



Scientific Facts on **Marine Litter**

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Level 2 - Details on Marine Litter

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This Digest is a faithful summary of the leading scientific consensus report produced in 2010 by The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP):

"Proceedings of the GESAMP International Workshop on micro- plastic particles as a vector in transporting persistent, bio- accumulating and toxic substances in the oceans"

The full Digest is available at: <https://www.greenfacts.org/en/marine-litter/>

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- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific consensus report which is faithfully summarised in Level 2 and further in Level 1.

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1. Introduction: plastic waste and micro-plastics in the oceans.

Global production of plastics is increasing every year (245 million metric tonnes in 2008) and the amount of plastic litter that is finding its way into the environment and into the oceans is also increasing, especially in the areas of the world where waste management practices are not keeping up with the rapid development.



The amount of plastic waste is increasing

There is however a lack of information on how much plastic debris finds its way to the oceans and how much of it there already is in the oceans. In order to identify the information needs and to explore what is already known and being done in the world, a workshop was held by the GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) which is sponsored by nine UN agencies that have jurisdiction over the oceans. This workshop's participants represented the scientific community, the plastics industry, policy makers and environmental NGOs, as well as regional bodies and developing as well as developed countries.

The initial focus of this workshop was on plastic particles as a vector in transporting persistent, bioaccumulating and toxic (PBT) substances. These plastic particles, or micro-plastics, result largely from the presence of plastic debris in the marine environment and, in turn, are directly related to the quantities of solid waste entering the oceans from land- and sea- based sources.

Once in the sea, a long-term process of transport and deterioration links our global and regional efforts in solid waste management with the occurrence of micro-plastics in the oceans. This process is impossible to influence except by controlling the amount of waste that enters the oceans. The workshop therefore surveyed the broader context of solid waste management, plastic waste recovery and recycling, as well as the behaviour of plastics in the marine environment.

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In recent years the existence of micro-plastics and their potential impact has received increasing attention. This concerns particles smaller than 5 mm, and particles as small as 1 μm (0,001 mm) have been identified. There is increasing evidence that such particles can be ingested by marine organisms, with the potential for: physical disruption and abrasion; toxicity of chemicals in the plastic; and, toxicity of absorbed persistent, bioaccumulating and toxic (PBT) substances. However, the available information is still scarce, experimental studies are few and far between and most of the ocean and coastal areas remains un-sampled.

2. What kind of plastic waste ends up in the marine environment?

The term plastic encompasses a wide range of polymeric materials, including rubbers, elastomers, textiles, and thermoplastics. Plastics can be fabricated from raw materials derived from petroleum, natural gas, or bio-renewables and have several advantages over other materials, being lightweight, durable, strong and extremely versatile.

Global production of plastics has increased from 1.5 million metric tonnes in 1950 to reach 245 million metric tonnes in 2008. Plastics production is spread around the globe and can be expected to rise to meet continuing demand.



Truly biodegradable plastics tend to be expensive and are not suitable for all applications.

As an example of main usages, in Europe, packaging accounts for 40% of the 45 million metric tonnes of plastics consumed in 2009, building materials account for 20%, and the automotive and electronics industries account for 7 and 6% respectively. Of these 45 millions tonnes, 23 million goes into the waste cycle and 11 ends up in landfills or in the environment. The rest of the waste is either recycled or burned for energy recovery. It is acknowledged by industry and Government alike that recovery of plastics needs to increase dramatically, as does the proportion recycled.

There are some newer plastic types on the market that are often assumed to be biodegradable. "Bio-plastic" (bio-based or bio-sourced) implies that the polymeric product has been made from a biological (living) or renewable source, e.g. corn, or sugar cane.

Bio-degradable means that the product may be broken down by living organisms, and a polymer can only be legitimately termed biodegradable when it passes a composting test under standard conditions and within a set timeframe, being broken down by living organisms in specific conditions into its constituent parts: carbon dioxide, water, inorganic compounds and biomass. These conditions may occur in industrial composters but not in the ocean, and thus many "biodegradable" plastics will not break down in the oceans any faster than other plastics. Truly biodegradable plastics, such as polylactic acid (PLA), tend to be more expensive and are not suitable for many applications requiring durability. "Bio-plastics" are not necessarily bio-degradable, and bio-degradable plastics are not necessarily bio-plastics.

As far as for the amount and types of plastics that make their way into the oceans it is very difficult to estimate because there are no worldwide figures, and current knowledge relies heavily on estimates from decades ago.

The majority of plastic waste entering the seas and oceans is considered to originate from land-based sources, and UNEP identified the following:

- street litter which is washed, blown or discharged into nearby waterways by rain, snowmelt, and wind,
- inappropriate or illegal dumping of domestic and industrial rubbish, public littering
- inadequately covered waste containers and waste container vehicles
- poorly managed waste dumps
- manufacturing sites, plastic processing, and transport;
- sewage treatment and combined sewer overflows
- people using the sea for recreation or shore fishing
- shore-based solid waste disposal and processing facilities

A lesser proportion can be attributed to:

- maritime transport,
- exploration and drilling platforms as well as fishing,
- accidental loss or system failure,
- poor waste management practices, and

- illegal disposal.

To the above sources, the GESAMP workshop added the following:

3. What are micro-plastics and how do they enter the marine environment?

The occurrence of small plastic particles on beaches and in coastal waters was first reported in the 1970s although the term 'micro-plastics' was not used until relatively recently. It has become evident that the distribution of particles is global, including isolated mid-ocean islands, the open ocean and at high latitude.



Pellets used in plastics manufacturing

Micro-plastic particles, defined here as particles of less than 5mm in size, can arise through four separate processes:

- deterioration of larger plastic fragments, cordage and films over time, with or without assistance from UV radiation, mechanical forces in the seas (e.g. wave action, grinding on high energy shorelines), or through biological activity (e.g. boring, shredding and grinding by marine organisms);
- direct release of micro particles (e.g. scrubs and abrasives in household and personal care products, shot-blasting ship hulls and industrial cleaning products respectively, grinding or milling waste) into waterways and via urban wastewater treatment;
- accidental loss of industrial raw materials (e.g. prefabricated plastics in the form of pellets or powders used to make plastic articles), during transport or trans-shipment, at sea or into surface waterways;
- discharge of macerated wastes, e.g. sewage sludge

It is likely that the amount of plastic waste in the ocean will continue to increase, driven primarily by the inexorable rise in plastics consumption (ca. 9% per annum), and the continued inadequacy of re-use, recycling and waste management practices in many parts of the world.

Interactions of large plastic items with animals such as seabirds, marine mammals and turtles through entanglement or ingestion are relatively well known, but the non-lethal impacts on individuals and populations are unclear. Even less is known about the potential impacts of micro-plastics on a wide range of smaller organisms, exposed to various particle sizes and chemical constituents.

Weathering and disintegration lead to a slow decrease in the size of the particles. This increases the likelihood that a wider range of animals, which are further down in the food chain, will ingest the particles. It also increases the surface area of the particles, which means that there is more opportunity for the particles to either absorb chemicals or to release them, through a process called chemical exchange. The limited studies of their occurrence in sediments suggests that, to the best of our current knowledge, distribution is patchy and cannot be related directly to sediment transport, and therefore it is not yet possible to predict sinks. Different plastics have different characteristics and among those differences is density. Basically some plastics float and some sink, and this has an impact on where the micro-plastic particles end up in the environment, although very little is known about their ultimate fate, for instance if they eventually sink to the seafloor.

The key questions are:

- to what extent do micro-plastics have a significant direct physical impact and
- to what extent do they provide an additional vector for chemical contaminants increasing or decreasing the exposure of sensitive organisms to PBTs.

In order to measure the amount of micro-plastics in the oceans there are a number of methods available, but common standards are only now being developed to ensure that everyone is measuring the same thing, making it difficult to build a coherent picture of the presence of micro-plastics. It would be valuable to add the measure of micro-plastics to the current marine monitoring programmes. There is a need to set a broad sampling programme with fixed transects in open water subject to regular sampling, to determine how ubiquitous micro-plastics have become in the environment and to gain an overall picture of distribution, type and in particular time trends.

4. Can micro-plastics transport contaminants into the marine environment?

Persistent, bioaccumulating and toxic compounds or PBTs can be transported in the atmosphere or in water. Plastics found in the ocean contains a wide-range of such organic contaminants like PCBs, chlorinated, brominated or fluorinated compounds as well as petroleum hydrocarbons. Three possible fates for the contaminants have been imagined:

Hypothesis 1; the way PBTs are attached to micro-plastics is reversible.

Micro-plastics then act as transporters of the PBTs between environments where their concentration is high to the cleaner areas contaminant concentration is lower.

Hypothesis 2; for most PBTs, atmospheric transport dominates.

Micro-plastics may matter as a source of PBT's only where long-range atmospheric transport is low. In view of the low concentrations of micro-plastics reported in the Ocean, it seems likely that long-range atmospheric transport will dominate along wind trajectories.

Hypothesis 3; micro-plastics are stable in the surface water

Micro-plastics then serve to stabilize the PBTs and reduce either their sedimentation or their uptake in the food web.

It is suspected that plastics may transfer those PBTs that do not undergo long-range atmospheric transport from coasts to the interior of Oceans. Time-scales of uptake and release are a function of the type of plastic, its size, the compound of interest and diffusion between plastic and water.

The workshop considered that the quantification of the size ranges and identification of the type of plastic particles present in the environment needs to be given priority; this will allow a better understanding of the kinetics of plastic-absorbed contaminants as well as potential chemical and physical effects related to particle size. Furthermore, uptake and distribution patterns of micro-plastic particles along food-chains needs to be analysed in different geographic areas.

5. What is the impact of micro plastics on the marine environment?

In the context of the overall marine litter problem, harm can be divided into three general categories:

- i. Ecological, e.g. mortality or sub-lethal effects on plants and animals through entanglements, captures and entanglement from ghost nets, physical damage and ingestion including uptake of micro-particles (mainly micro-plastics) and the release of associated chemicals, facilitating the invasion of alien species, altering the structure of communities living on the sea floor.
- ii. Economic, e.g. cost to tourism, damage to vessels, fishing gear and facilities, losses to fishery operations, cleaning costs; and
- iii. Social, e.g. a reduction in aesthetic value and public safety.



While the effect of large debris is well documented, the effect of small particles is less well known.

Ingestion of plastics by animals can already be considered an undesirable exposure, no matter what other implications it might have. In addition, this ingestion could have detrimental effects on the health of animals either directly through the presence of plastics in their digestion, or through the release of chemicals.

For most of the chemicals involved, their hazard, or potential to cause (eco)toxicological harm is already well known. These chemicals can be in the plastics already as additives, or either taken up by plastics once they are in the ocean. What remains unclear is their degree of bioavailability once adsorbed to plastics. The fact that such chemicals have been identified in plastics in the open ocean could on its own indicate that there is the potential for harm.

It has been shown that the organisms at the lower levels of the food chain can ingest small fragments of plastics, and so these particles make their way up the food chain through predators. Tiny plastic particles can even find their way into living cells, where they can stay for long periods of time

There is a need for further research to understand the impact of micro-plastics on different levels of the food chain. There is also a need for understanding which organisms are likely to ingest plastics, which animals could be used as indicators for the presence of PBTs in the food chain, and what impacts could there be on humans through their food. These contaminants are present in the environment and accumulate within the food chain also in the absence of plastics. The real unknown is to what extent plastics increase the exposure of organisms to contaminants.

One interesting approach to dealing with management of the coastal zone is to integrate the concepts of ecosystem services and their valuation which might make tackling the problem more attractive when considering the cost for action. It is however very difficult to apply cost-benefit analysis to ecosystems.

6. What is currently being done in the world about the marine litter?

6.1 Land-based sources: achievements within the UN system at a global scale

Marine debris as an environmental problem has gained increasing attention through recent UN Resolutions, global environmental agreements and decisions of international agencies.

UNEP has published a review of their global initiative on marine litter which revealed “a widespread lack of systematic, scientific knowledge on the amounts, sources, fates, trends and impacts (social, economic and environmental) of marine litter, which hampers development and implementation of effective mitigation actions”.

IOC and UNEP (Regional Seas Programme) have developed a set of guidelines for conducting consistent survey and monitoring programmes (UNEP/IOC, 2009) as well as guidelines on the use of market-based instruments to address the problem of marine litter (UNEP 2009b).

Despite these initiatives, there are still large gaps in our knowledge of marine debris, in particular micro-plastics, regarding inputs and potential impacts, especially at the local level and many questions still to be answered regarding the effectiveness of waste management measures. Capacity building in waste management is an area where much more effort needs to be mobilized since one of the main issues is the absence or poor development of waste management systems in large parts of the world.

6.2 Ship- and platform-based plastic litter – MARPOL 73/78 Annex V

By comparison to land-based sources, the contribution of garbage from shipping may not be as large as previously thought, although it remains a concern.

It is one of the few inputs of plastic and other debris which is directly controlled by international treaty. Annex V of MARPOL 73/78 aims to eliminate and reduce the amount of rubbish being dumped into the sea from ships. It explicitly prohibits the disposal of plastics anywhere into the sea.

In practice, it is broadly recognized it has struggled to achieve its goals and in 2005, the General Assembly invited the International Maritime Organization to review Annex V to the International Convention for the Prevention of Pollution from Ships. Proposed changes would lead to a strengthened regulation with more extensive record keeping, through which it would be clearer to all that disposal of garbage at sea is in principle prohibited unless under very special circumstances such as emergencies.

6.3 UN global assessment processes

At the World Summit on Sustainable Development (WSSD) in 2002 there was a decision to establish by 2004 “The regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects”. Assessments are a useful tool for decision-making, but a single assessment is not enough. It needs to be part of a process to draw up a coherent global picture.

In order to create this process, an Assessment of Assessments (AoA) was carried out to review the availability and quality and existing assessments of the marine environment. A Working Group of the UN General Assembly is currently working with the result of this assessment to develop the process

(http://www.un.org/Depts/los/global_reporting/global_reporting.htm)

The Global Environmental Facility, Trans-boundary Waters Assessment Programme (GEF-TWAP; <http://twap.iwlearn.org/>), aims to develop methodologies to assess trans-boundary water systems and to develop partnerships among UN and other agencies. The TWAP should help identify priority areas for intervention and must cover natural systems but also human systems including governance, the consequences for humans and the required stakeholder actions.

6.4 Examples of Regional Assessments

UNEP COBSEA - Marine litter in the East Asian Seas Region

COBSEA (Australia, Cambodia, China, Indonesia, Malaysia, Philippines, Singapore, Republic of Korea, Thailand and Viet Nam) commissioned a review (UNEP, 2008) on marine litter in the East Asian Seas region and concluded as follows:

- i. Marine litter from both land- and sea-based sources is one of the major threats to the world's oceans;
- ii. Very little is known about the extent and nature of the problem in the East Asian Seas region;
- iii. The problem of marine litter is likely to be particularly severe in the East Asian Seas region, due to development on the one hand and to the current lack of effective marine litter prevention and control measures in many countries of the region;
- iv. As a component of the broader marine litter problem, lost or abandoned fishing gear is likely to be a major concern in the East Asian Seas region, due to extremely large size of the fishing industry and lack of effective regulation of the industry in the region, including an extremely high level of IUU (illegal, unreported and unregulated) fishing in the region; and
- v. All countries in the region face significant barriers to the effective prevention and control of marine litter.

A regional action plan for marine litter had been agreed among COBSEA's 10 member states, to prevent, mitigate, raise awareness and monitor marine litter.

WIOMSA, Marine Litter in the West Indian Ocean Region: First Regional Assessment

The West Indian Ocean Marine Science Association carried out a Regional Seas Assessment on pollution status (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania) and, with regard to marine litter, concluded that:

- i. Very little data exist other than in South Africa. Nowhere has the economic impact of litter been adequately quantified;
- ii. Marine litter is not dealt with in policy or law as a separate category of waste;
- iii. Most countries do have laws and policies on solid waste management but in many instances they are not effectively implemented;
- iv. The most significant source of marine litter is solid waste in runoff of water from urbanised areas;
- v. The major constraints to effective waste management are inadequate awareness about impacts and/ or a shortage of funds to deal with it;
- vi. Sea-based sources of litter do not appear to be as significant as land-based sources and are even more difficult for countries in the region to control;
- vii. The extent to which solid waste generated on land is prevented from reaching the sea varies between countries, and regions within countries.
- viii. Although the overall levels of marine litter produced by the countries in the West Indian Ocean must be insignificant compared with levels from highly industrialized economies, the situation is considered serious enough to require urgent remedy.

AMEP - Assessment and Management of Environmental Pollution of the Wider Caribbean Region

AMEP covers 28 member countries in the Wider Caribbean region, including the overseas territories of the United Kingdom, The Netherlands and France. In the region, land-based solid waste represents the largest source of marine debris at 70-80% and AMEP places the major emphasis on prevention through the Cartagena Convention.

AMEP has considerable direct experience in confronting the marine litter problem in the Caribbean, as tourism in the region involves a high proportion of large cruise ships and yachts.

6.5 European Commission initiatives

The European Commission recognises that marine biodiversity is under severe pressure from habitat destruction, fragmentation and degradation, over-exploitation, unsustainable practices, invasive species, ocean acidification, pollution and climate change.

The EU is gradually developing legislation to protect the seas and a Marine Strategy Framework Directive was adopted in 2008. This lays out the plan that “the EU Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest”.

Good Environmental Status means the preservation of ecologically diverse and dynamic oceans and seas which are clean, healthy and productive, the use of the marine environment at a sustainable level, protecting the potential for uses and activities by current and future generations. To achieve this, each EU Member State must progressively put in place its own “Marine Strategy” action plan.

As far as research is concerned, the drivers for the Marine/Maritime research strategy in the European Union (EU) are:

- i. the maritime economy is of crucial importance and we need to further develop it;
- ii. there is an increasing environmental pressure from human activities and climate change, together with increasing competition for marine space ; and,
- iii. there is a need to better predict (and mitigate) the impact of climate change through marine science.

In order to achieve this, the European Commission has issued, within the framework of its research funding, calls for research projects on a wide range on topics touching to the state of the oceans, whether on maritime transport, spatial planning, energy, fisheries, aquaculture or marine biotechnologies. It is recognized that the seas are shared and major research infrastructure and programmes require funding beyond the capacity of single member states and call for new governance mechanisms.

6.6 USA, National initiatives

In the USA, a programme has been launched to support national and international efforts in understanding and reducing marine debris. This led to a number of workshops on the topic of micro-plastics.

The Marine Debris Program of the NOAA recognises the need for well standardised, long-term and consistent methods <http://marinedebris.noaa.gov/>. NOAA also supports the improvement in techniques related to sorting and analysis of micro-plastic particles and to the changes brought by degradation and weathering.

6.7 Coastal municipalities and local authorities

Coastal municipalities rely heavily on the marine environment and are therefore directly confronted with issues of global pollution over which they often have little control, including marine litter, which affect tourism and recreation, marine industries such as fishing and aquaculture as well as shipping.

Education, regulation and enforcement are seen as key solutions, together with economic instruments such as deposit/refund schemes, a plastic bag levy, no special-fee port reception facilities and improving plastic article design for recycling.

6.8 Chemical industry policies regarding marine litter

Europe

PlasticsEurope supports the UNEP view that the majority of marine litter originates from land-based sources and that we need to prevent it from entering marine habitats through integrated management of solid-waste. PlasticsEurope and the European Plastics Converters (EUPC) are therefore focussed on finding solutions to dramatically reduce the volumes of waste that ends up in the oceans. A growing concern is how to address the legacy of waste already present in the oceans?

Some 10 years of effort and over 50 million Euros of industry investment have been mobilized to reduce plastic waste and to encourage recycling. EUPC and PlasticsEurope fund nine work programmes covering topics such law enforcement, logistics, education and knowledge transfer.

PlasticsEurope and EuPC are setting up a long- term programme based on a strong EU partnership involving the plastics industry chain, NGOs, the waste and recovery industry, the EU and national authorities, the research and academic community and a National Educational programme. The aim is to develop a set of clear objectives and to select the right tools to achieve them, as well as to create awareness by working together in an open consortium towards solutions.

United States

A campaign by the American Chemical Council's (ACC) Plastic Division "Plastics – Too Valuable to Waste - Recycle." emphasizes their view that "plastics do not belong in the oceans; they belong in recycling bins after use."

The ACC's activities to reduce marine debris have included:

- Marine Debris Solutions Workshop that convened a broad spectrum of federal and state agencies, business and industry groups as well as NGOs.
- Sponsoring demonstration projects establishing 700 recycling bins for plastics and other materials along the California coast, primarily at beaches and rest stops.
- Promoting prevention of litter and recycling as a member of the national non-profit Keep America Beautiful (KAB) major upcoming antilitter campaign.
- Operation Clean Sweep (OCS) – a set of best practices for management to help companies that make or use plastic resins to implement good housekeeping and pellet containment practices.
- The ACC and its members also support local and national clean-up campaigns and marine debris research through NOAA and other organizations.

6.9 Non-governmental Organizations

International Coastal Cleanup (ICC)

The International Coastal Cleanup programme was initiated in 1986, with a single cleanup campaign by volunteers along the coast of Texas, USA. It has grown significantly since then, and in 2009 it was 498,818 volunteers from 108 countries and locations who participated and collected 3,357 tonnes of debris from over 6000 sites.

WWF

WWF considers the plastic litter problem to be a global one, requiring global solutions, which should focus on improved products while avoiding harm to marine life. An important part of this is through improved legislations on the international and national levels.

6.10 Round-table discussion

Key stakeholders need to be involved in policy strategies, as there is often a large gap between international efforts and local government levels. Local government is the most important stakeholder, but may be the weakest link in the chain, in terms of awareness and resourcing. Without addressing levels of capacity there is little hope of progress.

Beaches can be relatively easy to monitor for litter and micro-plastics, so building this parameter into existing monitoring programmes should not be too difficult.

One area where micro-plastics could be incorporated is through regional programmes of monitoring and there is a need for a consistent and clear micro-plastic parameter to introduce into regional monitoring programmes.

The workshop suggested also that NOAA's current methodologies for sampling the water column and sediments be adopted for monitoring micro-plastics, taking account of published work, and micro-plastic monitoring in the water column could be introduced into routine programmes of sampling of plankton

7. Is a global assessment of micro-plastics in the marine environment necessary?

A global assessment of micro-plastics impact on the marine environment could be beneficial at this time and there is both sufficient public concern and a need to provide further objective information on the topic to enable policy makers to act. This assessment would need to take into account not just micro plastics but marine litter in general also, in order to understand the general context and processes involved.

The participants recognised that with limited resources available, politicians, administrations and the plastics industry would understandably give priority to redressing the overriding problem of marine litter and its socio-economic impacts.

A primary motivation for a global assessment is the growth in the production of plastics, slow-progress in introducing practices of management to treat solid waste around the world and the continued, if not increased, input of plastics to marine habitats. It is important to understand their degradation and fragmentation, how these fragments behave and how they affect the environment. The possibility that micro-plastics could act as significant

transporter for contaminants also needs to be addressed since it is as yet unclear if it is the case.

8. Conclusions

The main gaps in knowledge that have been identified are:

- There is a need to identify and develop global environmental standards, as well as broadly applicable indicators, with which to benchmark these standards.
- There is a need for better understanding of the dynamics of compounds that are Persistent, Bioaccumulative and Toxic (PBTs) in relation with micro-plastics in the marine environment.
- The quantities of plastics entering the oceans are still largely unknown, and methods need to be developed to measure and to limit that input.

A global assessment of micro-plastics could be integrated with already existing programs such as the UN Assessment and the Transboundary Waters Assessment Programme (TWAP). There just needs to be a set of standardized methods to latch on to these existing initiatives, and the sampling methods developed by NOAA could be a useful tool for that.

The main conclusion is that there is still very limited information on micro-plastics in the marine environment. We do not know how much of it makes its way to the oceans and how it behaves once it is in the oceans, both in terms of movement in the ocean and in terms of degradation, fragmentation, and modification of properties due to weathering. In addition, very little is known on the degree to which micro plastics transport contaminants and on the physical and chemical effects plastic fragments on the ecosystem.

There is also a need for an assessment to follow on from UNEP's efforts, to collate the available scientific information and make recommendations that will be of use to the wide variety of policy, industry and societal organisations that have responsibility in this area. This assessment should take into account the overall marine debris and solid waste management problem.