering increases release rates, but not the total amount of liberated additives. Hence, the current data indicate that for risk assessment the total amount of released additives over time can be estimated from the amount of polymers released into the environment.

Furthermore, the ongoing degradation of substances in the leachates as a continuous process after liberation from the polymer needs to be taken into account for risk assessment. Estimation of microplastic hazard is hampered by the different metrics that are used in the studies (particle number-based or mass-based), by the predominance of studies on spherical microplastic particles and by the often high concentrations in effect studies that exceed environmental levels by several orders of magnitude. As for environmental sampling there is a large variety in sampling methods that exclude certain size fractions, and thus it remains at present difficult to compare the microplastic load in various areas and different environmental compartments.

WORK PACKAGE 8: PROJECT MANAGEMENT, DISSEMINATION, COMMUNICATION AND OUTREACH (LEAD: DR. A. JAHNKE, UFZ)

Objectives

- To develop a dialog between the partners to facilitate scientific discussion, collaboration and maximize synergies from the experimental planning stage to the paper and report writing stage;
- To establish a project website to maximize outreach of the conducted research to a range of target audiences, providing regularly updated information for the target groups of i) scientists, ii) regulators and other stakeholders and iii) the general public;
- To identify key stakeholders in the participating countries (e.g. regulatory authorities, environmental interest groups, teachers) and develop good communication formats (such as white papers, press releases, teaching materials).

This WP aimed at enhancing the interaction and synergies between the partners, with overall progress meetings taking place twice a year, with several smaller meetings in between. Skype meetings proved to be very effective to coordinate the work, enhance discussion, avoid duplication and maximize synergies. An additional aspect was facilitating exchange and discussion across consortia, which was further enhanced by a range of JPI Oceans conferences and meetings at conferences. The WEATHER-MIC project website was established and updated regularly; it can be accessed at: http://jpi-oceans.eu/weather-mic/about. In the section ”Publications”, both papers and scientific posters are shown. The section “Multimedia and education” contains videos that can be used in the classroom to test and/or demonstrate the floating and sinking behavior of plastic particles according to their density and the sinking of low-density microplastic fibers with turbulence. The section “Newsroom and links” features the major outcomes of our recent WEATHER-MIC stakeholder workshop, informs about the participation of WEATHER-MIC scientists in the Race for Water Odyssey, and gives the annual Stakeholder Reports. In addition, NGI has added a website on the WEATHER-MIC project that can be accessed at: https://www.ngi.no/eng/Projects/WEATHER-MIC-microplastics-in-the-marine-environment.

The WEATHER-MIC partners have established contact with both local and European stakeholders:

- European Commission (James Gavigan, Johannes Klumpers) / Science Advice Mechanism (SAM)
- JRC - MSFD Technical Group on Marine Litter (Georg Hanke)
- German Federal Environment Agency (Claus-Gerhard Bannick)
- Plastics Europe (Ingo Sartorius, Anne-Gaelle Collot)
- Goodfellow (Paul Everitt)
- ExxonMobil (Miriam Paumen, Aaron Redman)
- Continental (Maximilian Steinmetz)
- HELCOM Secretariat (Marta Ruiz)
- HELCOM Coordinator (Setälä Outi)
- ICES (Adi Kellermann)
- OSPAR (John Mouat)
- Norwegian Environment Agency (Hannah Hildonen)
- PTJ (Uwe Selig)
- HaV Coordinator (Johanna Eriksson)
- Naturskyddsföreningen (Andreas Prevodnik)
- Håll Sverige Rent (Eva Blidberg)

- Norwegian Environment Agency (Thomas Hartnik, Hannah Hildonen)
- Port of Oslo (Heidi Neilson)
- Flemish Institute for Agriculture and Fisheries (Johan Robbens)
- Flemish Environmental Agency (Lieve Jorens)
- Flemish Environmental Agency (Saskia Vangaever)
- Flemish Marine Institute (Jan Mees)
- VITO (Els Knaeps)
- OVAM (Annelies Scholaert)
- Aquafin (in charge of Flemish water treatment infrastructure) (Greet Degueldre)
- Race for Water Odyssey (Kim van Arkel)
- Pacific Garbage Screening (Tilman Floehr)
- The OceanCleanp (Matthias Egger)
- JPI-Oceans Secretariat (Willem De Moore, Isabelle Schulz)
- JPI-Oceans MP project coordinators (Gunnar Gerdts, Andy Booth, Ricardo Beiras)
- Related MP project MikrOMIK and MICROPOLL (Sonja Oberbeckmann)
- University Lecturer teaching a course about artists' perception of MP in the oceans (Roman Kroke)

We have sent annual newsletters to the stakeholders to inform them of the progress we have made and give them the opportunity of commenting on our ongoing research. These newsletters were also published on the WEATHER-MIC website at http://www.jpi-oceans.eu/weather-mic/news-room-links-weather-mic. In addition, we held a Stakeholder Workshop at KU Leuven on March 21, 2019, that was attended by about 20 participants from industry, policy making and science sectors. The workshop covered representatives of Norner Research, ExxonMobil, the European Commission, TG Environmental Research, the JPI Oceans Secretariat, OVAM, VITO, Pacific Garbage Screening and the University of Antwerp, in addition to the WEATHER-MIC consortium. We used the workshop to present key results of WEATHER-MIC and to set them into context in three keynote lectures with subsequent discussions. The outcomes were future research needs and their ranking, based on the different perspectives of the workshop participants. Based on these, we created a poster (comic, Figure 15) that is published on our website. Future research should move towards more realistic weathering scenarios for plastic litter, addressing emission sources, hot spots, and coastal zones, where microplastic pollution can best be managed.

Figure 15: Graphical output of the Stakeholder Workshop, focused on pupils in primary and secondary school.

IMPACT - OUTCOME

The WEATHER-MIC consortium has contributed to regulations, policies and management practices. One example is comments provided on the Position Paper by the Marine Strategy Framework Directive Technical Group on Marine Litter (MSFD TG-ML), while other contributions included a presentation at the JPI Oceans Side-Event to the UN Ocean Conference, "Multilateral science-policy processes generating the evidence to underpin SDG implementation", recommendations to the Swedish Chemicals Agency, to the Norwegian Scientific Committee for Food and Environment and to ICES.

A Short Course has been organized at the SETAC YES Conference, Stockholm, Sweden, in February 2017: “The ecotoxicology of plastic marine debris” led by E. Gorokhova, M. Ogonowski and Z. Gerdes. WEATHER-MIC has allowed for hiring two PhD students, Christoph Rummel (UFZ) and Kathrin Oelschlägel (IKTS). Furthermore, PhD students Berit Gewert, Zandra Gerdes, Asa Motiei and Sophia Reichelt (all SU) worked part-time within WEATHER-MIC. At KUL, Qilong Bi worked as a postdoctoral fellow related to WEATHER-MIC, and has been replaced by a new PhD student, Samor Wongsoredjo. In total, 10 Master’s, 1 Diploma and 3 Bachelor’s theses have been supervised by members of the WEATHER-MIC consortium.

The WEATHER-MIC consortium contributed with advice and exhibits to the mobile ship container-based exhibition “OceanPlasticsLab” that tours around the world to highlight impacts of plastic pollution in the environment (https://oceanplasticslab.net).

Through the intense research within WEATHER-MIC, we extended the consortium and submitted the proposal μ-PATH to the follow-up call. Furthermore, several follow-up projects have been secured based on the reseach outcomes of WEATHER-MIC as described above. As an example, some partners (UFZ, IKTS, SU) teamed up with new research institutions (IOW, AWI, Senckenberg) for the field-based project MICRO-FATE (“Characterizing the fate and effects of microplastic particles between hotspots and remote regions in the Pacific Ocean”) funded by the German Federal Agency for Education and Research (BMBF, 2019-2021), collecting plastic material in the North Pacific Garbage Patch and more remote regions in the Pacific Ocean on the research vessel SONNE. The project (https://blogs.helmholtz.de/on-tour/) will investigate the distribution, fate and effects of plastic debris and how it is impacted by weathering in the field.

In addition, methods developed during WEATHER-MIC by NGI to quantify microplastic in sediments have been used so far in two commercial projects by the NGI. The NGI is now offering this analysis in its catalogue of laboratory services. The collaboration between the Race for Water Odyssey and WEATHER-MIC was coordinated by Hans Peter Arp (NGI). Activities included:

- Attending the launch of the Race for Water Odyssey vessel, 7-9 April, 2017. Hans Peter Arp presented JPI Oceans, WEATHER-MIC and EPHEMARE at a news conference and gave several interviews to French and Swiss media.

- Sampling in Cuba, 2-7 August. Here we used the Race for Water Odyssey platform to collect microplastic samples along the Havana coast in collaboration with CEAC (Centro de Estudios Ambientales de Cienfuegos, Figure 11). Further, workshops and interviews with local media were held to raise local awareness regarding MPs.

Figure 16: Top left: Hans Peter Arp (L) with Marco Simoeni (R), president of the Race for Water foundation at the launch in Lorient, France; top right: Carlos Alonso-Hernandez (CEAC), Linn Merethe Brekke Olsen (NGI) and Hans Peter Arp during the Cuban sampling campaign; bottom left: the Race for Water and NGI team in Cuba, Havana. All photos © Peter Charaf / Race for Water

Contributions to social media and interactions with the general public

- Several contributions to Researchers' Nights events in Sweden and Germany
- Best paper of the year 2017 in Environ. Sci. Technol. Letters: https://pubs.acs.org/doi/10.1021/acs.estlett.8b00158
- Blog www.liviajosephine.de; Interview on marine plastic pollution, Christoph Rummel (in German) https://www.liviajosephine.de/2017/12/03/nachgefragt-welche-folgen-kann-plastikmuell-in-den-meeren-verursachen/

- Contributions on twitter.com: see search term" weather-mic" as well as #WEATHERMIC, and https://twitter.com/MattMacL/status/930433953403670528
- Interviews with citizens in relation to the Arts & Science project "Microplastic & Medusea" jointly at the Berlin University of the Arts and the Technical University Berlin (UFZ), http://roman-kroke.de/de/themes/microplastic-and-medusae/
- JPI Oceans announcement: http://www.jpi-oceans.eu/news-events/news/jpi-oceans-microplastics-projects-join-race-water-odyssey
- Race for water interview: http://odyssey.raceforwater.org/operation-weather-mic-a-cuba/?lang=en
- Race for water testimony: https://waterguardianexperts.thewaternetwork.com/post-FfV/hans-peter-arps-testimony-about-the-race-for-water-scientific-platform-CN0taZP7PiqZ22sf-VPhaQ
- Aftenposten (in Norwegian): https://www.aftenposten.no/norge/i/02bmJ/Forskerne-jobber-pa-spreng-for-a-finne-svar-Kan-mikroplast-gi-oss-hormonforstyrrelser
- Forskning.no: http://forskning.no/2017/03/nar-mikroplast-blir-en-del-av-naeringskjeden/produsert-og-finansiert-av/norges-geotekniske-institutt
- Youtube: Educational videos about plastic settling and sampling microplastic in Havana, WEATHER-MIC channel at: https://www.youtube.com/channel/UCjsxzEt2KsPZ8Z_4oqrDTtA
- Race for water youtube: https://www.youtube.com/watch?v=EjNwf6-BCwE
- Three interviews in the Swedish radio programs "Vetenskapsradion" (http://sverigesradio.se/sida/artikel.aspx?programid=406&artikel=6757600), "Klotet" and local radio, where Martin Ogonowski talked about MPs as emerging contaminants
- Blog www.ikts.fraunhofer.de; Interview on plastic in the ocean , Kathrin Oelschlägel (in German) https://www.ikts.fraunhofer.de/de/blog/plastik_im_meer.html
- OCEAN PLASTIC LAB Opening in Berlin, October 2018 (press conference, interviews) Dana Kühnel (in German)

Contributions to regulation, policies and management practices

- Participation of Elena Gorokhova in the reference group (Swedish EPA) working on microplastic as emerging environmental contaminants, their sources and effects. Two meetings have taken place (2016 and 2017) with involvement in reviewing of the governmental report on the status of microplastic pollution and developing a strategy to combat this issue in Sweden.
- Participation of Elena Gorokhova in the Water conference (Swedish EPA) to discuss microplastic issues with environmental managers.
- As an invited speaker, Martin Ogonowski talked about microplastic as emerging contaminants at the University of Gothenburg School of Business Economics and Law. The audience consisted of Swedish journalists, county administrative board representatives and other national authorities.

CONCLUSION

During the runtime of WEATHER-MIC, we made substantial progress in the following areas, which give valuable information to policy making and risk assessment:

- fingerprinting of polymers based on LC/HRMS as an alternative method for polymer identification
- identification and measurement of surface characteristics impacted by weathering
- measurement and modeling of sinking velocities of plastic material (with UV/vis aging, biofilm)
- 3D modeling of the distribution of plastic material in two reference areas
- effects of aggregation on the fate and effects of plastic debris

- impact of weathering on effects elicited by particles, particle fractions and leachates in cell- and organism-based bioassays
- accounting for weathering effects in risk assessment.

Our results indicate that weathering is an essential factor to take into consideration when assessing the fate and hazards arising from plastic pollution in the environment. Overall, the results of the project indicated that weathering processes affecting the particle size distribution of microplastic and the leaching of additives require the most attention. Of particular importance is biofilm-assisted aggregation of all size fractions to facilitate the formation of, e.g., marine snow, and fragmentation processes for smaller microplastic or in areas with heavy turbulence, like coastal areas. Seasonal (e.g., during the spring bloom) and coastal processes are therefore of particular importance for follow-up studies, along with further research on deep sea sediments, as many fate processes end with sediment accumulation, alongside nano/colloidal fraction accumulation in the water column.

Regarding the hazards, the internalization of plastic and the role of leachates are central to our understanding, and in particular how they differ from the hazards of natural particles. The clearest weathering-related hazard identified so far was related to hazardous substance additives in plastic, which are more substantial than hazards from pure polymer degradation products identified thus far. While our laboratory-based studies gave a good indication of the relevant processes of weathering and its impacts on the fate and distribution of plastic, we acknowledge that extrapolation of our accelerated artificial weathering in the laboratory to real-world conditions is challenging. Part of this challenge arises from the complex interplay of impacting factors which is a strong function of local factors and seasonality, amongst others. Initial modeling work we have done shows promise; however, field valication is hampered by lack of sufficient data for the most relevant parameters. Hence our recommendation is to carry out further research with field-weathered material and at environmentally relevant levels, along with field-relevant microplastic, in different settings, particularly at emission hot spots like coastal zones and riverine outflow areas, in order to further improve the accuracy of risk assessment for specific sites and conditions.

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Gewert, B., et al., 2018. Identification of Chain Scission Products Released to Water by Plastic Exposed to Ultraviolet Light. Environmental Science & Technology Letters. 5, 272-276.

Gorokhova, E., et al., 2018. Alterations in swimming behavior of Daphnia exposed to polymer and mineral particles: towards understanding effects of microplastics on planktonic filtrators. bioRxiv 406587, 10.1101/406587.

Jahnke, A., et al., 2017. Reducing Uncertainty and Confronting Ignorance about the Possible Impacts of Weathering Plastic in the Marine Environment. Environmental Science & Technology Letters.

Lee, B. J., et al., 2011. A two-class population balance equation yielding bimodal flocculation of marine or estuarine sediments. Water Research. 45, 2131-2145.

McGivney, E., et al., in prep. Physico-chemical changes in microplastic induced by biofilm formation.

Ogonowski, M., et al., 2018. Evidence for selective bacterial community structuring on microplastics. Environmental Microbiology. 20, 2796-2808.

Rummel, C. D., et al., 2019. Effects of Leachates from UV-Weathered Microplastic in Cell-Based Bioassays. Environ. Sci. Technol. . just accepted.

Rummel, C. D., et al., 2017. Impacts of Biofilm Formation on the Fate and Potential Effects of Microplastic in the Aquatic Environment. Environmental Science & Technology Letters. 4, 258-267.

Shen, X., et al., 2018a. A tri-modal flocculation model coupled with TELEMAC for estuarine muds both in the laboratory and in the field. Water Research. 145, 473–486.

Shen, X., et al., 2018b. Biophysical flocculation of suspended particulate matters in Belgian coastal zones. Journal of Hydrology. 567, 238-252.

Shen, X., et al., 2019a. An approach to modeling biofilm growth during the flocculation of suspended cohesive sediments. J. Geophysical Research – Oceans. in press.

Shen, X., et al., 2019b. Simulating multimodal floc size distributions of suspended cohesive sediments with lognormal subordinates: Comparison with mixing jar and settling column experiments. Coastal Engineering. 148, 36-48.

Toorman, E., et al., in prep. On the settling behavior of microplastic particles.

PART B - STATISTIC REPORT

This section summarizes the scientific and popular science output of WEATHER-MIC.

LIST OF SCIENTIFIC QUALIFICATIONS (PHD, MSC AND BSC THESES)

Theses

- Ernst, S. (Master, KUL, 2016), on the implementation of a flocculation model in the (open source) TELEMAC-3D software (www.openTELEMAC.org).
- Pfeiffer, J. (Master, TU Dresden, at IKTS and UFZ, 2016) on characterization and fractionation of weathered microplastic.
- Arb, J. (Master, University of Rostock, at UFZ, 2016-2017): Development of experiments on microplastic for students in the UFZ Students' Laboratory.
- Svensson-Grape, L. (Bachelor, Stockholm University, 2016-2017): Secondary microplastics' effect on food consumption and behaviour of Daphnia magna.
- Brekke Olsen, L.M. (Master, University of Bergen, extended summer student at NGI, 2017): Measuring the sinking behavior of microplastics and developing methods to quantify microplastic in organic-rich sediment samples.
- Mahat, S. (Master, NMBU, at NGI, 2017): Separation and quantification of Microplastics from Beach and Sediment samples using the Bautamicroplastic-sediment separator. https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2459114?locale-attribute=en
- Könnecke, O. (Master, Stockholm University, 2017): Biofilm-mediated effects on swimming behaviour of Daphnia magna exposed to microplastics.
- Puuranen, M. (Master, Stockholm University, 2017): A comparison between the effects of polylactic acid and polystyrene microplastics on Daphnia magna.
- Roman, C. (Bachelor, Stockholm University, 2017): Microplastic aggregation and the influence of biofilm.
- Mines, L. (Bachelor, Stockholm University, 2017): Application of plastic beads in feeding experiments: how classical methods can inform current ecotoxicological studies on microplastics?
- Gewert, B. Chemical Pollutants Released to the Marine Environment by Degradation of Plastic Debris. PhD Thesis, Department of Environmental Science and Analytical Chemistry, Stockholm Sweden, 2018. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1201270&dswid=3482
- Engström, V. Nedbrytning av olika plaster i akvatiska miljöer. Diploma Thesis. Stockholm University, Sweden 2018.
- Lilleeng, Ø. The presence of microplastics on the Norwegian Continental Shelf and in Rio Almendares, Havana. MSc Thesis. NMBU, Norway 2018. https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2570085.
- Singdahl-Larsen, S. Sediment core profiles of microplastics in Oslo harbor, Norway. MSc Thesis. University of Oslo, Norway 2019, in preparation.
- ERASMUS student Pedro Nunes (visiting student, University of Aveiro, Portugal, at UFZ, 2019): Effects of chemicals deliberated during plastic weathering on *Daphnia magna*.

- Hanna Schäfer (UFZ, 2018-2019): Chemical partitioning of the herbicide Terbuthylazin in a three phase polyethylene, water and biofilm system - a PICT approach (internship and Master's thesis).

LIST OF PUBLICATIONS

Peer-Reviewed Scientific Papers

1. Rummel, C. D.; Adolfsson-Erici, M.; Jahnke, A.; MacLeod, M. No Measurable "cleaning" of Polychlorinated Biphenyls from Rainbow Trout in a 9 Week Depuration Study with Dietary Exposure to 40% Polyethylene Microspheres. *Environmental Science: Processes & Impacts* **2016**, 18, 788–795.
2. Gewert, B.; Ogonowski, M.; Barth, A.; MacLeod, M. Abundance and Composition of near Surface Microplastics and Plastic Debris in the Stockholm Archipelago, Baltic Sea. *Marine Pollution Bulletin* **2017**, 120, 292–302.
3. Jahnke, A.; Arp, H. P. H.; Escher, B. I.; Gewert, B.; Gorokhova, E.; Kühnel, D.; Ogonowski, M.; Potthoff, A.; Rummel, C.; Schmitt-Jansen, M.; et al. Reducing Uncertainty and Confronting Ignorance about the Possible Impacts of Weathering Plastic in the Marine Environment. *Environmental Science & Technology Letters* **2017**, 4, 85–90.
4. Rummel, C.D.; Jahnke, A.; Gorokhova, E.; Kuehnel, D.; Schmitt-Jansen, M. Impacts of Biofilm Formation on the Fate and Potential Effects of Microplastic in the Aquatic Environment. *Environmental Science & Technology Letters* **2017**, 4, 258–267.
5. Potthoff, A.; Oelschlägel, K.; Schmitt-Jansen, M.; Rummel, C.D.; Kühnel, D. From the sea to the laboratory: Characterization of microplastic as prerequisite for the assessment of ecotoxicological impact. *Integrated Environmental Assessment and Management* **2017**, 13, 500–504.
6. Gewert, B.; Plassmann, M.; Sandblom, O.; MacLeod, M. Identification of Chain Scission Products Released to Water by Plastic Exposed to Ultraviolet Light. *Environmental Science & Technology Letters* **2018**, 5, 272–276.
7. Ogonowski, M.; Gerdes, Z.; Gorokhova, E. What we know and what we think we know about microplastic effects – A critical perspective. *Current Opinion in Environmental Science & Health* **2018**, 1, 41–46.
8. Ogonowski, M.; Edlund, U.; Gorokhova, E.; Linde, M.; Ek, K.; Liewenborg, B.; Könnecke, O.; Navarro, J.R.G.; Breitholtz, M. Multi-level toxicity-assessment of engineered cellulose nanofibrils in Daphnia magna. *Nanotoxicology* **2018**, 12, 509–521.
9. Ogonowski, M.; Motiei, A.; Ininbergs, K.; Hell, E.; Gerdes, Z.; Udekwu, K.I.; Bacsik, Z.; Gorokhova, E. Evidence for selective bacterial community structuring on microplastics. *Environmental Microbiology* **2018**, 8, 2796–2808.
10. Shen, X.; Joon Lee, B.; Fettweis, M.; Toorman, E.A. A tri-modal flocculation model coupled with TELEMAC for estuarine muds both in the laboratory and in the field. *Water Research* **2018a**, 145, 473–486.
11. Shen, X.; Toorman, E.A.; Joon Leeb, B.; Fettweis, M. Biophysical flocculation of suspended particulate matters in Belgian coastal zones. *Journal of Hydrology* **2018b**, 567, 238–252.
12. Gorokhova, E., Könnecke, O., Ogonowski, M., Gerdes, Z., Wiklund, A.E. Alterations in swimming behavior of Daphnia exposed to polymer and mineral particles: towards understanding effects of microplastics on planktonic filtrators. *bioRxiv* **2018a**, 406587. doi:10.1101/406587
13. Gerdes, Z., Hermann, M., Ogonowski, M., Gorokhova, E.. A serial dilution method for assessment of microplastic toxicity in suspension. *bioRxiv* **2018b**, 401331. doi:10.1101/401331
14. Shen, X., Toorman, E.A., Lee, B.J., Fettweis, M. Simulating multimodal floc size distributions of suspended cohesive sediments with lognormal subordinates: Comparison with mixing jar and settling column experiments. *Coastal Engineering* **2019a**, 148(6): 36-48, https://doi.org/10.1016/j.coastaleng.2019.03.002.
15. Shen, X., Toorman, E.A., Lee, B.J., Fettweis, M. An approach to modeling biofilm growth during the flocculation of suspended cohesive sediments. *J. Geophysical Research – Oceans* **2019b**. (Paper #2018JC014493RR), in press.
16. Gerdes, Z., Ogonowski, M., Nybom, I., Ek, C., Adolfsson-Erici, M., Barth, A., Gorokhova, E. Microplastic-mediated transport of PCBs? A depuration study with Daphnia magna. *PLoS ONE* **2019**, 14: e0205378. doi:https://doi.org/10.1371/journal.pone.0205378
17. Gerdes, Z., Hermann, M., Ogonowski, M., Gorokhova, E. A novel method for assessing microplastic effect in suspension through mixing test and reference materials. *Scientific Reports* **2019**; available online at www.nature.com/articles/s41598-019-47160-1
18. Carreres-Calabuig, J.A., Rogers, K.L., Gorokhova, E., Posth, N.R. Micro-by-micro interactions: how microbial communities influence marine plastic fate. *Limnology and Oceanography: Letters* **2019**; accepted.
19. Rummel, C.D., Escher, B.I., Sandblom, O., Plassmann, M.M., Arp, H.P.A., MacLeod, M., Jahnke, A. Effects of Leachates From UV-Weathered Microplastic in Cell-Based Bioassays. *Environmental Science & Technology*, ASAP, DOI: 10.1021/acs.est.9b02400

LIST OF CONFERENCE PRESENTATIONS

Contributions to Conferences

1. MacLeod, M.; Arp, H.P.H.; Gorokhova, E.; Toorman, E.; Potthoff, A.; Schmitt-Jansen, M.; Kühnel, D.; Jahnke, A. "WEATHER-MIC. How microplastic weathering changes its transport, fate and toxicity in the marine environment" at the "MICRO2016 - Fate and Impact of Microplastics in Marine Ecosystems: From the Coastline to the Open Sea" meeting, Lanzarote, Spain, May 2016
2. Gerdes, Z.; Ek, C.; Ogonowski, M.; Garbaras, A.; Adolfsson-Erici, M.; Gorokhova, E. PCB depuration via MP? A feeding experiment with Daphnia magna. Poster presentation MICRO, Lanzarote 2016
3. Jahnke, A. "WEATHER-MIC - How MICroplastic WEATHERing changes its transport, fate and toxicity in the marine environment" overview presentation at the Annual Science Conference of the International Council for the Exploration of the Sea (ICES) in Riga, Latvia, September 2016
4. Rummel, C.D., Adolfsson-Erici, M.; Jahnke, A.; MacLeod, M. "No measurable "cleaning" of polychlorinated biphenyls from Rainbow Trout in a 9-week depuration study with dietary exposure to 40% polyethylene microspheres" at the SETAC German Language Branch (GLB), Tübingen, Germany, September 2016
5. Rummel, C.D., Adolfsson-Erici, M.; Jahnke, A.; MacLeod, M. (2016). "No measurable "cleaning" of polychlorinated biphenyls from Rainbow Trout in a 9-week depuration study with dietary exposure to 40% polyethylene microspheres" at the 7th late summer workshop on Microplastic, Haltern am See, Germany, September 2016
6. Oelschlägel, K.; Potthoff, A. Conference: "7th Late summer Workshop on Microplastics in the aquatic environment" in Haltern am See (Germany); poster title: "Characterization of microplastics"
7. Oelschlägel, K.; Potthoff, A. Conference: "MWAS 2016" in Mülheim an der Ruhr (Germany); poster title: "Weathering of Microplastics"
8. Gerdes, Z.; Ogonowski, M.; Adolfsson-Erici, M.; Gorokhova, E. Effects of MP exposure combined with contaminant accumulation on life history traits. SETAC, Orlando 2016
9. Ogonowski, M.; Gerdes, Z.; Gorokhova, E. Microplastic mediated transport of persistent organic pollutants in Daphnia magna – an evaluation of a toxicokinetic model using experimental data. SETAC, Orlando 2016
10. Pfeiffer, J.; Oelschlägel, K.; Potthoff, A. Development of Characterization Methods for Nanoplastics and Application in Risk Assessment. SETAC YES meeting. Stockholm. 16.-20.02.2017.
11. Rummel, C.; Kühnel, D.; Schmidt, M.; Schmitt-Jansen, M. The Effect of Weathering Processes of Synthetic Polymers on Biofilm Formation. SETAC YES meeting. Stockholm. 16.-20.02.2017.
12. Brekke Olsen, L.M.; Berrojalbiz, N.; Issler, D.; Arp, H.P.H. The sinking behavior of microplastics. The influence of weathering on MP aggregation and settling. Miljøringen, Oslo. 16.03.2017.
13. Arp, H.P.H. Metodikk for kvantifisering av mikroplast. Avfallsforsk, Yearly meeting and workshop. Oslo. 27.04.2017.
14. Potthoff, A.; Oelschlägel, K.; Schmitt-Jansen, M.; Rummel, C.D.; Kühnel D. From the sea to the laboratory: Characterization of microplastic as prerequisite for the assessment of ecotoxicological impact. SETAC Europe meeting. Brussels. 07.-11.05.2017.
15. Brekke Olsen, L.M.; Berrojalbiz, N.; Issler, D.; Toorman, E.; Arp, H.P.H. The Sinking Behavior of Fresh and Weathered Microplastics in Surface Water. International Conference on Chemistry and the Environment. Oslo. 19.06.2017.
16. Ogonowski, M.; Wenman, V.; Bignert, A.; Danielsson, S.; Gorokhova, E. Abundance of ingested microplastic is not correlated to HOC concentrations in Baltic Sea herring. Conference on Environmental Science and Technology. Rhodes. 31.08.-02.09.2017.
17. Gorokhova, E.; Könnecke, O.; Ogonowski, M.; Gerdes, Z.; Eriksson-Wiklund, A.-K. Alterations in swimming behavior of Daphnia exposed to polymer and mineral particles: towards understanding effects of microplastics on planktonic filtrators. Conference on Environmental Science and Technology. Rhodes. 31.08.-02.09.2017.
18. Oelschlägel, K.; Potthoff, A. Imitating the weathering of microplastics in the marine environment. µMED International Conference on Microplastic Pollution in the Mediterranean Sea. Capri. 26.-29.09.2017. In: Cocca, M.; Di Pace, E.; Errico, M.; Gentile, G.; Montarsolo, A.; Mossotti, R. (eds) Proceedings of the International Conference on Microplastic Pollution in the Mediterranean Sea. ISBN: 978-3-319-71278-9. Springer Water. Springer, Cham.
19. Rummel, C. D., A. Jahnke, E. Gorokhova, D. Kühnel, Arp, H.P.H.; Schmitt-Jansen, M. Impacts of Biofilm Formation on the Fate and Potential Effects of Microplastic in the Aquatic Environment. BMBF – Fördermaßnahme "Plastik in der Umwelt; Quellen, Senken, Lösungsansätze" Kickoff Meeting Berlin. 17./18.10.2017.
20. Arp, H.P.H. Vertical transport of microplastics and quantification in sediment. Norsk Selskap for Farmakologi og Toksikologi fall meeting. Oslo. 19.10.2017.

21. Jahnke, A.; MacLeod, M.; Arp, H.P.H.; Potthoff, A.; Toorman, E. WEATHER-MIC - How MICroplastic WEATHERing changes its transport, fate and toxicity in the marine environment. JPI Oceans conference. Lisbon. 26.10.2017.
22. Jahnke, A.; Arp, H.P.H.; Escher, B.I.; Gewert, B.; Gorokhova, E.; Kühnel, D.; Ogonowski, M.; Potthoff, A.; Rummel, C.D.; Schmitt-Jansen, M.; Toorman, E.; MacLeod, M. Reducing Uncertainty and Confronting Ignorance about the Possible Impacts of Weathering Plastic in the Marine Environment. JPI Oceans conference. Lisbon. 26.10.2017.
23. Gewert, B.; Plassmann, M.M.; Sandblom, O.; MacLeod, M. Identification of chemicals released by weathering plastic materials. JPI Oceans conference. Lisbon. 26.10.2017.
24. Arp, H.P.H.; Brekke Olsen, L.M.; Berrojalbiz, N.; Issler, D.; Toorman, E. The Influence of Weathering on the Sinking Behavior of Microplastic. JPI Oceans conference. Lisbon. 26.10.2017.
25. Oelschlägel, K.; Potthoff, A. Imitating the weathering of microplastics in the marine environment. JPI Oceans conference. Lisbon. 26.10.2017.
26. Gerdes, Z.; Ogonowski, M.; Gorokhova, E. How do we know that microplastics are different from natural particles in their effects on biota? JPI Oceans conference. Lisbon. 26.10.2017.
27. Rummel, C.D.; Jahnke, A.; Kühnel, D.; Gorokhova, E.; Schmitt-Jansen, M. Impacts of Biofilm Formation on the Fate and Potential Effects of Microplastic in the Aquatic Environment. JPI Oceans conference. Lisbon. 26.10.2017.
28. Arp, H.P.H.; Brekke Olsen, L.M.; Lilleeng, Ø.; Mahat, S.; MacLeod, M.; Alonso-Hernandez, C.; Jahnke, A. WEATHER-MIC Outreach Activities. Poster. JPI Oceans conference. Lisbon. 26.10.2017.
29. Jahnke, A.; Arp, H.P.H.; Escher, B.I.; Gewert, B.; Gorokhova, E.; Kühnel, D.; Ogonowski, M.; Potthoff, A.; Rummel, C.D.; Schmitt-Jansen, M.; Toorman, E.; MacLeod, M. Reducing Uncertainty and Confronting Ignorance about the Possible Impacts of Weathering Plastic in the Marine Environment. SETAC North America Meeting. Minneapolis. 12-16.11.2017.
30. Toorman, E.; Bi, Q.; Shen, X.; Wongsoredjo, S.; Arp, H.P.H.; Issler, D. Modelling microplastics dispersal: anthropogenic cohesive particles and their fate in coastal waters. International Conference on Cohesive Sediment Transport Processes INTERCOH. 13.-17.11.2017.
31. Arp, H.P.H. Sedimenteringsprosesser av mikroplast / biofilmbærere av mikroplast og relevans for tiltak. Norsk vannforening seminar, Miljødirektoratet Oslo. 15.01.2018.
32. Arp, H.P.H. Hva skjer når plast fra tunnelbransjen havner i havet? Tekna - Tunneldagene 2018, Thon Hotel Arena, Lillestrøm. 11.04.2018.
33. Gerdes, Z. et al. How do we know that microplastics are different from natural particles in their effects on biota? Poster TU172; SETAC Europe 28th Annual Meeting, Rome, Italy, 13.-17.05.2018.
34. Gerdes, Z. et al. Exposure to conventional but not biodegradable microplastics impacts fitness in Daphnia magna Poster TU178 SETAC Europe 28th Annual Meeting, Rome, Italy, 13.-17.05.2018.
35. Jahnke, A.; Rummel, C.D.; Kühnel, D.; Schmitt-Jansen, M., Escher, B.I.; MacLeod, M. Weathering-induced changes in the effects of microplastic particles and their leachates. Poster at the SETAC Europe 28th Annual Meeting, Rome, Italy, 13.-17.05.2018.
36. Arp, H.P.H.; Brekke Olsen, L.M.; Issler, D.; Berrojalbiz, N.; Oelschlägel, K.; Potthoff, A.; Wongsoredjo, S.; Shen, X.; Toorman, E. The Influence of Weathering on the Sinking Behavior of Microplastic in Freshwater and all Surface Waters. SETAC Europe 28th Annual Meeting, Rome, Italy, 13.-17.05.2018.
37. Arp, H.P.H.; Knutsen, H.; Brekke Olsen, L.M.; Issler, D.; Berrojalbiz, N.; Oelschlägel, K.; Potthoff, A.; Wongsoredjo, S.; Shen, X.; Toorman, E. The Influence of Weathering on the Sinking Behavior of Microplastic in Freshwater and all Surface Waters. Emcon Oslo, 26.06.2018.
38. Arp, H.P.H.; Knutsen, H.; Wade, E.J.; Brekke Olsen, L.M.; Mahat, S.; Lilleeng, Ø. Quantification of microplastic in sediments from benthic and coastal environments. Nordrocs 2018 Copenhagen, Helsingør, Denmark, 05.09.2018.
39. Arp, H.P.H.; Brekke Olsen, L.M.; Lilleeng, Ø.; Mahat, S.; Alonso-Hernández, C. Microplastics in Havana and the Solar-powered Race For Water Odyssey. Norwegian Water Society Meeting, Oslo, 24.10.2018.
40. Oelschlägel, K.; Potthoff, A. Surface charge – An important parameter to evaluate the interactions of microplastics with environmental substances. Microplastics 2018 – Nano and microplastics in technical and freshwater systems. Ascona. 28.-31.10.2018
41. McGivney, E. et al. Physicochemical properties and toxicity of micro- and nano-plastics: a meta-analysis of weathering effects. Quasimeme workshop on microplastics – 27.-28.11.2018. Amsterdam.
42. Jahnke, A.; MacLeod, M.; Arp, H.P.H.; Potthoff, A.; Toorman, E. WEATHER-MIC – how microplastic weathering changes its transport, fate and effects in the marine environment. JPI Oceans conference. Lanzarote. 20.11.2018
43. Toorman, E.; Arp, H.P.H.; Gorokhova, E.; Issler, D.; Oelschlägel, K.; Potthoff, A.; Wongsoredjo, S.; Shen, X.; Hussenot, M.; McGivney, E. The influence of weathering on the sinking behavior of microplastic. JPI Oceans conference. Lanzarote. 20.11.2018

44. Rummel, C.; Jahnke, A.; Gewert, B.; Plassmann, M.; Sandblom, O.; MacLeod, M.; Escher, B.I. Chemical Identification and Effects of Leachates from Weathered Microplastic in Cell-Based Bioassays. JPI Oceans conference. Lanzarote. 20.11.2018
45. Gerdes, Z.; Hermann, M.; Puuranen, M.;Ogonowski, M.; Gorokhova, E. Ecological relevance of microplastic effect testing with a focus on weathering. JPI Oceans conference. Lanzarote. 20.11.2018
46. Pettersen, A.; Arp, H.P.H. The cost/information issue of MP quantification. JPI Oceans conference. Lanzarote. 20.11.2018
47. Potthoff, A.; Oelschlägel, K. Advanced particle characterization and weathering-induced changes (WEATHER-MIC). JPI Oceans conference. Lanzarote. 20.11.2018
48. Schmitt-Jansen, M.; Rummel, C.D.; Kallies, R.; Kühnel, D.; Jahnke, A. Impacts of Biofilm Formation on the Fate and Potential Effects of Microplastic in the Aquatic Environment. JPI Oceans conference. Lanzarote. 20.11.2018
49. Plassmann, M.M.; Gewert, B.; Sandblom, O.; MacLeod, M. Acute toxicity screening in Nitocra spinipes. JPI Oceans conference. Lanzarote. 20.11.2018
50. Oelschlägel, K.; Potthoff, A. The Relevance of Particle Characterization for Microplastic in the environment. JPI Oceans conference and MICRO 2018. Lanzarote. 19.-23.11.2018
51. Kühnel, D.; Rummel, C.D.; Schäfer, H.; Jahnke, A.; Kallies, R.; Oelschlägel, K.; Potthoff, A.; Schmitt-Jansen, M. Biological Effects of virgin and weathered Microplastic Particles and their Leachates. JPI Oceans conference and MICRO 2018. Lanzarote. 19.-23.11.2018
52. Wongsoredjo, S.; Toorman, E.A. Three-dimensional numerical simulation of microplastics dispersal from point sources in the Baltic Sea region. JPI Oceans conference and MICRO 2018. Lanzarote. 19.-23.11.2018
53. Gerdes, Z. et al. Exposure to conventional but not biodegradable microplastics decreases fitness in Daphnia magna. In: Baztan J., Bergmann M., Carrasco A., Fossi C., Jorgensen B., Miguelez Q., Pahl S., Thompson R.C., Vanderlinden J-P. (Eds.) 2018, MICRO 2018. Fate and Impact of Microplastics: Knowledge, Actions and Solutions. 414 pp. MSFS-RBLZ. ISBN 978-84-09-06477-9.
54. Toorman, E., Arp, H.P., Gorokhova, E., Issler, D., Oelschlagel, K., Potthoff, A., Wongsoredjo, S., Hussenot, M., Mcgivney, E. (2018). Towards improved predictions of dispersal of weathering microplastics in the aquatic environment by numerical modelling. In: Baztan J., Bergmann M., Carrasco A., Fossi C., Jorgensen B., Miguelez A., Pahl S., Thompson R.C., Vanderlinden J-P. (Eds.), MICRO 2018. Fate and Impact of Microplastics: Knowledge, Actions and Solutions. MSFS-RBLZ. ISBN 978-84-09-06477-9.
55. Cyvin, J.; Knutsen, H.; Møskeland, T.; Pettersen, A.; Arp, H.P.H. Microplastics in polychaetes from the Norwegian continental shelf. Methods for determination and preliminary results from analysis. Micro2018, Lanzarote, Spain, 19-23.11.2018.
56. Nybakk A.W., Arp, H. P., Knutsen, H., Olsen, L.M., Mahat, S. Wade, E.J., Lilleeng, Ø., Issler, D., Berrojalbiz, N. Pettersen, A., Oelschlägel, K., Potthoff, A., Wongsoredjo, S., Shen, X., Toorman, E., Laugesen, J., Møskeland, T. The sinking behavior of microplastic and their presence in various coastal environments. 11th International SedNet conference, Dubrovnik, Croatia, 03.-05.04.2019.
57. Arp, H. P., Knutsen, H., Olsen, L.M., Mahat, S. Wade, E.J., Lilleeng, Ø., Laugesen, J., Møskeland, T. The sinking behavior of microplastic and their presence in various coastal environments. Vatten och sediment, Mikroplaster och PFAS "Mikroplast i sediment fra Arktis til Tropene". Renare Marks Vårmöte, Arlanda Sweden, 20.-21.03.2019.
58. Arp, H. P., Knutsen, H., Olsen, L.M., Mahat, S. Wade, E.J., Lilleeng, Ø., Issler, D., Berrojalbiz, N. Pettersen, A., Oelschlägel, K., Potthoff, A., Wongsoredjo, S., Shen, X., Toorman, E., Laugesen, J., Møskeland, T. Microplastic in Sediments from the Arctic to the Tropics. Batelle 2019 Sediment Conference, New Orleans, USA, 11.-14.02.2019.
59. Kühnel, D., Rummel, C.D., Schäfer, H., Jahnke, A., Oelschlägel, K., Potthoff, A., Schmitt-Jansen, M., Biological Effects of virgin and weathered Microplastic Particles and their Leachates in the green algae Scenedesmus vacuolatus. SETAC 2019, Helsinki, 27.5.-30.5.2019.
60. Jahnke, A., Kühnel, D., Schmitt-Jansen, M., MacLeod, M., Gorokhova, E., Potthoff, A., Toorman, E., Arp, H.P.H. Weathering impacts on the fate of plastic debris in the marine environment. SETAC 2019, Toronto, 3.11.-7.11.2019 (accepted platform).

LIST OF NON-SCIENTIFIC, POPULARIZED PUBLICATIONS

Reports

1. Arp, H.P.H.; Knutsen, H.; Pettersen, A.; Huse, J.; Laugesen, J.; Møskeland, T. Microplastics in sediments on the Norwegian Continental Shelf II: Identification through FT-IR analysis. Miljødirketoratet Report M-1231/2018. Report No.: 2018-1226, Rev. 00 M-1231/2018, Document No.: 231601.
2. Arp, H.P.H.; Knutsen, H.; Cyvin, J.; Pettersen, A.; Huse, J.; Laugesen, J.; Møskeland, T. Microplastics in polychaetes from the Norwegian Continental Shelf, Miljødirektoratet. Report M1222/2018,

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Policy contributions

1. Jahnke, A. "WEATHER-MIC - How MICroplastic WEATHERing changes its transport, fate and toxicity in the marine environment" at the ICES ASC meeting, Riga, Latvia, 21/9-2016.
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3. Gorokhova, E.; Ogonowski, M.: A contribution at the national level, spring-summer 2018. Swedish Chemicals Agency. We provided scientifically based recommendations regarding the national proposal on microplastics ban in cosmetic products. The ban is active from 1 July 2018 (Förbud mot mikroplaster i hygien- och skönhetsprodukter; 2017/18:3895).
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6. Jahnke, A.: Provided comments on the Position Paper by the Marine Strategy Framework Directive Technical Group on Marine Litter (MSFD TG-ML), October – December 2018.

Press releases

1. Arp, H.P.H. et al.: R&D program WEATHER-MIC - microplastics in the marine environment https://www.ngi.no/eng/Projects/WEATHER-MIC-microplastics-in-the-marine-environment
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Interviews

Interview published in the KU Leuven newspaper Campuskrant (Dutch & English): https://nieuws.kuleuven.be/en/content/2019/ku-leuven-weather-mic-hydraulics-engineers-microplastics. Its main message (in Dutch) published by the Belgian national news agency Belga in their news overview of April 11, 2019.

LIST OF WORKSHOPS, STAKEHOLDER MEETINGS (ETC)

WEATHER-MIC Stakeholder Workshop at KU Leuven, March 21, 2019 (described in detail in WP8)

LIST OF PUBLIC ACTIVITIES - FLYERS, BROCHURE, VIDEO/FILM

WEATHER-MIC factsheets (JPI Oceans Secretariat)

Videos on YouTube (Lab demonstrations and Field work: https://www.youtube.com/channel/UCjsxzEt2KsPZ8Z_4oqrDTtA)

Race for Water: WEATHER-MIC Cuba mission. Articles, interviews and videos. https://www.raceforwater.org/en/the-race-for-water-foundation/learn/weather-mic/)

LIST OF SOCIAL MEDIA ACTIVITIES

Poster for primary and secondary schools (http://www.jpi-oceans.eu/weather-mic/multimedia-education-weather-mic); Twitter activities (See search term" weather-mic" as well as #WEATHERMIC)

As a result of the 2015 call for research proposals 'Microplastics in the marine environment', four projects (BASEMAN, EPHEMARE, PLASTOX and WEATHER-MIC) were funded under the framework of JPI Oceans by the following ministries and funding agencies:

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Bundesministerium für Bildung und Forschung

Marine Institute Foras na Mara

MIUR MINISTERO DELL'ISTRUZIONE DELL'UNIVERSITA' E DELLA RICERCA

NWO Netherlands Organisation for Scientific Research

The Research Council of Norway

FCT Fundação para a Ciência e a Tecnologia

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

FORMAS

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