JPI OCEANS

Key Results Microplastics Projects

Suggested Reference:
Diaz, K., Kandziora, J., Kiefer, T., De Moor, W., Beck, A., Brandt, L., Regoli, F., Sempéré, R., Vollertsen, J., Ziveri, P. (2024). Key Results JPI Oceans Microplastics Projects. Brussels, Belgium.
DOI: https://dx.doi.org/10.48470/95

Authors:
Kelly Díaz, JPI Oceans secretariat
Jella Kandziora, JPI Oceans secretariat
Thorsten Kiefer, JPI Oceans secretariat
Willem De Moor, JPI Oceans secretariat
Aaron Beck, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Germany (coordinator of project HOTMIC)
Luca Brandt KTH, Royal Institute of Technology, Sweden (coordinator of project microplastiX)
Francesco Regoli, Polytechnic University of Marche, Italy (coordinator of project RESPONSE)
Richard Sempéré, Université d'Aix-Marseille, France (coordinator of project ANDROMEDA)
Jes Vollertsen, Aalborg University, Denmark (coordinator of project FACTS)
Patrizia Ziveri, Universitat Autònoma de Barcelona, Spain (coordinator of project i-plastic)

Design: Raluca Dumitrache, JPI Oceans secretariat

Funding for the projects was provided under the framework of JPI Oceans by:

belspo

CONFAP
Conselho Nacional das Fundações Estaduais de Amparo à Pesquisa

Estonian Research Council

Republic of Estonia
Ministry of the Environment

anr agence nationale de la recherche

Bundesministerium für Bildung und Forschung

Marine & Freshwater Research Institute

Foras na Mara
Marine Institute

An Roinn Tithíochta, Rialtais Áitiúil agus Oidhreachta
Department of Housing, Local Government and Heritage

MUR
Ministero dell'Università e della Ricerca

Xjenza Malta

The Research Council of Norway

Ministerio de Ciencia, Innovación y Universidades
Agencia Estatal de Investigación

fct Fundação para a Ciência e a Tecnologia

FORMAS

Ministry of Education and Science Republic of Latvia

Innovation Fund Denmark

JPI OCEANS KEY RESULTS MICROPLASTICS PROJECTS

TABLE OF CONTENTS

Photo credit: © Flyd Mu

1.0 EXECUTIVE SUMMARY

Plastic production, use and disposal keep increasing, and with it, the presence of microplastics in the aquatic environment. Removing such tiny particles from the environment is difficult, resulting in their ongoing ultimate accumulation in the ocean. Although we do not yet fully understand the ecological effects of microplastics, it is increasingly evident that they are widespread throughout the environment, even found within human bodies, and generally go along with negative impacts.

Currently, no specific regulations are addressing microplastics in foodstuffs or food safety. Overall, few regulations suggest concrete limits or thresholds for microplastics and few established methods exist for measuring them, nor are there regulations for removing them from wastewater sludge. By funding research projects, JPI Oceans has contributed to furthering the current understanding of the ecological aspects of microplastics in the marine environment, as a basis to put in place science-based regulatory measures.

The projects funded though JPI Oceans have confirmed that estuaries, as transition zones between land and ocean, are key pathways for microplastic pollution into the ocean, with significant contamination linked to urban wastewater and rivers impacted by human activities. Additionally, coral reefs have been identified as microplastic sinks and hotspots for plastic pollution. Researchers also discovered that both household laundry and the textile industry contribute to microfibres in wastewater sludge at a concerning scale. Remarkably, microplastics can also spread from sea to air through sea spray.

In the ocean, animals in the mesopelagic layer function as a "plastic pump", transporting microplastics deeper into the ocean. On the seafloor, macrofauna further contributes to the burial of these particles into sediments. While copepods and crabs can partially reject or excrete microplastics, fish—especially in estuaries—often ingest large amounts. Many species consumed by people contain nanoplastics - tiny plastic particles that can penetrate biological membranes and tissues. Moreover, not only do microplastics pose a threat, but so do the organisms that attach to them. For instance, viruses that attach to and grow on microplastics can spread far and harm aquaculture species intended for human consumption.

To promote solutions, the projects developed predictive models to identify litter hotspots, which can guide the strategic placement of trash bins and potentially reduce beach waste by half. They also published best practices for analysing microplastics in clean water. Uptake of scientific knowledge, implementation of possible solutions, and formulation of adaptive regulations requires that the research and innovation efforts are complemented with targeted communication and dissemination to decision makers and other stakeholders. This approach aims to contribute to oceanic, environmental and ultimately human health and to defying the threats of unabated microplastics pollution.

2.0 INTRODUCTION

Plastic plays a crucial role in our daily lives, yet plastic litter and debris is a substantial environmental and economic worry. Every year, around 4.8 to 12.7 million metric tonnes of plastic end up in the world ocean, resulting in approximately 50 trillion microplastic particles floating on the surface.[1] These smaller micro- and nanoplastics particles come from the fragmentation and weathering of larger plastic items, such as synthetic textiles, tyres, and marine coatings, and are currently impossible to capture once released into the environment. Microplastics pollution stems from three main sources: the breakdown of larger abandoned, discarded, or improperly disposed plastics; intentionally added microplastics in products like cosmetics; and unintentional releases during product use or handling.[2]

Beginning in 2013, the member countries of the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) foresaw the growing threat of microplastics to ecological health well before it gained widespread attention. Accordingly, JPI Oceans launched a first transnational joint call in 2014 as part of the Joint Action "Ecological Aspects of Microplastics in the Marine Environment", one of its initial thematic activities. A second call followed in 2018, supported by thirteen JPI Oceans member countries, plus Latvia and Brazil. Six new projects were selected for funding to conduct research on micro- and nanoplastic sources, identification methods, and effects on marine ecosystems:

• ANDROMEDA - Analysis techniques for quantifying nano-and microplastic particles and their degradation in the marine environment

Coordinator: Dr. Richard Sempéré, Université d'Aix-Marseille, France

• HOTMIC - Horizontal and vertical oceanic distribution, transport, and impact of microplastics

Coordinator: Dr. Aaron Beck, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Germany

• FACTS - Fluxes and Fate of Microplastics in Northern European Waters

Coordinator: Prof. Jes Vollertsen, Aalborg University, Denmark

• MicroplastiX - Integrated approach to the fate of Microplastics towards healthy marine ecosystems

Coordinator: Prof. Luca Brandt, KTH Royal Institute of Technology, Sweden

• I-PLASTIC - Dispersion and impact of micro- and nano- plastics in the tropical and temperate oceans: from regional land-ocean interface to the open ocean

Coordinator: Prof. Patrizia Ziveri, Universitat Autònoma de Barcelona, Spain

• RESPONSE - Towards a risk-based assessment of microplastic pollution in marine ecosystems

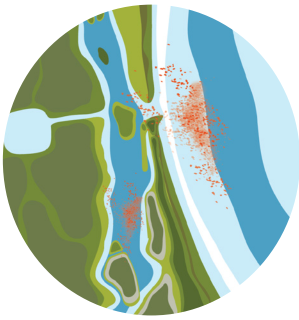
Coordinator: Prof. Francesco Regoli, Polytechnic University of Marche, Italy

This brochure summarises the key findings from these six projects of the JPI Oceans second joint call on marine microplastics, presenting their insights in an accessible format while maintaining scientific accuracy.

Photo credit: © Nick Russill

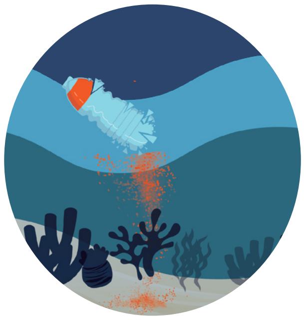
KEY INSIGHTS

Sinks and sources



Estuaries are gatekeepers for channeling land-based plastics into the ocean. The high rainfall season causes a 10-fold increase in remobilised microplastic concentrations in river plumes in Brazil, which are then carried vast distances to the open ocean by currents, tides, and waves.

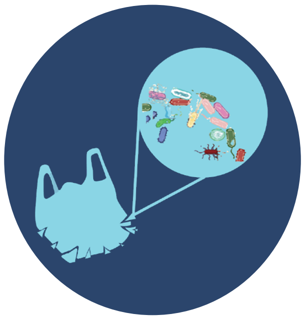
The seafloor acts as the ultimate sink for microplastics. Ocean currents, turbulent mixing, and biological transport processes lead to sinking of microplastics and their accumulation in seafloor sediments. Microplastics was found in estuary sediments deposited in the 1960s, rising sharply in concentration since then.

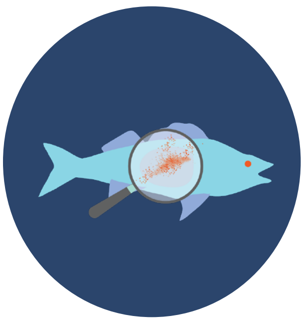


Microplastics can enter the atmosphere through sea spray. Breaking waves cause bubbles which burst and release the contained microplastics particles into the air. This makes the ocean not just a microplastics sink but also a source to the atmosphere.

Health and harm

The plastisphere on microplastics hosts diverse communities of organisms, including harmful bacteria, invasive worms, and dinoflagellates. Microplastics particles offer these organisms a substrate for growth and vector for distribution, with implications for ecosystems and human health.





Tuna was found to be highly contaminated with microplastics, primarily from ingesting polluted prey. **Fish meal** was also found to contain up to 100 mg of microplastics per kg, consumed by fish when fed in aquaculture. **Copepods,** on the other hand, managed to reject 80% of microplastics upon contact with their mouthparts.

Nanoplastics pose serious risks due to their small size which allows them to penetrate biological membranes like cells and tissues. On average, every European ingests about 2 mg of nanoplastics per year by eating mussels, which were found to retain ~88% of the plastics particles they consumed.

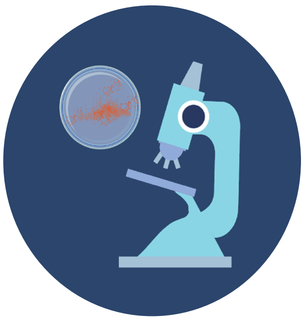
Causes and culprits

Plastic litter at mediterranean island beaches increased fivefold during peak tourist seasons compared to low tourist seasons. Best practice examples showed that pollution control measures and waste management systems succeeded in reducing beach litter by up to half.

Tyre-wear particles (TWP) abrased from road friction contain additives, some of which are toxic. The additives are slowly released into the environment, but high hydrostatic pressure in the deep ocean accelerates chemical leaching, with TWPs still releasing chemicals after a year.

Textiles are a significant microplastics polluter. PET microfibers were most abundant in wastewater sludge from treatment plants in Italy, up to 10 times the amount of polyamides. PET levels reached 1.5 g per kilogram of sludge, an amount released by washing of ca. 1 kg of polyester fabric in a first wash.

Tools and tech



Technological innovations of tools for microplastic analysis pushed boundaries by orders of magnitude towards being able to analyse tinier particle sizes, work at lower concentrations, manage higher throughputs, obtain better precision, lower analytical costs, cope with challenging matrices, and enable to carry out new, efficient types of lab simulations and experimentations.

3.0 POLICY CONTEXT

EUROPE

Although the EU lacks a comprehensive legislation for microplastics, specific laws do exist. Since 2008, the **Marine Strategy Framework Directive (MSFD)** has aimed to maintain clean, healthy, productive, and resilient marine ecosystems, requiring Member States to develop national strategies for "good environmental status". Descriptor 10 of the MSFD specifies that marine litter, including microplastics, should not cause harm.[3]

The European Union's **Zero Pollution Action Plan** aims to reduce plastic litter at sea by 50% and microplastic releases by 30% by 2050.[4] The **EU Mission "Restore our Oceans and Waters"** seeks to achieve tangible outcomes by 2030, focusing on restoring ocean health, protecting marine and freshwater biodiversity and ecosystems, eliminating pollution, and promoting a blue economy.[5]

In 1991, the EU adopted the **Urban Wastewater Treatment Directive** to protect the environment from the harmful effects of wastewater discharges.[6] It mandates wastewater treatment through physical, chemical, and biological processes. However, this directive does not address emerging pollutants like microplastics or microfibres. The European Commission therefore proposed a revised directive in 2022 with broader goals, including the monitoring of microplastics in wastewater sludge.[7]

In 2023, the EU ratified the **REACH** chemical legislation, which restricts intentionally added microplastics in products such as cosmetics, detergents, and toys. This legislation may prevent the release of approximately half a million tonnes of microplastics into the environment and focuses on synthetic polymer particles under 5 mm that are organic, insoluble, and resistant to degradation.[8] A proposal is currently before the European Parliament to address microplastic pollution from unintentional releases of plastic pellets.[9]

WORLD

Globally, the UN General Assembly's Implementation Plan for the **UN Decade of Ocean Science for Sustainable Development 2021–2030** includes Challenge 1 - "Understand and beat marine pollution," which aims to identify and mitigate land and sea-based pollutants.[10]

In 2022, the United Nations Environment Assembly (UNEA) adopted a resolution to create a legally binding international agreement on plastic pollution, covering the entire lifecycle of plastic from production to disposal. The Intergovernmental Negotiating Committee began its work in late 2022, with a goal to finalise the agreement by the end of 2024. This global treaty will address the significant environmental impact of plastic pollution, including microplastics, on marine ecosystems.[11]


Photo credit: ©Tom Fisk

4.0 MICROPLASTICS INTERACTIONS WITH BIOTA

Due to their omnipresence in the marine environment, microplastics—defined by the European Commission as plastic particles smaller than 5 mm[12] —inevitably interact with biota in all ocean regions, from the surface waters, throughout the water column, and at the seafloor. As they move through different marine environments, their interactions with organisms can become increasingly varied and complex.

Biofouling, the accumulation of organisms on surfaces, varies substantially between polymer types.[13] Biofouling can occur in particles closer to the sea surface as in submerged particles. To study this, researchers submerged plastic plates in coastal waters (0.5 to 12 meters deep) and observed polychaete (bristle worms) colonization after just three months.[14]

The plastisphere, composed of epiplastic organisms living on floating plastic forming biofouling communities on microplastics, harbours diverse communities with numerous ecological relationships,[15, 16] and can adsorb pollutants like trace metals.[17] Genetic diversity assessments showed that the plastisphere is diverse and site-dependent.[18] In the plastisphere, researchers have found taxa that can threaten the health of ecosystems and humans, such as bacteria (*Vibrio spp.*), invasive worms (*Hydroides elegans*), dinoflagellates (*Alexandrium spp.*), and even the White Spot Syndrome virus, a pathogen responsible for devastating outbreaks in aquaculture systems.[19 20] This way, microplastics can facilitate the spread of pollutants and pathogens to marine life. Floating plastics can carry them over long distances, while sinking plastics can concentrate pathogens near the seafloor, where filter-feeding animals like clams, mussels, and oysters are more likely to ingest both plastics and pathogens.

Transitioning to the water column, the role of zooplankton as microplastic carriers in the food web was investigated. Zooplankton, particularly copepods—the most abundant group—are crucial to oceanographic processes.

> Studies showed that copepods rejected 80% of microplastics upon contact with their mouthparts.[21]

This find suggests a low risk of microplastic entry into marine food webs through planktonic copepods and minimal trophic transfer potential.[22] However, exposure to tyre-wear particles (TWP) leachates caused mortality in copepods, indicating that while they may avoid ingesting some plastics, they remain vulnerable to other pollutants.[23] Although zooplankton can introduce microplastics into the food web, the quantities found in zooplankton and their faecal pellets are low compared to other marine organisms like mammals, birds, turtles, and fish.[24]

Estuarine fish, particularly opportunistic predators, exhibit elevated contamination rates due to ingesting fibre particles from effluent discharge.[25] High rainfall exacerbates this issue by increasing microplastic concentrations, some of which are similar in size to zooplankton, a crucial food source for fish and other species.[26] Coastal fish species, primarily feeding on mobile invertebrates, also ingest significant amounts of microplastics but at lower levels compared to estuarine fish.[27] In an Iberian Peninsula estuary, nearly all fish sampled had ingested microplastics, marking one of the highest global concentrations per fish.[28] In another study, most fish studied contained microplastics in their muscle and livers, with small particles dominating.[29]

Deep-sea species, traditionally believed to be less vulnerable to microplastic contamination due to their depth, might actually be susceptible to microplastics exposure. The mesopelagic layer of the ocean (200–1000 m depth) is a region with diminishing sunlight, transitioning to complete darkness at greater depths. While solar radiation in this zone is insufficient to support primary production, it harbours remarkable marine biodiversity.[30] This biodiversity plays a crucial role in sequestering carbon, recycling nutrients, and serving as a vital trophic link between primary consumers and organisms higher in the marine food web.[31] Deep-sea species, particularly those inhabiting the mesopelagic zone of the Atlantic Ocean, were found to transfer microplastics from shallow to deeper ocean layers, acting as a "plastic pump".[30 31 32] For example, the Vampire squid, which feeds on marine snow composed of sinking debris and on faecal pellets, exhibited high microplastic contamination. Similarly, mesopelagic fish showed varying contamination rates at different depths, with those in the upper mesopelagic zone (200–500 m) more exposed than those in the zone below (500–1,000 m).[30 31] Lanternfishes, feeding on fish larvae, are particularly prone to ingesting the tiniest microplastic fractions.[30] Interestingly, higher ingestion rates did not correlate with the abundance of microplastics in the water column, as contamination rates in fish along the continental slope were similar to those near ocean islands far from the continent.[37]

Researchers explored the relationship between microplastics and coral reef systems, discovering that reefs are susceptible to becoming major microplastic sinks. Microplastics can accumulate in coral reefs through adhesion to corals, ingestion by organisms, long-term sinks in skeletons and sediments, reduced sediment resuspension and turbulence, and transformation into sedimentary rocks containing microplastics.[33]

> These sinks increase the risk of tropical reefs becoming plastic pollution hotspots, severely impacting these environments.

The negative effects can include reduced coral growth and calcification, diminished immunity enzymes, decreased fertilisation, increased production of mucus, lowered fitness, and adverse effects on coral symbionts.[34] Microplastic pollution, therefore, adds to the growing list of stressors already threatening coral reefs, including prolonged warming, ocean acidification, deoxygenation, and intense heat waves.

The JPI Oceans projects also studied species commonly consumed by humans. Along the Catalan coast, 86% of European hake (*Merluccius merluccius*) and 85% of Norway lobster (*Nephrops norvegicus*) had microplastics or synthetic microfibers in their stomachs.[35 36] Although these microplastics didn't appear to affect the health of these species, the high levels of plastic fibres found both in the environment and in the stomachs *N. norvegicus* suggest that this species could serve as a good indicator of plastic pollution in seafloor areas.[35]

Additionally, a study found that all sampled yellowfin (*Thunnus albacares*) were contaminated with microplastics, primarily through their prey. Of the prey in their stomachs, 70% contained microplastics, with cephalopods and *Bramidae* fish being the most contaminated, indicating that microplastics can be transferred through the food chain.[37]

A study analysing fish meal—used in aquaculture and animal farming—found polystyrene and polyolefins at concentrations ranging from 50 to 100 mg per kg of fish meal, while polyethylene terephthalate (PET) contamination was quantified at 12.9 mg/kg. These findings highlight another potential pathway for microplastic contamination.[38] Additionally, filter-feeding organisms like mussels and sponges ingest significant amounts of microplastics due to their feeding methods and could offer bioremediation potential.* Polychaetes *Sabella spallanzanii* can store ingested microplastics in their tubes, preventing the particles from returning to the environment, and can be used in aquaculture to improve water quality.[39]

The Mediterranean mussels (*Mytilus galloprovincialis*), commonly consumed by humans, retain 88% of ingested microplastics, raising health concerns. While they can reject unwanted particles as pseudofeces and excrete larger particles after three days, smaller particles (5–20 µm) can still be found in their bodies.[39] Experiments with Mediterranean mussels found that both synthetic (polyester and polyamide) and natural (cotton) microfibers disrupt energy production and cause oxidative stress—which can lead to inflammation and weakened immunity. While synthetic microfibers caused more immediate and severe effects, cotton's impacts were delayed but still significant. Notably, these harmful effects persisted even after the mussels were moved to clean water, suggesting remaining vulnerability to future impacts after microplastic exposure.[40]

Although mussels are primary prey for crabs, microplastic levels in green crabs (*Carcinus maenas*) studied in Ria Formosa lagoon in Portugal were found to be lower, suggesting an ability to avoid biomagnification, i.e. the increase in concentration of microplastics or their chemical additives as they move up the food chain.[41] Consequently, higher-level predators tend to have higher concentrations of these substances compared to lower-level organisms.[42] The lower microplastic levels in crabs are likely due to their ability to excrete these particles, indicating that under the circumstances of the study environment, biomagnification for green crabs is not a significant issue.[41]

Peppery furrow shell clams (*Scrobicularia plana*) showed significant protein changes when exposed to polyethylene microplastics with benzo[a]pyrene (BaP)— the most toxic component of oil, commonly found in the ocean from oil spills and atmospheric deposition due to organic material combustion. These protein changes disrupt key functions like glucose metabolism and trigger oxidative stress. When the clams were exposed to microplastics with adsorbed BaP, this caused an even greater shift in protein expression, indicating an increased toxicity from this combination.[43]

Macrofauna that inhabit the ocean floor, such as worms and bivalves, play a crucial role in burying microplastics in the seabed through bioturbation—the disturbance of sediment by living organisms. In experiments, macrofauna led to the burial of 40% of surface microplastics into deeper sediment layers after one week, while seabeds without macrofauna showed that only 10% of microplastics reached deeper layers. This finding indicates that the presence of macrofauna promotes the downward movement of microplastics into the seabed through their burrowing, feeding, and bioirrigation activities.[44] In another study, all sea cucumber specimens collected from the Mediterranean Sea along the Salento Peninsula, Italy, were found to contain microplastics, with no variations observed among different areas.[45]

* The use of microorganisms for the removal of contaminants.

Nanoplastics, defined by the European Commission as materials measuring between 1 nm to 100 nm (0.001–0.1µm),[46] pose a particularly serious risk because their small size allows them to penetrate biological membranes, entering cells and tissues.[47] A study on farmed mussels from a local fish market in the Apulian region of Italy found all mussels contained nanoplastics, primarily ingesting particles between 20 and 200 nm, the smallest size class analysed. This suggests every European consumes on average approximately 2 mg of nanoplastics per year through eating mussel.[46] In marine mussels, ingestion of nanoplastics led to DNA damage, overwhelmed antioxidant defences, and oxidative damage in gills and digestive tissues.[48]

Understanding the interactions between microplastics and biota is crucial for assessing potential health risks to marine organisms and humans through consumption.

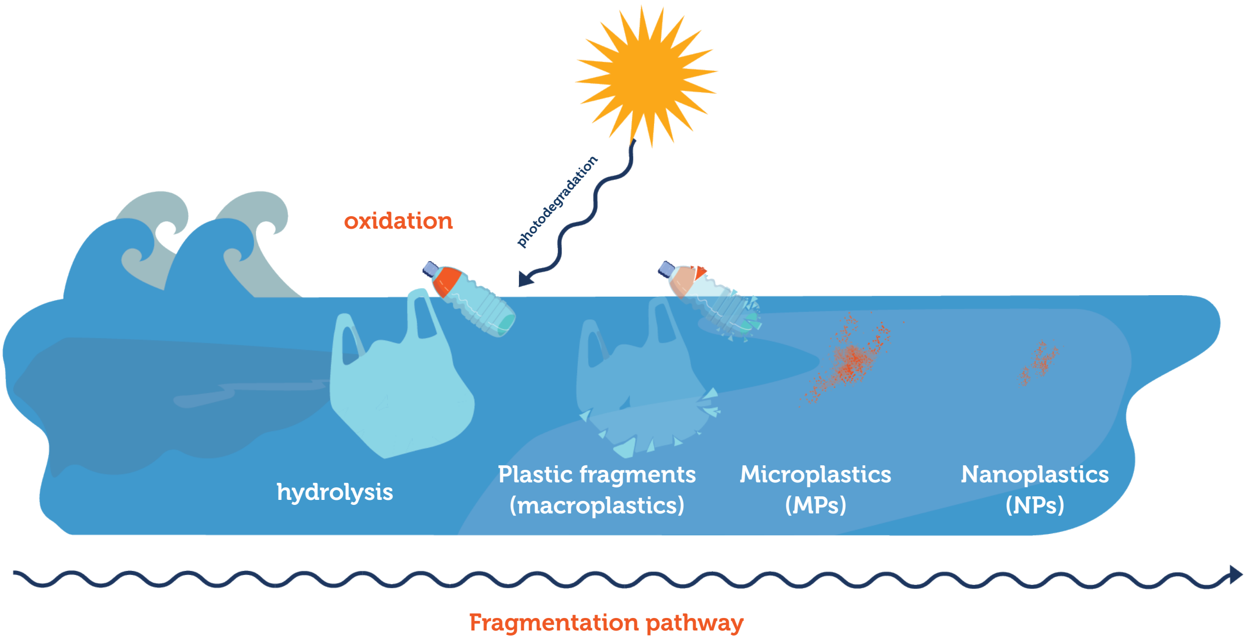
> Currently, no legislation specifically regulates microplastics in foodstuffs and food safety, as ingestion of these synthetic particles is not yet considered a significant threat to human health.[49]

However, growing awareness of the widespread presence of microplastics in marine habitats brings attention to their potential impact.

Research by JPI Oceans projects has advanced our knowledge of microplastics in marine species, highlighting potential risks to ocean ecosystems and human health. As our understanding of the effects of microplastics on marine species, particularly commercially important ones, improves, legislation can be further refined to protect public health.

5.0 MICROPLASTICS DISTRIBUTION: FROM RIVERS AND ESTUARIES TO THE OPEN OCEAN

The projects investigated how microplastics travel through environments such as fjords, estuaries, beaches, and the open ocean. While their widespread presence is well-known, these studies offer fresh insights into how tourism affects microplastic levels on beaches, as well as the concerning presence of microplastics in wastewater sludge, and its potential role in reintroducing these polymers into the environment due to its use as agricultural fertilizer.



The fragmentation process: from plastic items to microplastics and nanoplastics.[50]

In northern marine waters, one study examined the fjord's sea surface microlayer—a natural organic film of <1mm located at the water-air interface containing algae, diatoms, and lipids. Microplastics in the microlayer were typically found at similar abundances as in the underlying top metre of the water column. However, offshore urban and industrial areas, the microlayer contained notably higher concentrations compared to rural regions in the fjord.[51]

Estuaries, like fjords, are transitional zones between land and marine environments and serve as primary channels for terrestrial pollution to enter oceans through rivers. Two studies explored the role of estuaries in transporting land-based pollution to the sea. One study form Brazil found that high rainfall significantly increased microplastics concentration in river plumes, i.e. freshwater from river discharge that spreads over seawater and gradually mixes with the saline ocean water underneath. Researchers measured a tenfold rise during the wet season (45 particles/m^3) compared to the dry season (4 particles/m^3). During low rainfall, microplastic concentration in the bay increased, possibly due to reduced water movement trapping debris nearshore. In contrast, high rainfall increases river flow, flushing debris from the bay into the plume. This may increase the vulnerability of estuarine organisms that feed on zooplankton, as microplastics were found to be similar in size to this food source.[26]

Estuaries, however, are not the final destination for microplastics. Computer simulations showed that estuaries are primary pathways for plastic pollution entering the ocean through river discharge and plumes. While river discharge is the primary mechanism for plume formation, waves can also resuspend sediments from the riverbed. Once in the ocean, plastic particles are carried vast distances by natural forces such as currents, tides, wind, and waves. Researchers tracked particles off Brazil and in the Caribbean, measuring distances of 264 km covered in ~8 days and 7170 km in ~180 days, respectively. These plastics can reach far into the open ocean, serving as potential vehicles for the spread of invasive species that attach to the debris.[52]

Additionally, less dense plastics tend to be transported further offshore, while denser polymers remain near continental sources.[53] Another study of tropical coastal ecosystems found microplastics in all areas. Polypropylene and polyethylene dominated in the estuary, their buoyancy causing them to accumulate before being washed ashore or sinking. In contrast, nylon fibres, likely from fishing gear or estuarine plumes, were more concentrated mid-shelf, highlighting different microplastic movement patterns.[54]

Beaches, other connector between land and the ocean, can become heavily polluted during peak tourist seasons. Litter on Mediterranean island beaches increased around 5-fold during high tourist season, according to data collected over one year.[55] A separate study used a predictive model for litter hotspots to prioritise efforts for effective beach pollution management.[56] Another analysis estimated the potential of proposed pilot actions for reducing beach waste, such as installing new trash bins for recyclable waste, was estimated to be as much as 52.5%.[54]

Research along Germany's Baltic Sea coast revealed seasonal shifts in macro-litter, peaking in early spring before major cleanups and again in late autumn after tourism and cleaning declines. Meanwhile, microplastic levels remained constant throughout the year.[57] A study in a natural park in Tuscany, Italy, revealed significant pollution from polystyrene in sandy beaches, indicating that these low-density particles float and travel from their sources. The highest microplastic concentrations were found in beach dunes, where larger plastic debris is not removed by the cyclic swash action of waves and is prone to further aging and fragmentation.[58]

Managing macro-litter is crucial since plastic debris on beaches degrades into microplastics through processes like solar irradiance, mechanical degradation, and friction with sand, perpetuating irretrievable pollution of the costal and marine environment.[56]

In contrast to the clear seasonal patterns observed with macro-litter on beaches, determining seasonality for microplastic concentrations can be far more complex and context-dependent, especially in ecosystems influenced by a range of environmental and human factors. A study in Ría de Vigo, Spain, showed that coastal microplastic concentrations also exhibit significant seasonal variability, changing unpredictably from month to month, being influenced by factors such as winds, river runoff, upwelling/downwelling periods, and industrial activities. The Ría de Vigo is an ecosystem subjected to a strong human impact: it is Europe's main landing point for fishing, an area of ecological interest, a major focus of tourism, and a busy area of urban and industrial activities that coexist with mollusc aquaculture. Such microplastic seasonal heterogeneity can impact the results of monitoring programmes, highlighting the importance of considering the temporal fluctuations of a specific area in microplastic studies.[59]

Another source of pollution gaining attention is paint particles.

> Paint microplastics are generated through environmental weathering, maintenance, or decommissioning operations and originate from both land-based sources (houses, constructions) and maritime sources (ships, wrecks, and maritime structures).[60]

These particles pose environmental risks due to elements like tin, copper, and zinc. Additionally, the biocides used in maritime paints to prevent marine organism growth on maritime infrastructures can leach into the water, threatening marine life due to their toxicity. Current EU legislations aim to reduce waste from ships, such as Directive 2019/883, which regulates waste discharges from ships in EU ports and ensures adequate port reception facilities.[61] The Biocidal Products Regulation also controls the use of antibiotic biological substances, like antifouling paints used on ship hulls, to protect human health and the environment.[62] However, there is no legislation that explicitly addresses the waste produced by boat paint.

One of the projects studied wastewater sludge—the residue left from water treatment processes—from treatment plants in Tuscany, Italy, revealing PET (polyethylene terephthalate) microfibre concentrations ten times higher than those of polyamides. Microfibers might originate from sources such as textile industry wastewaters, illegal dumping, abandoned fishing gear, and household laundry. In this case, PET levels on wastewater sludge reached up to 1.5 g per kg, significantly higher than the levels of polyamides.[63] This amount is released by washing 0.5 to 1.3 kg of polyester fabric in the first wash, and 3.5 kg in subsequent washes.[64] The results of this study align with global production and consumption patterns, where PET fibres constitute approximately 50% of global textile fibre production, while polyamides account for about 5%.[59]

> The findings underscore the prevalence of these polymers in urban wastewater, highlighting the risks they pose to natural water bodies and the need to address their removal before the sludge is used as fertiliser and brought back into the environment.

The proposed 2022 revision of the EU's 30-year-old Urban Wastewater Treatment Directive (see Policy Context box, page 8), currently under review, aims to modernise regulations by including the monitoring of microplastics in wastewater sludge, with targets to be achieved by 2040.[7]

The MSFD requires the EU's Member States to develop national strategies for monitoring and reporting various aspects of the marine environmental status, including the pollution with marine litter (see Policy Context box, page 8).[3] However, the MSFD does not currently establish limits or thresholds for plastics and microplastics in habitats. Some existing legislation aims to control the amount of microplastics in the environment. For instance, the OSPAR Convention has guidelines for monitoring plastic particles in seabirds. OSPAR assesses plastics in the stomachs of Northern Fulmars (*Fulmarus glacialis*) as an indicator of environmental quality, with a long-term goal of less than 10% of fulmars exceeding a level of 0.1 grams of plastics in their stomachs.[65] Despite this, there is still no set threshold for microplastics in the overall environment.

Photo credit: ©Markus Spikse

6.0 MICROPLASTICS VERTICAL DISPERSION: FROM SEA SURFACE TO SEAFLOOR

In addition to microplastics being transported laterally over long distances and across ocean domains, its vertical dispersion also reveals fascinating dynamics. Less than 1% of the 4.8 to 12.7 million tons of plastic entering the ocean each year stays afloat for a long time. While high-density PET used in bottles and packaging sink rather quickly, the remaining fraction sinks over longer periods of time. Even lighter plastics, such as polyolefins used in single-use items like tableware, eventually sink due to degradation and fouling. Sunlight causes photo-oxidation, breaking the macroplastics into smaller pieces, increasing their density and their ability to absorb water. This process enhances the adsorption and absorption of organic environmental pollutants and promotes biofouling, leading to their sinking and eventual deposition in marine sediments.[66]

Interestingly, the ocean can also release microplastics to the atmosphere via sea spray. This occurs when breaking waves cause trapped air bubbles containing microplastics at the sea surface microlayer to rise and burst, releasing the particles into the atmosphere. The researchers estimated that 136,000 tons of microplastics are released globally into the atmosphere each year through sea spray,[67] which is roughly equivalent to 15 million plastic bottles every day.[** 68] These microplastic particles can be carried onshore and deposited on land or settle somewhere else in the ocean.[63] Supporting these findings, a model created to track atmospheric microplastics transport and dispersion identified both land-based and oceanic re-emissions as significant sources.[69] Therefore, the ocean, once considered only a sink for microplastics, also contributes to its airborne redistribution.

Projects also studied in detail how microplastics disperse vertically in the water column. In the shallow Kattegat/Skagerrak region in the Baltic Sea, microplastics were present at all depths from 0 to 80 meters, predominated by high-density polymers smaller than 300 µm.[70] A study of the large-scale transport of microplastics from Northern Europe to the Arctic found that the vertical distribution of microplastics varied considerably at different depths. Smaller microplastics (<300 µm) were more concentrated in surface (<1 m) and subsurface (~4 m) waters compared to deeper waters (17-1679 m). Notably, the smallest microplastics the study distinguished (<50 µm) constituted over 80% of all detected particles.[71]

In another study, a regional model simulated the release of four plastic types in the Sarno River, southern Italy. Here, biofouling caused polypropylene (PP) and high-density polyethylene (HDPE) particles to sink deeper in summer. Warmer temperatures stimulates faster biofilm growth, which increases sinking rates, an effect that is less pronounced in winter when biofilm growth slows down.

** Assuming the weight of a 1-litre PET bottle designed for containing water is approximately 25 grams.

On the other hand, heavier particles like polyvinyl chloride (PVC) and polystyrene (PS) consistently sank throughout the year. Meanwhile, smaller particles (1 and 0.1 µm) tended to remain suspended in the water column seemingly indefinitely, complicating pollution management.[72]

Buoyant microplastics may remain suspended in surface waters, but ocean currents and turbulent mixing disperse them throughout the water column, leading to their ultimate accumulation in seafloor sediments.[73 74] In Galway Bay, Ireland, high microplastic concentrations in benthic sediments relative to the surface waters confirmed the seafloor as a dominant sink for microplastics.[75] Findings from an Italian Marine Protected Area further highlight this role, with contamination levels of up to 1520 mg of microplastics per kg of sediment.[62] Oxygen exposure oxidises plastics, increases its density and ability to sink, leading to its deposition.[66] Sediment core analysis from the Ebro River delta, Spain, discovered plastics dating back to the 1960s.

> While the types of plastics found did initially not change significantly over time, the total amount has risen sharply, especially since the early 2000s.

After 2006, three types of plastics—polypropylene (PP), polyethylene terephthalate (PET), and polystyrene (PS)—became most common, making up most of the plastic found.[76]

The JPI Oceans projects revealed some peculiar findings while studying tyre-wear particles (TWP), particles formed from friction between roads and vehicle tyres from cars.[77] An analysis of road dust from drain covers at various intersections and roads in Germany showed significant differences between TWP and traditional microplastics. Car TWP were found to be up to 16 times more prevalent than truck TWP, indicating their greater pollution contribution. TWP concentrations in urban areas were substantially higher than those of traditional microplastics (5 g of TWP compared to 0.3 g of traditional MP per kg of road dust). In contrast, traditional microplastics are more mobile and therefore were found also in remote areas where TWP concentrations were low.[78] Higher concentrations of TWP near cities and reduced concentrations farther away indicate different transport behaviours compared to lower-density microplastics.[79]

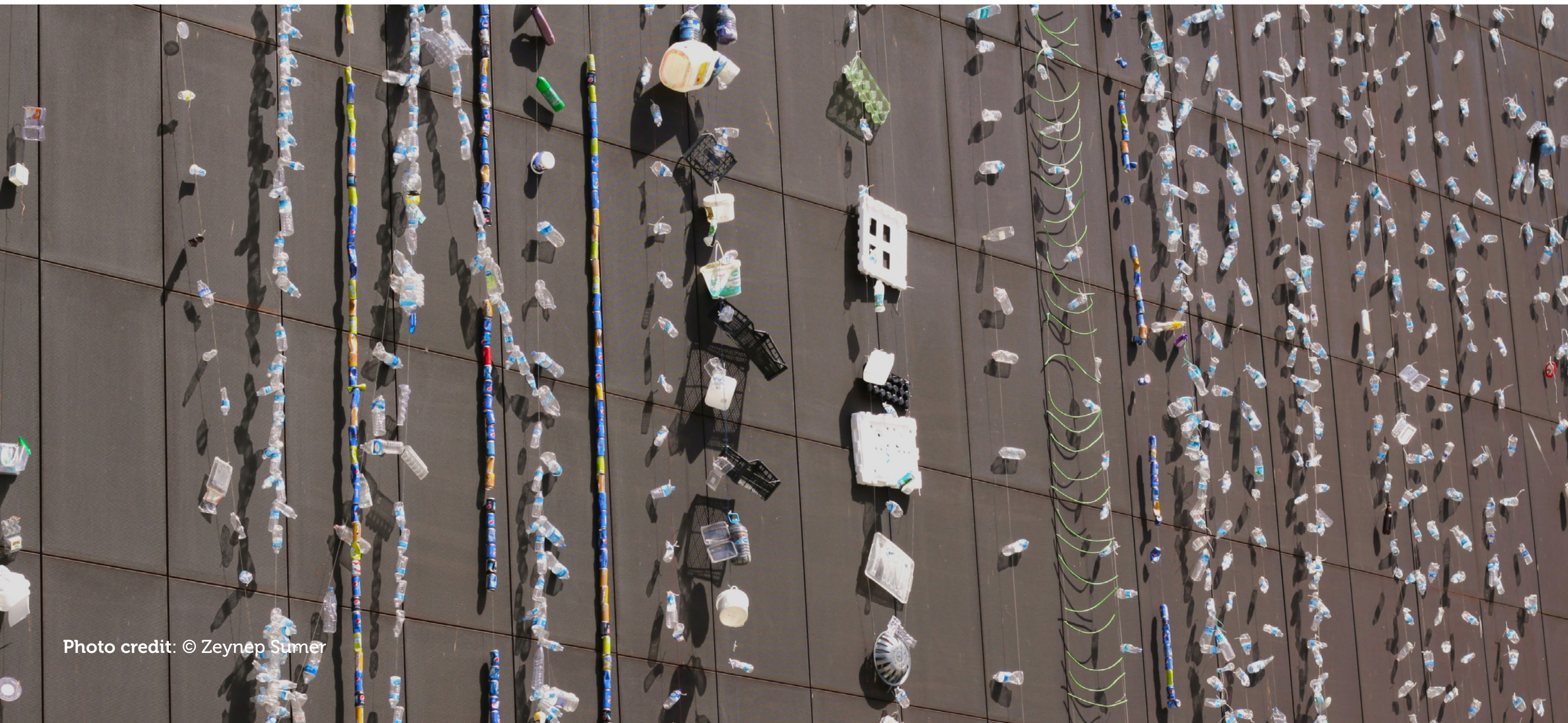
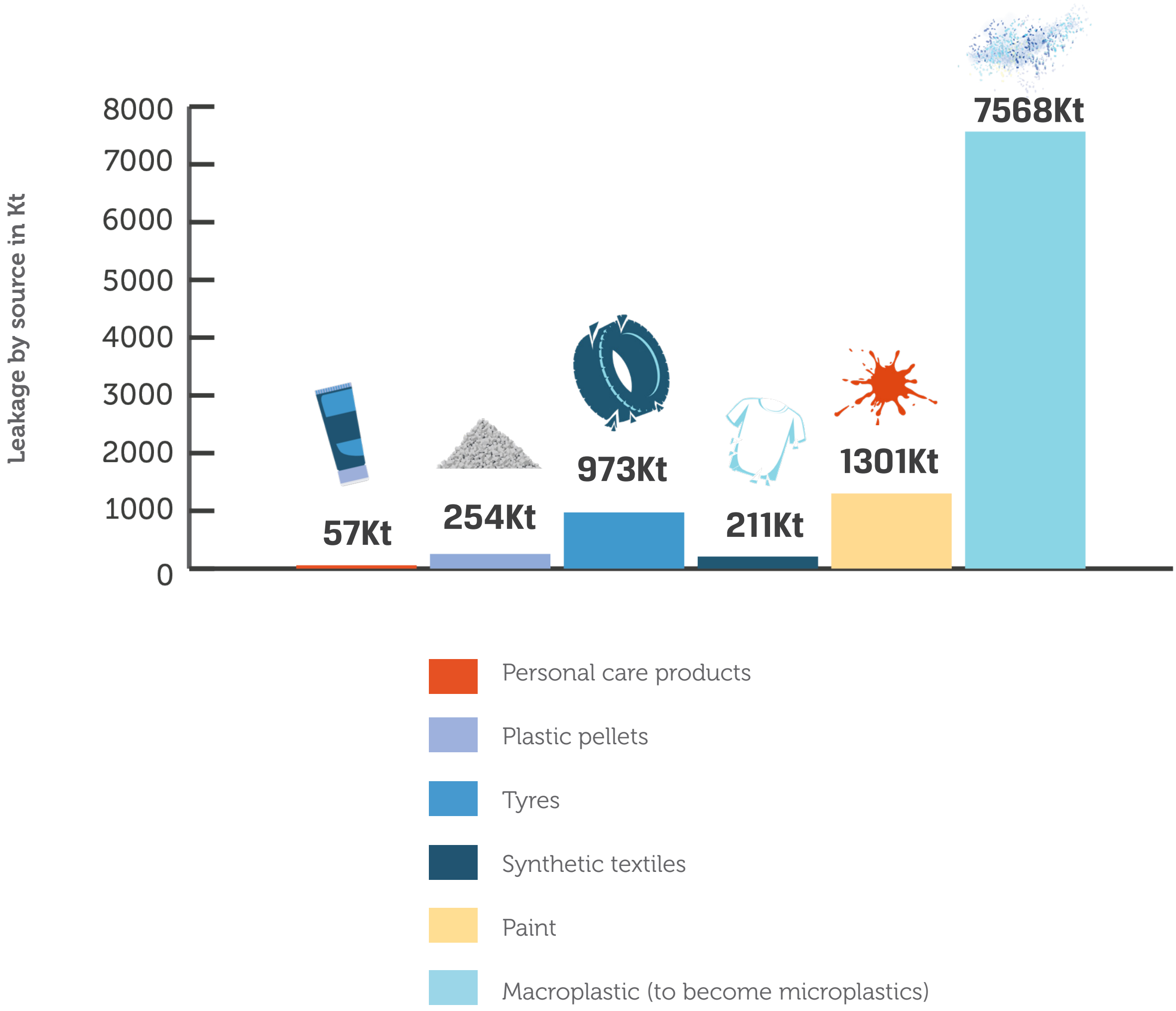


Photo credit: © Zeynep Sumer



The major sources of microplastics and their relative contributions to the marine environment, including macroplastics, which eventually fragment into microplastics. The contributions are illustrated as typical annual leakage to the ocean in kilotonnes (Kt).[80]

Tyres contain not just rubber but also around 60% additives. This includes fillers and chemicals that are gradually released, a process accelerated by environmental factors.[75]

> Once in the ocean, tyre-wear particles leach harmful substances like the toxic metals zinc, lead, and cadmium, which pose risks to marine ecosystems.[81]

In a lab experiment, exposure to TWP leachates led to mortality in different copepod species within 72 hours, with higher concentrations and longer exposure times leading to even greater mortality.[23] Additionally, phytoplankton species exposed to a medium containing 25% TWP leachates showed significant growth inhibition, with more harm caused as concentrations were increased. This is reason for concern. Since primary production sits at the base of the marine food web, even a moderate reduction of phytoplankton growth can cause an ecosystem imbalance.[78]

While it hasn't been demonstrated yet that current microplastic levels in open waters would harm phytoplankton, monitoring is crucial in areas particularly exposed to TWP, such as road-adjacent waters and urban wastewater sites.

Additionally, the high-pressure characteristic of deeper ocean areas influences the behaviour of TWP. A study found that high hydrostatic pressure at 2 kilometres water depth increases chemical leaching from TWP, promotes particle agglomeration, and releases phosphate, which boosts bacterial growth. Even after over a year in the ocean, weathered TWP were found to still release various chemicals, indicating a long-term environmental impact.[82]

Photo credit: © Naja Bertolt Jens

7.0 MICROPLASTICS PUSH INNOVATIONS IN ANALYSIS METHODS

As our demand for knowledge about microplastic occurrence, composition and impacts becomes more detailed and specific, the toolbox for analysing microplastics needs to keep pace. Accordingly, the JPI Oceans projects pushed methodological boundaries by advancing technologies, software, approaches and protocols.

TECHNOLOGIES AND SOFTWARE INNOVATIONS

Prompted by the request to extend their research to ever smaller (nanoplastics) particles, the projects pushed back the analytical limits. Based on the TUM-ParticleTyper 1, able to detect particles down to 10 µm,[83] they developed TUM-ParticleTyper 2 that can analyse microplastic particles as small as 1 µm and much faster than before.[84] The novel software automates the analysis process, including sample placement beneath a Raman microscope and calculation of material-dependent histograms of particle and fibre sizes.

Projects also innovated technologies for polymer identification. An automated hyperspectral image analysis was developed to identify microplastic types as small as 100 µm.[85] A new Laser Direct Infrared Imaging technique achieved high recovery rates for microplastics from fish gastrointestinal tracts from 100% recovery for large particles to 75% for microfibres.[86]

Automated fluorescence staining methods for microscopy offer a cheaper alternative to traditional spectroscopy-based techniques. Researchers therefore combined the fluorescent dye Nile Red with machine-learning algorithms into a cost-efficient semi-automated microplastic classification method. The algorithms do rather well - they identify with 96% accuracy whether particles are plastic or not, and classify the polymer type with 88% accuracy.[87]

ANALYTICAL PROTOCOLS AND METHODOLOGIES

As microfibres, with PET and polyamides being most prevalent, raise increasing concern as pollutants of water bodies, the projects introduced new analytical protocols and methodologies for their analysis. A new procedure allows to quantify reliably the total mass of each polymer. The method is so sensitive that it can be applied even at low concentrations in the range of parts per billion (ppb) and in environmental samples that contain diverse inorganic and organic materials.[60]

Limits were also pushed for the accuracy of spectral readings using Fourier-transform infrared (FTIR) and Raman spectroscopy. These techniques can detect microplastic particles as small as 10 µm but generate instrumental noise that complicates data interpretation. To address this, researchers developed an autoencoding network that, once trained with existing data, removes unwanted high noise levels, making the method more powerful and ideal for batch processing of large datasets.[88]

JPI Oceans projects further identified a need for standardised methods to detect microplastics in drinking water to protect public health as required by the EU Drinking Water Directive 2020/2184[89], Accordingly, project partners published standardised guidelines for analysing microplastics with micro-Raman and micro-infrared spectroscopy. The guidelines apply to various types of clean water, including drinking water, bottled and tap water, natural freshwater, and injectable water for medical use.[90] In addition, recognising that many microplastic analysis methods are costly and labour-intensive, predictive tools were developed to identify cost-effective techniques tailored to specific research scenarios.[91]

Further investigation focused on nanoplastic particles. Nanoplastics present significant challenges in their identification and quantification due to their small size and low mass occurrence in the environment. Researchers determined that multiple methods need to be combined for reliable results when studying nanoplastics, such as integrating chemical and size information from batch analysis and fractionation methods.[92]

METHODOLOGIES FOR ENVIRONMENTAL MATRICES

The projects also improved methodologies for different environmental mediums. The microplastic collector "MPVortex" is currently undergoing patent filing and refinement for use on water surfaces and submerged areas. They also optimised microplastics samplers for both water and air matrices.[93 94 95] An active air sampler setup now allows for continuous sampling of suspended microplastic particles.

To analyse microplastics in marine sediments, researchers introduced the Polymer Identification and Specific Analysis (PISA) method. PISA can measure the total mass of microplastics in marine sediments more accurately and quickly than traditional methods and accurately detects levels of polystyrene, polyamides, and PET within specific ranges.[63] Furthermore, a new method was developed to quickly analyse microplastics in plankton, an essential food source for many fish.[96]

METHODS TO STUDY ENVIRONMENTAL EFFECTS ON MICROPLASTICS

The projects addressed the environmental influence on microplastics, focusing on knowledge gaps on their lifecycle, such as weathering, degradation, and fragmentation processes.

New aggregation models were developed to integrate turbulence fluctuations and sinking dynamics across microscale dynamics (below millimetres), small-scale turbulence (millimetres to metres), and large-scale transport (kilometres). These models now allow to investigate microplastic particle transport phenomena seamlessly across scales.[70 71]

To study the weathering of plastics under natural conditions and plastic degradation, researchers optimised two methods to speed up polymer breakdown. Firstly, they produced a Portfolio of Microplastics Analyses Protocols, which includes using a UV solar simulator chamber to mimic natural plastic degradation influenced by sunlight and water in an experimental environment.[82] Secondly, they developed an alkaline hydrolysis method capable of degrading plastic particles into molecular fragments within just a few hours.[97]

In a study of microplastics from antifouling boat paints, a project developed a method to distinguish boat paint particles from natural materials using visual characteristics, such as colour and shape, and chemical characteristics, such as metal content. They found that the metal combination copper-zinc offered a promising compositional "fingerprint" to detect paint particles.[95]

8.0 COMMUNICATION AND OUTREACH

The six JPI Oceans projects from this call generated about 160 scientific publications and were featured in 90 press articles. However, they made strides in reaching not just the scientific community, but also industry professionals, educators, and local communities. Science communication was recognised as a precondition for impact in the form of science-based decision making, as one of the projects alluded to in a dedicated brochure.[98] Accordingly, all projects engaged in science communication, individually, teaming up among the projects, and engaging with external organisations.

Collaborations with ESO and IRIS, companies specialising in waste management and the circular economy, led to the development of GreenPlasma, a device that converts non-recyclable waste into hydrogen-rich gas.[99] A quantitative Weight of Evidence tool for analysing microplastics will soon be available to the public, aiding in monitoring guidelines and policymaking.[100] Furthermore, two innovative tools were developed to enhance citizen science. The "Twilitter" web application tracks public interest in marine plastic pollution by analysing Twitter data,[101] while the "ANDROMEDA" app allows users to monitor microplastics on beaches.[102]

The projects also advanced ocean literacy. One project created a Digital Teaching Kit for The Water Code Education Project, promoting global citizenship and sustainability among students and local communities.[100] Projects also engaged in awareness campaigns with Greenpeace and Keep the Planet,[103] and supported the exhibition "Plastics Culture: Art, Design, Environment" at the Omero Museum in Italy. A project involved citizens in collecting microplastics with the MicroPlastic Hunter Project, which engaged citizens in collecting microplastics from coastal surface waters using a "minimanta" from their kayaks.[104] Another project engaged over 6,000 people through workshops, webinars, and public activities across Europe and Brazil.[16] Brazilian partners, for example, conducted educational activities and beach clean-ups, collaborating with local schools and fishermen communities to emphasize marine biodiversity and plastic pollution. In collaboration with projects H20 and Unique Health in the Schools, they participated in beach and mangrove clean-ups.[105]

9.0 SCIENCE-POLICY INTERFACE

The JPI Oceans projects connected with European and international organisations, such as the EU MSFD Technical Group on Marine Litter, the Joint Research Centre (JRC), and the International Council for the Exploration of the Seas' (ICES) Working Group on Marine Litter. Additionally, the findings of all JPI Oceans projects were showcased at the European Parliament event "Small particles, big concerns: Marine microplastics revisited" in December 2023. This event highlighted the need for collaborative action and a comprehensive legislative approach to address microplastic pollution.[106] One project also delivered reports on microplastic contamination in Spain to the Catalan Parliament[107] and on plastic pollution in the Mediterranean to the European Parliament.[108]

A notable achievement is the development of a unique microplastics dataset that enhances the analysis of existing databases like EMODnet. This dataset, covering local to EU regional scales, will support the MSFD Technical Group on Marine Litter in setting thresholds for microplastic levels in water and sediment. Additionally, IWC-TUM, a partner in the HOTMIC project, has contributed to the standardisation of environmental plastics regulations by the International Organization for Standardization in the Technical Committee 61 on Plastics.

POLICY RECOMMENDATIONS

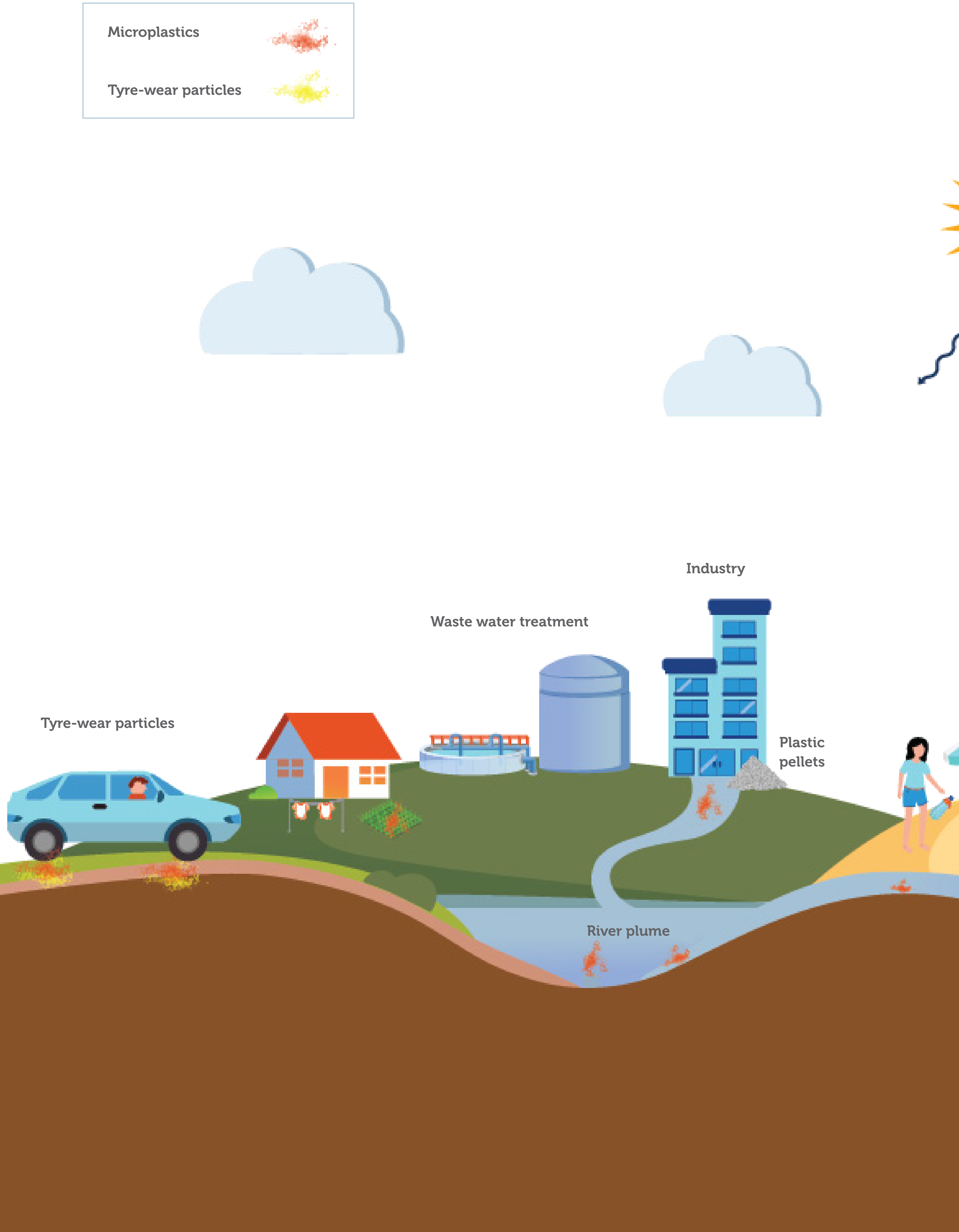
• **Human health:** The ingestion of microplastics and nanoplastics by humans is proven. Due to insufficient knowledge about their health effects and those of additive chemicals, human exposure should be limited by regulating unnecessary plastic use and by tackling plastic pollution.

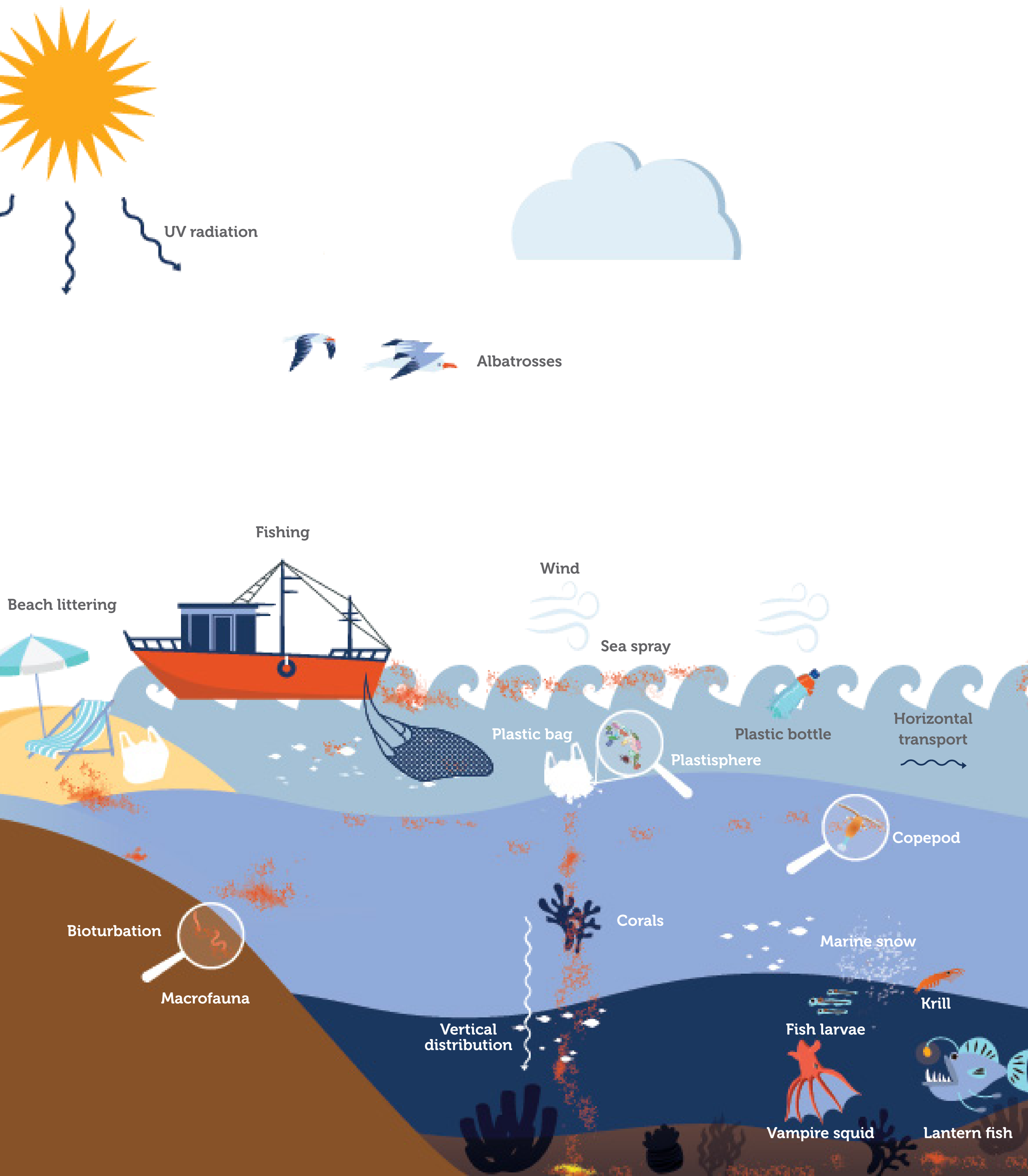
• **Industry:** To prevent future micro- and nanoplastics pollution and related chemical toxicity, industry should be encouraged to reduce non-essential packaging, develop alternative materials, and take greater responsibility for recycling through cradle-to-cradle design and production processes.

• **Regulation:** Clear and precise regulations and standards are needed for monitoring microplastics under the Marine Strategy Framework Directive and should be a key focus in upcoming policy consultations and initiatives.

• **Public engagement:** Citizen science fosters public engagement and brings communities closer to the issue of plastic pollution. They can also provide valuable data but require an effective strategy to be integrated into monitoring processes.


Photo credit: © Flyd Mu


Microplastics
Tyre-wear particles
Industry
Waste water treatment
Tyre-wear particles
Plastic pellets
River plume


UV radiation
Albatrosses
Fishing
Wind
Beach littering
Sea spray
Plastic bag
Plastic bottle
Horizontal transport
Plastisphere
Copepod
Corals
Bioturbation
Marine snow
Macrofauna
Krill
Vertical distribution
Fish larvae
Vampire squid
Lantern fish

10.0 REFERENCES

[1] Agamuthu, P., Mehran, S. B., Norkhairah, A., & Norkhairiyah, A. (2019). Marine debris: A review of impacts and global initiatives. *Waste Management & Research, 37*(10), 987–1002. https://doi.org/10.1177/0734242x19845041
[2] European Commission (2023). COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT REPORT Combatting microplastic pollution in the European Union Accompanying the document Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on preventing plastic pellet losses to reduce microplastic pollution, SWD/2023/332 final (2023).
[3] European Commission (2017). Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), OJ L 164, 25.6.2008, p. 19–40 (2017).
[4] European Commission (2022). Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions. First "zero pollution" monitoring and outlook. "Pathways towards cleaner air, water and soil for Europe," COM/2022/674 final (2022).
[5] European Commission (2023). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions EU Missions two years on: assessment of progress and way forward., COM/2023/457 final (2023).
[6] European Commission (1991). Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment, OJ L 135, 30.5.1991, p. 40–52 (1991).
[7] European Commission (2022). Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning urban wastewater treatment (recast), COM/2022/541 final (2022).
[8] European Commission (2023). Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, OJ L 396 30.12.2006, p. 1 (2023).
[9] European Commission (2023). Proposal for a Regulation of the European Parliament and of the Council on preventing plastic pellet losses to reduce microplastic pollution, COM/2023/645 final (2023).
[10] UNESCO-IOC. (2021b). *The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) Implementation Plan* (IOC Ocean Decade Series, 20.). UNESCO.
[11] UNEA Resolution 5/14 entitled "End plastic pollution: Towards an international legally binding instrument," UNEP/EA.5/Res.14 UNEP - UN Environment Programme (2022).
[12] European Commission (2017). Commission Decision (EU) 2017/848 of 17 May 2017 Laying down Criteria and Methodological Standards on Good Environmental Status of Marine Waters and Specifications and Standardised Methods for Monitoring and Assessment, and Repealing Decision 2010/477/EU, 2017)
[13] Lacerda, A. L. (2024, September). *The plastisphere: a comprehensive description of geographic and temporal patterns across the Mediterranean Sea and the Atlantic Ocean* [Conference presentation abstract]. MICRO 2024.
[14] Queiroga, R., Bartilotti, C., Chainho, P., Tuaty-Guerra, M., Lopes, C., Raimumdo, J., & Lobo-Arteaga, J. (2024, September 3). *Does marine fouling species selectivity work on plastics?* [Conference presentation abstract]. 13th International Conference on Biological Invasions NEOBIOTA 2024.
[15] Lacerda, A. L., Frias, J., & Pedrotti, M. L. (2024). Tardigrades in the marine plastisphere: New hitchhikers surfing plastics. *Marine Pollution Bulletin, 200*(116071). https://doi.org/10.1016/j.marpolbul.2024.116071
[16] Frias, J., Müller, C., & Capuano, T. A. (2024). Policy brief - Plastic pollution and the plastisphere: findings and recommendations. *Zenodo*. https://doi.org/10.5281/zenodo.10560911
[17] Lenoble, V., Cindrić, A.-M., Briand, J.-F., Pedrotti, M. L., Lacerda, A. L., Muniategui-Lorenzo, S., Fernández-González, V., Moscoso-Pérez, C. M., Andrade-Garda, J. M., Casotti, R., Murano, C., Donnarumma, V., Frizzi, S., Hannon, C., Joyce, H., Nash, R., & Frias, J. (2024). Bioaccumulation of trace metals in the plastisphere: Awareness of environmental risk from a European perspective. *Environmental Pollution, 348*(123808). https://doi.org/10.1016/j.envpol.2024.123808
[18] Lacerda, A. L., Pedrotti, M. L., Casotti, R., Donnarumma, V., Frias, J., Briand, J.-F., Barre, A., Lenoble, V., Muniategui-Lorenzo, S., Murano, C., Moscoso-Pérez, C. M., Fernández-González, V. F.-G., Kessler, F., & Brandt, L. (2022, September 20). *Biogeography, short and long-term effects of environmental factors, and influence of polymer type on plastics biofouling* [Conference presentation abstract]. The 7th International Marine Debris Conference (7IMDC).

[19] Lacerda, A. L., Briand, J.-F., Lenoble, V., Oreste, E. Q., Kessler, F., & Pedrotti, M. L. (2024). Assessing the Plastisphere from Floating Plastics in the Northwestern Mediterranean Sea, with Emphasis on Viruses. *Microorganisms, 12*(3), 444. https://doi.org/10.3390/microorganisms12030444
[20] Pedrotti, M. L., de Figueiredo Lacerda, A. L., Petit, S., Ghiglione, J. F., & Gorsky, G. (2022). Vibrio spp and other potential pathogenic bacteria associated to microfibers in the North-Western Mediterranean Sea. *PLoS ONE, 17*(11), e0275284. https://doi.org/10.1371/journal.pone.0275284
[21] Xu, J., Rodríguez-Torres, R., Rist, S., Nielsen, T., Hartmann, N., Brun, P., Li, D., & Almeda, R. (2022). Unpalatable Plastic: Efficient Taste Discrimination of Microplastics in Planktonic Copepods. *Environmental Science & Technology, 56*(10), 6455–6465. https://doi.org/10.1021/acs.est.2c00322
[22] Rodríguez Torres, R., Almeda, R., Xu, J., Hartmann, N., Rist, S., Brun, P., & Gissel Nielsen, T. (2022). The Behavior of Planktonic Copepods Minimizes the Entry of Microplastics in Marine Food Webs. *Environmental Science & Technology, 57*(1), 179–189. https://doi.org/10.1021/acs.est.2c04660
[23] Bournaka, E., Almeda, R., Koski, M., Suurlan Page, T., Elisa, R., & Gissel Nielsen, T. (2023). Lethal effect of leachates from tyre wear particles on marine copepods. *Marine Environmental Research, 191*(106163). https://doi.org/10.1016/j.marenvres.2023.106163
[24] Gunaalan, K., Gissel Nielsen, T., Rodríguez Torres, R., Lorenz, C., Vianello, A., Andersen, C. A., Vollertsen, J., & Almeda, R. (2023). Is Zooplankton an Entry Point of Microplastics into the Marine Food Web? *Environmental Science & Technology, 57*(31), 11643–11655. https://doi.org/10.1021/acs.est.3c02575
[25] Justino, A., Lenoble, V., Pelage, L., Ferreira, G., Passarone, R., Frédou, T., & Lucena Frédou, F. (2021). Microplastic contamination in tropical fishes: An assessment of different feeding habits. *Regional Studies in Marine Science, 45*(101857). https://doi.org/10.1016/j.rsma.2021.101857
[26] Lima, C. D. M., Melo Júnior, M., Schwamborn, S. H. L., Kessler, F., Oliveira, L. A., Ferreira, B. P., Mugrabe, G., Frias, J., & Neumann-Leitão, S. (2023). Zooplankton exposure to microplastic contamination in a estuarine plume-influenced region, in Northeast Brazil. *Environmental Pollution, 322*(121072). https://doi.org/10.1016/j.envpol.2023.121072
[27] Justino, A., Ferreira, G., Fauvelle, V., Schmidt, N., Lenoble, V., Pelage, L., & Lucena-Frédou, F. (2023). Exploring microplastic contamination in reef-associated fishes of the Tropical Atlantic. *Marine Pollution Bulletin, 192*(115087), 115087–115087. https://doi.org/10.1016/j.marpolbul.2023.115087
[28] Guilhermino, L., Martins, A., Lopes, C., Raimundo, J., Vieira, L. R., Barboza, L. G. A., Costa, J., Antunes, C., Caetano, M., & Vale, C. (2021). Microplastics in fishes from an estuary (Minho River) ending into the NE Atlantic Ocean. *Marine Pollution Bulletin, 173, Part A* (113008). https://doi.org/10.1016/j.marpolbul.2021.113008
[29] Research Council of Norway. (n.d.). *Fluxes and Fate of Microplastics in Northern European Waters.* Retrieved 15 May 2024, from The Research Council of Norway database. https://prosjektbanken.forskningsradet.no/en/project/FORISS/312695?Kilde=FORISS&distribution=Ar&chart=bar&calcType=funding&Sprak=no&sortBy=score&sortOrder=-desc&resultCount=30&offset=0&Fritekst=FACTS
[30] Ferreira, G., Justino, A., Eduardo, L., Schmidt, N., Martins, J., Ménard, F., Fauvelle, V., Mincarone, M., & Lucena-Frédou, F. (2023). Influencing factors for microplastic intake in abundant deep-sea lanternfishes (Myctophidae). *Science of the Total Environment, 867*(161478). https://doi.org/10.1016/j.scitotenv.2023.161478
[31] Justino, A., Ferreira, G., Schmidt, N., Eduardo, L. N., Fauvelle, V., Lenoble, V., Sempéré, R., Panagiotopoulos, C., Mincarone, M. M., Frédou, T., & Lucena-Frédou, F. (2022). The role of mesopelagic fishes as microplastics vectors across the deep-sea layers from the Southwestern Tropical Atlantic. *Environmental Pollution, 300*(118988), 118988. https://doi.org/10.1016/j.envpol.2022.118988
[32] Ferreira, G., Justino, A., Eduardo, L., Lenoble, V., Fauvelle, V., Schmidt, N., Junior, T., Frédou, T., & Lucena-Frédou, F. (2022). Plastic in the inferno: Microplastic contamination in deep-sea cephalopods (Vampyroteuthis infernalis and Abralia veranyi) from the southwestern Atlantic. *Marine Pollution Bulletin, 174*(113309). https://doi.org/10.1016/j.marpolbul.2021.113309
[33] Soares, M. O., Rizzo, L., Ximenes Neto, A. R., Barros, Y., Martinelli Filho, J. E., Giarrizzo, T., & Rabelo, E. F. (2023). Do coral reefs act as sinks for microplastics? *Environmental Pollution, 337*(122509), 122509. https://doi.org/10.1016/j.envpol.2023.122509
[34] de Oliveira Soares, M., Matos, E., Lucas, C., Rizzo, L., Allcock, L., & Rossi, S. (2020). Microplastics in corals: An emergent threat. *Marine Pollution Bulletin, 161, Part A*(111810), 111810. https://doi.org/10.1016/j.marpolbul.2020.111810
[35] Carreras-Colom, E., Cartes, J., Rodríguez-Romeu, O., Padrós, F., Solé, M., Grelaud, M., Ziveri, P., Palet, C., Soler-Membrives, A., & Carrassón, M. (2022). Anthropogenic pollutants in Nephrops norvegicus (Linnaeus, 1758) from the NW Mediterranean Sea: Uptake assessment and potential impact on health. Environmental Pollution, 314(120230). https://doi.org/10.1016/j.envpol.2022.120230
[36] Muns-Pujadas, L., Dallarés, S., Constenla, M., Padrós, F., Carreras-Colom, E., Grelaud, M., Carrassón, M., & Soler-Membrives, A. (2023). Revealing the capability of the European hake to cope with micro-litter environmental exposure and its inferred potential health impact in the NW Mediterranean Sea. *Marine Environmental Research, 186*(105921). https://doi.org/10.1016/j.marenvres.2023.105921
[37] Justino, A., Ferreira, G., Fauvelle, V., Schmidt, N., Lenoble, V., Pelage, L., Martins, K., Travassos, P., & Lucena- Frédou, F. (2023). From prey to predators: Evidence of microplastic trophic transfer in tuna and large pelagic species in the southwestern Tropical Atlantic. *Environmental Pollution, 327*(121532). https://doi.org/10.1016/j.envpol.2023.121532
[38] Castelvetro, V., Corti, A., Bianchi, S., Giacomelli, G., Manariti, A., & Vinciguerra, V. (2021). Microplastics in fish meal: contamination level analyzed by polymer type, including polyester (PET), polyolefins, and polystyrene. *Environmental Pollution, 273*(115792). https://doi.org/10.1016/j.envpol.2020.115792
[39] Fraissinet, S., Arduini, D., Vidal, O., Pennetta, A., Egidio, G., Malitesta, C., Giangrande, A., & Rossi, S. (2023). Particle uptake by filter-feeding macrofoulers from the Mar Grande of Taranto (Mediterranean Sea, Italy): potential as microplastic pollution bioremediators. *Marine Pollution Bulletin, 188*(114613). https://doi.org/10.1016/j.marpolbul.2023.114613
[40] Pittura, L., Nardi, A., Cocca, M., De Falco, F., d'Errico, G., Mazzoli, C., Mongera, F., Benedetti, M., Gorbi, S., Avella, M., & Regoli, F. (2022). Cellular disturbance and thermal stress response in mussels exposed to synthetic and natural microfibers. *Frontiers in Marine Science, 9*. https://doi.org/10.3389/fmars.2022.981365

[41] Vital, S. A., Cardoso, C., Avio, C., Pittura, L., Regoli, F., & Bebianno, M. J. (2021). Do microplastic contaminated seafood consumption pose a potential risk to human health? *Marine Pollution Bulletin, 171*(112769). https://doi.org/10.1016/j.marpolbul.2021.112769
[42] Wang, T., Hu, M., Xu, G., Shi, H., Leung, J. Y. S., & Wang, Y. (2021). Microplastic accumulation via trophic transfer: Can a predatory crab counter the adverse effects of microplastics by body defence? *Science of the Total Environment, 754*(142099). https://doi.org/10.1016/j.scitotenv.2020.142099
[43] Bebianno, M. J., Mendes, V. M., O'Donovan, S., Carteny, C. C., Keiter, S., & Manadas, B. (2022). Effects of microplastics alone and with adsorbed benzo(a)pyrene on the gills proteome of Scrobicularia plana. *Science of the Total Environment, 842*(156895), 156895. https://doi.org/10.1016/j.scitotenv.2022.156895
[44] Panto, G., Aguilera Dal Grande, P., Vanreusel, A., & Van Colen, C. (2022, November 16). *Macrofauna bioturbation promotes seabed burial of microplastics: a laboratory study* [Conference presentation abstract]. MICRO 2022.
[45] Martines, A., Furfaro, G., Solca, M., Muzzi, M., Di Giulio, A., & Rossi, S. (2023). An Analysis of Microplastics Ingested by the Mediterranean Detritivore Holothuria tubulosa (Echinodermata: Holothuroidea) Sheds Light on Patterns of Contaminant Distribution in Different Marine Areas. *Water, 15*(8), 1597. https://doi.org/10.3390/w15081597
[46] European Commission (2022). Commission Recommendation of 10 June 2022 on the definition of nanomaterial, C229, 1-5 (2022).
[47] Fraissinet, S., De Benedetto, G., Malitesta, C., Holzinger, R., & Materić, D. (2024). Microplastics and nanoplastics size distribution in farmed mussel tissues. *Communications Earth & Environment, 5*(128). https://doi.org/10.1038/s43247-024-01300-2
[48] Gonçalves, J. M., Sousa, V. S., Teixeira, M. R., & Bebianno, M. J. (2022). Chronic toxicity of polystyrene nanoparticles in the marine mussel Mytilus galloprovincialis. *Chemosphere, 287, part 4*(132356). https://doi.org/10.1016/j.chemosphere.2021.132356
[49] Garrido Gamarro, E., & Costanzo, V. (2022). *Microplastics in food commodities - A food safety review on human exposure through dietary sources* (Food Safety and Quality Series No. 18). FAO. https://doi.org/10.4060/cc2392en
[50] Di Giulio, T., De Benedetto, G. E., Ditaranto, N., Malitesta, C., & Mazzotta, E. (2024). Insights into Plastic Degradation Processes in Marine Environment by X-ray Photoelectron Spectroscopy Study. *International Journal of Molecular Sciences, 25*(10), 5060. https://doi.org/10.3390/ijms25105060
[51] Goßmann, I., Mattsson, K., Hassellöv, M., Crazzolara, C., Held, A., Robinson, T.-B., Wurl, O., & Scholz- Böttcher, B. M. (2023). Unraveling the Marine Microplastic Cycle: The First Simultaneous Data Set for Air, Sea Surface Microlayer, and Underlying Water. *Environmental Science & Technology, 57*(43), 16541–16551. https://doi.org/10.1021/acs.est.3c05002
[52] Soares, M., Garcia, T., Giarrizzo, T., Martinelli, E., Tavares, T., Ziveri, P., Smith, T., Bejarano, S., & Eduardo, C. (2023). Marine debris provide long-distance pathways for spreading invasive corals. *Science of the Total Environment, 900*(165637). https://doi.org/10.1016/j.scitotenv.2023.165637
[53] Beck, A. J., Kaandorp, M., Hamm, T., Bogner, B., Kossel, E., Lenz, M., Haeckel, M., & Achterberg, E. P. (2023). Rapid shipboard measurement of net-collected marine microplastic polymer types using near-infrared hyperspectral imaging. *Analytical and Bioanalytical Chemistry, 415*, 2989–2998. https://doi.org/10.1007/s00216-023-04634-6
[54] Lins-Silva, N., Marcolin, C. R., Kessler, F., & Schwamborn, R. (2021). A fresh look at microplastics and other particles in the tropical coastal ecosystems of Tamandaré, Brazil. *Marine Environmental Research, 169*(105327), 105327. https://doi.org/10.1016/j.marenvres.2021.105327
[55] Grelaud, M., & Ziveri, P. (2020). The generation of marine litter in Mediterranean island beaches as an effect of tourism and its mitigation. *Scientific Reports, 10*. https://doi.org/10.1038/s41598-020-77225-5
[56] Brabo, L., Andrades, R., Franceschini, S., Oliveira Soares, M., Russo, T., & Giarrizzo, T. (2022). Disentangling beach litter pollution patterns to provide better guidelines for decision-making in coastal management. *Marine Pollution Bulletin, 174*(113310). https://doi.org/10.1016/j.marpolbul.2021.113310
[57] Lenz, M., Brennecke, D., Haeckel, M., Knickmeier, K., & Kossel, E. (2023). Spatio-temporal variability in the abundance and composition of beach litter and microplastics along the Baltic Sea coast of Schleswig-Holstein, Germany. *Marine Pollution Bulletin, 190*(114830). https://doi.org/10.1016/j.marpolbul.2023.114830
[58] Corti, A., La Nasa, J., Biale, G., Ceccarini, A., Manariti, A., Petri, F., Modugno, F., & Castelvetro, V. (2023). Microplastic pollution in the sediments of interconnected lakebed, seabed, and seashore aquatic environments: polymer-specific total mass through the multianalytical "PISA" procedure. *Analytical and Bioanalytical Chemistry, 415*, 2921–2936. https://doi.org/10.1007/s00216-023-04664-0
[59] Carretero, O., Gago, J., Filgueiras, A. V., & Viñas, L. (2022). The seasonal cycle of micro and meso-plastics in surface waters in a coastal environment (Ría de Vigo, NW Spain). *Science of the Total Environment, 803,* 150021. https://doi.org/10.1016/j.scitotenv.2021.150021
[60] Gondikas, A., Mattsson, K., & Hassellöv, M. (2023). Methods for the detection and characterization of boat paint microplastics in the marine environment. *Frontiers in Environmental Chemistry, 4*. https://doi.org/10.3389/fenvc.2023.1090704
[61] European Commission (2019). Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC (Text with EEA relevance), OJ L 151, 7.6.2019, p. 116–142 (2019).
[62] European Commission (2012). Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products Text with EEA relevance, OJ L 167, 27.6.2012, p. 1–123 (2012).
[63] Castelvetro, V., Corti, A., Ceccarini, A., Petri, A., & Vinciguerra, V. (2021). Nylon 6 and nylon 6,6 micro- and nanoplastics: A first example of their accurate quantification, along with polyester (PET), in wastewater treatment plant sludges. *Journal of Hazardous Materials, 407*(124364). https://doi.org/10.1016/j.jhazmat.2020.124364
[64] Sillanpää, M., & Sainio, P. (2017). Release of polyester and cotton fibers from textiles in machine washings. *Environmental Science and Pollution Research, 24,* 19313–19321. https://doi.org/10.1007/s11356-017-9621-1
[65] Kühn, S., Van Franeker, J. A., & Van Loon, W. (2022). Plastic Particles in Fulmar Stomachs in the North Sea. OSPAR, 2023: The 2023 Quality Status Report for the Northeast Atlantic. OSPAR Commission, London.
[66] Castelvetro, V., Corti, A., La Nasa, J., Modugno, F., Ceccarini, A., Giannarelli, S., Vinciguerra, V., & Bertoldo, M. (2021). Polymer Identification and Specific Analysis (PISA) of Microplastic Total Mass in Sediments of the Protected Marine Area of the Meloria Shoals. *Polymers, 13*(5), 796. https://doi.org/10.3390/polym13050796

[67] Allen, S., Allen, D., Moss, K., Le Roux, G., Phoenix, V., & Sonke, J. (2020). Examination of the ocean as a source for atmospheric microplastics. *PLoS ONE, 15*(5), e0232746. https://doi.org/10.1371/journal.pone.0232746
[68] Nisticò, R. (2020). Polyethylene terephthalate (PET) in the packaging industry. *Polymer Testing, 90*(106707). https://doi.org/10.1016/j.polymertesting.2020.106707
[69] Goßmann, I., Herzke, D., Held, A., Schulz, J., Nikiforov, V., Georgi, C., Evangeliou, N., Eckhardt, S., Gerdts, G., Wurl, O., & Scholz-Böttcher, B. (2023). Occurrence and backtracking of microplastic mass loads including tire wear particles in northern Atlantic air. *Nature Communications, 14*(3707). https://doi.org/10.1038/s41467-023-39340-5
[70] Gunaalan, K., Almeda, R., Vianello, A., Lorenz, C., Iordachescu, L., Papacharalampos, K., Nielsen, T. G., & Vollertsen, J. (2024). Does water column stratification influence the vertical distribution of microplastics? *Environmental Pollution, 340*(122865). https://doi.org/10.1016/j.envpol.2023.122865
[71] Wu, F., Reding, L., Starkenburg, M., Leistenschneider, C., Primpke, S., Vianello, A., Zonneveld, K. A. F., Huserbråten, M. B. O., Versteegh, G. J. M., & Gerdts, G. (2024). Spatial distribution of small microplastics in the Norwegian Coastal Current. *Science of the Total Environment, 942*(173808). https://doi.org/10.1016/j.scitotenv.2024.173808
[72] Capuano, T. A., Botte, V., Sardina, G., Brandt, L., Grujić, A., & Iudicone, D. (2024). Oceanic realistic application of a microplastic biofouling model to the river discharge case. *Environmental Pollution, 359*(124501). https://doi.org/10.1016/j.envpol.2024.124501
[73] Grujić, A., Bhatnagar, A., Sardina, G., & Brandt, L. (2024). Collisions among elongated settling particles: The two-fold role of turbulence. *Physics of Fluids, 36*(1). https://doi.org/10.1063/5.0177893
[74] Sugathapala, T. M., Capuano, T., Iudicone, D., Brandt, L., & Sardina, G. (2023, November 19). *The role of ocean turbulence on the vertical motion of biofouled microplastic particles in a marine environment* [Conference presentation abstract]. APS 76th Annual Meeting of the Division of Fluid Dynamics.
[75] Frias, J., Joyce, H., Brozzetti, L., Pagter, E., Švonja, M., Kavangh, F., & Nash, R. (2024). Spatial monitoring of microplastics in environmental matrices from Galway Bay, Ireland. *Marine Pollution Bulletin, 200*(116153). https://doi.org/10.1016/j.marpolbul.2024.116153
[76] Simon-Sánchez, L., Grelaud, M., Lorenz, C., Garcia-Orellana, J., Vianello, A., Liu, F., Vollertsen, J., & Ziveri, P. (2022). Can a Sediment Core Reveal the Plastic Age? Microplastic Preservation in a Coastal Sedimentary Record. *Environmental Science & Technology, 56*(23), 16780–16788. https://doi.org/10.1021/acs.est.2c04264
[77] Foscari, A., Schmidt, N., Seiwert, B., Herzke, D., Sempéré, R., & Reemtsma, T. (2023). Leaching of chemicals and DOC from tire particles under simulated marine conditions. *Frontiers in Environmental Science, 11*. https://doi.org/10.3389/fenvs.2023.1206449
[78] Goßmann, I., Halbach, M., & Scholz-Böttcher, B. M. (2021). Car and truck tire wear particles in complex environmental samples – A quantitative comparison with "traditional" microplastic polymer mass loads. *Science of the Total Environment, 773*, 145667. https://doi.org/10.1016/j.scitotenv.2021.145667
[79] Mattsson, K., Aristéia de Lima, J., Wilkinson, T., Järlskog, I., Ekstrand, E., Andersson Sköld, Y., Gustafsson, M., & Hassellöv, M. (2023). Tyre and road wear particles from source to sea. *Microplastics and Nanoplastics, 3*, 14. https://doi.org/10.1186/s43591-023-00060-8
[80] Thompson, R. C., Courtene-Jones, W., Boucher, J., Pahl, S., Raubenheimer, K., & Koelmans, A. A. (2024). Twenty years of microplastics pollution research—what have we learned? *Science, 0*. eadl2746. https://doi.org/10.1126/science.adl2746
[81] Page, T. S., Almeda, R., Koski, M., Bournaka, E., & Nielsen, T. G. (2022). Toxicity of tyre wear particle leachates to marine phytoplankton. *Aquatic Toxicology, 252*(106299). https://doi.org/10.1016/j.aquatox.2022.106299
[82] Schmidt, N., Foscari, A., Garel, M., Tamburini, C., Seiwert, B., Herzke, D., Reemtsma, T., & Sempéré, R. (2024, September). *Leaching of Organic Compounds from Tire Particles Under Conditions Simulating the Deep Sea* [Conference presentation abstract]. MICRO 2024.
[83] von der Esch, E., Kohles, A. J., Anger, P. M., Hoppe, R., Niessner, R., Elsner, M., & Ivleva, N. P. (2020). TUM-ParticleTyper: A detection and quantification tool for automated analysis of (Microplastic) particles and fibers. *PLoS ONE, 15*(6), e0234766. https://doi.org/10.1371/journal.pone.0234766
[84] Jacob, O., Ramírez-Piñero, A., Elsner, M., & Ivleva, N. (2023). TUM-ParticleTyper 2: automated quantitative analysis of (microplastic) particles and fibers down to 1μm by Raman microspectroscopy. *Analytical and Bioanalytical Chemistry, 415*, 2947–2961. https://doi.org/10.1007/s00216-023-04712-9
[85] De Witte, B., Power, O-P., Fitzgerald, E., & Kopke, K. (2024). ANDROMEDA Portfolio of Microplastics Analyses Protocols. *ANDROMEDA Deliverable 5.5. JPI Oceans ANDROMEDA Project*. https://doi.org/10.13140/RG.2.2.21010.06088
[86] López-Rosales, A., Andrade, J., Fernández-González, V., López-Mahía, P., & Muniategui-Lorenzo, S. (2022). A reliable method for the isolation and characterization of microplastics in fish gastrointestinal tracts using an infrared tunable quantum cascade laser system. *Marine Pollution Bulletin, 178*(113591), 113591. https://doi.org/10.1016/j.marpolbul.2022.113591
[87] Meyers, N., Catarino, A., Declercq, A., Brenan, A., Devriese, L., Vandegehuchte, M., De Witte, B., Janssen, C., & Everaert, G. (2022). Microplastic detection and identification by Nile red staining: Towards a semi-automated, cost- and time-effective technique. *Science of the Total Environment, 823*(153441). https://doi.org/10.1016/j.scitotenv.2022.153441
[88] Brandt, J., Mattsson, K., & Hassellöv, M. (2021). Deep Learning for Reconstructing Low-Quality FTIR and Raman Spectra - A Case Study in Microplastic Analyses. *Analytical Chemistry, 93*(49), 16360–16368. https://doi.org/10.1021/acs.analchem.1c02618
[89] European Commission (2020). Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast), OJ L 435, 23.12.2020, p. 1–62 (2020).
[90] Schymanski, D., Oßmann, B. E., Benismail, N., Boukerma, K., Dallmann, G., von der Esch, E., Fischer, D., Fischer, F., Gilliland, D., Glas, K., Hofmann, T., Käppler, A., Lacorte, S., Marco, J., Rakwe, M. E., Weisser, J., Witzig, C., Zumbülte, N., & Ivleva, N. P. (2021). Analysis of microplastics in drinking water and other clean water samples with micro-Raman and micro-infrared spectroscopy: minimum requirements and best practice guidelines. *Analytical and Bioanalytical Chemistry, 413*, 5969–5994. https://doi.org/10.1007/s00216-021-03498-y
[91] Meyers, N., Kopke, K., Buhhalko, N., Mattsson, K., Janssen, C., Everaert, G., & De Witte, B. (2024). Value for money: a cost-effectiveness analysis of microplastic analytics in seawater. *Microplastics and Nanoplastics, 4*(4). https://doi.org/10.1186/s43591-024-00081-x

[92] Huber, M. J., Ivleva, N. P., Booth, A. M., Beer, I., Bianchi, I., Drexel, R., Geiss, O., Mehn, D., Meier, F., Molska, A., Parot, J., Sørensen, L., Vella, G., Prina-Mello, A., Vogel, R., & Caputo, F. (2023). Physicochemical characterization and quantification of nanoplastics: applicability, limitations and complementarity of batch and fractionation methods. *Analytical and Bioanalytical Chemistry, 415,* 3007–3031. https://doi.org/10.1007/s00216-023-04689-5
[93] ANDROMEDA. (2023). *ANDROMEDA Newsletter Issue No. 1.*
[94] ANDROMEDA. (2023). *ANDROMEDA Newsletter Issue No. 2.*
[95] Alling, V., Lund, E., Lusher, A., van Bavel, B., Snekkevik, V. K., Hjelset, S., Singdahl-Larsen, C., Consolaro, C., Jefroy, M., Martinez-Frances, E., Rødland, E., Pakhomova, S., Knight, J., Schmidt, N., & Herzke, D. (2023). *Monitoring of microplastics in the Norwegian environment (MIKRONOR).* Norwegian Institute for Water Research.
[96] López-Rosales, A., Andrade, J. M., Grueiro-Noche, G., Fernández-González, V., López-Mahía, P., & Muniategui-Lorenzo, S. (2021). Development of a fast and efficient method to analyze microplastics in planktonic samples. *Marine Pollution Bulletin, 16*8(112379), 112379. https://doi.org/10.1016/j.marpolbul.2021.112379
[97] Sarno, A., Olafsen, K., Kubowicz, S., Karimov, F., Sait, S., Sørensen, L., & Booth, A. (2020). Accelerated Hydrolysis Method for Producing Partially Degraded Polyester Microplastic Fiber Reference Materials. *Environmental Science & Technology Letters, 8*(3), 250–255. https://doi.org/10.1021/acs.estlett.0c01002
[98] Agnew, S., Kopke, K., Dozier, A., Power, O-P., Fitzgerald, E., Mateos-Cárdenas, A., & Regoli, F. (2023). *Science Communication and Marine Plastic Pollution: Perspectives on the (mis) Communication of Microplastics.* JPI Oceans-funded RESPONSE project. https://doi.org/10.13140/RG.2.2.15212.33928
[99] RESPONSE. (2023). *RESPONSE Project Newsletter Issue No: 2.*
[100] Regoli, F., d'Errico, G., Nardi, A., Pittura, L., Mazzoli, C., Orsini, M., Vivani, V., Gorbi, S., & Benedetti, M. (2023, June 6). *Development of a Quantitative Weight-Of-Evidence Model for risk assessment of microplastics pollution within Response project* [Conference presentation abstract]. ASLO Aquatic Sciences Meeting 2023
[101] Otero, P., Gago, J., & Quintas, P. (2021). Twitter data analysis to assess the interest of citizens on the impact of marine plastic pollution. Marine Pollution Bulletin, 170(112620). https://doi.org/10.1016/j.marpolbul.2021.112620
[102] ANDROMEDA. (2022). ANDROMEDA microplastics (Version 1.0.5) [Mobile app]. Google Play. https://play.google.com/store/apps/details?id=com.seasus.andromeda&hl=en
[103] RESPONSE. (2023). *RESPONSE Project Newsletter Issue No: 1.*
[104] Minetti, R., Costa, E., Liconti, A., Tixi, L., Lategola, M., Verna, U., Di Penta, C., Genocchio, S., Catta, M. C., Faimali, M., & Garaventa, F. (2022). MICROPLASTIC HUNTERS PROJECT. *[Poster].*
[105] MicroplastiX. (2022b). *MicroplastiX Newsletter Issue No. 4.*
[106] European Parliament Intergroup on Climate Change, Biodiversity & Sustainable Development. (2023). Small particles, big concerns: Marine microplastics revisited.
[107] Farré, M., Fernàndez, P., Grelaud, M., Llorca, M., Romera Castillo, C., Sánchez-Vidal, A., Ziveri, P., & Ros, J. (2021). *Informe CAPCIT: Microplàstics en el medi ambient (especialment, a la Mediterrània).* Consell Assessor del Parlament sobre Ciència i Tecnologia (CAPCIT).
[108] Ziveri, P., Grelaud, M., & Pato, J. (2023). *Research for REGI Committee – Study on Actions of cities and regions in Mediterranean Sea area to fight sea pollution*. European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.

FUNDING PARTNERS

JPI OCEANS

Rue du Trône 4 I 1000 Brussels | Belgium
Tel. +32 (0)2 62616 60 I info@jpi-oceans.eu
www.jpi-oceans.eu