Overview of The Guidelines For The Monitoring and Assessment of Plastic Litter in The Ocean

Introduction/ background

The effort to promote a more harmonised approach to the design of sampling programmes for the monitoring and assessment of marine litter, including the selection of appropriate indicators (i.e. type of sample and litter item), the collection of samples or observations, the characterisation of sampled material, dealing with uncertainties, data analysis and reporting the results, is the direct result of UN Environment, supported by IOC-UNESCO being tasked with supporting countries to implement methodologies and procedures to report against target 14.1 '*By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution*' under Sustainable Development Goal 14.

There has been a growing concern about the quantity of plastic and microplastic debris in the ocean over the years. In June 2014, the United Nations Environment Assembly (UNEA) adopted resolution 1/6 on marine plastic debris and microplastics. As part of implementing the resolution a report was prepared to support the specific request in Paragraph 14 to the Executive Director:'*… building on existing work and taking into account the most up-to-date studies and data, focusing on:*

a) *Identification of the key sources of marine plastic debris and microplastics;*
b) *Identification of possible measures and best available techniques and environmental practices to prevent the accumulation and minimize the level of microplastics in the marine environment;*
c) *Recommendations for the most urgent actions;*
d) *Specification of areas especially in need of more research, including key impacts on environment and on human health;*
e) *Any other relevant priority areas identified in the assessment of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection;'*

The report summarised the state of our knowledge on sources, fate and effects of marine plastics and microplastics, and describe approaches and potential solutions to address this multifaceted conundrum[1].

1 Marine Plastic Debris and Microplastics- Global Lessons and Research to inspire action and guide policy change (UNEP 2016): http://wedocs.unep.org/handle/20.500.11822/7720?show=full

[2]One of the summary conclusions in the report was that there is a need to strengthen and harmonise monitoring and assessment efforts, to meet global commitments under the UN Sustainable Development Goals targets, and to target and gauge the effectiveness of marine litter reduction measures.

As a result new terms of reference and a work plan were prepared for a third phase of work on the Sources, Fate and Effects of Plastics and Microplastics in the Marine Environment by the working group 40 of the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). The results of this study will be available in the first quarter of 2019 as a GESAMP technical report "Guidelines for the monitoring and assessment of plastic litter in the ocean".

The report covers all size ranges of plastic litter encountered in different compartments of the marine environment, i.e. stranded on shorelines, floating on the sea surface, suspended in the water column, deposited on the seafloor or associated with biota (ingested/encrusted/entangled). The guidelines may also be used for the monitoring of items originating from specific sources, e.g. Abandoned or Lost Derelict Fishing Gear (ALDFG), or specific items to evaluate the efficiency of dedicated reduction measure.

The guidelines include recommendations, directed primarily to assist national authorities and regional bodies in setting up programmes to establish the status and trends of marine contamination by plastic litter, including (indicator selection, method harmonisation, and baselines establishment) in waters under their jurisdiction. The report is intended to complement established monitoring and assessment programmes, such as those developed in the framework of the Regional Seas, the European Union and by several individual countries. These existing initiatives, together with the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation (UNEP/IOC-UNESCO) guidelines published in 2009[3], provided a key input to the development of these updated guidelines. Deciding on what constitutes the target or preferred state of marine litter is beyond the scope of the report. This decision is part of the governance process, irrespective of the geographical or political level, informed by scientific evidence, taking account of other social, economic and political factors.

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2 United Nations Environment Programme (UNEP), Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change (United Nations Environment Programme, Nairobi, 2016).

3 http://wedocs.unep.org/xmlui/handle/20.500.11822/13604

The role of monitoring and assessment

Monitoring the marine environment for the presence of plastic litter is a necessary part of assessing the extent and possible impact of marine litter, devising possible mitigation methods to reduce inputs, and assessing the effectiveness of such measures. However, it is important to use consistent and reliable methods of sampling and sample characterisation (e.g. number, size, shape, mass and type of material) to gain greatest benefit.

There must be flexibility to design programmes that are appropriate for the policy questions being addressed and the environmental, social and economic constraints that apply in each situation.

The design of the sampling programme needs to consider policy concerns, questions and management objectives (e.g. compliance, efficacy of reduction measures), the environmental setting and the most appropriate indicators to be targeted.

Some examples of relevant questions that can be asked by policy makers are:

- ❏ *Where, what and how much litter is there?*
- ❏ *Is there a trend in space or time?*
- ❏ *What are the potential sources?*
- ❏ *Can mitigation measures be identified?*
- ❏ *Are mitigation measures effective?*

Examples of policy concerns

- ❏ *Biodiversity and animal welfare*
- ❏ *Human health issues and injuries*
- ❏ *Seafood safety*
- ❏ *Food security- ghost fishing*
- ❏ *Tourism and recreation*
- ❏ *Maritime safety (Navigation)*

Indicators are selected to describe the 'state' of the environment, such as the quantity of litter per unit of measurement (i.e. area, length, number of organisms). It is usual to compare the measured 'state' against a baseline or reference state. But, as plastic litter is ubiquitous in the ocean it is unlikely to be possible to assume a baseline of zero. There needs to be a degree of consistency in the techniques used and in the frequency and location of sampling, to allow reliable estimates to be made of changes in space and time. The magnitude of the change to be detected, coupled with the inherent variability in the measured parameter, determines the sampling effort required to reliably detect spatial and temporal trends.

The scope of the guidelines

The report is intended to provide a step-by-step approach to designing and implementing a programme for monitoring marine plastic litter, assuming no prior knowledge (Figure 1). Using definitions and terminology that are widely accepted and understood by the user group is key to creating a harmonised approach and increasing the potential for sharing data and information.

Chapter 1 presents the background of the report while Chapter 2 provides definitions of common terminology used in existing marine litter monitoring.

Chapter 2 focuses on definitions and terminology. The use of common definitions aids the process of harmonising the methods used to measure contamination of the ocean and the interpretation of data. In this way, any organisation with an interest in monitoring the state of the ocean can use similar methods, descriptors and data handling, encouraging the pooling of resources and integration of datasets.

Chapter 3 gives a description of some basic principles of monitoring and assessment that are applicable in most cases. This is designed to maximise the utility of the data gathered, recognising that in many cases resource constraints will limit the scale of any monitoring programme.

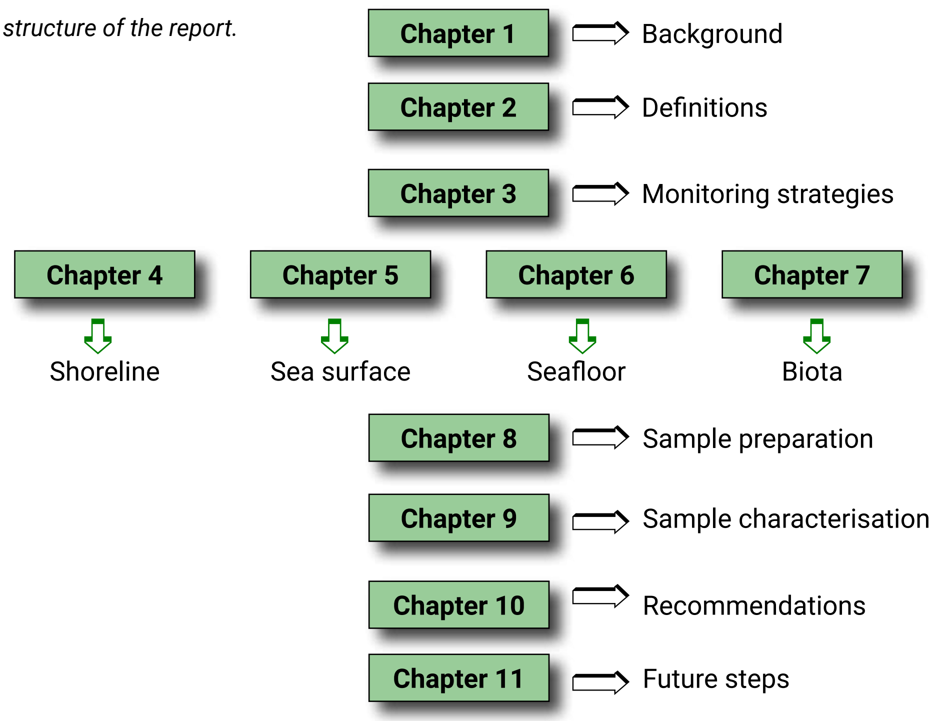
Chapters 4 – 7 describe the environmental settings, selection of monitoring strategies and special considerations for each of the environmental compartments: shoreline, sea-surface and water column, seafloor and biota.

Chapter 8 and 9 deals with sample processing and the methods of physical, chemical and biological characterisation of plastic litter respectively. Some degree of sample preparation in the laboratory is usually required, whichever sampling methods are used in the field.

Chapter 10 brings some recommendations for sampling strategies and methods for marine litter characterization considering costs (resource requirements for sampling and processing) and benefits (policy relevance) trade-offs.

Chapter 11 deals with future steps to improve monitoring and assessment of marine plastics in the ocean.

Figure 1. Logic structure of the report.



Links are provided throughout the report to sources of supplementary information, including existing monitoring programmes, as well as more detailed descriptions of methods and case studies.

The marine compartments and sizes of litter under investigation

Physical descriptors of marine litter are important and should include size, shape and colour. For larger items it is recommended to use additional descriptors of the type and category of item (e.g. bottle, fishing net, plastic bag), as this can aid identifying the source and devising appropriate reduction measures. Nano-sized particles (< 1µm) have not been considered in the guidelines. It is thought likely that plastic nano-particles are present in the ocean but we lack suitable methods for sampling them in the field.

Recommended common definitions of size classes of marine litter for use in monitoring programmes: Micro - < 5mm, Meso – 5-25mm, Macro – 25mm-1m, Mega - > 1m

Four compartments and different sizes of particles, from macroplastics to microplastics, were considered considered, with several strategies and sampling methods:

1. *Stranded litter on the shoreline (Chapter 4; Figure 2)*
2. *Litter at the surface of the sea (Chapter 5; Figure 3)*
3. *Litter on the sea floor (Chapter 6; Figure 4)*
4. *Marine debris interactions with biota (Chapter 7; Figure 5)*

Biota is a very important and informative compartment to assess and monitor marine litter. Where marine litter is present in the environment, there are four policy relevant aspects that can be assessed when utilizing biota as a monitoring tool:

1. *The impact on biota.*
2. *The impact on human health.*
3. *The impact on ecosystem.*
4. *The overall ecosystem contamination of marine litter.*

Figure 2. *Sampling buried macro-litter on a sandy beach, using a team of students to sieve the top 15 cm of sand from a 1-m wide transect running up the beach profile. (Photo: Peter Ryan).*

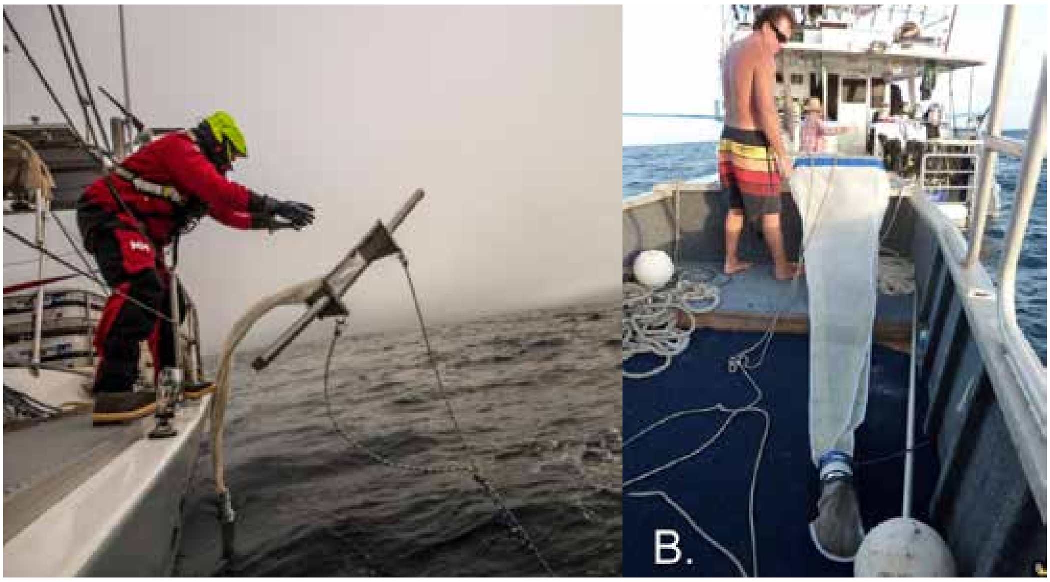


Figure 3*. The manta trawl has wings and can float unassisted* ***(A)****. The neuston net must be suspended at or below the water's surface* ***(B)****. (Photo: Marcus Eriksen)*

Figure 4*. Common approaches to monitor mega and macro litter at the bottom. Diving in shallow waters of US west coast* ***(A; >30m)****, trawling on soft bottoms of the NW Mediterranean sea* ***(B; 50m)*** *and Remote Operated Vehicle on rocky/mixed bottoms* ***(C; 1000m)*** *(Source: NOAA; IFREMER).*

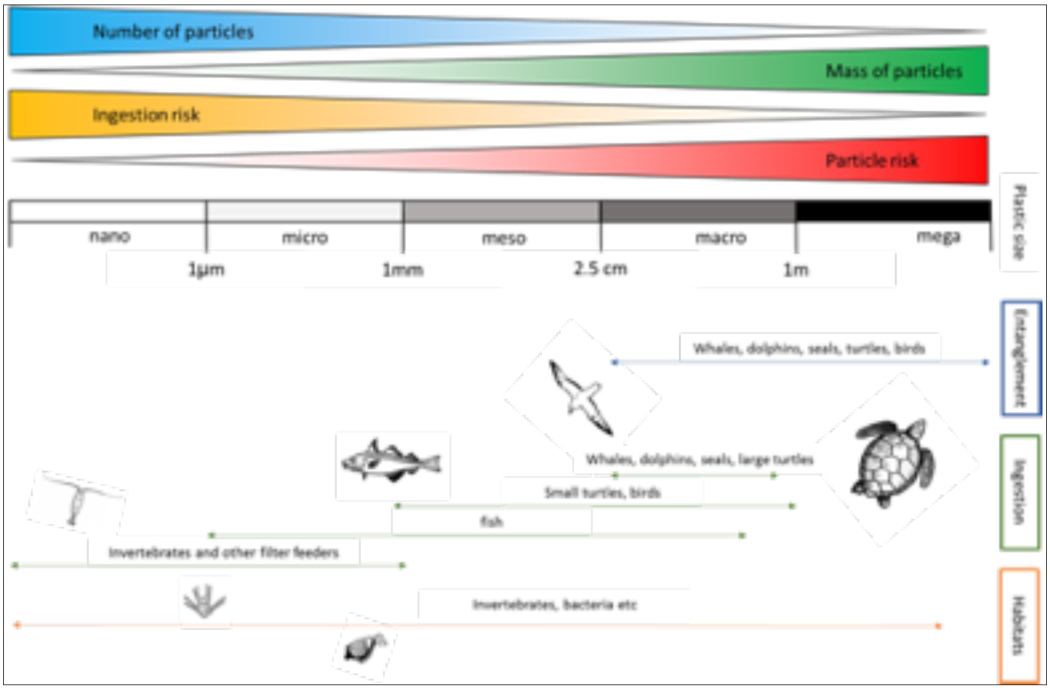


Figure 5*. Schematic representation of the impacts of different sized plastics on marine biota including entanglement, ingestion and habitat associated risk (Adapted from GESAMP 2015).*

Monitoring and Citizen Science

The involvement of citizen science volunteers has a long tradition in marine litter research (Hidalgo-Ruz and Thiel 2015, Zettler et al. 2017) and is argued as an additional strategy to support litter monitoring and assessment. Given their easy access and attraction for people, most citizen science studies have been conducted on sandy beaches, but may be implemented in all above compartments. Citizen scientists participate in a wide range of research activities, ranging from the reporting of incidental findings to collection of specific samples (e.g. pellet watch) and active participation in data evaluation and publishing the findings.

Many of the common sampling protocols for sandy beaches can benefit from the participation of motivated and well-trained citizen scientists. The use of apps can improve the output, as it provides a harmonised approach and a ready data framework. Furthermore the use of the collected data is facilitated when being submitted to a dedicated project or initiative.

Marine litter is a good opportunity to involve the citizenry, building capacity and adding to the pressure for decision makers (Figure 6). While the focus here is on the participation of citizen scientists in marine litter monitoring for the purpose of generation of scientific information, the involvement of the wider general public in research can generate additional outcomes, including increasing pressure on policy makers to take action.

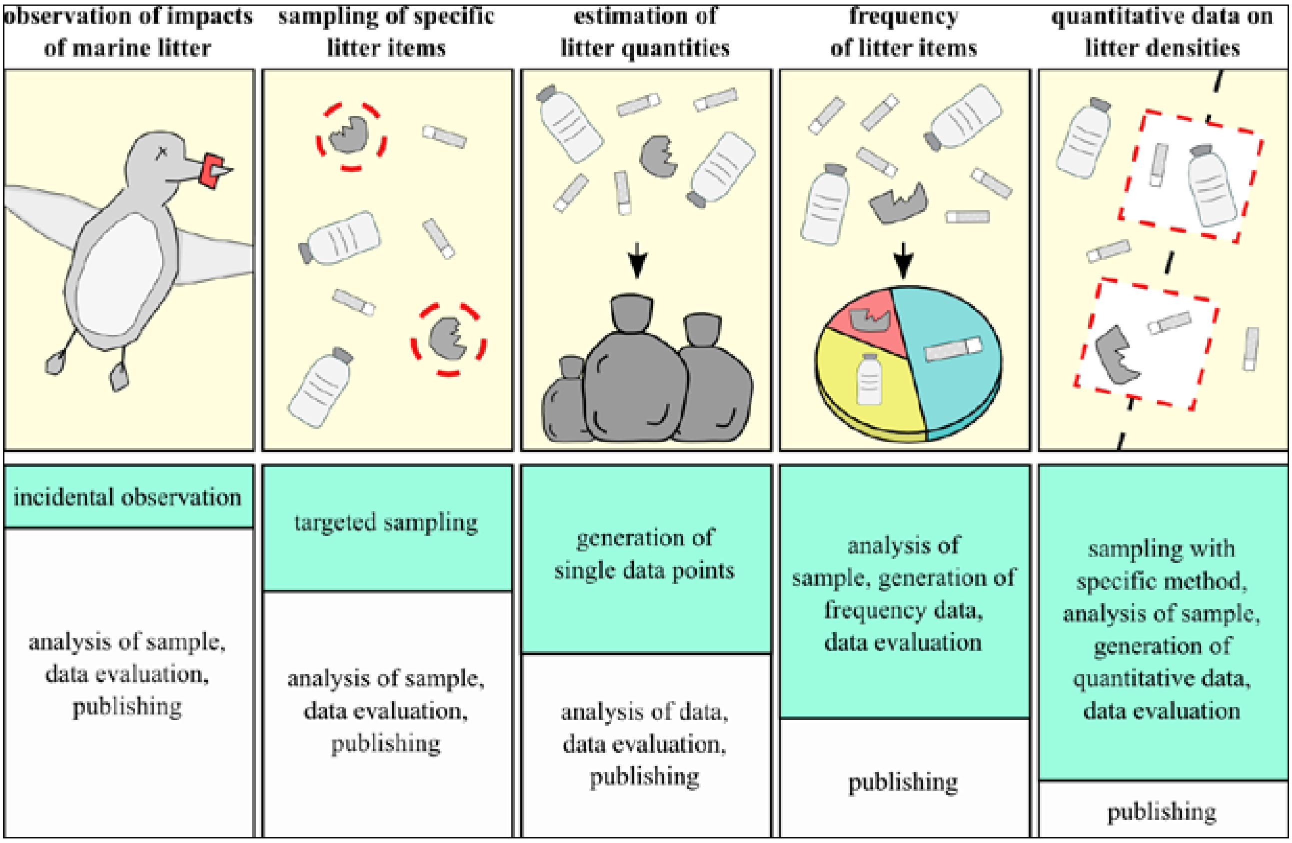


__Figure 6.__ Levels of participation of citizen scientists in marine litter research. Top panels illustrate methods and type of data gathered by citizen scientists. Bottom panels show the degree of involvement by citizen scientists (green area) in the scientific process (entire box). Figure authors: Tim Kiessling and Martin Thiel (Creative Commons BY-NC 4.0 licence).

Sample processing and characterisation

Plastics represent a mixture of particles differing in properties with varying physical, chemical, and biological characteristics (e.g., size, shape, polymer, and surface characteristics). This huge diversity of particle characteristics presents several challenges in terms of understanding the consequences of plastic presence in the environment, transport and fate, interaction with biota, implications to ecosystem service and humans, and the subsequent risk management.

Historically, once obtained, samples have been processed through physical methods, such as visual identification alone (macroplastics) and/or density separation followed by filtration/sieving combined with visual identification (micro- and meso- plastics). Each of these methods can be used in isolation or in concert, going from less to more complex (Figure 7). A selection of common procedures for sample processing to allow further characterisation is included in Chapter 8, where methods of physical, chemical and biological separation of plastic litter are discussed.

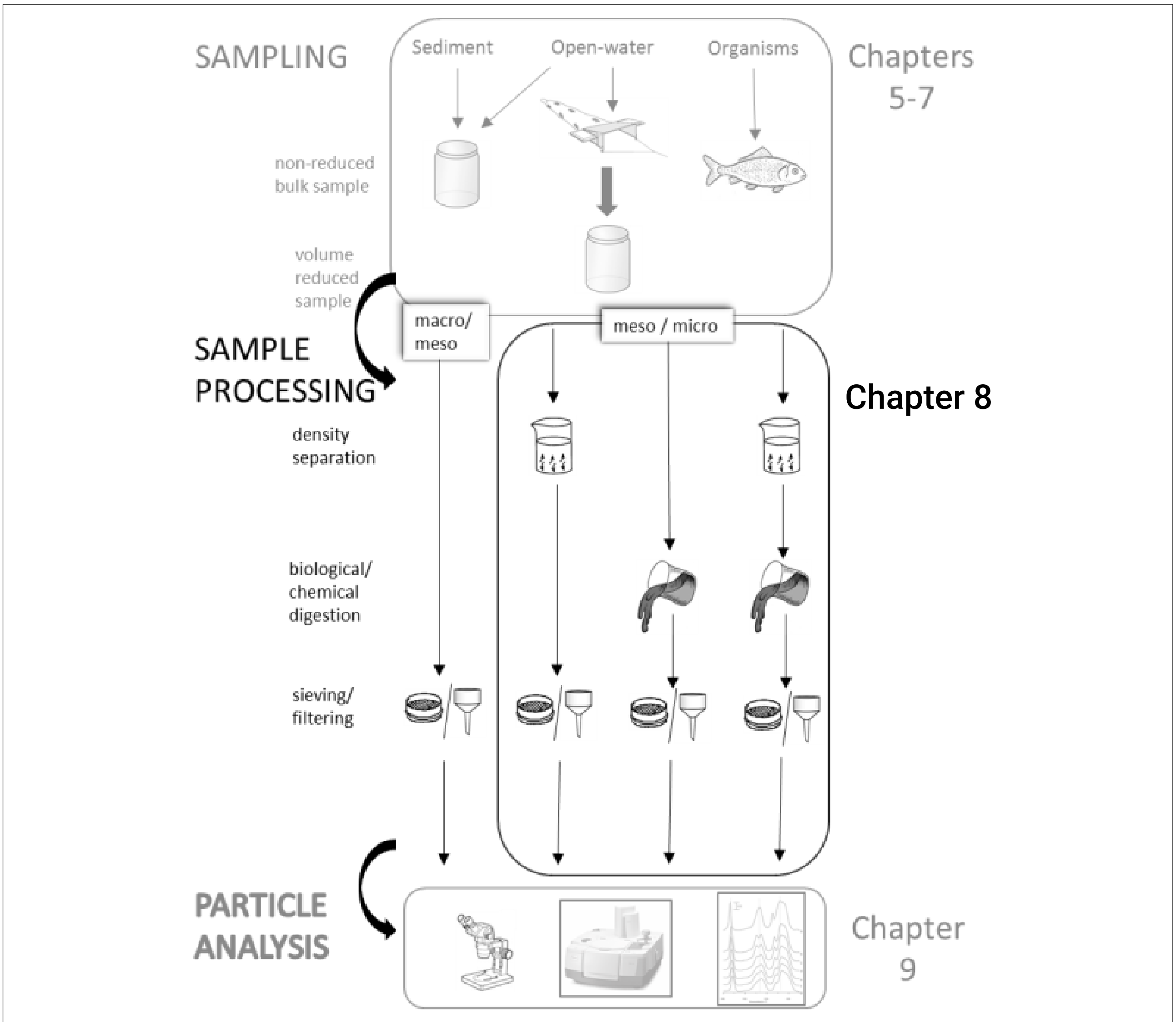


Figure 7*. Samples collected via methods discussed in chapters 4-7, can be processed via a number of methods (Chapter 8), before characterisation of particles (Chapter 9).*

Obtaining information to support management decisions requires a thorough and detailed understanding of plastic particle characteristics (Figure 8). This is presented in Chapter 9 and includes appropriate analytical methods to characterise physical (shape, size, colour and functional information), chemical (polymer composition, weathering status, and additive chemicals, and sorbed contaminants) and biological (associated biota etc.) properties of plastics.

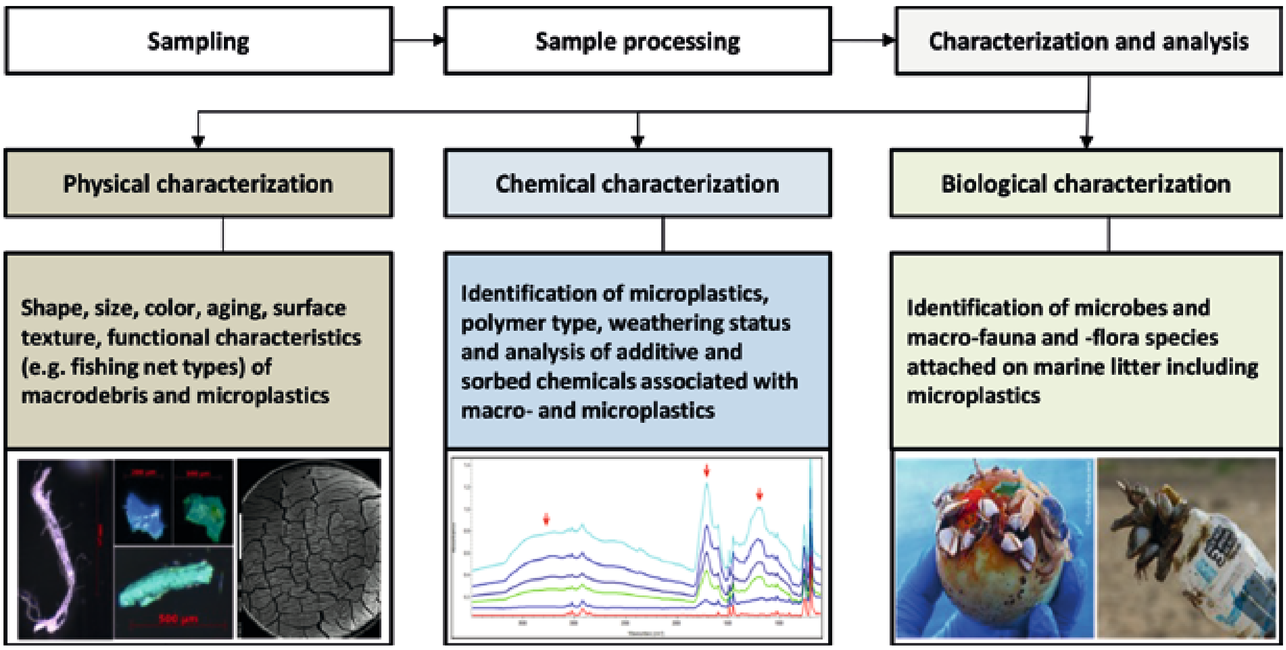


Figure 8. *Flow chart of different methods to characterise marine litter*

UN Environment, supported by Intergovernmental Oceanographic Commission of the United Nations Educational Scientific and Cultural Organisation, are tasked with supporting countries to implement methodologies and procedures to report against target 14.1 ***'By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution'*** under Sustainable Development Goal 14. There are currently numerous partners working on many facets of this topic and various levels and scales. It is recognised that there is considerable variability on how data is being collected, assimilated, packaged and made available for users. There is continuing need to facilitate the process to help designated entities in countries to understand what is available, and make determinations on how best to utilize assessment methods and information products to support reporting against the marine pollution target in this case on floating plastics. Under the SDG process the vision is for harmonization of the methodology at the global level, with the assistance of the UN family agencies and various partnerships and support mechanisms available. These guidelines will provide the necessary support to countries with the desire to report on SDG 14.1a and to support the process of developing methodology for data collection of the indictors under the target, potentially moving the indicator from tier three to tier two under the process of reporting.

Recommendations

The report concludes (Chapter 10) with a series of recommendations, including selection criteria dependent on marine compartment, particle size and both resource/capacity limitations and policy questions being addressed (Table 1).

	COMPARTMENTS & PLASTIC SIZE			RESOURCE SAMPLING AND PROCESSING REQUIREMENTS (COSTS INCREASE FROM LEFT TO RIGHT)							EXAMPLES OF POLICY CONCERNS									
													IMPACTS ON							
Feasibility	Compartment	Sub-compartment	Plastic size	People	Basic field equipment	Sieves	Nets	Dissecting microscope	Ship	Chapter	Distribution & Abundance	Source identification	Tourism	Seafood safety	Human health and injuries	Navigational hazards	Fisheries & aquaculture	Animal welfare	Biodiversity	Policy relevance index
1	SL	BE	MA	R	R					5	R	R	R		R				R	5
2	SL	BE	ME	R	R	R				5	R		R						R	3
3	SF		MA	R			R		R[a]	7	R	R				R	R		R	5
3	SF		MA	R[b]	Y					7	R	R	R			R	R	R	R	7
4	B	FISH	ME MI	R		R		R		8	R			R				R	R	4
4	B	INV	ME MI	R						8	R			R				R	R	4
5	B	SEAB[c]	ME MI	R		R		R		8	R	R						R	R	4
5	B	MEG[c]	MA ME MI	R				R		8	R							R	R	3
6	SS		ME MI	R		R	R	R	R[d]	6	R						R		R	3
7	SS		MA	R	R				R[e]	6	R					R	R	R	R	5

Table 1. Summary of the recommended sampling approaches for different compartments and plastic sizes, regarding their feasibility (1, more feasible; 7, less feasible; based on resource sampling and processing requirements) and common policy concerns addressed, with reference to the specific chapters in the report. The policy relevance index is the sum of the policy concerns addressed by the sampling approach.

Compartments:
SL – shoreline,
SF – seafloor,
B – biota,
SS – sea surface.

Sub-compartments:
BE – beach,
FISH – fish,
INV – invertebrate,
SEAB – seabird,
MEG – mega-fauna.

Plastic sizes:
MA – macro-plastic,
ME – meso-plastic,
MI – micro-plastic.

[a]*Opportunistic sampling using fishing vessel,*
[b]*Opportunistic observations using recreational divers,*
[c]*Stranded organisms,*
[d]*Research vessel,*
[e]*Ship of opportunity, visual observation*

Future steps to improve monitoring and assessment.

SDG 14.1.1 indicator development

A key intention of the guidelines is to support the further development of the marine litter monitoring framework under SDG 14.1.1. This includes the selection of sub-indicators related to the source (or attribution), the environmental state and the impacts of marine litter. Using more harmonised methods will encourage the development and implementation of regional or global monitoring programmes, and facilitate the exchange of monitoring results. In so doing it is expected that it will be possible to move SDG 14.1.1 from tier three to tier two.

Regional Seas Programmes and action plans have actively been involved in the development of harmonised methodologies for monitoring and have been involved in the review of the guidelines. In addition, the guidelines will be considered by the Open-ended ad hoc expert group on marine litter, under the UN Environment Assembly (UNEA) process.

Data management

The greater harmonisation of sampling protocols and reporting will help to reduce barriers to data sharing, and support the development of effective global data management, linked to existing regional and global platforms where possible. For example, at a regional scale the European Commission has developed the European Marine Observation and Data Network (EMODnet)[4], a system designed to collect, harmonise and share a wide range of marine environmental data in partnership with those Regional Seas covering the NE Atlantic (OSPAR), Baltic (HELCOM), Mediterranean (UN Environment MAP) and the Black Sea (Black Sea Commission). Recently, EMODnet has been extended to include data on marine litter, specifically from the shoreline, seafloor (trawl surveys) and sea surface (microplastics).

At a global scale, the Deep-sea Debris Database was launched in March 2017 to allow public access to seafloor images collected since 1983. The database is managed by the Global Oceanographic Data Center (GODAC) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC)[5]. It contains data from multiple sources from the North and South Pacific, Indian, North and South Atlantic Oceans. The deepest record was of a plastic bag found at 10898 m in the Mariana Trench.

A key priority will be to ensure the inter-operability of different databases, to ensure that disseminated data storage and management is not a barrier to data exchange and integrated regional and global monitoring.

Towards more effective monitoring programmes

The guidelines are based on sampling and analysis methods that generally are accepted, and that are commonly available at least in relatively well-resourced institutions. They are not intended for research purposes. They have been based on techniques developed for investigating natural features of the environment, such as the

4 www.emodnet.eu

5 Chiba et al. 2018. Human footprint in the abyss: 30 years of deep-sea plastic debris. Marine Policy, 96, 202-212. https://doi.org/10.1016/j.marpol.2018.03.022

abundance of zooplankton using towed nets (floating microplastics) or fish stock assessment using bottom trawls (seafloor macro-litter). Both techniques under-sample smaller size categories of litter. This means that estimates of litter abundance based on these methods will be subject to a consistent bias. There may be an advantage to improving how we capture a more representative sample of the actual size range of marine litter present in the environment. However, this will also present a challenge when comparing spatial or temporal trends of marine litter that were obtained using different sampling methods.

A common challenge is to account for the inherent heterogeneity of marine litter distributions, resulting in variations of abundance that may exceed a factor of 10 at any one 'site'. This needs to be addressed as part of the overall sampling strategy. In future, increasing automation of sampling and sample analysis may allow a greater throughput of material and reduce some of the uncertainty in the measurements. The UN Decade of the Ocean presents an opportunity to collaborate with the wider ocean science community, to develop a more effective, more reliable and more cost-effective global monitoring framework to address this pressing issue.

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