82

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GESAMP

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

Proceedings of the GESAMP International Workshop on Microplastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the ocean

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Proceedings of the GESAMP International Workshop on micro-plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans. 28-30th June 2010, UNESCO-IOC, Paris.

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No. 82

Proceedings of the GESAMP International Workshop on micro-plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans. 28-30th June 2010, UNESCO-IOC, Paris.

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Executive Summary

A workshop was held at UNESCO-IOC in Paris from the 28th to the 30th of June 2010 as part of GESAMP's remit to advise its sponsoring agencies (IMO, FAO, UNESCO-IOC, UNIDO, WMO, IAEA, UN, UNEP, and UNDP) on ***'new and emerging issues'*** in relation to the state of the marine environment. The invited 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 aim was to create a forum where key stakeholders could discuss the broader issues and inform GESAMP on the topic.

There are two principle sources of micro-plastic particles: i) plastic resin pellets either used in the plastics manufacturing process or purposefully fabricated as abrasives for shot blasting or in cosmetic facial scrubs; and ii) plastic fragments arising from the structural deterioration and disintegration of plastic objects, mainly litter, which can include packaging, articles of clothing, household items such as toothbrushes and razors as well as building materials, lost or discarded fishing and aquaculture gear, amongst many others.

Given the rise in global plastics production year on year (245 million metric tonnes in 2008), it can be concluded that the input of marine plastic litter, and thereby micro-plastics, will increase in those rapidly developing regions of the world lacking adequate solid waste management practices. There is however a dearth of information on the actual inputs of plastics to the oceans; this needs to be urgently addressed by Governments, municipalities, the plastics industry and multi-national retailers because land-based sources are expected to have a far greater contribution than maritime activities.

Knowledge of the distribution and fate of micro-plastics is only beginning to emerge. Some recent studies have revealed no significant trend in the concentration of particles in near-surface waters in areas of mid-ocean accumulation (N Pacific and NW Atlantic gyres). In some cases, this may well be due to improvements in sea- or land-based waste management. However, the characteristics and behaviour of the plastic particles may also have a role to play in determining the quantities we are able to sample and measure. For much of the oceans we have little or no information on trends, either at the macro or micro level.

The advent of compostable (so-called biodegradable) or bio-sourced plastics is expected to have limited effect on either the marine litter or the micro-plastics problem, as the conditions required for their degradation are simply not present in the marine or terrestrial environment.

It is well documented that plastic litter causes physical harm to marine mammals, fish and invertebrates and instances of death by entanglement, asphyxiation or blockage of organs are common. It is also known that plastic particles tend to accumulate persistent, bioaccumulating and toxic contaminants such as PCBs, DDT and PBDEs. Microplastics have larger surface to volume ratios, potentially facilitating contaminant exchange and have been shown to be ingested by a range of organisms. One of the greatest uncertainties is whether this leads to the bioaccumulation of the contaminant load (absorbed and plastic additives), and hence whether micro-plastics represent an additional and significant vector for transferring pollutants. The conclusion from the Workshop was that this will remain unresolved until the results of additional studies and data collations are available. Recent modelling studies show that the flux to remote areas of contaminants associated with micro-plastics is small compared with that from oceanic and especially long-distance atmospheric transport processes. The difference is that plastics with their accumulated contaminant load are directly ingestible by organisms. A definite cause for concern is that particles, including microplastics have recently been found in the circulatory systems and other tissues of filter feeding organisms such as the blue mussels following experimental exposure and caused typical inflammatory responses. Whether the presence of acid conditions or surface active digestive substances in the guts of such marine organisms can desorb and release contaminants in significant quantities to cause such effects, or whether such a response is to their physical presence, remains to be answered.

The Workshop recommended that a global assessment of micro-plastics in the context of the marine litter problem as a whole should be initiated under the leadership of GESAMP and with the cooperation of the UN Agencies, Regional and National Administrations, IGO's and NGO's in order to further advise policy-makers on the many aspects of the marine plastic debris problem which are currently poorly known and understood. It is recognized that any such assessment would of necessity have to compile data from primary sources including the scientific literature, as few of the available regional assessments provide quantitative data overviews on this topic. Without waiting for all of the unknowns to be filled in, such an assessment will of necessity need to develop agreed methodologies for estimating inputs, distribution, and fate of plastics. The diversity of methodologies for microplastics quantification presently employed requires further standardization in order to ensure data comparability in particular focused on providing estimates of plastics inputs to the oceans. Any such assessment should aim at providing estimates of plastics inputs to the oceans, describe the rates of fragmentation to micro-plastics, as well as their fate and distribution. It should also aim to provide a definitive answer to the scale of the impact both physically and chemically on marine organisms and the potential for impacts on human health from the consumption of these.

The workshop participants felt that a major effort is required to control plastics in the marine environment and that the issue of micro-plastics and their potential effects in the global oceans is still emerging; despite several regional overviews and a large number of recent papers in the scientific literature, much of the process remains to be discovered. The problems are complex and require a truly multidisciplinary science and engineering approach. The problem of micro-plastics stems clearly from plastic waste entering the oceans and the ultimate solutions are to be found in improved solid waste management on land and at sea; they require the participation of all sectors (politicians, the plastics and retail industry, science, education and the general public).

It is hoped that this Workshop report will provide a balanced and reliable perspective as well as a good starting point for such a global assessment. GESAMP would like to thank all the participants who gave generously of their time and ideas both during the workshop and the writing of this report.

1. Introduction

1.1 Rationale for holding the Workshop

This report is the record of a workshop organized by GESAMP as part of its "New and Emerging Issues" Programme. It was held at UNESCO headquarters in Paris from 28 to 30 June, 2010 and hosted by the Intergovernmental Oceanographic Commission (IOC). The workshop was generously sponsored by the Swedish International Development and Cooperation Agency (Sida) and the European Commission, Directorate General for Research. The Workshop agenda is reproduced in Annex I and the list of participants in Annex II.

GESAMP has a remit to advise its sponsoring UN Agencies on "New and Emerging Issues" in relation to the state of the marine environment. Members of the Joint Group of Experts and its Working Groups may propose new topics for GESAMP to consider in the form of a short proposal. Once approved, GESAMP may appoint a correspondence group to prepare a scoping paper. Upon discussion of the scoping paper, GESAMP with the support of its Sponsoring Organizations may recommend an International Workshop to bring stakeholders together in order to formulate advice on the weight and merits of the issue in question. As a final step, GESAMP may recommend that a Working Group be set up to provide a global Assessment of the topic in order to advise policy makers.

The issue of microplastics was first proposed to GESAMP at its 35th session in Accra, 2008, which recommended the formation of a correspondence group to produce a scoping paper and make recommendations. The scoping paper, *Micro-plastics and associated contaminants – occurrence and potential impact in the oceans* was discussed at GESAMP's 36th session in Geneva, 2009; (see GESAMP, in press) where it was concluded that the most appropriate next-step was to organize a workshop and encourage participation from a wide variety of sectors (science, industry, regional and global policy and Non-governmental organizations (NGOs). The workshop was therefore designed as a collaborative exercise to include different views from stakeholders. A key objective was also to hear from developing country representatives and from regional bodies directly involved with the problem of marine litter.

As the title suggests, the initial focus of this workshop was on plastic particles as a vector in transporting persistent, bioaccumulating and toxic (PBT) substances. 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, which is impossible to influence except from the supply side, therefore links our global and regional efforts in solid waste management with the occurrence of micro-plastics in 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. This report is a record of these discussions and is intended to lay the groundwork for a possible global assessment in the future and to highlight information gaps. Additional information from the scoping report (GESAMP, in press) and the published literature has been included in some sections to provide further illustration or evidence for topics discussed in the workshop, but <u>the report is not intended to be an assessment of micro-plastic in its own right.</u>

1.2 Background to assessing the impact of marine micro-plastics

Marine debris is defined by Galgani et al., (1996) as: *any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment*. A large proportion of marine debris consists of plastics (UNEP, 2009a). 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, e.g. Derraik (2002). 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 due to their polymeric nature and intended durability and because UV absorption by seawater and relatively low temperatures slow deterioration.

In recent years the existence of micro-plastics and their potential impact has received increasing attention, e.g. Arthur et al. (2009). Micro-plastics have a range of compositions and can be demarcated by usage and origin as:

> i) 'primary', pellets used as a feedstock in the plastics industry, and in certain applications such as abrasives; and,
>
> ii) 'secondary', fragments resulting from the degradation and breakdown of larger items.

Particles as small as 1 µm have been identified with an arbitrary upper bound of 5 mm based on the propensity to be ingested (Arthur et al., 2009). The global occurrence of plastic pellets in coastal regions began to be reported in the 1970s, (Carpenter et al., 1972; Carpenter and Smith Jr, 1972; Gregory, 1977; Morris and Hamilton, 1974). Laist (1987) was one of the first to review the biological effects of plastic debris. 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 still appears to be scarce, experimental studies are few and far between and most of the ocean and coastal areas remains un-sampled.

2. Plastics and waste: production, types and uses (sessions E, H)

2.1 Types of plastics

Plastics are man-made, non-metallic polymers of high molecular weight, made up from repeating macromolecules. The term plastic encompasses a wide range of polymeric materials, including, rubbers, technical elastomers, textiles, technical fibers, thermosets and thermoplastics, with some 200 plastics families in production including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC), polyethylene terepthlate (PET), nylon, polyvinyl alcohol (PVA) and acrylonitrile butadiene styrene (ABS) synthetic rubbers. Plastics can be fabricated from feed-stocks derived from petroleum, natural gas, or bio-renewables and have several advantages over other materials, being lightweight, durable, strong and extremely versatile.

2.2 Plastics production

The workshop was informed by PlasticsEurope that Global production of plastics has increased from 1.5 million metric tonnes in 1950 at an average rate of 9% per year to reach 245 million metric tonnes by 2008 with a slight decline to 230 million metric tonnes per year in 2009 According to PlasticsEurope (www.plasticseurope.org), 25% was produced in Europe (EU 27 members states plus Norway and Switzerland; EU27+2), 23% in the NAFTA region including the USA, 16.5% in Asia (excluding China), 15% in China, 8% in the Middle East, 5.5% in Japan 4% in South America and the rest of the world 3%. Plastics production is therefore spread around the globe and can be expected to rise to meet continuing demand.

In the EU, as an example of a developed region, albeit with strong N-S and E-W differences, packaging accounts for 40% of the 45 million metric tonnes of plastics consumed in 2009, with low density PE (LDPE), high density PE (LDPE), PP, and PET as the predominant materials. It should be noted that production and consumption vary from region to region, e.g. Europe produced 55 million metric tonnes but only consumed 45 in the same year (2009). Building materials account for 20%, with PVC as the main component followed by HDPE, epoxidised polysulphides (EPS) and polyurethane (PUR), while the automotive and electronics industries account for 7 and 6% respectively, using a much wider range of materials. However, there are significant differences in the pattern of production within Europe. It is known that the cost of raw material may induce the substitution of different polymers for the same purpose in other regions, so the pattern of production and use is not consistent worldwide.

2.3 Waste production and reduction

Of the 45 million metric tonnes of plastics consumed by converters in 2009 in the EU, just over 50% or 23 million metric tonnes goes to waste with 11.2 million metric tonnes being disposed of and 13.1 million metric tonnes being recovered (up from 12.8 in 2008), of which latter quantity, 5.5 million metric tonnes is recycled with 7.6 million metric tonnes being incinerated for energy recovery.

According to the US-EPA municipal solid waste statistics for 2008 (US EPA, 2008) 30 million tons of plastic waste is produced annually, of which only 7.1% is recovered. A further 19.8 million tons of rubber, leather and textiles, containing a substantial polymer component achieved 15% recovery. While overall recovery of plastics for recycling in the USA is relatively small, at 2.1 million tons in 2008, PET soft drink bottles were recovered at a rate of 37% and HDPE milk and water bottle recovery was estimated at about 28%. An additional 12.6% is burned with energy recovery. It is acknowledged by industry and Government alike that recovery of plastics needs to increase dramatically, as does the proportion recycled, and the workshop was informed of efforts by the plastics industry in the EU and the USA over the last 10-15 years to promote recovery and recycling.

PlasticsEurope informed that in the EU the amount of plastic waste going to landfill has been stable in recent years despite rising plastics consumption. A total of 9 of the EU27+2 countries have achieved plastic waste recovery of greater than 80% and of these, Germany as the largest waste producer recycles the highest proportion (ca.35%) of its ca. 4 million metric tonnes of recovered plastic waste annually, most of the rest being combusted with energy recovery. One important feature is that these 9 countries with substantial recycling sectors all have strong

Municipal waste management: two cases

Malaysia
The workshop was informed that peninsular Malaysia produced ca. 17.5 million metric tonnes of solid waste in 2002, showing a 0.4 million metric tonnes rise in each of 2000 and 2001; between 9 and 17% consisted of plastics. About 76% of waste generated is collected, meaning that 24% is unaccounted for, 1 to 2% is recycled nationally and only about 5% of waste collected in Kuala Lumpur is reused and recycled. Over 40% of 175 disposal sites are operating as dumpsites and intermediate treatment is limited to small-scale thermal treatment plants on tourist resort islands. The waste contains large amounts of organic material (40.6 to 76.8%; wet waste) and many older sites are poorly managed.

The Philippines
In Quezon City, with a population of 2.77 million people, 98% of 736,083 t of solid municipal waste is recovered to controlled disposal, 250,455 t by the informal sector and 476,407t by the formal municipal sector. Only 9,221 t is lost or goes to uncontrolled disposal (compare this to the figures given in the main text on the left). The total valorised or diverted waste is 39.12%, of which 229,842 t by the informal sector and 58,130t by the formal sector. The informal sector is therefore responsible for the majority of recycling. The proportion of polymeric materials reported is: Plastic 16.00% (PET 1.87%, HDPE 1.61%, Film Plastic/LDPE 12.45%), Diapers/Cigarette Butts 4.55%, Textiles 2.88%, Rubber 0.33% (these latter two groups may only be polymeric in part (Source: UN-Habitat, 2009)

legislation restricting the use of landfill sites for plastics disposal. Recovery figures for the remaining 20 EU27+2 countries are all much lower than the above. The UK with the second highest annual plastic waste production of 3.47 million metric tonnes has only a 26% plastic waste recovery rate.

2.4 Bio-sourced and "Biodegradable" plastics

The workshop looked specifically at some newer plastic types which are often assumed to be biodegradable and their implications for the problem of marine litter.

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. Regarding bio-plastics, the American Chemistry Council supports such innovation but also calls for the application of Life Cycle Assessment (LCA) to assess the trade-offs associated with alternatives to oil or gas based polymers, including:

- the potential to reduce/increase energy consumption and greenhouse gas emissions,
- the true impacts of agricultural production of the feedstock, including water use, fertilizers, eutrophication and especially, the impacts of land-use changes, e.g. deforestation,
- socio-economic factors, including potential impacts on the food supply and food prices, where a bio-sourced material competes with people for the same (food) resource.

Bio-degradable means that the product may be broken down by living organisms, such as bacteria and fungi (eventually becoming wholly or partly mineralized to CO_2 and water). In fact, a polymer can only be legitimately termed biodegradable when it passes a composting test under standard conditions and within a set timeframe[1]. However, such conditions are not found in the environment at large and such polymers therefore do not biodegrade to any significant extent under natural conditions; this includes the marine environment. Being bio-based does not mean a material is bio-degradable and conversely, being bio-degradable does not mean that a material is bio-based. The California Integrated Waste Management Board (CIWMB, 2007) reported an experimental study on bio-plastics degradation finding that everyday household articles and carrier bags fabricated from: sugar cane, PLA, PHA and 'Ecoflex' bags were all mineralised to >60% CO_2 and H_2O in several experimental and industrial composters within 180 days. Oxo-degradable bags on the other hand showed no degradation. Only PHA bags demonstrated some disintegration in ocean water, while none

[1] a) International Standards Organization: ISO 14855-1:2005 *Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions- Method by analysis of evolved carbon dioxide*.

b) The European Norm EN 13432, titled "*Requirements for packaging recoverable through composting and biodegradation. Test scheme and evaluation criteria for the final acceptance of packaging*.

c) The American Society of Standards & Testing: ASTM D6400 - 04 *Standard Specification for Compostable Plastics.*

of the other products disintegrated at all. CIWMB also concluded that biodegradable plastics and plastics that degrade in oxygen or sunlight reduce the quality and impair the mechanical properties of finished products manufactured with recycled content from recovered plastics.

2.5 Sources and inputs of plastic waste to the marine environment

UNEP (2009a) reported that "*there are no recent and certain figures on the amounts of marine litter worldwide. Nor are there any such global figures on the annual input of marine litter to the marine and coastal environment*". Our knowledge of the possible quantity of marine litter entering the seas and oceans still relies too heavily estimates such as the US National Academy of Sciences (1975) value of 6.4 million metric tonnes of marine litter per year. This number is compiled exclusively from maritime sources, i.e. "*litter generated in the oceans*", such as by shipping, fishing and the military transport and does not include land-based sources.

Land-based sources are considered to contribute the largest input of plastics (and therefore micro-plastics) entering the oceans (UNEP, 2009a). Rivers and wastewater discharge are important point sources and estimating the contribution of river systems could be key to quantifying inputs. Rivers fall under national jurisdictions and an improved knowledge of plastics and micro-plastics inputs may encourage local policy making.

Shipping is a major source of marine litter in some regions (van Franeker et al., 2009) and although Annex V of the Marpol 73/78 convention covering garbage is currently being reviewed (See Section 5.2), data still remain scarce as to how much plastic enters the sea from ships and offshore platforms. A fuller overview of marine litter sources is given at the end of this section.

Ribic et al. (2010) provided decadal trend data for beach debris along the Eastern Atlantic seaboard of the USA, noting that:

a) The Southeast Atlantic region had low land-based and general-source debris loads and no increases despite the largest percentage increase in coastal population;
b) The Northeast region, with a smaller percentage population increase, also had low land-based and general-source debris loads and no increases;
c) The Mid-Atlantic fared the worst, with an increasing coastal population and heavy land-based and general-source debris loads that increased over time;
d) Ocean-based debris did not change in the Northeast region where the fishery is relatively stable while it declined significantly over the Mid-Atlantic and Southeast regions.

Bravo et al. (2009; see Table 1 below) summarized the densities of anthropomorphic marine debris world-wide, expressed in numbers of items per m^2. These numbers show (outliers "[a]" removed) that there are on average 1.3 plastic items for every m^2 of the worlds' shoreline (201 beaches on all five continents) and often much more. This however gives no impression of size or type of the items involved.

Table 1. Densities of 'anthropogenic marine debris' reported from beaches throughout the world. Adapted from Bravo et al. (2009).

Country	Number of surveyed beaches	Average densities, items m^{-2}	Maximum densities, items m^{-2}	Reference
Australia	1	0.5	0.5	Foster-Smith et al., 2007
Australia	6	0.1	0.3	Cunningham and Wilson (2003)
Scotland	16	0.4	2.3	Velander and Mocogni (1999)
Brazil	2	0.7	2.1	Araújo et al. (2006)
Brazil	10	0.14	ca.0.5	Oigman-Pszczol and Creed (2007)
Chile	43	1.8	82.7	Bravo et al. (2009)
Indonesia	21	4.6	-	Evans et al. (1995)
Ireland	1	0.2	-	Benton (1995)
Israel	6	-	0.9	Bowman et al. (1998)
Japan[a]	34	45	280,000	Fujieda and Sasaki (2005)
Japan[a]	18	3.4	2,200	Kusui and Noda (2003)
Jordan	3	4	7.4	Abu-Hilal and Al-Najjar (2004)
Oman	11	ca. 0.4	ca. 0.9	Claereboudt (2004)
Panama	19	3.6	-	Garrity and Levings (1993)
Pitcairn Islands	2	0.2	0.4	Benton (1995)
Russia	8	0.2	16.7	Kusui and Noda (2003)

a These studies counted individual pellets of fragmented Styrofoam, an item usually not counted in most other studies.

Table 2 below, shows relative proportions of different types of items being listed in Center for Marine Conservation/Ocean Conservancy reports from 1989 to 2007 (UNEP, 2009a) and provides a clear indication of the prevalence of plastic being washed up on beaches.

Table 2. 'Top ten' marine debris items; adapted from UNEP (2009a), compiled from annual ICC data reports, Center for Marine Conservation/Ocean Conservancy (1989-2007).

Debris items	Number of items	Percent of total
Cigarettes/cigarette filters	25,407,457	24.6
Bags (paper & plastic)	9,711,238	9.4
Caps/lids	9,398,977	9.1
Food wrappers/containers	9,191,575	8.9
Cups/plates/forks/knives/spoons	7,426,964	7.2
Beverage bottles (plastic) <2 litres	5,684,718	5.5
Beverage bottles (glass)	4,991,860	4.8
Beverage cans	4,796,554	4.6
Straws, stirrers	4,508,085	4.4
Rope	2,215,329	2.1
Total debris items	**103,247,609**	**80.7**

UNEP (2009a) provides statistics on 'standing stocks' of litter (kg/km) on beaches around the world, collected through UNEP Regional Seas participation in ICC events in 2005, 2006 and 2007. Cleaner beaches have generally a few kg/km of litter, intermediate beaches have tens to hundreds of kg/km and occasionally, heavily littered beaches have one to several tonnes/km of coastline.

The North Western Pacific Action Plan (NOWPAP, 2009), a UNEP Regional Seas Programme reported a survey of marine litter in Japan, which demonstrated between 2.2 and 46 tonnes/km/year of marine litter on 11 beaches monitored during a 1 year survey; this consisted for 11 to 39% of plastics.

The majority of plastic waste entering the seas and oceans is considered to originate from land-based sources, and UNEP (2009a) 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[2];
- 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, although it is recognised that in some localities, these may be dominant sources of marine litter and plastics. Some debris enters the water from accidental loss or system failure, while other debris comes from poor waste management practices, and illegal disposal.

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

- sewage sludge dumping grounds at sea;
- sea-based aquaculture activities: some recent studies (Hinojosa & Thiel, 2009; Astudillo et al, 2009) have identified aquaculture activities as major sources of marine plastic debris.

[2] Plastic pellets (sometimes referred to as ‘nurdles’ or Mermaid’s tears) and powders (e.g. for roto-moulding) used in the manufacture of articles are ubiquitous around the world and are an indicator of poor transport and transhipment practices. Plastic powders are used as an alternative to sand for shot blast cleaning and plastic, grains are increasingly used in cleaning products and cosmetics.

3. Micro-plastics in the marine environment (sessions C, D, H, I)

3.1 An introduction to micro-plastics research and current questions

The occurrence of small plastic particles on beaches and in coastal waters was first reported in the 1970s (Carpenter et al., 1972; Carpenter and Smith Jr, 1972; Gregory, 1977; Morris and Hamilton, 1974) although the term 'micro-plastics' was not used until relatively recently (Thompson et al., 2004). It has become evident that the distribution of particles is global, including isolated mid-ocean islands, the open ocean and at high latitude Barnes, et al. (2009). There has been a rapid increase in the number of recent publications in the scientific literature on the distribution of fragments.

Some general trends are likely, 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. Particles will reduce in size as weathering and disintegration takes place, increasing the surface area and the possibility of chemical transport (absorption of chemicals into or leaching out of microparticles; e.g. Teuten et al. 2009) and increasing the potential for ingestion by a wider range of biota further down the food-chain. 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.

Interactions of large plastic items with biota such as seabirds, marine mammals and turtles through entanglement or ingestion are relatively well known (see Moore, 2008 for a recent review), but the sub-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. Several recent studies have identified potential effects of plastic particles, including:

- desorption of persistent, bioaccumulating and toxic (PBT) substances from plastics,
- leaching of additives from the plastics
- physical harm

The key questions are: i) to what extent do micro-plastics have a significant direct physical impact and ii) to what extent do they provide an additional vector for chemical contaminants increasing or decreasing the exposure of sensitive organisms to PBTs. The potential impacts of micro-plastics may be quite subtle (for example, compared with the entanglement of a marine mammal) and it may be difficult to extrapolate experimental results to population and ecosystem scales.

GESAMP (2001) in the last global assessment of the state of the marine environment which was focused on land-based sources reported that "*Solid waste, or litter, is concentrated near urban areas, on beaches near villages and in shipping lanes, but is found throughout the oceans. Plastics are the largest component, followed, in urban areas, by steel and aluminium* *cans. Litter causes mortality to marine organisms, notably sea turtles, marine mammals, and sea birds. The extent of this mortality is unknown, but there is no evidence that it has major effects at the population level. Litter also has negative aesthetic impacts, thereby affecting recreation and tourism, and can be a navigational hazard. Better solid waste management is the overarching solution to problems of marine litter."* Since this was written, cause for concern has increased as further evidence for effects emerges.

3.2 The origin of micro-plastic particles

The Workshop adopted the NOAA-recommended definition of a micro-particle as being 5mm in diameter or less (Arthur et al., 2009).

Micro-plastic particles can arise through four separate processes:

i) 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);
ii) 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;
iii) 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;
iv) discharge of macerated wastes, e.g. sewage sludge

3.3 Methods of sampling and analysing micro-plastics

3.3.1 Existing methods

Methodologies for the sampling of sediments and the water column are available (e.g. Thompson et al., 2004; Eleftheriou and McIntyre, 2005) but there is a need for improved techniques and for standardisation.

The smallest particle size to be detected needs to be determined and a standardised sampling regime should be developed on this basis. It was felt that NOAA's efforts in standardization of quantitative methods provided a good starting point. It was considered that there are major problems in handling the volume of samples potentially needed globally. Often particles are recovered during biological sampling so the size range is limited by the purpose and collection efficiency of the sampling device in question (e.g. 330 µm mesh neuston net for sampling zooplankton; Continuous Plankton Recorder; see: www.sahfos.ac.uk).

It was pointed out where sediment sampling and sorting is concerned that basic techniques had been developed many decades ago in benthic ecology for sorting organic material and organisms from sediments, and that cost-effective, low-technology techniques are available which might be usefully applied to separating and identifying micro-plastics, e.g. elutriation using fluidized sand beds created by water flowing through sintered disks allows larger samples to be accurately sorted (Southwood and Henderson, 2000; p226). This has the potential to replace high-density chemicals. One participant also demonstrated the usefulness of a polarizing microscope in quickly separating by eye and identifying plastics from other materials (see Section 3.5). Some issues to contend with are the reporting units (mass per mass or mass per volume), the vertical and horizontal variability in occurrence and the presence of organic matter.

Sampling for marine debris using biota has included birds (e.g. Fulmars), fish stomachs and filter-feeding invertebrates (e.g. *Mytilus* sp. , Browne et al., 2008). The group also considered the potential for particles to act as a vector for the transport of biota, including microbial colonisation of micro-plastics and discussed ways of assessing this.

There are two common methods used to chemically analyse the bulk composition of plastic particles: Fourier transform infrared spectroscopy (FT-IR); and, Raman-spectroscopy. Both are expensive but they can be used as diagnostic tools. Raman spectroscopy can also provide more information on the crystalline structure of the polymer and thus, its sorption behaviour for PBT.

3.3.2 Information and research requirements

More information was required about plastic and microplastic inputs, spatial and temporal distributions, including transport dynamics, interactions with biota (e.g. plankton) and potential accumulation areas.

It was felt that some form of 'taxonomy' of plastic particles would be useful (size, shape, density, chemical composition and properties) as would a method to derive the 'age' of particles, linked to suitable standards. This could be incorporated into Environmental Quality Standards to inform policy makers (e.g. Good Environmental Status under the EU MSFD). It could also be incorporated in the development of guidelines for sampling and reporting.

In terms of capacity building and raising awareness, the workshop proposed the development of an abundance map (linked to a database via the internet using, for example, GoogleEarth™) as well as encouraging the development of the International Pellet Watch and related initiatives. This might also tie in the GEF/UNEP/IOC Transboundary Waters Assessment programme (See Section 5.3.2).

The workshop would like to see the incorporation of marine litter and if feasible, micro-plastics in existing and new monitoring programmes as appropriate, bearing in mind the often limited resources available in many countries for marine monitoring.

3.4 Transport, distribution and fate including deterioration and degradation routes

3.4.1 Transport and distribution

Most common plastics have specific gravities (SG) from ca. 0.6 to 1.5 but some finished products containing fillers can reach as high as 3.0 (see http://www.plasticsusa.com/specgrav.html). PE, PP natural and synthetic rubbers all have SG ranges of less than 1.0 and float on water. Many other common plastic types have an SG of slightly more than 1.0, e.g. polystyrene but given the higher density of seawater as opposed to freshwater many still float in the marine environment. PVC and POM have much higher SGs at around 1.4 and tend to sink. Finally, some speciality polymers such as polytetrafluoroethylene (PTFE) may have an SG of up to 2.3. The behaviour of different types of plastics in the water column needs further study.

The ocean are complex heterogeneous water bodies. On a smaller scale, 'plugs' or 'slabs' of water tend to remain intact for long periods of time, characterised principally by their temperature and salinity, while currents, eddies and gyres dominate at a larger, oceanic scale. As hydrographical and 'accidental' drifter studies have shown, floating debris may often move quite predictably along well travelled paths in the oceans, e.g. the Gulf steam which casts floating objects originating in the Caribbean onto Eastern North Atlantic shores (Ebbmayer & Scigliano, 2009 provide a useful introduction to drifter studies). The same authors note the Azores in the North Atlantic (ca.1800 km W of Spain) and the coastal barrier islands of the Western Gulf of Mexico as known litter hotspots. Mapping of such hotspots of macro-debris may help to some extent to decipher the distribution of microplastics.

Thus far there has been an *ad hoc* scientific approach to determining the presence of micro-plastics in the pelagic and sedimentary environment – our knowledge of distribution is therefore very patchy. There is a need to set a broad sampling programme with fixed transects in open water, to determine how ubiquitous micro-plastics have become in the environment and to gain an overall picture of distribution and in particular trends.

Relatively constant levels of plastic particles has been observed in the Western North Atlantic Ocean between 1991 and 2007 (Morét-Ferguson et al., 2010; Law et al 2010). Ribic et al., (2010) have also shown that there has been little or no increase in beached and oceanic litter in recent years; only one of three sectors of US coastline showed increases. This may be related to improvements in solid waste management practices along the relevant coastlines (See Section 5).

We still know relatively little of the fate of micro-plastics, e.g. whether particles are being deposited in deep-sea sediments, or whether they are more limited to the shelf and the coastline. The vertical movement of various types and sizes of particles is also an area which needs attention, e.g. plastics fragments with biofilms may sink, but once the biofilm has been removed, it may become buoyant again (Ye & Andrady 1991). The density of the plastic itself may also play a role. As noted above, the workshop reiterated that further information needed to be gathered on locations where macro plastic debris accumulates and also where microplastics are likely be deposited in sinks. The behaviour of different sized particles also needs consideration.

3.4.2 The relevance of plastic particles as a contaminant transport route

The workshop considered the importance of plastics as a possible transport route for PBTs relative to the atmosphere or in dissolved or adsorbed form in seawater. It has been demonstrated that marine microplastics contain a wide-range of organic contaminants including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, organochlorine pesticides (DDTs, HCHs), polybrominated diphenylethers (PBDEs), alkylphenols and bisphenol A (BPA), at concentrations from sub ng/g to µg/g (Mato et al., 2000; Rios et al., 2007, Teuten et al., 2009). Concentrations of PBTs adsorbed on plastics showed distinct spatial variations reflecting global pollution patterns (Ogata et al., 2009). Together with the spatial pattern, non-uniform distribution (i.e., piece-to-piece variation) in the concentrations of PBTs in the microplastics was observed (Endo et al., 2005; Ogata et al., 2009).

The workshop discussed three basic scenarios, with which the fate of transported chemicals in microplastics might be examined. It should be stressed that what follows here are hypotheses and that the workshop did not reach conclusions on the specifics of this issue:

Hypothesis 1; the sorption of PBTs to micro-plastics is reversible.

> Micro-plastics will act as reversible passive samplers of pollutants to and from the water column (and atmosphere). This could mean that micro-plastics take up (absorb) PBTs in regions where PBT concentrations are high, and could release (desorb) PBTs in cleaner, remote regions. Depending on the type of micro-plastic, sorption could be slow due to internal diffusion (e.g., LDPE), resulting in the core of the micro-plastic not being in equilibrium with the outer surface of the particle.

Hypothesis 2; for most PBTs, atmospheric transport dominates.

> Micro-plastics may matter as a source of PBT's <u>only</u> where long-range atmospheric transport (LRAT) 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 (i.e., within hemispheric transport cells, and into the Arctic;

cross-equatorial transport in the troposphere is slow - a year or more - but transport to remote ocean regions within a hemisphere is rapid).

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

Micro-plastics will serve as a stable phase in addition to organic matter in the water column and biota, so stabilizing PBTs in the water column, thereby reducing their sinks. PBTs then partition between air, water, sediment and biota, preferentially into the organic carbon and lipid phase of the latter. The presence of micro-plastics will provide an additional, mostly attractive phase for PBTs to diffuse into. As micro-plastics are not expected to be degraded in an organism's gut, micro-plastics could stabilize PBTs in the environment and reduce other sinks, such as sedimentation with organic carbon.

Zarfl and Matthies (2010) estimated mass fluxes of polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and perfluorooctanoic acid (PFOA) sorbed on plastics to the Arctic via the main ocean currents and compared this route to the dissolved state and via the atmosphere. Substance fluxes of these chemicals in which atmospheric transport or sea water currents account for several tons per year are predicted, whereas those mediated by plastics are four to six orders of magnitude smaller. However, these authors also considered that the significance of various pollutant transport routes does not depend only on absolute mass fluxes but also on bioaccumulation in marine food chains.

There is a strong theoretical basis and also plenty of empirical data to show that PE and other (micro) plastics emitted to the environment can absorb chemicals of concern, adsorption capacity is increased by deterioration and depends on the type of polymer, e.g. Endo et al. (2005), Ogata et al. (2009), Teuten et al. (2009) and Frias et al. (2010). Plastic pellets (nurdles) are even utilized as passive samplers, e.g. Ogata et al. (2009), Lohmann and Muir (2010) and Smedes et al (2009).

Based on the fugacity modelling approach a "fugacity-capacity" can be estimated to assess the tendency of chemicals to partition between air, water, plastics and organic carbon present in sediments as a result of their relative volumes. Previous work has established that in general, plastics favours the accumulation of organic chemicals with high octanol-water partitioning coefficient (log K_{OW}), thus acting similar to lipids in organisms and organic carbon in sediments (See Box below for an example).

A limitation to modelling approaches, which are based on equilibrium partitioning, is that they fail to consider the dynamics of the system, for instance the kinetics of partitioning between environmental media and the plastic or the influence of accumulating plastic with time. Additionally, this model assumes an unrealistically uniform distribution of both pellets pellets and PBTs.

3.4.3 Contaminant uptake and release

It is suspected that plastics may transfer PBTs which do not undergo long-range atmospheric transport from coasts to the interior of Oceans (See Zarfl and Matthies, 2010 in relation to transport routes to the Arctic and the possible role of plastic particles). Time-scales of sorption and desorption are a function of the type of plastic (Teuten et al. 2009), its size, the compound of interest and diffusion across the water-plastic interface. Karapangioti and Klontza (2008) studied the absorption kinetics of phenanthrene in plastic pellets and concluded that the material from which the pellet is made, the size of the plastic particle and its state of ageing or weathering can influence kinetic processes of uptake and the diffusion rate within the polymer. For LDPE, times to reach equilibrium are ca. 50 – 100 days for particles the size of plastic pellets, but far shorter, e.g. a couple of days for PE films that are 50 µm thick.

Modelling approaches

An example was presented of a modelling approach to assess the potential behaviour of chemicals absorbed in PE beads that have been released to the environment as a consequence of their use as an exfoliator in personal care products such as facial cleansers (Fendall and Sewell, 2009). It is estimated that ca. 260 tonnes is currently formulated per year in the USA (with an estimated per capita consumption of 0.88g/person/year). A typical concentration of PE beads in formulations is 0.5 – 5%, and the particles are from 4 µm to 1mm with a median of 250 µm. Based on a conservative estimate, for modelling purposes, it is assumed that only 25% of PE beads discharged to municipal waste water treatment plants (WWTPs), as a result of there use in facial cleansers, is retained and that therefore 75% can escape to surface waters. It is further estimated that ca. 43m^3/y might reach the sea along the west coast off the USA. Modelling was then applied using and area of 1000 km x 100 km to represent the California coastline) with the help of chemical space diagrams. However, with only 43m^3 of PE micro-plastic, in this area, it was demonstrated that chemicals will partition predominately between air and water. Adding a sediment compartment results in an increase of partitioning of substances with Log $K_{PE\text{-}W}$ > 5 to accumulate in sediment, i.e. introduces competition with the plastic. Therefore due to the volume ratios in the scenario, a significantly large amount of PE micro-plastic would be needed to be present in the aquatic environment from the above source to result in significant partitioning; otherwise biological exposure to chemicals in the water and air will be of much greater concern.

Among the microplastic studies by Endo et al., (2005) and Ogata et al. (2009), pellets with sporadic high concentrations of PCBs were observed. Large (up to 3 orders of magnitude) piece-to-piece variation was observed among the plastic resin pellets collected from a single beach, indicating slow sorption/desorption. These microplastics with sporadically high concentrations of PCBs could expose significant amount of PCBs to biota which ingest the plastics (Endo et al., 2005). For instance, if we recognize that it takes 7 to 180 days for substances with a high log Kow such as PCB's and PBDE's to reach equilibrium in plastic particles (200µm thick, then it is reasonable to expect that it may take a comparable amount of time for contaminants to desorb once ingested by an organism, if environmental conditions within the gastrointestinal gut of an organism are such that desorption would be favoured.

Teuten et al. (2007) carried out adsorption/desorption experiments *in-vitro* with combinations of clean media and phenanthrene equilibrated sediments and PE particles and predicted that the presence of phenanthrene contaminated plastic particles was likely “to give a significant increase in phenanthrene accumulation in the lugworm *Arenicola marina,* a sedimentary deposit feeder known to ingest plastic particles. Citing Voparil & Mayer (2000), who demonstrated experimentally that the presence of digestive surfactants in polychaete worms increases the ‘bioaccessibility’ of sediment-bound contaminants Teuten et al. (2007) considered that gut-surfactant mediated desorption may play an important role in the transfer of contaminants from plastic particle to benthic deposit feeders. In this context, Voparil and Mayer (2000) noted that gut fluid concentrations of high molecular weight PAHs are greater than those predicted from equilibrium partitioning theory, indicating the importance of the digestive pathway for hydrophobic organic contaminant exposure and bioaccumulation.

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.

3.5 Impact of micro-plastics on the marine environment- concepts of harm

Definitions of harm were explored by the workshop, as the EU MSFD had introduced this concept into EU legislation and it was felt that it might provide some insights that could be applied elsewhere. A typical dictionary definition of harm is as follows: *physical injury, especially that which is deliberately inflicted, material damage and damage to health, actual or potential ill effects or danger, adverse effects*.

According to Galgani et al. (2010) “Harm” in the context of the marine litter problem 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 benthic community structure.*

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;*

Note the specific mention of micro-plastics in this context. The fact that the fulmar population in the North Sea contains high levels of ingested plastics could be considered as an undesirable exposure, regardless of its other implications. Recent findings of plastic ingestion by planktivorous fishes in the North Pacific Central Gyre (Boerger, et.al. 2010, in press) indicate an undesirable exposure within a food web.

The workshop considered three more concrete and science-based concepts:
i) an undesirable exposure;
ii) evidence of uptake and biological effects;
iii) an extra cost on the energy budget of an organism.

For most of the chemicals involved, their hazard, or potential to cause (eco)toxicological harm is already well known. 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. This is in addition to potential detrimental health effects in marine organisms simply due to the presence of particles within the organism.

The workshop did not attempt to reach a definite conclusion, noting that at this juncture some of the potential risks which might make the problem more or less urgent were unclear. It was pointed out that not only plastics but also other forms of marine debris may adsorb contaminants and therefore all forms of marine debris should be considered.

Ingestion of microplastics has been demonstrated in many invertebrate organisms, i.e. those lower down the food-chain which usually serving as prey for higher organisms. Thompson et al. (2004) showed in laboratory studies that amphipods (detritivores), barnacles (filter feeders), and lugworms (deposit feeders) ingest small PVC plastic fragments with a mean size of 230µm. Ward and Shumway (2004) in a review on particle selection in bivalve molluscs report several laboratory experiments which show that scallops and mussels can filter and take up polystyrene spherules. Browne et al (2007 and 2008) reported that the blue mussel *Mytilus edulis* ingests and accumulates polystyrene beads as small as 2 µm in their gut cavity. Mussels were exposed to treatments containing seawater and microplastic (3.0 or 9.6 µm). After transfer to clean conditions, the microplastics were tracked in the hemolymph. Particles were translocated from the gut to the circulatory system within 3 days and persisted - after a peak at 12 days - for over 48 days. Smaller particles were more abundant than larger particles. They reported that this short-term pulse exposure used did not result in significant biological effects.

Koehler et al. (2008) demonstrated the uptake of silicon dioxide particles (3-7µm) into the epithelial cells of the gills and the digestive gland tubules of the blue mussel *Mytilus edulis* with consequent effects on the stability of lysosomal membranes and the production of lipofuscin (an indicator of oxidative stress). The authors considered this to be a cause effect relationship. The workshop was informed of more recent work (Koehler & von Moos pers. com. Eds.), with the same species which demonstrates its ability to take up plastic particles in the size range 1-80µm into the vacuoles of the digestive gland, also with indications of granulocytoma formation (inflammation), increase in SB haemocytes after 48h and a significant decrease in lysosome stability after 48h.

Bowmer et al. (1991) discussed the histopathological condition of freshwater mussels in the River Maas and the Netherlands delta region in relation to pollution and other environmental factors, noting that responses such as granulocytomas and even degeneration of the digestive gland can be widespread in stressed populations.

3.6 Current state of knowledge

The workshop summarised the state of knowledge as follows:

i) The distribution of various sizes of plastic particles is inherently patchy;
ii) Plastics do transport contaminants and a distinction can be made between sorbed pollutants and plastics additives, the latter of which might not otherwise reach the oceans.
iii) The same theoretical rules of partitioning and behaviour should apply to additives as to the sorbed pollutants, however, knowledge of the whole transport process is generally lacking;
iv) Plastics of various sizes are ingested by a range of organisms and where effects are concerned, all particle sizes are relevant.
v) A fraction of organic pollutants which is as yet difficult to quantify may desorb from plastics into organisms - there is evidence in seabirds for transfer of PCBs from plastics to the tissues;
vi) Plastics of specific sizes have been reported by Browne et al, 2007 and Koehler et al., 2008) to pass through cell membranes – other particles also do this – the difference being that the plastics are solely anthropogenic in origin;
vii) Once taken up, according to Browne (op. cit.) particles can be retained for long periods (weeks).
viii) There is evidence of an inflammatory response in the blood compartment plus pathologies in other tissues following such accumulation of particles (Koehler, 2008).

3.7 Research priorities

3.7.1 Environmental effects

The workshop declared interest in a wide range of relevant indicator organisms from birds to invertebrates and the following selection criteria were suggested:

i) the impact of micro-plastics on different trophic levels needs further study, e.g. filter feeders, surface benthic feeders, deposit feeders, predators (including sea-birds).
ii) the organisms likely to ingest plastics in their diet could be most useful - a focus on altered behaviour of organisms as opposed to passive encounters would be useful;
iii) organisms with a greater fat content could be a better indicator of bioaccumulation of PBTs although it would be necessary to distinguish natural bioaccumulation with the added effect of plastics.
iv) Human health impacts through the food-chain should also be considered as part of an attempt to assess the socio-economic consequences.

With regards to laboratory species/model organisms, these should be globally available, e.g. the blue mussel (*Mytilus* sp.) and marine worms but not restricted to those requiring running seawater. With laboratory studies and active bio-monitoring (placing clean animals in the field to assess contaminant uptake), the duration of the exposures should fit known ecotoxicological timescales, e.g. it may take several weeks for PCB's to passively desorb (depending on fugacity capacity) from plastics. Residence times following ingestion and ingestion pressure as well as surface to volume ratios and nature of digestive fluid will determine the degree of leaching from PE, PP and PVC, as will ageing. The challenge is how to identify the added or reduced chemical impact of micro-plastics relative to the 'natural' bioaccumulation of PBTs from water and through the food-chain. This makes for a complex chain of circumstances that needs to be carefully considered in designing laboratory bioaccumulation experiments.

One participant suggested that porosity might be a contributing factor in determining adsorption and desorption of PBTs; another recommended that the identification of additional chemical impact of micro-plastics relative to the 'natural' bioaccumulation of PBTs from water and through the food-chain might be deciphered using radio-labelled PBTs under experimental conditions.

3.7.2 Environmental fate

i. The identification of sources, sinks and hot-spots for plastics and micro-plastics would be beneficial rather than focussing on specific habitats.

ii. Good reference sites need to be identified.

iii. The availability of reference materials, e.g. pellets of various types and sizes of plastic was felt to be important to facilitating research and the industry representatives present offered their help in finding appropriate materials.

iv. Desorption remains a key imponderable – testing under extreme conditions could be a way forward and there is a preference for a kinetic approach to provide a hypothesis against which to design experiments.

4 Socio-economic aspects (session G)

An invited expert on socio-economic analysis gave a presentation to the workshop on "*Marine and coastal ecosystem services and coastal zone management"*. This presentation looked primarily at how the ecosystem services and valuation concepts can be integrated into coastal zone management.

The Workshop considered the potential role of 'ecosystem services valuation' in developing solutions to reduce the marine debris problem. Valuing ecosystem goods and services might make tackling marine litter more attractive and encourage action, when compared to the potential costs associated with leaving it in situ. This incentive might lead to the provision of a range of abatement measures and regulatory controls which could be weighed up as part of a cost-benefit analysis used by policy makers. A key question is how to value the services, and on the other hand, how to value the loss of services through environmental damage. There is a general relationship to biodiversity, but is it efficient to conserve, regardless of who pays? Some participants felt that there was a danger of miss-applying cost-benefit analysis. You might get the desired benefit(s) but it remains very difficult to place monetary values on all the elements.

Although the focus of the workshop was on micro-plastics, it was recognised that solutions are related to how society deals with all marine debris and by extension solid waste, management. There is a need for scientists to express 'damage' in terms that can be easily understood by the general public. Where resources are limited, it will be important to focus on policies that deliver benefits to the largest proportion of the population on the most important sociological/health issues and micro-plastics might fare better in this regard when considered as a sub-set of the marine litter problem.

5. Policy implementation at global, regional and national scales (sessions F, H, J)

This section provides an overview of international activities in relation to marine debris, plastic litter and micro-plastics. It is intended to provide background information and a potential starting point for a global assessment of marine litter and microplastics in the future.

5.1 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. 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 (UNEP, 1995). It was listed as being of concern by GESAMP in a report entitled "*Protecting the ocean from land-based activities*" (GESAMP, 2001). More recently, in 2005, the problem of marine debris and the need for increased national and international control, was dealt with by the 60th session of the United Nations General Assembly within the context of its annual resolutions on oceans and the law of the sea (A/RES/60/30, paragraphs 65-70) and sustainable fisheries (A/RES/60/31, paragraphs 77-82). In 2005, marine debris was also one of the topics of focus of the sixth meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (see report A/60/99).

UNEP together with partners IOC, FAO and IMO, using the Coastal and Oceans GPA as a clearing house and its Regional Seas Programme, has done much to raise awareness by providing practical guidance and policy advice and to encourage the development of national and local solutions to prevent waste reaching the seas. UNEP (2005), provided a useful review 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/FAO (2009). UNEP has pursued this issue within the Regional Seas Programme and has published a review of their global initiative on marine litter (UNEP, 2009a). The objective was to present and analyse available information on marine litter produced by the 12 regional seas programmes and to propose recommendations for addressing the problems associated with marine litter worldwide. It does not claim to be a comprehensive overview of global marine litter, but it does provide information on the marine litter issue in the Baltic Sea, Black Sea, Caspian, East African Seas, Eastern Africa, Mediterranean, Northeast Atlantic, Northwest Pacific, Red Sea and Gulf of Aden, South Asian Seas, South Pacific, and Wider Caribbean. According to UNEP (2009a), this study 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 (UNEO/IOC, 2009) to assist policy makers and support efforts by regions, countries, Regional Seas Programmes and other relevant organizations to address the problem of monitoring and assessment of marine litter. These guidelines include a comparative analysis of information from around the world on existing experience and methods for surveys, monitoring, reporting protocols and assessment of marine litter. UNEP has also produced 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. (See UNGA resolution 60/30, paragraph 12) Many regions have identified marine litter as a problem, but the overriding issue remains the absence of, or poorly developed, waste management systems in large parts of the world. A key question is how to best distribute recently accumulated knowledge to the areas where it is most needed and how to best influence policy and decision-makers. The tendency to advocate actions such as classical monitoring programmes for marine (plastic) litter may not be the best use of scarce resources when considered globally. A clearer focus on specific areas, e.g. ‘hot spots’, might translate more quickly and effectively into policy decisions. All forms of marine litter need to be assessed, not just plastics, and structured monitoring activities need to be established in key areas – not every mile of coastline needs to be monitored. Hot spots need to be associated with management issues, which will help align such efforts with policy development.

5.2 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 also one of the few inputs of plastic and other debris which is directly controlled by international treaty.

Annex V of MARPOL 73/78 (see side bar), covers garbage from ships and partly from offshore structures. It entered into force on 31 December 1988 and its aim is to eliminate and reduce the amount of rubbish being dumped into the sea from ships. Garbage includes all kinds of food, domestic and operational waste generated during the normal operation of the vessel and Governments are obliged to ensure port reception facilities to accept ship garbage. Annex V explicitly prohibits the disposal of plastics anywhere into the sea.

In practice, it is broadly recognized that Annex V has struggled to achieve its goals and in 2005, the General Assembly invited the International Maritime Organization, in consultation with relevant organizations and bodies, to review Annex V to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, and to assess its effectiveness in addressing sea-based sources of marine debris". Further information on the significance of special areas under Marpol 73/78 is given in the text box. Of the six Annexes of MARPOL 73/78, some have already been radically revised in recent years, e.g. Annexes I and II covering respectively, mineral oil and bulk liquid chemicals. These latter revisions, which took longer than a decade to complete, should provide significant improvements in the safe

International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)

This provides a comprehensive approach to dealing with ocean dumping by creating international guidelines for pollution prevention from ships. There are six annexes associated with MARPOL:

- I - Discharge of oil;
- II -Control of hazardous liquids;
- III-Transport of hazardous materials in a packaged form;
- IV - Discharge of sewage;
- V - Disposal of plastics and garbage
- VI - Air pollution

Annex V is of particular importance to the maritime community (shippers, oil platforms, fishers, recreational boaters and cruise lines) as it prohibits the disposal of plastic and regulates the disposal of other types of garbage at sea. Under Annex V, garbage includes all kinds of food, domestic and operational waste, excluding fresh fish, generated during the normal operation of the vessel and liable to be disposed of continuously or periodically. It also requires ports and terminals to provide garbage reception facilities for boats. As of 31 July 2010, 140 countries have ratified Annex V controlling the disposal of plastics and garbage into the oceans.

"Special Areas" are designated by MARPOL Annex V as locations where, due to the site's unique oceanographic, ecological, or traffic conditions all overboard discharges of garbage (except ground-up food wastes) are prohibited. To date MARPOL has designated nine Special Areas: Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, Persian Gulf, Gulf of Aden, North Sea, Antarctic area, and the Wider Caribbean (including the Gulf of Mexico http://www.imo.org

http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258

transport of chemicals and oils as far as the environment is concerned. Revision of Annex V commenced in 2006 and an MEPC correspondence group led by New Zealand produced a submission containing a new draft text of the Annex which was tabled at IMO's Marine Environment Protection Committee's 61st session in October 2010. An overview of the proposed amendments to Annex V of Marpol 73/78 is given in Table 3 below.

Table 3. MARPOL 73/78, ANNEX V: summary of proposed amendments and permitted discharges.

Garbage type	Current	New
Plastics	No discharge	No discharge
Dunnage, lining and packing materials	Outside 25nm	No discharge
Food wastes	If comminuted outside 3nm. If untreated outside 12nm unless comminuted.	Ship must be *en route.* If comminuted outside 3nm. If untreated outside 12nm unless comminuted. In Special Areas must be 12nm from land or ice shelves. In the Antarctic must not contain poultry products unless sterile.
Cargo residues	Outside 3nm.	Ship must be *en route* Must not be a marine pollutant. Outside 12nm. In Special Areas only when contained in hold wash water and where ship not leaving the area between ports and no reception facilities exist.
Paper products, Rags, Glass, Metal, Bottles, Crockery, Incinerator ash	If comminuted outside 3nm. If untreated outside 12nm unless comminuted.	No discharge
Cleaning agents for deck washing	Not regulated.	Discharge allowed with wash water but must not be a marine pollutant.
Animal carcasses	Not regulated	Outside 100nm Maximum possible water depth Split to ensure they sink.
Non-Synthetic fishing gear	Not regulated	No discharge except in emergencies to protect vessel, crew or environment.

The above changes once adopted 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. Other significant changes that are proposed to Marpol 73/78 are as follows:

i. The exceptions have been expanded to permit food discharge where the ship is at anchor for extended periods and there is a health risk to the crew.

ii. The ship size requiring a garbage management plan has been reduced from 400 gross tonnes to 100 gross tonnes.

iii. The requirement for a garbage management plan and garbage record book may be extended to include offshore installations.

iv. Garbage management plans are to include procedures for minimizing waste.

v. The loss of any fishing gear should be recorded in the record book or ship's log – with additional detail about gear type, position etc.

vi. The loss of fishing gear that poses an environmental or navigation list (eg. Nets, long-lines) must be reported to the flag and coastal State.

vii. Consequential amendments will be made to the garbage record book and to the IMO Guidelines for implementation.

Finally, in discussing international legislation and its possible application to the marine litter and microplastics problem, some participants considered that other fixed or floating structures that shipping an drilling/production platforms such as offshore aquaculture operations and wind generator parks should fall under some international legislation, noting that aquaculture in particular can be a significant source of garbage including plastic debris (Hinojosa & Thiel 2009). It was suggested that such legislation might only be applicable in international waters.

5.3 UN global assessment processes

5.3.1 The Regular Process for the assessment of the marine environment.

The countries of the world decided at the World Summit on Sustainable Development (WSSD) in 2002 to establish by 2004 "*The regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects*" (http://www.unga-regular-process.org).

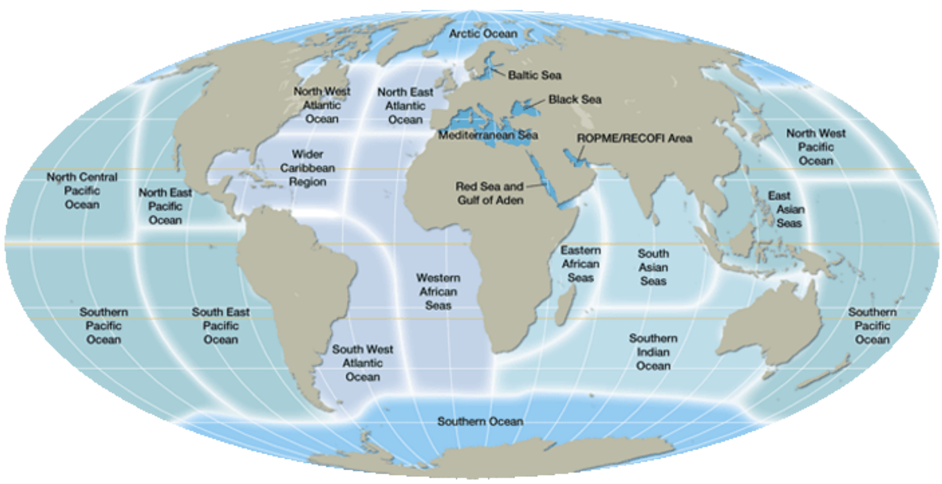
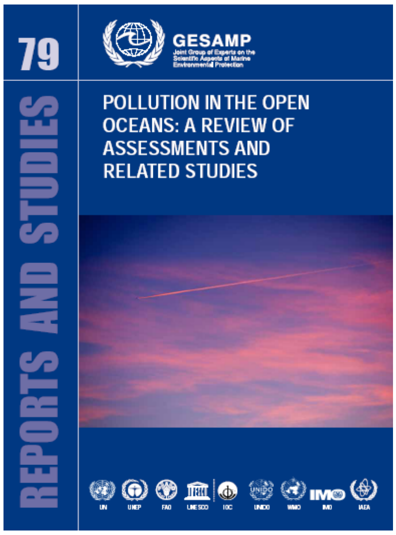


Fig. 2. Ocean regions considered in the Assessment of Assessments

Assessments are the basic tools for understanding what is happening in the oceans, why, and how effective response measures have been. Assessments assemble this knowledge in a form useful for decision-making. However, a regular repeat of assessments (See Fig. 2), i.e. a definite process is needed to encourage adaptive management in response to changing conditions. It is essential to build on, guide and strengthen existing marine assessments in order to advance a more coherent global system that clarifies and recognizes linkages in order to provide an overview of the state of the marine environment and its interaction with the world economy and human society.

As a prelude to the Regular Process, an Assessment of Assessments (AoA) was carried out to review the availability and quality and existing assessments of the marine environment, in order to: assemble information about marine assessments; undertake a critical appraisal of the assessments in order to evaluate their scientific credibility, policy relevance, legitimacy and usefulness; identify a framework and options to build the Regular Process; consider the communication of the results of existing assessments, their different scales, and how best to build on existing efforts. This resulted in The Assessment of Assessments Report (IOC-UNESCO, 2009).



No global databases on marine litter inputs from land-based activities were identified. It was concluded that national and regional data were to a large extent generated from spot surveys of beaches and, to a much lesser extent, marine areas. A number of studies were identified concerning ship-based sources of debris, at global and ocean-basin scales. GESAMP contributed at the request of UNESCO-IOC a report on the “Pollution in the open oceans: a review of assessment and related documents” (GESAMP, 2009) and also provided in-kind support to the work of the AoA group of experts. An ad-hoc Working Group of the UN-General assembly is currently working to develop the Regular Process and has set up a group of experts.

Table 4. Timing for the first Regular Process assessment cycle (IOC-UNESCO,2009)

2012 – Rio+20, WSSD+10
2014 – twenty years on from UNCLOS entry into force
2015/2016 – Commission on Sustainable Development reports on Oceans
2010 – 2015 – important WSSD goals
2010 – 2014 is the appropriate time frame for the first cycle of a Regular Process

5.3.2 The Global Environmental Facility, Trans-boundary Waters Assessment Programme (GEF-TWAP)

The objectives of TWAP are to develop an indicator-based methodology for assessment of trans-boundary water systems (Open Ocean, Large Marine Ecosystems, Rivers, Lakes, Groundwater), as well as to develop a partnership among UN and other agencies, and the arrangements for the conduct of a global assessment of trans-boundary waters. This GEF Full-Sized Project is expected to commence in 2011-2014 and would allow for the prioritization of interventions and of allocation of financial resources and would allow the GEF to track results of their interventions.

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. It should monitor evolving trends, and predict issues / stresses at a relatively high level of integration, i.e. with a small number of indicators which should be simple, tractable measures with global coverage.

The TWAP must be scientifically credible and the recently highlighted lack of data in open oceans (GESAMP, 2009), particularly of ecosystem state, requires an expert assessment of best available science (IPCC-style). A GESAMP task team is currently partnering the TWAP Open Oceans and LME modules.

With regards to contaminants/pollution where GESAMP might be able to contribute, the following issues have been identified as needing further investigation.

i) Nitrogen / Iron from atmosphere – where are the main inputs, where is the ocean limited and can we make predictions?
ii) Mercury – this is a cross-cutting issue in TWAP and it might be useful to refocus on mercury in exploited fish species
iii) Persistent Bioaccumulating and Toxic substances – global indicator-based assessments need to be developed and can micro-plastics be included as part of this?
iv) Litter – we have many isolated and anecdotal data points but what might be a simple, global assessment indicator? The focus should be on number, form, size , mass and types of microplastic, e.g. as identified using FT-IR or Raman.
v) Large Marine Ecosystems – what are key risks associated with contaminants/pollution and the links between watersheds the coastal environment and the open ocean?
vi) Hypoxia.

5.4 Examples of Regional Assessments

A brief overview of selected, recent marine litter assessments is given in this section and some of their key conclusions are summarised. The following assessments are listed in the

Assessment of Assessments database maintained by the UNEP-World Conservation Monitoring Centre (UNEP-WCMC, 2010).

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Table 5. Regional Seas Assessments listing marine litter in the UNEP WCMC Gramed database

WIOMSA, A Region Overview & Assessment of Marine Litter Related Activities in the West Indian Ocean Region (2007).	Narrow Assessment
COBSEA, Marine litter in the East Asian Seas Region (2008)	Narrow Assessment
CPPS, Marine litter in the Southeast Pacific Region: a review of the problem (2007)	Broad Assessment
OSPAR Pilot Project on Monitoring Marine Beach Litter: Monitoring of marine litter on beaches in the OSPAR region (2007)	Narrow Assessment

5.4.1 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, including source differentiation, zones of accumulation and degree of ecological, environmental and socio-economic impacts;
iii) The problem of marine litter is likely to be particularly severe in the East Asian Seas region, due in part to the massive industrial and urban development under-way in the coastal zones of the region. This is combined with an exponential and sustained growth in shipping activity serving the region's rapidly expanding economies, and the current lack of effective marine litter prevention and control measures in many COBSEA member countries, and in many cases, cultural and awareness barriers often impedes political will to address the problem;
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 fishing in the region; and
v) All countries in the region face significant barriers to the effective prevention and control of marine litter.

The final conclusion above is the most telling, as it refers to a long list of measures which, with the exceptions of Australia, Singapore and Republic of Korea are generally lacking in this rapidly developing region, including fundamental: "*lack of or inefficiencies with broader national waste management systems*". This was illustrated at the GESAMP workshop by the presentations of experts from Vietnam and Malaysia and was documented in the East Asian Seas/COBSEA regional marine litter assessment (UNEP, 2008).

A regional action plan for marine litter had been agreed among COBSEA's 10 member states, to improve the quality of marine and coastal environments of the East Asian Seas and which addresses the issue of marine litter through regional cooperation and partnerships. Its objectives are:

i) to prevent and reduce litter in marine and coastal environments of EASs.
ii) to mitigate the environmental and socio-economic impacts of litter in marine and coastal environments of the EASs.
iii) to raise awareness about marine litter and its impacts, amongst all relevant stakeholders in the EAS region, including but not limited to government decision makers, the private sector such as fisheries, shipping, ports and the plastics and packaging industries, and the general public.
iv) to monitor and assess the types, sources, distribution, quantities and trends of litter in marine and coastal environments of the EASs, in order to provide science-based information for policy-making and management planning.

5.4.2 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 (UNEP, 2009c) 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 on quantities, types, trends, sources and sinks of marine litter, 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; it is considered to be part of the general waste stream in the West Indian Ocean region;
iii) Most countries do have laws and policies that govern solid waste management, to varying degrees, 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. This is true for all countries in the West Indian Ocean, as is the fact that the degree of successful management of the litter problem varies greatly between countries;
v) The major constraints to effective waste management, so reducing marine litter, 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; the West Indian

Ocean has a high density of commercial shipping and fishing vessels. Loss of fishing-gear and dumping of rubbish is prevalent;

vii) The extent to which solid waste generated on land is prevented from reaching the sea varies between countries, and regions within countries. Participants are found to fall into two distinct groups with respect to their land-based solid waste management capacity:

  a. Mauritius, Seychelles and South Africa presently have the motivation and human and material resources to manage waste fairly adequately, and they contribute relatively little to marine littering.
  b. Comoros, Kenya, Madagascar, Mozambique and Tanzania appear to have very poor abaility to manage their waste. Basic removal, treatment, recycling and disposal services for solid waste do not exist in certain coastal areas of these countries. In many places waste is dumped directly onto the coast either for dispersal via the sea or as a barrier against erosion. These countries are amongst the poorest in the world with the smallest gross national incomes and human development indices.

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.

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

The Workshop was informed that AMEP was set up under the Cartagena Convention to "*control, prevent and reduce pollution of the coastal and marine environment from land and marine-based sources and activities thereby enabling countries of the Wider Caribbean to meet their obligations under the Land Based Sources of Marine Pollution and Oil Spills Protocols of the Cartagena Convention*". It covers 28 member countries in the Wider Caribbean region, including the overseas territories of the United Kingdom, The Netherlands and France; it is also the only regional convention covering the environment (www.cep.unep.org/about-cep/amep).

The development of integrated management approaches to waste, including marine debris need to gain prominence in the region. Land-based solid waste still represents the largest source of marine debris at 70-80% and AMEP places the major emphasis on prevention through the Cartagena Convention. Policy makers generally only act when there is a threat or an impact on health, industry, tourism or fisheries, and in this sense micro-plastics only adds another form of pollutant to the long list which the region is already unable, or only poorly able to deal with. Micro-plastics as an issue therefore clearly needs to be considered in the wider context of marine debris and integrated solid waste management and needs to be integrated into existing programmes, projects and activities.

The Workshop was informed that 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. IMO is a strong partner and on 1 May, 2011 the Caribbean will implement the region's MARPOL 73/78, Annex V "Special Area" designation. . The Caribbean experience shows that effective waste management at sea is in fact a broader land management issue, i.e. dealing with the garbage collected on land is the biggest part of the problem. A country-by-country survey was necessary to influence policy and to make sure that ships' waste and port reception facilities are integrated into national waste management plans. This requires regional standardization of charges and changes to port-state control. Port reception facilities and cost recovery mechanisms have to be introduced in all the 28 member states for the policy to be effective.

5.5 European Commission initiatives

5.5.1 Directorate General Environment (DG-ENV)

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, e.g. in the areas of urban waste water, nitrates and chemicals management, as well as the bird and habitat directives. However, it was recognized that there is a need for a more integrated management of human activities, and this can be seen in the more recent legislation such as the Water Framework Directive, 2000, which includes coastal waters, and the Recommendation on Integrated Coastal Zone Management (2002). Finally, the unique position of the oceans was recognised in July 2008, when the Marine Strategy Framework Directive 2008/56 (MSFD) was adopted. This strives to ensure 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"*.

EU marine Strategy Framework Directive: Good Environmental Status (GES)

1. Biodiversity is maintained
2. Non-indigenous species not adversely alter the ecosystem
3. Population of commercial fish species healthy
4. Elements of food webs ensuring long term abundance and reproduction
5. Eutrophication minimised
6. Sea floor integrity ensures functioning of the ecosystem
7. Permanent alteration of hydrographical conditions not adversely affect ecosystem
8. Concentration of contaminants give no effects
9. Contaminants in seafood below safe levels
10. Marine litter not to cause harm
11. Introduction of energy (incl. underwater noise) not adversely affect ecosystem

To achieve this, each EU Member State must progressively put in place its own "Marine Strategy" action plan. They must cooperate among themselves and also with neighbouring countries, where possible within Regional Sea Conventions (e.g. OSPAR, Barcelona, Helcom, Black Sea). Where the development of marine strategies is concerned there are three implementation milestones:

- *15 July 2010*: The EC will develop criteria and methodological standards on "good environmental status" (GES) for the Member States to use.
- *15 July 2012*: The Member States will develop a description and assessment of current environmental status, including the environmental impact of human activities and socio-economic analysis. In order for GES to be achieved, precise ecological objectives need to be defined in the form of environmental targets and associated indicators.
- *15 July 2014*: The member states will develop monitoring-programmes for all marine waters (adapted to the assessment of progress towards GES).
- *2015*: All Marine Strategies will culminate with a programme of measures.
- *2020*: Good Environmental Status will be attained.

Good Environmental Status means the preservation of ecologically diverse and dynamic oceans and seas which are clean, healthy and productive, the use of marine environment at a sustainable level, protecting the potential for uses and activities by current and future generations. Under the MSFD, the indicators specifically chosen for marine litter will focus on the characteristics of litter and its impact on the marine environment, including the trends in amount washed ashore, its composition, spatial distribution and source; the trends in amount in water column and deposited on sea floor and finally, the trends in amount, distribution and, where possible, composition of micro-plastics**.** As an indicator of the impacts of litter on marine environment, trends in amount (number or mass) and composition of litter ingested by marine animals will be monitored.

5.5.2 Directorate General for Research Technology & Development (DG-RTD) – marine research needs in the EU

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.

Hypothesis-driven science is needed to support policy to help understand the impact of human activities on the marine environment. In this way it is an essential element in developing ''Good Environmental Status" in the context of the MSFD. Science is also required to understand the impact of change on the marine environment as well as climate/ocean interactions to better predict climate change and its impacts. A significant number of projects financed by EU Framework Programmes provided the development of tools to support Integrated Coastal Zone Management (ICZM) and Maritime Spatial Planning (MSP). Europe therefore needs to reflect on a way forward to maintain the momentum and world renowned European research leadership in the area of marine observatories which have the potential to provide a great leap forward in terms of our understanding of the marine environment. ESONET/EMSO projects, working on seabed observatories, and the EuroSITES project working on free standing moorings, could lead to the establishment of an ocean observing capability in Europe similar to that being developed in US.

Special attention is being paid by the European Commission since 2009 through the "ocean of tomorrow" joint calls for research projects. The current "ocean of tomorrow 2011 call" embraces all aspects presented during this session whether on maritime transport, spatial planning, energy, fisheries, aquaculture or marine biotechnologies and puts, this year, a specific emphasis on innovation.

Table 6. Sources of pressure in the marine environment and policy drivers

Sources of pressure	Political drivers
Direct human activities Over- and destructive fishing Agriculture (nutrients, pesticides) Industrial pollution, contaminants Maritime transport, oil spills, litter	1. MSFD, 11 pressures (a big part related to biodiversity) 2. CBD, 2010 year of biodiversity 3. Common Fisheries Policy (CFP)
Climate Change Ocean acidification Sea level rise, coastal erosion Extreme events	1. Prediction/mitigation of climate change impact - IPCC 2. CO_2 emissions, renewable energy objectives (20/20/2020)

In support of innovation, science has a different role, e.g. to mitigate the impact of "traditional" activities on the marine environment through the application of green technologies, better MSP, etc. Science is also instrumental in developing the potential of new sea-based activities for the marine bio-economy, including renewable energy but also in optimizing measures to counteract climate change impacts (sea level rise, coastal erosion, extreme events).

The Commission recognises that the member states still have a way to go to achieve this ideal world and that we need more marine research infrastructure to observe and understand the impact of human activities and climate change on the marine environment. There is a growing recognition that such issues are inter-disciplinary and our research programmes are generally thematic, and that there is therefore a need for integration of knowledge. The seas are shared and major research infrastructure and programmes require funding beyond the capacity of single member states, demanding an improved synergy within an inter-disciplinary, multi-sector scientific and industrial community, which in turn calls for new governance mechanisms. This is, broadly speaking, the structure and aims of the EU marine/maritime research strategy in which an overarching international dimension is clearly recognised.

5.6 USA, National initiatives

A programme has been launched to support national and international efforts in understanding and reducing marine debris. This led to the first "International Research Workshop on The Occurrence, Effects, and Fate of Micro-plastic Marine Debris", organised by NOAA (Arthur et al., 2009) – a second workshop at SETAC USA in Tacoma, WA is planned for Nov. 2010 – aimed at developing a framework for assessing the risk of microplastic.

NOAA-MDP recognises the need for well standardised, long-term and consistent methods, through the development of protocols, particularly for shoreline and surface water monitoring transects, and the dissemination of the methods among the research community. NOAA also supports the improvement in techniques of micro-plastic sorting and analytical identification e.g. the in-vitro desorption of chemicals from plastics in simulated gut contents, as well as investigations into the changes in chemical properties of polymers based on degradation and weathering.

5.7 Coastal municipalities and local authorities

Coastal municipalities rely heavily on the marine environment and are therefore directly confronted with issues of pollution including marine litter which affect tourism and recreation (including ecotourism as beaches attract ca. 60% of visitors to the coast), marine industries such as fishing and aquaculture as well as shipping. KIMO represents 150 municipalities (including coastal) in 15 NW European Countries (KIMO: Kommunenes Internasjonale Miloorgasasjon; http://www.kimointernational.org). Coastal municipalities can be subjected to global pollution over which they often have little control and the socio-economic impacts of marine litter are a large concern, e.g. the costs of beach cleanups, loss of tourism, fouled propellers, and other impacts. KIMO sees education, regulation and enforcement and 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. To influence policy, KIMO has fully participated in OSPAR Committees, UNEP's 2009 marine litter assessment and the EU-Marine Strategy Framework Directive implementation.

5.8 Chemical industry policies regarding marine litter

5.8.1 Europe

Plastics*Europe* supports the UNEP (2009) 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. Plastics*Europe* and the European Plastics Converters (EUPC) are therefore focussed on finding solutions to dramatically reduce the volumes of waste that are being deliberately dumped in the oceans or are accidently ending up in the oceans. A growing concern is how to address the legacy of waste already present in the oceans? Consistent and reliable figures about the quantity of debris, especially plastics entering the oceans, are lacking as is information on their origin. As a result there is a need for further investigation. Plastics are, however, only part of the litter issue and the toxicological aspects are important in deciding which plastic to use. The plasrtics industry needs to collaborate with authorities and the scientific community in helping to finding and funding solutions to stop marine littering.

Some 10 years of effort and over 50 million Euros of industry investment have been mobilized to reduce plastic waste and to encourage recycling. In particular, within *Vinyl 2010* the whole PVC chain industry committed in 2000 to recycle 200.000 t PVC waste/yr by 2010 and this objective will be reached. The Workshop heard that feedstock recycling is generally not regarded as economically viable and PET feedstock recycling is the most favourable example, while plastics to diesel recycling is only achieved on an experimental scale.

EUPC and Plastics*Europe* fund nine work programmes: law enforcement and lobbying, port-side waste logistics, 'Operation Clean Sweep', knowledge improvement, education and awareness raising, global knowledge transfer, ocean cleanup concepts, communication and the impact of waste mangement strategies. Plastics*Europe* 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.

5.8.2 United States

A campaign by the American Chemical Council's (ACC) Plastic Division "Plastics – Too Valuable to Waste - Recycle.℠" makes it clear the plastics industry agrees that "plastics do not belong in the oceans; they belong in recycling bins after use." Littered materials can end up in rivers, oceans and on beaches from land-based sources in the form of packaging, other containers and resin pellets, and from marine-based sources such as trash/garbage and derelict fishing gear from boating, maritime transport and fishing activities. International Coastal Cleanup results show that all types of materials are present in the composition of the debris that is tabulated each year. The ACC's activities to reduce marine debris have included a **Marine Debris Solutions Workshop** held at La Jolla, California in 2007 that convened a broad spectrum of federal and state agencies, business and industry groups as well as NGOs, where participants recommended efforts to reduce plastic waste (thereby helping to reduce the marine component), reuse where possible and increase recycling. The ACC's Plastics Division also has sponsored demonstration projects that have established 700 recycling bins for plastics and other materials along the California coast, primarily at beaches and rest stops. The plastics industry also promotes prevention of litter and recycling as a member of the national non-profit Keep America Beautiful (KAB) major upcoming antilitter campaign.

The US plastics industry is also working to spread product stewardship practices through 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 for all aspects of handling, use and transport. Although developed as a voluntary program in the US, OCS has served as the basis for legislation in California, and adoption is spreading through the industry in other countries. The ACC and its members also support local and national clean-up campaigns and marine debris research through NOAA and other organizations.

5.9 Non-governmental Organizations

5.9.1 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. The ICC takes place every year in September and has grown significantly in the intervening years. In 2009, 498,818 volunteers from 108 countries and locations collected 3,357 tonnes of debris from over 6000 sites (Conservancy, 2010) (http://www.oceanconservancy.org). Many Regional Seas Programmes have collaborated with the ICC to raise awareness of the marine debris issue in their regions.

5.9.2 WWF

WWF has characterised the micro-plastic issue as: "*A global process of unlimited pollution of the oceans by plastic wastes which fragment and degrade to become microscopic plastic particles that become more widely distributed and dispersed in the sea, while being eaten and integrated into food chains*". 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. WWF recognises the importance of improved legislation in the form of the marine strategy Framework directive in the EU, a revised Annex V of Marpol 73/78 covering garbage from ships at sea and the implementation of REACH in the EU and similar chemical safety legislation elsewhere.

5.10 Round-table discussion

Key stakeholders need to be involved in policy strategies, as there is often a large gap between international efforts (in waste management and marine litter prevention) and local government levels – this latter stakeholder is the most important 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. On the other hand, 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 the representative of UNEP's Caribbean Environment Programme challenged the workshop participants to recommend a consistent and clear micro-plastic parameter to introduce into regional monitoring programmes. In the ensuing discussion, the workshop suggested that NOAA's current methodologies for sampling the water column and sediments be adopted for monitoring micro-plastics, taking account of other published work (Thompson et al., 2004, Browne et al., 2010). The IOC-UNEP Guidelines were published before the NOAA methods were developed. It was also pointed out that micro-plastic monitoring in the water column could be introduced into routine programmes of sampling of plankton and that there were often 20-30 years of archived records (samples) in many laboratories, especially (SAFOS, UK).

6 Panel discussion on the need for global assessment (session K)

6.1 Questions to the Panel

The Workshop concluded with a Panel Discussion (see Annex 2 for membership) on the need for a global assessment, and was asked to respond to 6 specific questions:

i) Is a global assessment of micro-plastics necessary?
ii) What are the overriding reasons in support of any of these options to the UN stakeholders?
iii) Is there sufficient information to do this now, bearing in mind that it could take up to three years to complete?
iv) What needs to be done to fill the remaining gaps sufficiently (research & technology agenda, policy development needs, capacity building, etc)?
v) How do we link such activities to the UN-GA Regular Process and the Trans-boundary Waters Assessment Programme (TWAP)?
vi) What sources of funding are available?

6.2 Conclusions of the Panel Discussion

6.2.1 Is a global assessment of micro-plastics necessary?

The workshop considered that a global assessment of micro-plastics could be beneficial at this time and recognised that there was both sufficient public concern and a need to provide further objective information on the topic to enable policy makers to act.

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. Furthermore, an assessment of the scientific status of micro-plastics alone would not be helpful. Instead, the workshop advised that a global assessment of micro-plastics should be firmly embedded in the wider scientific context of marine debris, making clear the key processes involved.

6.2.2 What are the overriding reasons in support of any of these options to the UN stakeholders?

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. Once there, they cannot be recovered or removed in a cost-effective manner, or on a sufficiently large-scale to bring about a significant reduction.

There is a tendency to see the fragmentation of plastics as 'natural' degradation – out of sight, out of mind - this is far from the truth as the plastics do not degrade on any meaningful timescale; they merely fragment and accumulate in sinks. Of even more concern is that they may behave differently as they become smaller (Browne et al., 2008), potentially impacting different organisms and environmental compartments. In order to be able to act in an appropriate and timely manner, it is essential for policy makers to be fully informed and an assessment could be used to assist on this issue, as well as to focus future research more efficiently.

It is still not clear from the Workshop discussions if micro-plastic indeed act as significant vector for transporting PBT's, such as PCBs and PBDEs; the potential for transfer of toxic chemicals into organisms was seen as one of the key missing factors that needed to be addressed. There is, however, a concern that they might transport chemicals which would not otherwise reach the oceans by other routes such as by atmospheric transport; this needs urgent attention. Any assessment should take account of the extensive literature regarding relations between the concentration of the contaminant and it's toxicological effect. In addition there is the, largely un-quantified, potential of physical harm from micro-plastic particles of different sizes entering the body, organs and cells of a wide variety of organisms (But see Browne et al., 2008).

Representatives for the European Commission pointed out that marine debris (including micro-plastics) had been named as an indicator in the implementation phase of the EU Marine Strategy Framework Directive – marine debris is therefore very relevant for the member States and scientific support will be needed to develop the required Global Environmental Standards, so it is more a question of how soon such an assessment could be completed.

It was felt by the workshop that while there were some direct inputs of micro-plastics (pre-production pellets, facial scrubbers etc) overall, the generation of micro-plastics should be considered as a subsidiary part of the marine plastic litter problem; gaps in our understanding would be inevitable in such an assessment. The scale of the assessment and level of integration are important issues to consider. This assessment would therefore have to be more broad-based than the title of the current workshop implies. The broad consensus of the Workshop was of the need to reduce the sources of pollution, for which an improved knowledge of the sources was critical.

Marine plastic litter has an impact on socio-economics and health of humans, and public awareness has reached a level that demands action. Policy-makers will need to take an integrated view of the whole process and develop a range of options for policy, including packaging and treatment of/integrated wastemanagement from collection to final disposal. It was pointed out that society has been able to address two global issues successfully: the depletion of the ozone layer and acid rain. All of society and the industry is involved to some extent. More effective use and recycling of plastics and other materials could be seen as the next frontier.

6.2.3 Is there sufficient information to do this now, bearing in mind that it could take up to three years to complete?

A global thematic assessment usually sources its information from regional assessments and from other review documents summarizing the state of the art. Where specific review or regional data are missing, the assessment has to either accept that aspect as an unknown or can choose to carry out a survey of the scientific literature, to summarise the state of affairs, and insert this information in the overall assessment. Where an emerging issue such as micro-plastics is concerned, it is likely that a global assessment would have to summarize much of its input data directly from the scientific literature.

6.2.4 What needs to be done to fill the remaining gaps sufficiently (research and technology agenda, policy development needs, capacity building, etc)?

The EU representatives emphasised the need to identify and develop global environmental standards as well as to select a small number of broadly applicable indicators, with which to benchmark these standards. The workshop, in discussing such indicators, considered that the most obvious and easily measured would probably work best, e.g. the work on seabirds but also the trends in quantities of micro-plastics on beaches and in the water column Impacted areas should be compared with reference areas.

It is recognised that PBTs, by definition, have long lifetimes in the environment that should be taken into account in any assessment. The consensus was that there is insufficient evidence of chemical hazard to quantify the risk from PBTs associated with micro-plastics; for example, the bioavailability of contaminants from ingested plastics.

The quantities of plastics entering the oceans are still largely unknown. Certain locations are known to be 'hot-spots' of microplastics accumulation but information is incomplete. Such knowledge is critical in order to get to grips with the marine plastic litter and micro-plastics problem. Modelling of surface currents might help to order to predict the occurrence of microplastic hotspots throughout the world.

From the point of view of policy, it is considered that whatever interventions are recommended to reduce the problems of marine (plastic) debris, their effectiveness should be measurable using established methods (Underwood 1997). Others felt that the only sure solution was to prevent plastics from entering our waterways and reaching the sea.

6.2.5 How do we link such activities to the UN-GA Regular Process and the Transboundary Waters Assessment Programme (TWAP)?

Marine plastic debris and micro-plastics are both parts of the same trans-boundary issue. The first step in linking up to global assessment programmes was considered by the workshop to be the provision of a robust assessment of micro-plastics in the broader context of marine litter, recognizing that there is an urgent need for the recommendation of global indicators. GESAMP is in a position to provide such an assessment at the request of its UN sponsors, in particular UNESCO-IOC and UNEP.

The workshop also recommended that standardisation of methods will assist the assessment process greatly, e.g. by adopting NOAA's already developed sampling methods and strategies, which are partially based on the UNEP/IOC Guidelines (Cheshire et al., 2009) and other established international protocols.

6.2.6 What sources of funding are available – multi-stakeholder effort?

Given the convergent policy needs of the UN system and the European Union in developing global indicators of marine debris, including plastics and micro-plastics, the workshop participants were optimistic that funding for a global assessment could be found through a multi-stakeholder approach, including the plastics industry. It was suggested that links could be developed with the World Tourism Organization. The message from the workshop was clear that the interest of the stakeholders would be greater if micro-plastics was considered in the broader context of the marine litter problem and, in that respect, the relatively narrow focus of the current workshop on micro-plastics as a transport mechanism for PBTs would need to be expanded to look at the issues in an integrated manner.

7 General Conclusions of the GESAMP micro-plastics Workshop

i) We have very limited information on the quantities of micro-plastics entering the oceans or on the processes and time-scales leading to fragmentation and the production of micro-plastics by industry;

ii) There is limited information about the potential long-term hazards of micro-plastics either due to their physical or chemical properties (intrinsic and absorbed PBTs);

iii) There is a need for an assessment to follow on from UNEPs efforts and 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;

iv) Any assessment of micro-plastics must take full account of the overall marine debris and solid waste management problem arising from land and marine-based sources and activities.

v) Micro-plastics should be included in new and existing programmes of monitoring in marine habitats, especially National programmes and those of Regional Seas bodies.

8 Recommendations of the GESAMP micro-plastics Workshop

1. GESAMP should approach the sponsoring Agencies of GESAMP, and other relevant Bodies, with a request to consider sponsoring a GESAMP-led Working Group to conduct an assessment of micro-plastics in the coastal and open ocean.
2. The assessment should be complementary to, and embedded in, other assessments and initiatives tackling the problem of marine debris, including UNEP, UNEP Regional Seas, other Regional bodies, and national and Regional Administrations such as NOAA, and the EU. It should also feed in to the UNGA Regular Process and the GEF/UNEP/IOC Transboundary Waters Assessment Programme
3. Research priorities / Key research programmes
   a) Basic mapping of the pelagic and benthic environment to assess their global distribution, the form and relative abundance of different types of polymer;
   b) Sources of plastics need to be prioritized, e.g. coastal and land based sources, especially sewage treatment and riverine inputs as well as from shipping;
   c) The long-term implications of micro-plastics given the predicted increasing inputs, particularly with regard to the impact on marine organisms and accumulation along food chains; in the coming years;
   d) Modelling oceanographic parameters to define micro-plastic movement, including oceanic currents, weather, tides, wind, etc. to predict the way plastics move away from point sources and where they re-accumulate - this would also help to determine where to monitor;
   e) The degree to which micro-plastics accumulate in the sediment and the role of oceanic cycling in transferring micro-plastics from pelagic environment to sediments - some plastics have a greater density than water, and the pattern of deposition and the local and regional distribution for a range of particle densities is unknown;
   f) The significant factors in the breakdown of plastics, e.g. ageing, UV, physical fragmentation, bio-degradation - different plastics may be more durable and have different degradation behaviour depending on the environment (e.g. Fulmar stomach, coastal wave environment).
4. A global assessment should among other aspects focus on:
   a) developing methods for estimating the inputs of plastics to the oceans from land-based and maritime sources;
   b) clarifying rates of fragmentation and the production of (fragmented) microplastics;
   c) quantifying the amount of plastics and micro-plastics washed ashore, their composition, form, size and spatial distribution;
   d) determining the amount of plastics and micro-plastics in the water column and deposited on sea floor in the coastal zone and the oceans; and

e) further exploration of the potential for the transfer of PBT's from plastics to organisms and their biological effects.

5. As an indicator of the impacts of litter on marine environment, trends in the amount and composition of litter ingested by marine animals should be monitored.

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Annex I Workshop Programme

Day 1, Monday 28th June

Registration & Coffee 09:00 -10:00

Sessions A – C
Chair: Luis Valdés; rapporteur: Andreas Odhage
Session A Opening Session, 10:00 – 10:40

- Welcome from IOC – ***Luis Valdés***, IOC
- GESAMP introduction – mandate in the field of New & Emerging issues - what GESAMP wants to get from this – why the initiative – expected outcome/products. – ***Tim Bowmer,*** *Chairman of GESAMP*

Session B. Tour de Table, 10:40 - 11:00
An opportunity for the participants to introduce themselves (background & interests in the topic) and state their expectations and preferred outcomes from the Workshop

Session C. Keynote presentation, 11:00 - 12:00 (including discussion)

- Scene setting: nature and scale of the problem - ***Richard Thompson,*** *Univ. Plymouth*

Lunch Break 12:00 - 13:00

Session D. Reports of related initiatives, 13:00 – 14:15 (10 minutes talk + 5 minutes questions per presentation)
Chair: Tim Bowmer; rapporteur: Andreas Odhage

- UNEP Marine Litter programmes – ***Christopher Corbin***, *AMEP*
- NOAA initiatives – ***Lisa DiPinto***, *NOAA*
- SETAC Europe - ***Thomas Maes***, *Cefas*
- WWF expert meeting June 2010 – ***Karin Bilo***, *WWF*
- Royal Society Initiative – ***Richard Thompson***, *Univ. Plymouth*

Round-table discussion, 14:15 - 15:15
Summarizing the outcomes of those initiatives – what is well covered, what is not?

Coffee break 15:15 - 15:45

Session E. Types of common plastics and uses, 15:45 - 17:00
Chair: Tim Bowmer; rapporteur: Andreas Odhage

- Composition, production statistics and new trends, e.g. biodegradable plastics & recovery ***Wolfgang Siebourg,*** *Plastics Europe* **& *Keith Christman,*** *American Chemistry Council;*

Day 2, Tuesday 29th June

Session F Policy & Stakeholders forum, 09:00 - 10:30 (10+5mins per presentation)
Defining the policy & regulatory framework and responses (monitoring & mitigation) at scales from global to local.

Chair: François Galgani; rapporteur: Thomas Maes

F1 - Plastics industry

- American Chemistry Council - ***Keith Christman***
- Plastics Europe/EUPC - ***Jean-Paul deGreve***

F2 - Regional, local, tourism, municipality

- KIMO - ***John Mouat***
- AMEP - ***Christopher Corbin***
- PEMSEA & COBSEA - ***Thang Le Dai***

Coffee break 10:30 - 11:00

Session F (Cont.) Policy & Stakeholders forum, 11:00 – 11:45

F3 - Policy making/policy support

- EU Marine Strategy Framework Directive and related policies - ***Leo de Vrees,*** *DG-ENV*
- EU Marine Environmental Research policies and supporting projects - ***Pierre Mathy,*** *DG-RTD*
- US perspectives, ***Lisa DiPinto****, NOAA*

Round-table discussion, 11:45 - 12:30

Synthesis of policy and stakeholder concerns, proposals and programmes

Lunch 12:30 - 13:30

Session G. Socio-economic perspectives, 13:30 – 14:00

Chair: Peter Kershaw; rapporteur: Bill Francis

This session will provide an introduction to the concept of ecosystem services (supporting, regulating, provisioning and cultural) and the role of environmental economics in providing a means of estimating the value of such services, and the economic cost of their degradation.

- Marine and coastal ecosystem services and coastal zone management – ***Tiziana Luisetti****, UEA*

Round-table discussion, 14:00 - 14:30

Synthesis of socio-economic aspects of importance and potential role in developing risk assessment methods, management and regulatory controls

Session H. State of the art – micro-plastic as vectors for PBTs (Persistent, Bioaccumulating & Toxic compounds), *14:30 - 17:30 with Coffee Break at 15:00 - 15:30 (10+5 min presentations)*

Chair: Peter Kershaw; rapporteurs: Helen Keenan & Andreas Odhage

This session is intended to cover the main technical topics related to s. It provides an opportunity to hear a range of short presentations, providing examples and posing questions for more detailed discussion in three break-out groups.

H1 - Long-range transport vectors

- Are marine plastic particles transport vectors for organic pollutants to the Arctic? - ***Christiane Zarfl****, Univ. Osnabruck*
- Long -Range Transport of micro-plastic and sorbed PBTs across the Pacific Ocean - ***Rainer Lohman****, Univ. Rhode Island*
- Algalita: Monitoring for micro-plastic and POPs in the Pacific, N. Atlantic and Indian Oceans - ***Bill Francis****, Algalita*

H2 - Monitoring & assessment

- International Pellet Watch: Global monitoring of persistent organic pollutants (POPs) and understanding the potential chemical effects of marine plastics on marine ecosystem **-** ***Hideshige Takada****, Tokyo Univ.*

- Plastic pellets on beaches, transport of persistent organic pollutants, pollution monitoring in Greece – ***Hrissi Karapanagioti**, Univ. Patras*
- New research programme in Portugal - ***Paula Sobral**, IMAR*
- Solid waste management in Malasia - ***Mohd. Nizam Basiron**, Mar. Inst. Malasia*
- Marine litter management in Vietnam – ***Thang Le Dai**, MONRE*
- Tridimensionality in distribution at sandy beaches - sampling implications – ***Alexander Turra**, Univ. Sao Paulo*

H3 - Biological impacts

- Ecotoxicity and other effects - ***Angela Koehler***
- Plastic soup and seabirds - ***Jan van Franeker***
- A tiered approach for assessing chemicals sorbed to micro-plastics – ***Todd Gouin**, Unilever*

Brief instruction on aims of breakout sessions, 17:30 - 17:35

Gathering information on knowledge gaps, standards and quality, research priorities, key research programmes and review references

Session I. Breakout groups on technical topics, 17:35-18:30

I1 - Sampling & identification techniques – methodology – are there marker techniques that can be used to monitor particular plastics and more especially the transfer of contaminants?
Chair: Martin Thiel; rapporteur: Jae Oh

I2 -Distribution and fate (including deterioration and degradation routes)
Chair: John Mouat; rapporteur: Carly Brookes

I3 - Ecotoxicology and potential biological effects
Chair: Angela Koehler; rapporteur: Tim Bowmer

Workshop Dinner at UNESCO's Restaurant (19:30) Please note that this will be in the Place de Fontenoy building a short walk from Rue de Miollis.

Day 3, Wednesday 30th June

Session I. *continued* **Breakout groups on technical topics – reprise and report writing,** 09:00 -10:30

Coffee break 10:30-11:00

Reports of breakout groups to plenary, 11:00 – 12:00

- Group 1 Sampling and identification techniques – report & discussion - ***Jae Oh***
- Group 2 Distribution and fate – report & discussion – ***Carly Brooks***
- Group 3 Ecotoxicology and potential biological effects – report & discussion – ***Tim Bowmer***

Session J. UN global assessment processes, 12:00 – 12:30

- UN system: UNGA-Regular Process for the assessment of the marine environment & the Transboundary Waters Assessment Programme (TWAP) – relevance of marine litter & micro-plastic - ***Julian Barbiere & Albert Fischer**, IOC*

Lunch 12:30-13:30

Session K. Panel discussion: answering GESAMP's challenge – summary session, 13:30- 14:30
Panel Discussion Chair: Richard Thompson; rapporteur: Helen Keenan
Panel: Jacques de Gerlache, Waddah Saab/ Nicoleta-Ariana Nastaseanu, Francois Galgani, Lisa DiPinto, Bill Francis

a) Is there a need for a Global Assessment?
b) What are the overriding reasons in support of this to the stakeholders?
c) Is there sufficient information to do this now, bearing in mind that it could take up to three years to complete?
d) If not, what needs to be done to fill the gaps sufficiently (research & technology agenda, capacity building, etc) to carry out a global assessment?
e) How do we achieve a global assessment and link it to both the UN-GA Regular Process[3] and GEF-IOC-UNEP's Transboundary Waters Assessment Programme (TWAP), as well as other regional initiatives?
f) What sources of funding are available?

Session L. Outputs & Closing statements, 14:30-15:00

Outputs - ***Tim Bowmer***

- Report: The GESAMP Office will provide a report of the workshop in the electronic "Reports to GESAMP Series".
- Peer reviewed publication – participants may want to consider preparing a publication covering some or all of the Workshop proceedings

Closing statements - ***GESAMP Tim Bowmer, IOC Luis Valdés,***

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Annex III Glossary

Organizations

ACC	American Chemistry Council
AMEP	Assessment & Management of Environmental Pollution (Countries of the Wider Caribbean)
Cefas	Centre for Environment Fisheries and Aquaculture Science, UK
CEFIC	European Chemical Industry Council
COBSEA	Coordinating Body on the Seas of East Asia
EU, DG-RTD	European Commission, Research Directorate General
EU, DG-ENV	European Commission, Environnement Directorate General
EUPC	European Plastics Converters,
GEF	Global Environment Fund
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
IAEA-MEL	International Atomic energy Agency – Marine Environment Laboratory, Monaco
ICC	International Coastal Cleanup Programme
IMO	International Maritime Organization, London
IOC-UNESCO	Intergovernmental Oceanographic Commission of the United Nations Educational Scientific and Cultural Organization
JCIA	Japan Chemical Industry Association
KIMO	Kommunenes Internasjonale Miljoorganisasjon (Local Authorities International Environmental Organisation)
NOAA	US National Oceanic and Atmospheric Administration
SETAC	Society of Environmental Toxicology & Chemistry
Sida	Swedish International Development and Cooperation Agency
TNO	The Netherlands Organization for Applied Scientific Research; *Toegepast Natuurwetenschappelijk Onderzoek*
TWAP	Transboundary Waters Assessment Programme: th long-term goal of which is to promote real investment in management and development of transboundary water systems
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund

Technical Terms

ABS	Acrylonitrile butadiene styrene - synthetic rubbers
Ecoflex	Co-polyester based on 1,4-butanediol, adipic acid and terephthalic acid
EPS	Epoxidized polysulphides
HDPE	High-density polyethylene
LDPE	Low-density polyethylene
LME	Large Marine Ecosystem
LRAT	Long Range Atmospheric Transport

PBDE	Polybrominated diphenylethers
PBT	Persistent Bioaccumulating and Toxic substances, as defined by degradation half-life, bioconcentration factor and eco-toxicity; some regions and national administrations, e.g. the EU also include human health criteria in the PBT classification, specifically, carcinogenicity, mutagenicity and reprotoxicity. A contributing factor to PBT classification is also the potential for long-range atmospheric transport.
PCBs	Poilychlorinated biphenyls
PE	Polyethylene
PET	Polyethylene terepthlate
PHA	Polyhydroxy alkanoate
PLA	Polylactic acid
POM	Polyoxymethylene
POP’s	Persistent Organic Pollutants as defined by the Stockholm Convention, i.e. those substances listed on Annexes A, B and C – mainly PBT’s with a strong tendency towards long-range atmospheric transport
PP	Polypropylene
PS	Polystyrene
PUR	polyurethane
PVA	polyvinyl alcohol
PVC	Polyvinyl chloride
WWTP	Waste water treatment plant