GESAMP Working group 40
Sources, fate & effects of micro-plastics in the marine environment - a global assessment

Report of the Inception Meeting
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Report of the Inception Meeting ¹
(13-15\textsuperscript{th} March 2012, UNESCO-IOC, Paris)

Cover image: micro-plastic particles collected from the Irish Sea, courtesy of Thomas Maes,
Cefas, UK

Whilst every attempt has been made to provide an accurate and balanced report of the
Workshop, the editors take full responsibility for any errors, omissions or inconsistencies.

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Executive summary

The Inception Meeting of GESAMP Working Group 40 was held in Paris on 13th – 15th March 2012, hosted by UNESCO-IoC. It was attended by ten Members, representatives of sponsoring organizations (IMO, IOC, UNEP, UNIDO, ACC, Plastics Europe) and a number of invited Observers (DG ENV, OECD, UNEP/MAP). An unexpected delay in finalizing some contractual arrangements led to fewer than intended participants. Despite this, the meeting proved to be a lively and challenging event, consisting of a number of invited presentations, break-out groups and feedback sessions.

The main purpose of the meeting was to provide an opportunity for the WG Members, sponsoring Agencies and invited observers, to discuss and agree the overall objectives, key questions and intended outputs. Three invited Members gave overviews of the current state of knowledge and knowledge gaps on; i) sources, distributions and trends of micro-plastics; ii) properties and degradation of polymers; and, iii) physical and chemical effects of micro-plastics. These followed by several shorter presentations on related programmes (e.g. NOAA, Gulf of Mexico LME, UNEP, ACC/PE, NCEAS working group) before the meeting split into two break-out groups to consider the scope and approaches required to conduct an assessment: i) sources, distribution and trends; and, ii) properties and effects. Periods for discussion and feedback were included in the meeting timetable, with rapporteurs appointed to record the key points.

There was agreement on the need to set the assessment in a recognised assessment framework, and a number of options were described. This needed to be placed in an appropriate Road Map and a revised time-line for the work programme was recommended for approval by GESAMP 39 (due to take place in New York, hosted by UNDP, 15th – 20th April 2012). The proposed accelerated start to some of the Terms of Reference (ToR) was a consequence of the increased financial support since G38, where a phased approach had been recommended, spreading the work of the group over four years. The increased support will allow all the ToRs to be initiated at the start. The meeting also questioned whether there was a need for an additional ToR, to consider how to address social and economic concerns, including public perceptions (Annex 2). While scientific evidence illustrates the presence and potential dangers of micro-plastics in the marine environment, the attention on this as a major threat that policy makers need to address has largely come from NGOs, the media, and the general public.

1. Background and context

1.1 Brief introduction to GESAMP

GESAMP was created in 1969 to provide a number of UN Agencies, having marine and maritime interests and responsibilities, with access to authoritative and independent scientific advice on a wide range of issues. In most instances GESAMP responds to requests
from the Agencies on specific topics. This may lead to the setting up of a Task Team or Working Group to which leading experts are invited to contribute on a *pro bono* basis. In most cases the result is some form of assessment on a particular theme. The current structure of GESAMP is presented in Figure 1.1. GESAMP welcomes partnerships with a wide range of organizations, on a formal or informal basis. Further information and a list of previous publications may be found and downloaded at [www.gesamp.org](http://www.gesamp.org). Working Group 40 (WG40), on ‘Sources, fate and effects of micro-plastics in the marine environment – a global perspective’, is the most recent example of GESAMP’s work.

![Figure 1.1. Current structure of GESAMP](image)

1.2 Rationale for selecting the topic

It is widely recognised that marine debris can have significant ecological, human health, social and economic impacts. Plastics form a large proportion of marine litter, and the widespread occurrence of macroscopic plastic debris and the direct impact this can have both on marine fauna and legitimate uses of the environment, sometimes remote from industrial or urban sources, has been well documented. In general, plastic debris comes in a wide variety of sizes and compositions and has been found throughout the world ocean, carried by ocean currents and biological vectors (e.g. stomach contents of fish, mammals and birds). Plastics degrade extremely slowly in the open ocean, primarily due relatively low temperatures. In recent years the existence of micro-plastics and their potential impact has received increasing attention (e.g. (Betts 2008; Thompson, Moore et al. 2009)). Micro-plastics have a range of compositions and can be demarcated by usage and source as: i) ‘primary’ particles, such as micro-plastic resin pellets used in the plastics industry, and in certain applications such as industrial abrasives and skin-care products; and, ii) ‘secondary’ micro-plastics resulting from the degradation and breakdown of larger items.

Litter was one of the categories incorporated in the 1995 Washington Declaration concerning a Global Programme of Action (GPA) for the protection of the environment from land-based sources (Gulin and Stokozov 2005). It was listed as being of concern in the GESAMP 71 report on land-based activities (GESAMP 2001). More recently, the problem of marine debris, and the need for increased national and international control, was dealt with
at the 60th session of UNGA within the Oceans and the law of the sea session ((Bailly du Bois and Dumas 2005); paragraphs 65-70). A more definitive assessment was provided by the analytical overview of marine litter, initiated by UNEP with input from IOC, IMO and FAO (UNEP 2005). This provided a useful overview of the issue, including type, source and distribution of litter, and measures to combat the problem. FAO has expressed concern over lost, abandoned or otherwise discarded fishing gear and has addressed this issue through a correspondence group with IMO and in a joint study with UNEP (Hughes, Brown et al. 2005). UNEP has pursued this issue within the Regional Sea Programme and has published a review of their global initiative on marine litter (Yeager, Santschi et al. 2004). Subsequently, marine debris was one of three topics selected for inclusion in the 2011 UNEP Year Book, with specific emphasis on micro-plastics as an emerging issue of environmental concern (UNEP 2011)

1.3 Micro-plastics as a new and emerging issue

One of the important roles that GESAMP Members are expected to undertake is to keep a watching brief for any topics of emerging concern and bring these to the attention of the sponsoring UN Agencies. The potential influence of micro-plastic particles on the transfer of pollutants, from seawater to biota, was raised as an emerging issue within GESAMP, leading to the preparation of a scoping paper that was reviewed and approved at GESAMP 37 in Bangkok (GESAMP/IMO/FAO/UNESCO-IOC/UNIDO/WMO/UN/UNEP 2010). Since then GESAMP has been involved in a number of initiatives related to marine plastics, marine micro-plastics and associated contaminants that have been supported by several of the Sponsoring Organizations. Following approval by GESAMP 37, an International Workshop on Plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans, was hosted by UNESCO-IOC in Paris in June 2010 (GESAMP 2010).

One of the main recommendations of the Paris workshop was that there was a need for a global assessment to explore the extent to which micro-plastics represented a hazard to the marine environment. Subsequently GESAMP contributed to the UNEP Year Book 2011 (UNEP, 2011); the 2nd NOAA Scientific Workshop on Micro-plastics held in Tacoma, Washington, United States in October 2010 (Arthur and Baker 2011); a special session at SETAC (Society for Environmental Toxicology and Chemistry) 2010; special sessions at PICES (North Pacific Marine Science Organisation) in 2010 and 2011; and, the 5th International Marine Debris Conference held in Honolulu, Hawaii, United States in March 2011. The Terms of Reference and overall draft work programme for WG40 were approved at GESAMP 38 in Monaco in May 2011. This was followed by a period of revision and working closely with potential sponsors. GESAMP was very fortunate to attract support from NOAA and the plastics producers, as represented by Plastics Europe and the American Chemistry Council (ACC), in addition to support from the UN Agencies UNESCO-IOC, IMO, UNIDO and UNEP. A schematic showing the evolution of WG40 is shown in Annex 4.

1.4 Terms of Reference

A draft set of Terms of Reference was discussed and agreed at GESAMP 38 in 2011. The work programme was envisaged to take place over a four-year period, with five key topics divided into 3 main phases:

1st Phase
1. Estimate rates of inputs of micro-plastic particles (e.g. resin pellets, abrasives, personal care products) and macro-plastics (including main polymer types) into the ocean; to include developing methodology, using monitoring data, identifying proxies (e.g. population centres, shipping routes, tourism revenues);

2. Review modelling of surface transport, distribution & areas of accumulation of plastics and micro-plastics, over a range of space- and time-scales;

2nd Phase
3. Review processes (physical, chemical & biological) controlling the rate of fragmentation and degradation, including estimating long-term behaviour and estimate rate of production of ‘secondary’ micro-plastic fragments;

4. Review long-term modelling including fragmentation, seabed and water column distribution, informed by the results of ToR 3;

3rd Phase
5. Review uptake by biota, physical biological impacts at a population level.

One of the intentions of the inception meeting was to allow WG40 members, sponsors and other observers to discuss the ToRs, work programme and outputs. As a result there was a proposal to slightly modify the ToRs (section 6, Annex 5), to be presented for approval at GESAMP 39 (New York, 15 – 20 April 2012).

2. Introduction to the Inception Meeting

2.1 Welcome by UNESCO-IOC

The Workshop was opened by Luis Valdez, who welcomed participants on behalf of UNESCO-IOC. He emphasized the importance IOC place in demonstrating the utility of sound science. Marine debris is considered a high priority and is a feature of the UN Regular Process that IOC is helping to coordinate (section 4.9). IOC needs to be able to produce good guidelines for monitoring and assessment of plastics in the ocean to be used to carry out the first assessment of the Regular Process due in 2014. All participants were encouraged to introduce themselves and explain their interest in the work of WG40.

2.2 Overview of objectives, scope and target audience

Heather Leslie discussed various aspects of the approach to the work ahead in WG40 and set out the overall goal: to conduct an independent, expert, global assessment of the sources, fate and effects of micro-plastics in the ocean based on existing information; to include potential physical effects (ingestion, bio-film substrate, invasive species); and, to include potential effects of chemicals present within the plastic (e.g. additives, sorbed contaminants). It is important for the scientific team to decide on a suitable Assessment Framework to be applied. Some of the elements that need to be considered are as follows:

- Literature review: a critical review and assessment of existing reports / synthesis of collective knowledge
- Can we find new ways of thinking about these existing data?
- To what extent can this be considered a classic risk assessment (i.e. exposure x hazard = risk)?
- What assumptions and proxies will be needed for modelling purposes?
- Mono-disciplinary assessments vs. holistic?
- To what extent should/can we include the ecosystem approach (social-ecological systems)?
- Do we assess based some kind of quality criteria?
- Do we map areas where Good Environmental Status (GES) exists and where it doesn’t (e.g. in the gyres, coastal zones with big populations and inadequate waste management)
- How will we apply the assessment framework?
- What are our key specific questions and why are the answers important?

It is important to pay attention to how the assessment will be used by the sponsoring agencies and other interested parties:
- Conducting the ecosystem stock-taking, presenting the indicators as the ‘information pillar’ and directing information into the decision-making process
- Helping to create a vision for the policy makers
- Providing support for decision-making
- Input for the plans of action (e.g. Plan-Do-Check-Act management cycle)
- How specific could/should mitigation recommendations be?
- How do we link this work to the overall ecosystem approach to marine environmental management?

We discussed some key questions to try to make our WG40 goals realistic:
- How to make it a global assessment with a lack of national/regional data?
- Is the current uncertainty of models and sources/effects estimates acceptable?
- Will there be enough micro-plastic eco-effects data for a comprehensive assessment?
- How do we come up with recommendations that we know are feasible?

The sources of micro-plastics provide the links to solutions – therefore it is important to investigate:
- Defining representative types of micro-plastics, out of the many thousands of potential types;
- Defining and quantifying the most significant sources of micro-plastics;
- We are aware of some sectors that create micro-plastic litter – but how do we really define a ‘source’?
- What approaches are available to estimate rates of input, and are these realistic or reliable?
- How much do we need to know about the different sources – does this depend on the type of mitigation?

The fate of micro-plastics is a key aspect of understanding the overall risk and, with this understanding, effective prevention and mitigation policies have a better chance of being implemented. Fate is controlled by:
- Extreme persistence (degradation half-life of micro-plastics?);
- Rate of formation of micro-plastics by fragmentation of macro-plastic litter;
- Potential interaction with naturally occurring ‘marine snow’;
- Sinks: Sediments, seabed, beaches;
Transport pathways (requiring modeling);
- Food chain and interactions with biota.

Effects of micro-plastics are another key aspect of understanding the overall risk, and as for fate, is crucial to support policy implementation:
- Ecological effects;
- Effects on individuals (e.g. reduced fitness, inflammation, reduced primary production, mortality);
- Effects on ocean chemistry (indirect effects on biological systems);
- Toxic effects of sorbed chemicals;
- Particle toxicity effects;
- Biodiversity / community composition effects (biofilms);
- Invasive species (e.g. microbial, viruses)

Our tasks during this inception meeting include:
- Defining the assessment framework;
- Focusing and fine-tuning the research questions;
- Organising and structuring the upcoming work;
- Keeping the plan specific, fit-for-purpose and realistic (within the constraints of time and budgets of the WG40);
- Considering how to make the work programme complementary and not duplicate efforts elsewhere;
- How to go about sharing literature databases, etc.

2.3 Feedback from participants

Participants were encouraged to provide their initial ideas and reactions to the introductory presentation, and they raised a wide range of issues including requests for clarification and opinions on how the assessment should be carried out. Policy makers need guidance on the scale of the problem and the necessity of incorporating micro-plastics within existing or proposed legislation. Perhaps the most important issue is the high level of uncertainty about the potential ecological impacts of micro-plastics. Of those UN Agencies with the greatest interest at present: i) UNEP wants science-based information on the effects of micro-plastics, with important questions outstanding about fate, population level effects, and food chain effects; ii) UNIDO is very interested in harmonized monitoring protocols and prioritization of key research questions in general; and, iii) IOC needs to be able to produce good guidelines for monitoring and assessment of plastics in the ocean to be used in the Regular Process. In addition, the Directorate General Environment (DG ENV) of the EU has recognized the importance of addressing marine litter as part of the new Marine Strategy Framework Directive (MSFD)\textsuperscript{2}. This includes the distribution of litter on beaches, the seabed and water column, including ingestion by biota. DG ENV and DG Research have funded several projects with a marine litter theme and it is expected they will deliver results that WG40 will be able to make use of over the period 2012 - 2015. These include projects on sources of litter and loopholes in recycling. The OECD is concerned with providing guidelines for monitoring, particularly in the field of nanotechnology, which represents one end-

\textsuperscript{2} EU JRC, 2011. Marine litter – technical recommendations for the implementation of MSFD requirements, EUR 25009.
member of the size spectrum of micro-plastics. One output of the WG should be a series of time-lines covering the various research, assessment and legislative activities.

There is a need to combine existing information, from a broad range of disciplines, in new ways. The fate of micro-plastics is a key unknown. We may assume that plastics will fragment to smaller sizes but the existence of temporary or permanent sinks has not been established. The most complete time-series records do not reveal an overall increasing or decreasing trend in micro-plastics in the open ocean, begging the question ‘where do they go?’. There was a consensus that, if possible, the ‘fate and effects’ ToR should not be temporally split from the other ToRs. In addition to working with in an assessment framework (section 6), there is a need for the WG to consider the current lack of harmonization of methods and regional differences in data coverage.

In a comprehensive assessment of marine litter there is a need to include social and economic harm, as well as economic harm. The WG needs to decide how far it is appropriate to include socio-economic aspects. It was pointed out that there has been a disproportionately strong response by NGOs, the media and the public to emerging information about the extent of marine debris and micro-plastic contamination in the ocean, compared with the known impacts of POPs such as PCBs. There will be a public demand for action and WG40 can help by providing a sound scientific basis for decision-making.

3. Overview of current state of knowledge and knowledge gaps

3.1 Sources, distributions and trends
Invited presentation by Prof. Richard Thompson, University of Plymouth, UK

Richard Thompson (RT) provided an introduction to the current status of research into micro-plastics (MPs) in the marine environment. Although MPs have been reported in the scientific literature since the early 1970s, interest increased in the mid 1990s as a result of work of a relatively small number of individuals (Thompson, Olson et al. 2004). MPs have been operationally defined as particles of up to 5 mm – that being the size range likely to be most readily ingested by many organisms (Arthur, Baker et al. 2009). Particles as small as 1.6 µm have been reported but there is no clear cut-off to nano-particle sizes. MPs can be considered to be of two types: i) ‘primary’ particles representing material used in manufacture of plastics (resin beads), for industrial processes (e.g. as abrasive powders for air blasting, powders using in roto-moulding), and in domestic cleaners and personal care products (Figure 3.1); and, ii) ‘secondary’ particles resulting from the breakdown of larger pieces of plastics and composite materials, including textiles, by fragmentation and degradation processes.
A horizon scan of conservation issues concluded that the effects of plastics depended on size (large to microscopic), potential for ingestion (low to high), abundance (low to ubiquitous) and potential for chemical transport (low to high). The terrestrial environment may represent a significant temporary repository for micro-plastics that eventually may enter the marine environment, but is not being explicitly included in the current assessment.

The traditional methodology for separation and identification is largely based on visual observation and time-consuming. Identification of particular polymers can be achieved using analytical techniques such as Fourier Transform Infra-Red Spectroscopy (FT-IR). It is thought that current methods may underestimate the quantities present (e.g. by using relatively large mesh sizes in sampling nets: 330 µm, Figure 3.2). MPs have a global distribution but knowledge of sinks is very limited. There are a limited number of time-series available, but those that exist, based on the analysis of archived samples, do not show clear trends of increase or decrease (Law et al., 2010; (Thompson, Olson et al. 2004). A study has commenced to review plankton samples obtained from 50 years of data captured for the Sir Alister Hardy Foundation using the Continuous Plankton Recorder (CPR) (Sadri et al. year), which may shed some light on this phenomenon. Spatial and temporal trends have been obtained from studies of bird ingestion. For example, examination of the stomach contents of the northern fulmar *Fulmarus glacialis* revealed higher concentrations near the industrialised regions of the southern North Sea. Over the past decade the total average mass has remained relatively constant although the proportion of industry-related material has declined, and there is some evidence of a decrease in particle size.
3.2 Properties and degradation of polymers

*Invited presented by Prof. Tony Andrady, North Carolina State University*

This presentation provided a general introduction to plastics, their composition and properties, and the processes of degradation in the marine environment. Plastic usage per capita has been highest in North America and Europe, but usage is correlated with Gross National Income (Figure 3.3) and is increasing rapidly in Asia. New products are constantly being brought to market, including major developments such as planes, ships and bridges.

![Figure 3.3 Relationship between plastic consumption and gross national income](image)

There are about 10,000 different plastics being produced but only seven varieties or classes are produced in high volumes (PP, PVC, HDPE, LLDPE, LDPE, PS, PET, PUR Figure 3.4) and each has different weathering properties that also depend on additives compounded into them. About 50% of the global population lives within 100 km of the coast, and population growth is greatest in the coastal region. This land-based contribution represents the main source of plastics to the marine environment. Of the various sources of micro-plastics, Prof. Andrady considered ‘sand’ blasting to be a greater source than cosmetics, and generation from larger fragments to be a greater source than direct emissions. Discarded fishing gear also represents a significant source of litter. It tends to sink rapidly and will degrade slowly on the seabed. Ship-breaking, which occurs on beaches in some regions, may be a significant but under-reported source of plastics.
Several types of plastics have a low specific gravity and float in seawater (Table 3.1). These are commonly used in packaging and are commonly found as litter on beaches. However, colonization by biological films and foul ants is ubiquitous in the marine environment and this can lead to an increase in the overall density of the particle causing the particles to sink.

<table>
<thead>
<tr>
<th>Type</th>
<th>Usage</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>Plastic bags, six-pack rings, gear</td>
<td>0.91-0.95</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>Rope, caps, gear, strapping</td>
<td>0.90-0.92</td>
</tr>
<tr>
<td>Polystyrene (expanded)</td>
<td>bait boxes, floats, cups</td>
<td>0.01-1.05</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>utensils, containers</td>
<td>1.04-1.09</td>
</tr>
<tr>
<td>Polyvinyl chloride (flexible)</td>
<td>Film, pipe, containers</td>
<td>1.16-1.30</td>
</tr>
<tr>
<td>Polyamide or Nylon</td>
<td>Gear, rope</td>
<td>1.13-1.15</td>
</tr>
<tr>
<td>Polyethylene terephthalate</td>
<td>Bottles, strapping, gear</td>
<td>1.34-1.39</td>
</tr>
<tr>
<td>Polyester resin + glass fibers</td>
<td>Textile</td>
<td>&gt;1.35</td>
</tr>
<tr>
<td>Cellulose Acetate</td>
<td>Cigarette filter</td>
<td>1.22-1.24</td>
</tr>
<tr>
<td>Sea water</td>
<td></td>
<td>~ 1.02</td>
</tr>
</tbody>
</table>

An understanding of terminology is important when considering the fate of plastics in the ocean. *Complete degradation* refers to the destruction of the polymer chain and its conversion into small molecules such as carbon dioxide or methane. *Degradation* refers to an alteration in the plastic's properties (e.g. embrittlement, discolouring; Figure 3.5). Few plastics undergo complete degradation in the marine environment. Polylactic acid, for instance, is truly biodegradable but it is much more expensive to produce. But, for many applications it is the durability of plastics that is the most sought after property; it is not clear if the existing biodegradable plastics deliver the mechanical integrity and durability needed for most applications.

There are four main environmental degradation mechanisms: i) photo-induced oxidative breakdown (beaches and surface water); ii) thermo-oxidative breakdown (beaches and
surface water); iii) biodegradation (extremely slow and occurs in sediment, water column – under the best conditions proceeds at a rate of only 1-3% per year); and, iv) hydrolysis (not significant). Products on beaches degrade more rapidly, while in water and on the sea bottom this process is severely retarded because of low UV and low temperature. Weakening and fragmentation leads to different perspectives of degradation and potential harm. A reduction in size may reduce the likelihood of entanglement, and the visible effects of littering. But micro-plastics may still be having a physical or chemical impact, especially on micro-fauna that is not readily observable.

![Diagram of polymer degradation](image)

**Figure 3.5 Simple model of polymer degradation**

Improved monitoring methods would help to increase our knowledge about the distribution and fate of micro-plastics. There is potential to combine techniques to produce automated detection systems. For example, introducing Nile Red (a red dye absorbed by lipids) may allow detection of plastics by flow cytometry or fluorescence microscopy.

### 3.3 Chemical and physical effects of micro-plastics

*Invited presentation by Heather Leslie (IVM-VU Amsterdam, the Netherlands)*

The presentation summarised the chemical and physical components of the potential ecological effects of micro-plastics. We can look for these effects at the level of cells, individuals, populations and ecosystems. The effects can be direct and indirect, abiotic (e.g. synthetic chemicals, particle toxicity), or biotic (e.g. pathogens, invasive species, predation, etc.). It is common in ecotoxicity studies for acute effects to be identified at higher doses, while lower doses may cause chronic effects (in many cases the chronic effects observed are sub-lethal). Classic ecotoxicology regards risk as being the product of exposure x hazard; for
example, this is the basis of OSPAR assessments. Hazard is a word for the intrinsic toxic properties of the micro-plastic. Mixture toxicity of chemicals is commonly observed in the environment because chemicals are rarely present alone. If micro-plastics contain more than one chemical (e.g. additives, sorbed POPs, residual monomers), mixture toxicity could be at play. But an organism can also be exposed to “multi-stress” via a combination of chemical and particle toxicity, and other stressors (“stress ecology”). Multiple modes of toxic action, multiple hazards, may potentially lead to multiple symptoms when organisms are exposed to micro-plastics; e.g. inflammation, physiological stress, neurotoxicity, endocrine disruption, carcinogenicity and behavioural changes.

The currently existing field exposure data for micro-plastics consists of several studies reporting numbers of micro-plastic particles sieved out of a volume of seawater e.g. surface water (manta trawl) or 10 m depth (Continuous Plankton Recorder surveys), marine sediments and marine biota (ingestion and biofilm colonization). In the lab, exposure data has been collected for human and other mammalian systems (mostly nano-plastic size ranges), and marine invertebrates.

POPs have been measured sorbed to/into plastic particles collected at sea or on beaches, and certain additives have been observed to leach out of macro-plastic, although additive leaching from pellets or micro-plastic fragments has not been studied in detail yet (Figure 3.6). Polymer science on the other hand has broad knowledge on the residence time of the additives in polymers due to the need to know that additives will last and remain function in the material throughout the product lifetime.

Figure 3.6 The potential of chemical transfer between plastic particles and biota. H. Leslie

Chemical toxicity data for plastic additives, monomers and sorbed environmental contaminants such as POPs have been extensively reported in the literature. Synthetic polymer materials contain between 4 and 80% additives in addition to the polymer chains. In principle, these chemicals could to a certain degree leach out to the water phase, or into tissues of biota which consumes them or which use the micro-plastic as substrate.

There are several challenges to characterising hazard globally:

i. dedicated micro-plastics studies are not numerous yet and many different types of information has to be combined to address the question of hazard;
ii. particle toxicity is size- and shape-dependent;
iii. toxicity is dependent on the specific chemical make-up of the micro-plastic particle (poly-, di-, monomer, additives, sorbed contaminants);
iv. there may be many different types of micro-plastics in any given environmental matrix;
v. there is a wide variety of possible uptake routes and accumulation patterns in vastly different marine life forms and habitats;
vi. there is a great diversity of potential ecological effects (e.g. substrates and/or vectors for viruses and invasive species; food chain transfer; biogeochemical cycle effects; and, biodiversity).

Persistence (P), bioaccumulation (B), toxicity (T) and long-range transport (LRT) are characteristics examined in risk assessments of chemicals. The synthetic polymers of micro-plastics are undoubtedly persistent, they may bio-accumulate to various degrees in living organisms (Table 3.2), and can be potentially intrinsically toxic (especially if toxic additives, toxic monomers or other chemicals are present or if particles << 1 mm). Particles which cannot be excreted, such as in found in the Northern fulmar *Fulmarus glacialis* (1-5 mm) may also lead to inflammation, immuno-toxicological responses and effects in the Gi tract or other affected tissues. Micro-plastics are transported over long distances, leading to their accumulation in mid-ocean gyres.

Table 3.2 Methods used to sample micro-plastics in a range of biota

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fur seal scat</td>
<td>&gt;0.5 mm Field-collected seal scats frozen and later broken apart with water in a series of two sieves with mesh diameter of 1 mm and 0.5 mm. Sigma Scan-Pro image analysis for measurement. SEM photos made. Thin slices scanned with FTIR.</td>
</tr>
<tr>
<td>Laboratory mussels</td>
<td>3.0 or 9.6 μm Fluorescent beads were used. Mid gut tissue and isolated haemolymph. Histological analysis and imaging techniques.</td>
</tr>
<tr>
<td>Planktivorous fishes from the N Pacific Central Gyre</td>
<td>μm-mm Neuston samples from manta trawl (tows 1.5 to 5.5 h). Fixed in 5% formalin, soaked in fresh water, transferred to 70% isopropyl alcohol. Fish stomach removed. MP size, color and type examined using dissecting microscope. Weighed.</td>
</tr>
<tr>
<td>Fulmars (frozen corpses)</td>
<td>&gt;1 mm Sieving the gut content with sieve over 1 mm. Smaller sizes are not included and the sieve often gets plugged. Microscopic inspection.</td>
</tr>
<tr>
<td>Fish</td>
<td>μm-mm Inventory of the presence of plastics in the digestive tract.</td>
</tr>
<tr>
<td>Nephrops norvegicus</td>
<td>μm-mm Stomach contents analysis: mid guts removed from 120 animals; 24 h. in 0.04% formaldehyde, then stored in 70% ethanol. Light microscope 400x. Categories: up to five strands; strands and ball; ball.</td>
</tr>
</tbody>
</table>

The introduction of micro-plastic particles has created a new habitat in the sea, providing an artificial substrate potentially acting as a vector for the dispersal of alien species, exotic diseases and anthropogenic chemical compounds. The extent to which this represents a significant risk is an important gap in knowledge. Limited particle toxicity data for micro-plastics have been generated for the nano-plastic size range. However, there is a large body of scientific data available on the toxicity and the human health effects of small micrometer range fine particulates, and this may provide some insight into the potential effects of micro- and nano-size plastics.

### 3.4 Feedback from participants

Several issues were raised in discussion. There was a consensus that potential effect of POPs is a key concern. The extent to which non-packaging waste (containing a greater proportion
of additives such as flame retardants) contributes to the overall micro-plastics population needs to be addressed.

The fact that there has been such a large public reaction to plastics ending up in the ocean means that the scientific community has a responsibility to provide authoritative and independent advice on which policy and management decisions can be based. One participant likened the emerging knowledge on micro-plastic pollution and effects to the situation for PCBs many decades ago (starting back in the 1930s), when environmental occurrence, fate and human health effects for these novel chemicals were starting to be uncovered by government scientists and chemical industry workers. This led to a wider discussion of the extent to which social and economic issues should be included in the work of WG40, and the potential of including an addition ToR (Section 7.2, Annex 5). Ultimately social-ecological interactions are essential factors in ecosystem-based marine environmental governance.

4. Review of related initiatives

4.1 NCEAS Working Group on marine debris

*Kara Lavender Law, Sea Education Association*

Kara described the objectives and expected outputs of a current Working Group on *Marine debris: scale and impact of trash in ocean ecosystems*, organized through the National Center for Ecological Analysis and Synthesis, based at the University of California at Santa Barbara (http://www.nceas.ucsb.edu/projects/12645). Until recently the NCEAS working group programme was supported by the USA National Science Foundation. The marine debris WG is now supported by the Ocean Conservancy. The study is designed to be scientifically based, solutions-orientated and applicable to management and policy. The aims are to produce a credible summary statement of the magnitude of the problem; increase the ‘brains trust’ of reputable scientists that research marine debris and its impacts; and, create connections between the academic community and industry experts. The research and synthesis goals are: i) to conduct a meta-analysis and synthesis of the effects of marine debris; and, ii) quantify the contribution of plastics as marine debris. The meta-analysis will include risk assessment and look for evidence of effects, including spatial and temporal patterns. Sources will be divided into land-based, marine and catastrophic events. Two further WG meetings are planned (October 2012, June 2013) with an Expert Meeting in February 2013.

4.2 European Union DG Environment

*Leo de Vrees of DG Environment*

**Marine Strategy Framework Directive**

The Marine Strategy Framework Directive (MSFD) represents a significant attempt by Member States of the European Union to define and achieve Good Environmental Status (GES) of Europe’s Seas, through the application of environmental descriptors, indicators, targets, monitoring and measures. Descriptor 10 covers marine litter and the overall objective is to ensure that: *Properties and quantities of marine litter do not cause harm to the coastal and marine environment*. A technical sub-group on marine litter was established to provide technical recommendations for the implementation of the MSFD and reported in
Micro-plastics are included as a potential target and 3 monitoring tools have been suggested for possible use. A number of research recommendations were made, including the need for more information about the degradation process and the physical and chemical effects of micro-plastics.

![Figure 4.1 Abundance of plastic particles according to size category: a) Bering Sea 2006; and b) US west coast 2006 – 2007. Taken from the 2011 report of the MSFD GES Technical Subgroup on marine litter](image)

**EU-funded research**

Leo described the wide range of interests and activities in the area of marine debris being conducted by the European Union ([http://ec.europa.eu/environment/index_en.htm](http://ec.europa.eu/environment/index_en.htm)). He pointed out the current lack of harmonization of European monitoring programmes set up to monitor different maritime sectors, with implied potential savings in effort. The regional seas conventions OSPAR, HELCOM and MED-POL use different categories for litter.

Several research projects are being funded looking at aspects of waste management and litter mitigation, including an education-based project looking at public attitudes and the impact of land-based behavior on the state of the marine environment (MARLISCO).

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3 MSFD GES Technical Subgroup on Marine Litter, 2011. Marine litter – technical recommendations for the implementation of MSFD requirements. EUR 25009 EN – Joint Research Centre – Institute for Environmental Sustainability
addition 3M euro project is due to be awarded in 2012. This includes a component on microplastics and it is anticipated that the winning consortium will work closely with WG 40.

The EC is interested in getting commitment from a variety of stakeholder (e.g. retailers, shipping, plastics industry) to develop a toolbox of measures, in the run-up to Rio+20. A Green Paper on plastic waste in the environment is being developed. ‘Fishing for litter’ is a new project designed to financially encourage fishers to use no-fishing days to trawl for litter. This is somewhat controversial and should not be confused with existing Fishing for litter voluntary scheme, promoted by KIMO International to encourage fishers to land marine debris accidentally caught in their nets (www.fishingforlitter.org). In addition, the European Environment Agency (EEA) is developing a tool for reporting litter as part of a Citizen Science initiative.

4.3 NOAA Marine Debris Program

Prof. Joel Baker, University of Washington

Joel described the NOAA Marine Debris Program, set up under the 2006 Marine Debris Research, Prevention and Reduction Act. The program website contains a wealth of information both about NOAA activities in this field and related initiatives (www.marinedebris.noaa.gov). Micro-plastics are acknowledged to be an issue of emerging concern and program activities are designed to assist in coordination of research to determine the effects of micro-plastics and better manage the impacts. NOAA organized two International Research Workshops on micro-plastic debris in 2008 and 20104. The first focused on occurrences, impacts of exposures and effects on biogeochemical cycling. The second attempted to apply risk assessment principles to the micro-plastic issue. Outstanding issues include effluents as a source, the potential for bioaccumulation and chemical (de)sorption. A number of research grants have been awarded covering monitoring protocols, analytical methods and chemical impacts.

Studies of micro-plastics in cosmetics and other consumer products suggest that they are so small that we are not capturing this material in field research, where standard techniques typically are restricted to sampling larger material; for example, manta trawls capture material > 330 µm (Figure 4.2).

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4.4 SETAC
The Society for Environmental Toxicology and Chemistry (SETAC) is holding a session at the forthcoming SETAC Europe meeting (22 May 2012; www.berlin.setac.eu) on; plastics – an emerging risk to the marine environment, as part of its Emerging Contaminants programme. This follows similar sessions in 2010. Several members of WG40 are expected to attend.

4.5 Gulf of Mexico Large Marine Ecosystem
Virginia Garcia-Rios, Gulf of Mexico Large Marine Ecosystem

Virginia explained that there were limited monitoring data in the GoM LME, with a lack of long time-series and a lack of harmonization of scales and units between Agencies and within the academic community. She demonstrated the trans-boundary nature of marine litter, both in terms of river catchments and long distance transport from Central and Southern America and the west coast of Africa. Harmonized protocols for measurements/monitoring are needed for comparison purposes and to assess the scale of the marine litter problem.

4.6 Plastics Industry initiatives
Roberto Gomez, Plastics Europe and Keith Christman, American Chemistry Council

Plastics Europe and ACC are involved in a number of initiatives and research projects addressing materials recycling, waste management (e.g. Operation Clean Sweep) and marine litter prevention (e.g. provision of waste receptacles on beaches). In addition, they represent the signatories of the Global Plastics Associations Declaration and Global Action plan (http://www.plasticseurope.org/plastics-sustainability/marine-litter.aspx; Figure 4.3). Their actions include a focus on minimizing pellet loss, litter prevention, beach cleaning and education, with zero littering as a primary target. They are currently funding about 100 projects worldwide, including a study in Belgium on the ingestion of micro-plastics by mussels and lugworms. They are co-sponsoring WG40, for which GESAMP wishes to express its gratitude.
4.7 UNEP initiatives

*Tessa Gorse, UNEP Division of Early Warning and Assessment (DEWA)*

**Global Initiative on Marine Litter and Regional Seas**

This programme was initiated in 2003 by UNEP’s Regional Sea Programme and the Global Programme of Action (for the Protection of the marine Environment from Land-based Activities*). It has attracted support from a range of UN bodies, donor agencies, the private sector and NGOs. UNEP supported the development of 12 Regional Action Plans and has produced a number of key reports. Tessa argued that there needs to be a mix of regulatory and non-regulatory responses, with better integration into national and regional strategies. The outputs of WG40 should contribute to the Action Plans. The strategy for the next four years of the GPA was reviewed in January 2012 at the third inter-governmental review in Manila. UNEP is due to lead an Inter-Agency Task Force on marine litter within the UN Oceans framework ([www.unoceans.org](http://www.unoceans.org)).

**Honolulu Strategy**

UNEP and NOAA jointly provided technical and financial support in the development of this Framework document, developed around the time of the Fifth International Marine Debris Conference (5IMDC, Honolulu, March 2011). It is intended to be used as: a planning tool for spatially or sector-specific programmes; a common frame of reference for collaboration and sharing best practice; and, a monitoring tool to measure progress. There are 3 overarching goals:

- **Goal A** - Reduced amount and impact of land-based sources of marine debris introduced into the sea
- **Goal B** - Reduced amount and impact of sea-based sources of marine debris, including solid waste; lost cargo; abandoned, lost, or otherwise discarded fishing gear (ALDFG); and abandoned vessels, introduced into the sea

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*http://www.gpa.depiweb.org/gpa-pollutant-source-categories/marine-litter.html*
• Goal C: Reduced amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters

**UNEP marine litter Strategy – 2012 - 2016**

The strategy aims to manage and prevent litter from land-based sources. It has a number of elements:

1. An on-line forum, to be developed by UNEP and NOAA
2. Developing a global partnership on marine litter, as part of the Global Partnership on Waste Management[^6]
3. Developing regional programmes: e.g. COBSEA, NOWPAC, Caribbean; regional training; scientific and technical support
4. Demonstration projects: e.g. plastic recycling

**GEF-STAP Marine Debris – solutions-based framework**

A report was prepared in 2011 for the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility on Marine debris: defining a global environmental challenge (Thompson et al., 2011). STAP proposed that GEF should adopt a five-step framework:

1. The Global Environment Facility (GEF), the largest multilateral fund supporting measures improving the state of the global environment in the context of sustainable development, has a special opportunity and could play a leading role in global efforts to tackle the marine debris problem. As a cross-sectoral issue, most interventions aimed at marine plastic debris prevention, reduction and management fall under existing mandates of several GEF focal areas including International Waters, Climate Change, Biodiversity and Chemicals, Small Grants Program and the GEF Earth Fund and public-private partnership platforms, as well as new programmatic initiatives such as Management of Marine Areas Beyond National Jurisdiction (ABNJ).

2. STAP is encouraging GEF partners to *mainstream* interventions addressing marine debris into existing and planned GEF projects and programs, specifically projects supporting management of Marine Protected Areas and fish refuges, ecosystem-based management of ABNJ and Ecologically and Biologically Significant Areas or Vulnerable Marine Ecosystems, projects supporting activities aimed at the reduction of pollution sources from land-based activities, and projects and programs promoting the use of waste-to-energy technologies with plastics waste as a source category. Participants in the Small Grants Program in relevant countries are also encouraged to consider interventions aimed at marine debris prevention, reduction and management.

3. Given the limited resources available in the GEF and the global scale of plastic debris problem in the marine environment, STAP is advising the GEF Council and GEF partners to focus support in GEF-5 on two types of activities that serve as catalysts for actions and can generate sustainably global environmental benefits. These two types of activities are based on principles embedded in the framework on marine debris management introduced in the Advisory Document:

i) A project or program testing the life cycle approach to marine debris prevention, reduction, and management in one of the areas covered by the Regional Seas Conventions and Action Plans. Building on the existing baseline and institutions and mechanisms in the selected region, GEF investments could play a catalytic role in mobilizing public and private sector resources for specific market transformation in the production, consumption, and utilization of marine debris sources such as plastics.

II) By combining the efforts of the plastics production, packaging and retailer associations, civil society organizations, multilateral institutions, and utilizing opportunities provided by the Earth Fund platforms or similar private sector initiatives, the GEF could promote, facilitate or establish a global public-private partnership to transform single-use plastics packaging markets to more environmentally friendly alternatives on a global scale. Through this initiative, the GEF would build a strong partnership with the private sector to encourage innovation and to expand assistance to developing countries and countries with economies in transition seeking to transform their use and utilization of single-use plastics packaging to protect the global environment. This initiative would simultaneously help reduce reliance on non-renewable resource, reduce waste and carbon dioxide emissions.

4.8 UNEP-MAP/MED-POL

*Michael Angelidis, UNEP – Mediterranean Action Plan*

MAP covers the whole of the Mediterranean. Litter is considered a serious issue in the region, with potential effects on the tourist industry. A strategic framework has been developed, based on the ecosystem approach, which includes marine litter on beaches, in the water column and seabed, and effects on biota (e.g. stomach contents). Micro-plastics are included in the framework and UNEP-MAP is looking to WG40 for guidance. An Action Plan will be developed during 2013 – 2014 with the intention of having a monitoring programme in place by 2014, to be aligned with the EU MSFD (Annex 6). UNESCO-IOC is willing to assist UNEP/MAP.

4.9 UN Regular Process

*Julian Barbiere, UNESCO-IOC*

The Regular Process represents an attempt to provide a regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects. The guiding principles are: to build on existing regional and global assessments (as captured in the 2009 Assessment of Assessments Report); design a process to gather information; gather information from nations and regional bodies; and, build capacity. A variety of structures for the report are being considered based on: drivers/pressures, habitats and ecosystem services, with a summary for decision makers. Marine debris is included as resulting from human activities, with questions about the economic and ecological effects. A Pool of Experts is being assembled to carry out the assessment, the first iteration of which is based in 2012 – 2014.

5. Achieving a global assessment – assessing scope and approaches

5.1 What needs to be addressed

Two break-out groups were selected etc

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5.2 Break-out group A – sources, distribution and trends

Richard (chair), Kara (rapporteur), Joel, Won Joon, Virginia, Michael, Tessa, Roberto, Luis

Sources
Definitions:
Primary or direct sources (arrives as microplastic): scrubbers (LDPE), pellets, powders, fibers
Secondary or indirect sources: generated by breakdown of larger items

How much enters marine environment as primary and secondary microplastics?
Objective: quantify each type and/or identify data gaps
Approach for primary sources: estimate from production numbers
Approach for secondary sources:
1. Use NCEAS production estimates
2. Subtract amount recycled, incinerated, and properly managed waste (contained in landfills)
3. Breakdown by application, which will be useful to assess amount of additives entering environment (for example), making use of a “taxonomy” of materials
4. Use degradation/fragmentation rates to estimate generation rate of secondary microplastics

Consideration: Is there any measurable atmospheric deposition of plastic as dust?

What are input rates of microplastics into marine environment?
Can we use a historical baseline to constrain production rate of microplastics?
- earliest production was ~1950s
- 1st observations of microplastics in open ocean were in 1970’s
- should we expect a time lag in microplastic increase because of this?
- has all production of secondary plastics occurred on beaches (UV, higher temps, wind/wave energy available), or is time frame (~60 yrs) long enough that significant amount of fragmentation may have occurred at the sea surface (UV, low temps, wind/wave energy available)?

Consider timeline of regulations, environmental management, etc.
- MARPOL
- wastewater/sewage treatment evolution
- environmental management practices in resin factories (e.g. measures to capture wastewater, which indirectly captures spilled pellets as well)

Note: system is probably not in equilibrium, still dealing with historical plastic that deteriorates into micro-plastics over its lifetime
- can’t say a whole lot about this until we have some estimate of the fragmentation/degradation rates and lifetime of plastic in the marine environment

Distribution of microplastics in the marine environment
Hypothesis to test: Spatial distribution of microplastics is surprisingly uniform
- on a beach, microplastics < 1 mm in size are relatively homogeneous (Won Joon data), but > 1 mm are more heterogeneous in distribution
- on beaches worldwide, presence ubiquitous. A weak positive relationship with human population density but the overall picture is, perhaps surprisingly, of a relatively consistent distribution abundance of fibers abundance of fibers not related to obvious drivers (Browne and Thompson data)
- at sea surface from city center to offshore, concentrations are fairly uniform (Joel Baker data)
- there are large gradients from coastal sea surface to gyre sea surface (Sea Education Association data)

This might mean that micro-plastics abundance is useful as global indicator (e.g. of ocean health), but possibly less useful for monitoring secondary sources (i.e. fragmentation)?

Analysis: Literature review to collate abundance data to test this hypothesis with respect to compartments (ocean surface/seabed/beach, gyre/coastal /beach)
- are we seeing noise in single compartments because material is moving between compartments?
- what are the scales of sampling/analysis? 10’s-100’s m on beaches, or coastal-gyre, or gyre-gyre?

Also need to estimate the quantity of microplastics in biota
- important not only for distribution, but also as measure of exposure risk or harm

Time trends in distribution
No trend is observed in a variety of data sets (SEA data, North Sea seafloor data, Richard’s data, Jan’s data, Peter Ryan’s data, and Doyle data)
WHY?
Hypothesis 1: Variability is too high and we are simply observing noise
Hypothesis 2: Microplastic concentrations are increasing in the marine environment, but we have not yet looked in the right place to measure them

Conclusion
It is critical to estimate fragmentation and sinking rates, and/or to measure size distribution and vertical distribution in water column

5.3 Break-out group B – properties and effects
Tony (chair) Heather (rapporteur), Angela, Alexander, Keith

Group B came up with some key questions about the fate of microplastics:
**What is the ultimate fate of micro-plastics in the ocean environment a) degradation b) transport?**
- **A) Degradation** – so far no studies have been dedicated to collecting empirical evidence (for or against) microplastics mineralizing or fragmenting to smaller sizes like nanometer range in the underwater, marine environment (with or without UV, at any temperature). However, there is a large body of knowledge available regarding the factors that control the kinetics of degradation and mineralization of synthetic polymers. There is hope for developing a model for this process, and research is currently proposed in the EU to work on this in the coming 3 years. We propose to recommend what kind of model could be made and how the model could be validated with new data.
- **B) Transport** – modeling of transport of microplastics in water column or in sediments is in its infancy but we do have some monitoring data for sediments in coastal areas, CPR, surface manta trawl monitoring data in some parts of the world, (albeit with little quality control of the sampling or the analysis). These data could be coupled to pre-existing hydrodynamic models of sedimentation, fish eggs, marine
snow, plankton models, which could be adapted to estimate transport of microplastics – this can’t be modeling work is not in the scope of our assessment group (no new research may be performed) but we can recommend how to do this with the expertise in the WG40 (Maximenko et al., 2012). Micro-plastic transport models are expected to be further developed in upcoming research projects.

Secondly, this group posed questions regarding the effects of microplastics:

- Does ingestion of microplastics with sorbed POPs increase (and if so by what factor) the POPs body burden of organisms which consume these microplastics as part of their diet? - there is limited empirical evidence for this (Japan, Teuten et al., )
- If POPs exposure effectively increases upon ingestion of micro-plastics, what is the increase in POPs exposure to humans at the top of the marine food chain?
- Which additives are likely to be in the ocean because of microplastics/litter? Which (if any) additives can be detected in marine microplastic litter?
- What are the different toxic effects (e.g. oxidative stress, inflammatory response, histopathological effects like necrosis and granulocytoma in short term studies – this data is available for mussels) to be expected from different categories of size, shape, polymer, exposure level, and chemical properties. What are the chronic effects of micro-plastics? There is no empirical data now on marine microplastic adverse effects on marine organisms – but there should be some publications (maybe<5, ca. 2 PhD students) by 2014.

(This list of questions we regard as a starting point, but not exhaustive.)

5.4 Feedback from participants

The discussion was wide-ranging and it was difficult to capture all the points raised. However, a common view was that ‘this should not be simply another review’ and this led to a discussion of the difference between a review and an assessment (section 6.1). There was some consensus on the importance of rigorously assessing what we know now (i.e. science, gaps in knowledge, degradation, monitoring), evaluating the degree of confidence we can attach to this knowledge, and stating how we intend to meet our goals. Various frameworks were discussed including the Driver-Pressure-State-Impact-Response (DPSIR) and Status-Trends-Impacts, coupled to, and placed within the context of the Honolulu Strategy for marine debris reduction. Goal-Orientated Project planning and the use of SMART principles (Specific, Measurable, Achievable, Realistic, Timely). One suggestion was we could adopt a mass-balance approach to include plastic production, recycling rates and use of landfill to estimate releases to the ocean, but generally this was thought to be unrealistic in many regions where basic infrastructure is inadequate and data are lacking.

6. Assessment frameworks

6.1 The structure and purpose of an assessment

The global assessment of marine micro-plastics can be regarded as one of several elements in the overall assessment of the environmental state of the world’s oceans. Modern assessment and marine protection approaches requires the consideration of multiple stressors that affect ecosystems and how the interaction of these stressors may or may not
lead to adverse effects. Some stressors (e.g. hypoxia) have dramatic, visible effects, while others exhibit more sub-lethal, chronic effects. However, effects on growth can have significant effects on populations and may be equally important to assess. Marine litter is recognized as one of the threats to marine ecosystem health. The EU’s MSFD recognizes ‘micro-particles, in particular micro-plastics’, as part of the overall marine litter problem.

**Essential features of an assessment**

In the present context an assessment can be defined as a synthesis and critical evaluation of information, for purposes of guiding decisions on a complex, public issue. It should the following features:

- be policy relevant, but not prescriptive - use "if ...then” approach;
- be conducted by a credible group of experts with a broad range of disciplinary and geographical experience, in a balanced and transparent way;
- reduce complexity but add value by summarising, synthesis and sorting what is known and widely accepted from what is not known (or not agreed);
- relate to the situation at a particular time and in a given geographical domain;
- be conducted according to an open, transparent, representative and legitimate process;
- Be technically accurate;
- Incorporate different views;
- Take a local, regional and global perspective;
- Include risk assessment, management and communication

<table>
<thead>
<tr>
<th align="left">Table 6.1 Summary of main differences between a review and an assessment</th>
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<tbody>
<tr>
<td align="left"><strong>Audience</strong></td>
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<tr>
<td align="left">Scientists/specialists</td>
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<td align="left"><strong>Conducted by</strong></td>
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<td align="left"><strong>Topic</strong></td>
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<td align="left"><strong>Identifies gaps in:</strong></td>
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<td align="left"><strong>(Un)certainty statements</strong></td>
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<td align="left"><strong>Judgement</strong></td>
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<td align="left"><strong>Coverage</strong></td>
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<tr>
<td align="left"><strong>Synthesis</strong></td>
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**6.2 DPSIR**

The assessment should be set within some form of framework to provide a necessary context. WG40 will use the DPSIR Framework, recognizing DRIVERS-PRESSURES-STATE CHANGES-IMPACTS-RESPONSE. This is illustrated in Figure 6.1, taken from the EU-funded Knowseas project (Knowledge-based sustainable management of Europe’s Seas), where yellow area represents those elements within human society and the area in blue represents
natural systems. The Drivers are high-level, related to economic development, population growth, demand for consumer products and advances in advances in engineering design, for example. Pressures are represented by deliberate or inadvertent releases into the marine environment from a wide range of sources and activities (e.g. shipping, tourism, poor waste management, wind-blown). The presence of litter can be described as a State Change, which may lead to an Impact, depending on the criteria used to define this. For natural scientists an Impact may be defined as an effect that has a significant influence on the viability of an organism to survive and reproduce. For social scientists an Impact may only be triggered if there is a welfare impact on the human population; i.e. society decides it does not like the state change (e.g. littering on beaches discourages use; entanglement of an iconic species raises objections). This may lead to a Response when, due to societal pressure, actions are taken to reduce the Impact, by introducing restrictive measures on one or more of the Drivers or Pressures (e.g. IMO MARPOL Convention Annex V).

Figure 6.1 An example of the DPSIR framework, www.knowseas.com

7. Discussion of the Terms of Reference and Work Programme

7.1 Goals, scope, objectives, audience & outputs

The overall objectives of WG40 were considered to be appropriate by the majority of the participants. One prominent participant questioned whether WG40 would be able to advance the state of knowledge above that already presented by the NOAA International Workshops, and suggested that the WG might be premature. We were fortunate to have one of the main authors of those reports at the meeting. He was able to state that NOAA is looking to WG40 to advance the assessment process. The need for this assessment, the make-up of WG40 and the timelines it is operating under were strongly supported by the majority of the participants.

7.2 Revisions to Terms of Reference and Work Programme – for discussion and possible approval at GESMP 39
The WG Members and workshop participants considered the ToRs and Work Programme appropriate. But, there was agreement that all ToRs should be initiated at the start, so that the effects ToR would not become separated from the others. The staggering of the start times was partly a consequence of uncertainties in the budget when the draft programme was drawn up. Given the generous support from the plastics industry and NOAA we believe we should have the resources to tackle all the ToRs together. There was discussion about the need to include an additional ToR incorporating social/welfare aspects, including the public perception of micro-plastics in the ocean. This will be raised at the GESAMP 39 meeting in New York in April 2012.

At present the WG lacks sufficient expertise in the fields of sediment processes (seabed, sediment accumulation), particulate behavior in the water column and microbial colonization (i.e. biofouling).

### 7.4 Inter-sessional activities

The WG co-chairs will be considering options for setting up a remote office for use by the WG members, as well as a website. This will be done in consultation with IMO, UNESCO-IOC and possibly other bodies. Telephone conferences will be arranged in the coming months with all members of the WG, especially those who were unable to attend the inception meeting. Further discussion about the work programme, location and timing of future meetings and related matters will be addressed at GESAMP 39.

### 7.5 Road Map

Revised time-line – for approval at GESMP 39
It was agreed that WG40 should construct a Road Map of its activities, taking into account various related initiatives and time-lines. This will be developed intersessionally.

8. Conclusions & recommendations

1. The proposed ToRs and Work Programme are appropriate and justified, and the WG is timely. We will plan to work closely with other initiatives and make use of earlier studies to make cost-effective use of the limited resources.
2. We know enough to undertake an assessment, and to work on exposure pathways. There are missing blocks in the conceptual structure of our understanding, but we need to find out what these are.
3. Recent publications have started to suggest ecological effects of micro-plastics are occurring and it is important that WG40 looks at the evidence impartially. Whether micro-plastics are having a significant ecological impact is perhaps the most important question WG40 should address. As well as individual effects, we should consider ecosystem/population effects.
4. Monitoring programmes for micro-plastics are under development. We need to be able to link monitoring data with effects data to advise whether we are looking at the most appropriate targets/indicators and in the most appropriate places.
5. An assessment of present monitoring techniques can be included under ToR 1, and link to related initiatives such as under the MSFD Technical Sub Group.
6. Available time-series do not show convincing trends in micro-plastic concentrations, implying we are missing important pathways (e.g. sinking particles) or failing to sample representatively. Greater rigour is needed when assessing particle properties.
7. Rates of degradation are critical, and it is important to link expertise on materials science with expertise on physical, chemical and biological oceanography.
8. There is a need to place micro-plastics in context with other particulate matter (e.g. nano-particles, black carbon).

9. We need to consider the bio-concentration of micro-plastics, as well as their role in the bio-magnification of POPs.

10. We need to be able to advise Agencies and decision makers on whether monitoring is needed.

11. At present the WG40 lacks sufficient expertise in the fields of sediment processes (seabed, sediment accumulation), particulate behavior in the water column and microbial colonization (i.e. biofouling).

12. There is significant public misperception of the state of plastics in the ocean, illustrated by phrases such as: island of trash and more plastic than plankton. The role of WG40 is to improve the science base but in so doing we should consider who to make information available to (e.g. UN Agencies, other sponsoring agencies, Regional Seas bodies, general public).

13. We should keep in mind the guiding principles of conducting an assessment: add value, reduce complexity, and synthesise knowledge.

14. We should try to be flexible, while fulfilling the agreed work programme, and retain the option of suggesting an addition to the ToR if the group thinks this is justified.

15. We need to develop a Road Map to ensure WG40 keeps on track, and to provide links to other initiatives.

9. References


GESAMP (2010). Proceedings of the GESAMP International Workshop on micro-pastic particles as a vector in transporting persistient, bio-accumulating and toxic substances in the


Annex 1 List of participants

<table>
<thead>
<tr>
<th>NAME</th>
<th>ORGANIZATION</th>
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<td>Mr. Keith CHRISTMAN</td>
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<td>Mr. Michael ANGELIDIS</td>
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<td>Ms. Mar GONZALEZ</td>
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<tr>
<td>Mr Leo de VREES</td>
<td>OBSERVER – EU DG Environment</td>
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Annex 2 Revised Agenda

GESAMP Working Group 40:  
Sources, fate and effects of micro-plastics in the environment – a global assessment.  
Inception Meeting: 13\textsuperscript{th} - 15\textsuperscript{th} March 2012, UNESCO-IOC, 7 Place de Fontenoy, Paris 7ème Room VI (floor -1) (contact Christiane Le Conan +33 (0) 1 4568 4023)  
Revised Agenda  
(timings are approximate)  
Start Tuesday 13\textsuperscript{th}, 09:30  
Day 1  
1. Welcome – UNESCO-IOC  
2. Introductions – round table (2 minutes max. each)  
3. Appointment of rapporteurs(s)  
4. WG40 objectives  
   4.1 Background to GESAMP & WG40 – Peter Kershaw  
   4.2 Overview of objectives, scope, audience & outputs – Heather Leslie
4.3 Initial feedback from WG members, from funding agencies & observers

11:00 – 11:30 coffee break

5. Invited presentations on current state of knowledge and knowledge gaps
   5.1 Sources & distributions – Richard Thompson (30 mins)
   5.2 Properties of plastics and behaviour of micro-plastics - Tony Andrady (30 mins)

Lunch – 13:00 -14:00
   5.3 Physical and chemical effects - Heather Leslie (30 mins)
   5.4 Feedback from group (30 mins)

6. Other initiatives
   6.1 NCEAS Working Group on Marine Debris – Kara Law (15 mins)
   6.2 EU DG Environment – Leo de Vrees (15 mins)
   6.3 Feedback from group (10 mins)

16:00 – 16:30 coffee break

7. UN and other sponsoring agency bodies – perspectives & initiatives
   7.1 NOAA Marine Debris initiatives – Joel Baker (15 mins)
   7.2 UNIDO – Gulf of Mexico LME – Virginia García Ríos (10 mins)
   7.3 Plastics industry perspective (PE/ACC) – Roberto Gomez, Keith Christman (15 mins)
   7.4 UNEP Initiatives – Tessa Goverse (10 mins)

8. Summing up the day

Close 18:00

Day 2

09:00

7.5 UNESCO-IOC – Regular Process - Julian Barbiere (15 mins)

9. Break-out groups –
   a. Plenary – How to approach the global assessment - audience, ‘burning questions’, limitations, goals, outputs, lessons from other disciplines, lessons from other assessments? Heather Leslie (10 mins)
   b. Sources, distribution & trends in the context of a global assessment – Richard Thompson
   c. Particle properties & effects in the context of a global assessment – Tony Andrady

11:00 – 11:30 coffee break
   d. Plenary – reporting back

Lunch – 13:00 – 14:00

16:00 – 16:30 coffee break
   d. Plenary – reporting back continued

Day 3

09:00
10 Plenary – potential changes to work programme or Terms of Reference, agree audience, goals & outputs, required expertise (45 mins)
11 Plan inter-sessional activities by WG and agree responsibilities, filling expertise gaps, WG ‘remote office’ (45 mins)
12 Drafting Inception report (30 mins)

11:00 – 11:30 coffee break
13 Finalise inception report
14 Date & location of next meeting

Meeting closed lunchtime on 15th March

Acronyms:
ACC – American Chemistry Council  http://www.americanchemistry.com/
GESAMP – Joint Group of Experts on Scientific Aspects of Marine Protection www.gesamp.org
NCEAS - National Center for Ecological Analysis & Synthesis www.nceas.ucsb.edu
NOAA – National Oceanic and Atmospheric Administration, Marine Debris Program http://marinedebris.noaa.gov/
PE – Plastics Europe http://www.plasticseurope.org/
SETAC – Society of Environmental Toxicology and Chemistry www.setac.org
UNEP-DEWA – United Nations Environment Programme, Division of Early Warning and Assessment www.unep.org/dewa
UNIDO – United nations Industrial Development Organization www.unido.org
# Annex 3 List of Working Group Members

This represents the current list of WG40 members as of May 2012

<table>
<thead>
<tr>
<th>GESAMP WG40 invited members to the initial 'Core Group'</th>
<th>name</th>
<th>no.</th>
<th>expertise</th>
<th>institute</th>
<th>country</th>
<th>sponsor</th>
<th>e-mail</th>
<th>Inception meeting,</th>
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<tbody>
<tr>
<td>Chair - Peter Kershaw</td>
<td>Chair - Peter Kershaw</td>
<td>1</td>
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Annex 4 Micro-plastics as an emerging issue

Schematic showing the evolution of the GESAMP approach to dealing with emerging issues. In the case of micro-plastics this issue was raised in the media in 2006 and this triggered a series of responses, including the preparation of a scoping report and organization of an exploratory Workshop in Paris in June 2010 (GESAMP, 2010).
Annex 5 Revised Terms of Reference and Work Programme

The following is extracted from the report of the 39th session of GESAMP, held in New York 15-20th April 2012.

Activities of the Working Group

The main activity was the Inception Meeting, held in Paris on 13th – 15th March 2012, and hosted by UNESCO-IOC. It was attended by ten Members, representatives of sponsoring Agencies and a number of invited Observers. Confirmation of the meeting dates was only possible about 3 weeks before the event, because of difficulties in finalising the contractual arrangements. This delay, combined with prior commitments, meant that the number of Members and Observers was fewer than had been intended. Despite the missing participants, the Inception Meeting proved to be a lively and challenging event, consisting of a number of invited presentations, break-out groups and feedback sessions. Edited versions of the presentations will be made available on-line and a summary of the discussions, conclusions and recommendations will be included in the Inception Report.

Three invited Members gave overviews of the current state of knowledge and knowledge gaps on; i) sources, distributions and trends of micro-plastics; ii) properties and degradation of polymers; and, iii) physical and chemical effects of micro-plastics. These followed by several shorter presentations on related programmes (e.g. NOAA, Gulf of Mexico LME, UNEP, ACC/PE, NCEAS working group) before the meeting split into two break-out groups to consider the scope and approaches required to conduct an assessment: i) sources, distribution and trends; and, ii) properties and effects. Periods for discussion and feedback were included in the meeting timetable, with rapporteurs appointed to record the key points.

There was agreement on the need to set the assessment in a recognised assessment framework, and a number of options were described. This needed to be placed in an appropriate Road Map and a revised time-line was recommended for approval by GESAMP 39, reflecting the increased support that will allow all the ToRs to be initiated at the start. The meeting also agreed that there was a need for an additional ToR, to consider how to address social concerns, including public awareness. This reflected the perceived role of NGOs, the media and the public in raising the profile of micro-plastics as an issue that policy makers needed to address, without there necessarily being solid scientific evidence to justify this.

Action taken by GESAMP

GESAMP agreed to the minor modification to the ToRs to emphasise the focus on assessment and remove any ambiguity that the group was intending to carry out new modelling. In addition GESAMP agreed on a 6th ToR to take account of social aspects. It was agreed that social aspects should be included at an early stage and it was suggested SCOPE may be able to provide links to suitable Corresponding Members. UNEP and IOC have a great deal of expertise to advise the group on the assessment process, and producing suitable outputs to benefit decision makers, and making recommendations. They are considering a policy brief on marine debris to which WG40 can contribute. Several other organisations are likely to be interested in micro-plastics including UNEP DTIE, UNEP Chemicals, AMSA,
Environment Australia, Basel and Bern Conventions, IMO Hong Kong Convention (ship recycling; WG on the inventory of harmful substances).

**Future activities of the Working Group**

The Inception Report will be circulated for comment and approval by WG40, after which it will be placed on the GESAMP website and circulated to those on a distribution list, to be maintained by IMO and the Co-Chairs. The Report will include a detailed outline of roles, responsibilities, scope, expectations and intended outputs. A series of telephone-conferences will be held, to include those Members who were unable to attend the Inception Meeting. Options for setting up a remote office will be explored (e.g. IOC IWLEARN, UNEP websites) for maintaining working documents.

A second WG meeting will be held within 12 months, with the period 3rd – 14th December being considered the preferred option at present. UNIDO will investigate the possibility of hosting a WG40 workshop in Manila or Mexico.

Additional ‘Corresponding Members’ will be identified as appropriate to cover gaps in expertise and regional coverage, and opportunities will be taken to link with related organisations and events. For example, an informal side event will take place at the 2012 SETAC Congress in Berlin, on 22nd May, in association with a special session on micro-plastics being co-convened by Courtney Arthur (NOAA), and several WG40 Members are expected to attend.

It will be critical to keep the ToRs under review and re-define the aims, content and intended audience of the various assessment outputs.

**Revised Terms of Reference**

i. **Assess** inputs of micro-plastic particles (e.g. resin pellets, abrasives, personal care products) and macro-plastics (including main polymer types) into the ocean; to include pathways, developing methodology, using monitoring data, identifying proxies (e.g. population centres, shipping routes, tourism revenues);

ii. **Assess** modelling of surface transport, distribution & areas of accumulation of plastics and micro-plastics, over a range of space- and time-scales;

iii. **Assess** processes (physical, chemical & biological) controlling the rate of fragmentation and degradation, including estimating long-term behaviour and the rate of production of ‘secondary’ micro-plastic fragments;

iv. **Assess** long-term modelling including fragmentation, seabed and water column distribution, informed by the results of ToR 3;

v. **Assess** uptake of particles and their contaminant/additive load by biota, as well as their physical and biological impacts at a population level.

Additional ToR:

vi. **Assess** the social including public awareness.
Annex 6 Related assessment timelines

MSFD

Figure A6.1 Representation of the timeline for implementation of the MSFD; this represents a product of the EU-funded FP7 Knowseas project (Knowledge-based sustainable management of Europe’s Seas; www.knowseas.com) and should not be taken as the official interpretation of the Commission.

UN Road Map
Figure A6.3 Schematic timeline showing approximate target dates for the implementation of the ecosystem approach to the assessment and monitoring of marine litter within the UNEP-MAP programme (based on a sketch by Michael Angelidis of UNEP-MAP)

NCEAS Working Group on marine debris

- October 2012 – 2nd WG meeting
- ~ February 2013 – mid-term ‘expert’ meeting
- 2013 – 1-2 additional WG meetings
- March 2014 – WG concludes
- Products – publications in scientific literature

Annex 7 Key questions raised by members prior to inception meeting

Questions posed by WG40 Members prior to the Inception Meeting

1. to what extent are micro-plastics harmful to marine life?
2. can we distinguish the relative importance of natural lipids/surfaces and micro-plastics as actual contaminant sources?
3. what is the long-term fate of micro-plastics?
4. should we consider socio-economic factors & effects?
5. who needs our assessment and how can GESAMP contribute meaningfully and practically?

1. How long are half-lives of different plastics in various marine environmental conditions?
2. What are leaching rate and mechanism of plastic additives and degradation products?
3. Is pollution trend of microplastics in increasing trend globally?
4. Is pollution status of microplastics alarming to marine organisms?
5. What are biological adverse effects on various marine organisms?

1. What are the major sources of plastic to the ocean (legitimize the “80%-from-land” statistic so often quoted)?
2. What are the primary plastic materials present in different marine habitats, and have these changed over time?
3. What are the time scales of fragmentation and degradation that might explain observed trends in (floating) plastic debris?
4. What is the evidence that POPs on debris 1) enter animal tissues 2) bioaccumulate?
5. How have management and policymaking influenced the input of plastic into the ocean, and how can management and policymaking prevent future input?

1. Sampling protocols to quantitatively evaluate microplastics in sandy beaches and in the oceans;
2. Characterization of the processes that govern dispersal and accumulation of microplastics and the identification of “hot sinks”;
3. Strategies (types of studies, hypothesis, experimental design) to evaluate the effect of microplastics on the biota;
4. Strategies to reduce the input of microplastics into the oceans;
5. Strategies for long term monitoring microplastics in sandy beaches, oceans, and possibly in the biota.

1. Microplastics have millions of sources – to what level of detail is it still relevant for us to want to understand understanding sources of microplastics in the marine environment?
2. What kind of assessment framework is appropriate for this WG to operate on?
3. How can we make the assessment global, considering the current lack of national/regional assessments?
4. How do we couple our assessment outcomes to mitigative strategies and policy options?
5. What do policy developers need to know and can we find it out in the coming 3 years?

1. Via which routes are microplastics taken up into organisms?
   Is there a preferred organ/tissue of microplastic accumulation.?
2. What is the specific toxicology/damage of different source types of marine plastics?
3. What have consumers of Seafood to fear? How is information of microplastic risks to human health communicated?
4. Does a blood brain-gonad barrier exist for microplastics?
5. What is the specific toxicology/damage of different source types of marine plastics?

1. What will be the harmonized protocols to follow for quantificación, characterization and distribution of microplastics in the environment?
2. What are the effects of different types of microplastics on biota?
3. What organisms can be more susceptible to the microplastics effect?
4. What are the main sources of microplastics?
5. What are the dynamics of plastic degradation in the marine environment?