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Agenda Item 4:Development of Guidelines for Monitoring Riverine inputs of Marine Litter

Draft Guidelines for Monitoring Riverine inputs of Marine Litter

UNEP/MAP
Athens, 2022

Note by the Secretariat

The 19th Meeting of the Contracting Parties to the Barcelona Convention adopted in 2016 the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP) (Decision IG. 22/7). Furthermore, the Roadmap and Needs Assessment for the 2023 Mediterranean Quality Status Report was adopted in 2019, during COP21 (Decision IG.24/4), and its implementation was detailed by the 8th Meeting of the Ecosystem Approach Coordination Group (9 September 2021; UNEP/MED WG.514/3).

The 10th Ecological Objective (EO10) of IMAP focuses on Marine Litter including two common and one candidate indicator. Common Indicator 22 focuses on beach marine litter; Common Indicator 23 addresses seafloor and floating marine litter, including microplastics; while Candidate Indicator 24 focuses on the effect of marine litter on marine biota having a particular focus on its effect (i.e., ingestion and entanglement) on marine turtles.

Rivers constitute the major pathways connecting land-based sources with the marine and coastal environments, the impacts of which are particularly evident for major rivers, as well as for small rivers, seasonal torrents and water streams, which is the case for the Mediterranean. In view of the fact that riverine inputs of marine litter were not properly addressed through IMAP, as well as in the framework of the Updated Regional Plan on Marine Litter Management in the Mediterranean, the latter was recently updated in December 2021, to also address relevant provisions.

The Secretariat is also implementing the EU-funded Marine Litter MED II project which aims in part to further progress the work pertinent to monitoring riverine inputs of marine litter in the Mediterranean, with the view to introduce this aspect in the framework of new or updated IMAP indicator. In this regard, several pilots are undergoing in two countries (Israel and Morocco) targeting the acquisition of datasets for their use during the preparation of the 2023 MED QSR.

Considering the needs to fill the methodological gaps on all different aspects of marine litter monitoring, UNEP/MAP aims to introduce through the present document a first approach for elaborating guidelines for monitoring riverine inputs of marine litter. This document is based on the 2020 UNEP Report on "Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies" and is also taking into consideration existing initiatives (e.g., EU JRC RIMMEL Project), including the early experience from the implementation of the aforementioned pilots. This document also addresses different methods for monitoring riverine inputs of marine litter, including: (i) visual observation; (ii) deployment of nets; (iii) use of existing smartphone applications; and (iv) advanced tacking methods.

While the use of the first two methods (i.e., visual observation and deployment of nets) seem to better suit the Mediterranean needs and characteristics, the present document is submitted to the CORMON Marine Litter Meeting for review for further guidance and elaboration, with the ultimate aim of approval for submission to the subsequent CORMON Marine Litter and MED POL Focal Points Meetings foreseen later in 2022 and mid-2023, respectively.

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List of Abbreviations / Acronyms

EU	European Union
IMAP	Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria
JRC	Joint Research Centrum
MSFD	Marine Strategy Framework Directive
PVC	Polyvinyl Chloride
QSR	Quality Status Report
TGML	Technical Group for Marine Litter
UAV	Unmanned Aerial Vehicle
UNEP	United Nations Environment Programme
UNEP/MAP	United Nations Environment Programme / Mediterranean Action Plan

1. Introduction

1. The present draft guidelines are developed in the framework of the EU-funded Marine Litter MED II Project. The Marine Litter MED II Project addresses challenges and solutions with regards to the operational aspects and monitoring processes of implementation of the 2021 Regional Plan on Marine Litter Management in the Mediterranean. The project envisages to expand marine litter monitoring and assessment efforts also to riverine inputs, focusing on filling the knowledge and data gaps through the development of a guideline for monitoring and assessing riverine inputs of marine litter, further, to taking stock of existing efforts and initiatives (e.g., UNEP[1], JRC/RIMMEL[2] and EU MSFD TGML) and aiming to adjust them to the Mediterranean needs.

2. The Draft Guidelines for Monitoring Riverine Inputs for Marine Litter aim to supplement, support and enrich the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP). The data acquired from the present guidelines will prepare the ground for expanding the marine litter Common Indicators under IMAP auspices, also to include new indicators such as riverine inputs, and contribute to the development of the 2023 Mediterranean Quality Status Report (MED QSR).

3. The guidelines describe sampling methodologies for both macro- and micro-litter, and in particular plastics, originating from rivers around the Mediterranean. It also defines and describes laboratory techniques and analysis pertinent to the identification, characterization, and quantification of macro- and micro-litter, aiming to provide technical guidance and harmonized approaches to the Contracting Parties of the Barcelona Convention, including for the development of dedicated national monitoring programmes.

2. Riverine inputs of marine litter

4. Several studies have been dedicated to documenting and assessing riverine inputs of marine litter entering into the marine environment (van der Wal et al., 2015; González et al., 2016; Schirinzi G.F et al., 2020). All conclude that riverine systems play a major role in transporting land-based plastic waste into the world's oceans (van Emmerik, T., et al., 2020). Once plastics enter the estuary, the combination of riverine and tidal dynamics determines the fate of plastics and its entrance to the marine environment. Rivers have been identified as major pathways that connect land-sources of plastics with the marine environments.

5. Freshwater bodies such as lakes and reservoirs and rivers are impacted by plastics contamination in the same way as the marine environment. Despite the relevance, the current understanding of transport processes, loads and impacts of marine litter in freshwater bodies is limited, mainly because data are lacking and most published data on freshwater plastics come from individual projects which apply different sampling and analysis techniques. This lack of harmonization hampers the comparison and ultimately the synthesis of data.

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[1] United Nations Environment Programme (2020). Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies. Nairobi

[2] https://mcc.jrc.ec.europa.eu/main/dev.py?N=simple&O=380&titre_page=RIMMEL&titre_chap=JRC%20Projects

3. Methods for monitoring riverine inputs of marine litter

6. River mouths can provide substantive information on the accumulation and composition of litter entering into the marine ecosystem. However, due to the different characteristics of the riverine areas (e.g., seasonality of waters, safe and reliable sampling areas, flow velocity etc.), sampling directly at the river mouth might not provide the desirable results. For example, in river deltas, it is recommended to select a location a bit more upstream of the deltaic section of the river. The ideal sampling location (Figure 1) depends on the available information that will be in place regarding the site area and the sampling location opportunities such as the presence of bridges, pontoons or any elevated area that facilitates the observation of litter and the deployment of sampling devices. If the sampling location cannot be performed in the riverine mouth, it is very important to measure the distance between the sampling area to the mouth of the river.

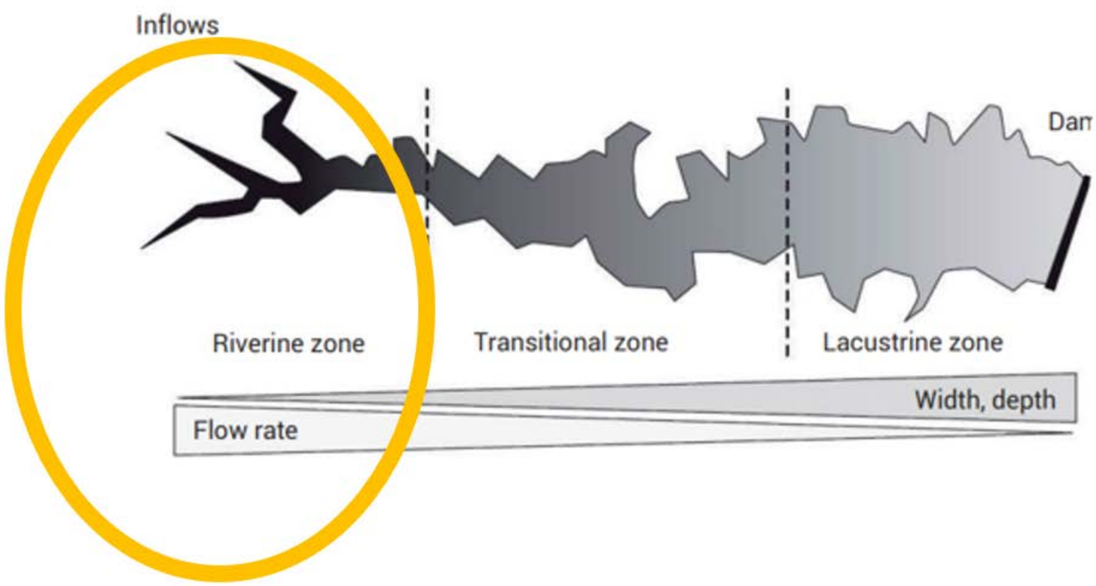

Figure 1: Riverine sampling location (Adapted from Uhlmann et al. (2011) and UNEP 2020).

7. The use of available metadata (e.g., river discharge, typical fish populations, etc.) enables the development of an adequate and efficient plan based on the available monitoring resources. Information on the most common activities carried out around the sampling area can also provide substantive information on the type of litter that is expected to be found and which area (e.g., agricultural areas, city infrastructures, industries etc.) would be relevant for the implementation management measures. Moreover, importance must be given to the administrative borders between the districts to avoid any possible disagreements.

8. Riverine areas are subject to complex flow dynamics and are influenced by the tides and freshwater discharges. Flow velocity and direction may change on hourly timescales, which in turn influences litter and plastic transport and export to the marine environment. Ideally, the monitoring should be focus on relatively frequent and long-term monitoring in a modest number of locations, rather than sampling sporadically in several locations.

9. Three basic categories of monitoring strategies can be applied for macrolitter on water surface: (i) visual observation methods; (ii) sampling net methods (van Emmerik et al. 2018); and (iii) advanced methods using unmanned aerial vehicle (UAV) and automated cameras (Tramoy et al. 2020).

10. A brief overview of the aforementioned methods is presented hereunder focusing on consistent, widely used and cost-effective methods that could be considered for use by the Contracting Parties for this purpose.

4. Visual observation

11. In the marine environment, methodologies and protocols for visual observation at sea have been proposed by several institutions and scientific research groups such as European Commission (EC JRC, 2013), NOAA Marine Debris Program (NOAA, 2013) and UNEP/MAP (2016). Visual counting of plastic litter can be performed in both marine and freshwater environments, consisting of a rather simple method to determine litter transportation. Despite the shortcomings that visual observation may impose (e.g., submerged floating items are not visible in turbid rivers and items can only be identified during the shore time they float by), it is a low-cost option which enables high frequency monitoring in many sites.

12. To acquire more accurate data on plastic composition and mass transportation, it is advisable to perform also physical samplings to convert the measured transport in items per unit of time to actual mass transport.

13. The European Commission Joint Research Centre (EC JRC) within the RIMMEL project developed a harmonized collaborative approach using a tablet computer application for the collection of data in river estuaries. The methodology is based on visual observations using a common agreed list of litter items and size categories. The RIMMEL Application allows real time data acquisition during monitoring sessions, thus providing a tool for data collection and reporting.

14. A similar method for observation and collection of information could be harmonized through the development of relevant region-wide agreed reporting templates. The use of a smartphone application is an option, and it could be further developed at a later stage such as to facilitate data collection and harmonization.

4.1 Site selection and preparation

15. The selection of an elevated position is recommended to start the visual observations (e.g., bridges, piers, pontoons). Taking into consideration the river width and the number of people being involved in the sampling, the sampling area should be divided into respective sections. The definition of observation section width (i.e., the section which the observer uses for identification the identification of the litter items) would allow the estimation of litter fluxes in relation to the river section total width (i.e., distance between the two margins at the monitoring). The height and width from the sampling location influence the width of the section that can be observed comfortably, therefore the width equal to the observation height generally is recommended.

16. Visual observations methodologies present some limitations such as weather conditions, sun orientation, the height of the observation site (i.e., from bridges or vertical distance), as well as characteristics of the litter items (i.e., color, size, shape, and floatability).

17. In the framework of the EU Marine Strategy Framework Directive (MSFD), floating macro-litter monitoring refers to items >2.5 cm, due to their buoyancy properties and capability of floating or suspending in the river surface layer. Therefore, the height of the selected observation site (i.e., vertical distance between observer's eyes and river surface) should allow the detection of litter items down to 2.5 cm (lower limit for macro litter). The use of binoculars might help in the identification of litter items if necessary. Nevertheless, as river characteristics and bridges vary greatly between locations, the deployed protocol should be always fine-tuned to the respective needs and site specificities.

18. To design of a monitoring campaign or a programme, the location of the observed site should be considered. For example, it is easier to visualize macro-litter from bridges, and ideally the surveyor should be located as close as possible to the river mouth.

4.2 Sampling duration and frequency.

19. The river surface water speed must be measured when establishing the duration of the sample as well as for the surface flux calculation later. For rivers with considerable variation in flow velocity, such as riverine areas (Figure 1), it is recommended to take measurements at least once per hour.

20. The load of litter transportation will influence optimal observation duration. For rivers with more than 1,000 items per hour, it is recommended to measure one or two minutes per section. For rivers with less than 100 items per hour, it is recommended to measure at least 15 minutes per section (UNEP 2021). The duration of each measurement should be equal to one hour divided by the number of sections. In addition, frequent samplings will provide an expected high temporal variability in litter loads, thus weekly or bi-weekly observations are recommended (JCR 2018).

4.3 Data collection

21. Each visible floating and superficially submerged plastic piece must be counted, independent of its size. An estimation of the minimum average size of plastic debris must be taken into consideration and if the item is uncertain in terms of description, it is recommended that the item is not counted as plastic.

22. The counted litter should be normalized over time and space to arrive at a plastic transport profile over the river width, and total plastic transport in items per unit of time (items per hour). The number of items per hour per section provide the spatial variation over the river width, and the sum of the sections provide the total number of floating pieces of plastic per hour over the whole river width.

23. To categorize the observed items the common agreed list for beach marine litter items (IMAP Common Indicator 22) could be used after possible adaptation to narrow down the available options in line with the items that are mostly recorded in the respective riverine areas (Annex I).

4.4 Meta data

24. The river surface flow velocity must be measured several times during the survey, and certainly every time that an alteration is observed. The assessment of the river water surface (e.g., turbulence and presence of natural foam), wind direction and intensity, cloud/rain, light conditions (e.g., reflections, direction of the sun and shades), tidal conditions and visibility (e.g., fog) must also be recorded.

25. For each observed section, the GPS coordinates (grades and thousandths, GG, GGGGG) must be recorded in WGS 84 UTM 32.

5. Deployment of nets (limnological neuston, plankton nets and manta trawl)

26. To determine plastic composition, different net deployments for sampling purposes can be deployed. The methods will vary according to the characteristics of the riverine area and the available resources. Limnological neuston, plankton nets and manta trawl are amongst the available options whereas the first two seem to be preferable for the case of the Mediterranean. The different net types can be deployed with boats, lifting cranes on bridges, or direct deployment from riverbanks or bridges. A trawl net in principle requires netting bags which are placed in the water surface/column to catch the floating particles entering the ocean through the river mouth. Trawls are often called “towed gear or dragged gear” and are commonly used for fishery practice.

27. Plankton net-based approaches are common techniques used for water column and surface sampling in rivers, while manta nets have been used occasionally in stationary sampling, attached to fixed structures on the river (e.g., bridges) (Faure et al., 2015). Stationary hand nets or cranes are also methods used to sampling microplastic in riverine areas (Moore et al., 2011).

28. Plankton or Neuston nets are designed to collect samples from the surface layer but can be used for horizontal and vertical sampling too. The selection of the nets will depend on the river characteristics and available resources.

5.1 Limnological neuston, plankton nets

29. The Plankton Net (Fig. 2) consists of a circular metal device[3] from which a net cone is attached, having a final collection sock (or any other relevant collection equipment) at its very end, where the microplastics and the organic matter are collected. A Mechanical flow meter is also attached at the net opening. (Baini M. et al. 2018; Abeynayaka A. et al., 2020).

5.1.1 Plankton net mesh size:

30. To select the mesh size of the Plankton net, it is advisable to entail a trade-off between the lower cut-off of particle sizes and the risk of clogging due the presence of suspended sediment and organic material such as plankton and leaves.

31. The standard mesh size for a limnological plankton net targeting phytoplankton is 55 µm, while even finer nets are available (UNEP 2021). Most plankton net samples on microplastics focus on the large fractions of microplastics, and most studies are using a mesh size ranging between 300 and 500 µm (Hidalgo-Ruz et al., 2012; Moore et al., 2011; Hohenblum et al., 2015). However, small fractions of microplastic would necessitate techniques that appropriately address other sizes and therefore smaller mesh sizes must be used.

32. The net cone, which is attached to the metal device, should be made of a net with a mesh size of approximately 300 µm. It is important to constantly check the effectiveness of sampling to avoid problems of regurgitation following clogging, especially in eutrophic waters.

[3] Rectangular shapes are also used on several occasions.

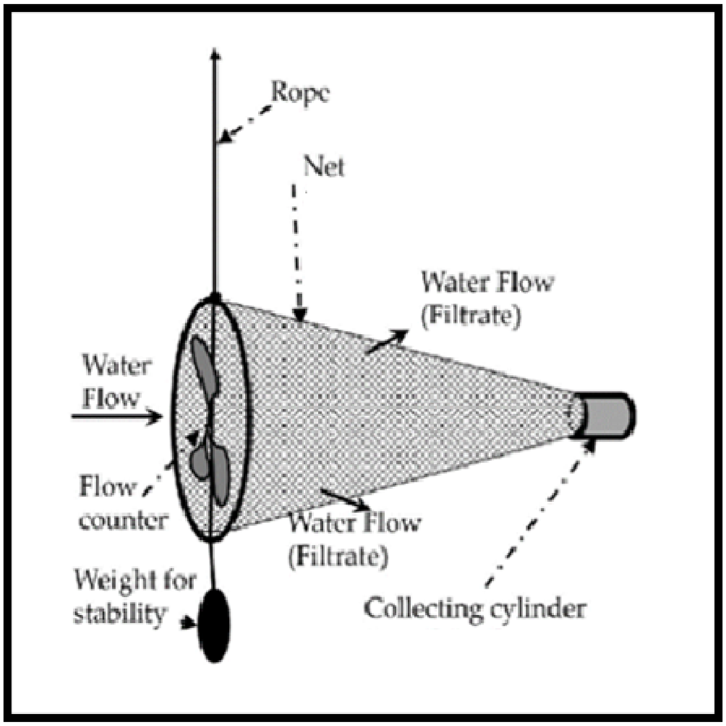

Figure 2: Plankton Net (adapted from Abeynayaka A et al., 2020).

33. The net dimension opening diameter will determine the depth of the surface layer sampled (e.g. a conical net filter would measure the top 0.5 meters of water column). Some authors report as items per surface area, but the configuration of the net also includes floating and suspended particles, depending on the net submersion depth.

34. In order to ensure consistency and harmonization of sampling methodologies, it is recommended to use mesh size of 300 μm.

5.1.2 Use of limnological plankton nets:

35. The monitoring can be done over a bridge, where the Plankton net is lowered, and at least two people are required. Depending on the riverine characteristics and sample areas, the net can be fixed in structures on the river or using a boat.

36. The design of a monitoring campaign requires the definition of the optimal sampling location, which should be as close as possible to the river mouth. Flow velocity and direction may change on hourly timescales, which in turn influence plastic transport and export into the sea. In the case of strong hourly variations, it is recommended to plan several high frequency sampling sessions, for example, hourly measurements during a full tidal cycle.

5.1.3 Data collection and processing - sample in situ:

37. Once the material is collected it cannot be allowed to dry, it must be covered for transport and further analyses. Filter water and glass vessels are required. The contents of the net or sieve that are collected during sampling must be flushed to a glass sample vessel with filtered water. Glass vessels are preferable to avoid microplastic contamination. It is crucial to perform several collections and rinsing steps for a sieve. The final volume of the sample should be kept small and if biota will be analyzed, the final sample should be preserved or cooled.

5.1.4 Meta data:

38. The river surface flow velocity must be measured every time a section is sampled. The assessment of the river water surface (e.g., turbulence and presence of natural foam), wind direction and intensity, cloud/rain, light conditions (e.g., reflections, direction of the sun and shades), tidal conditions and visibility (e.g., fog) must be recorded.

39. For each sampling area the GPS coordinates (grades and thousandths, GG°, GGGGG) must be recorded in WGS 84 UTM 32.

5.1.5 Replicates:

40. Because of the variability of floating microparticles distribution, it is necessary to increase the data representativity. For this reason, it is recommended to carry out three replicates from the same sampling point.

5.1.6 Calculating the surveyed areas:

41. `The calculation of the amount of microplastics should be expressed in number of microplastic particles per square meter based on the following methodological approach whereby the surface area of surveyed water (S) is calculated using the following formula:

$$\mathbf{S = D \times W}$$

[D: Flowmeter | W: Width of the Mount of the Net]

5.2 Manta nets

42. The Manta Net or Manta Trawl is the most commonly used sampling equipment for monitoring floating microplastics at sea (Figure 3). This tool is specifically designed to collect samples from the surface layer of the sea. The use of Manta Net allows the sampling of large volumes of sea water, retaining at the same time the target material (i.e., microplastics), however its application in rivers is more complicated because of the risk of clogging.

Figure 3: Manta net being operated in calm sea, outside of the bow wave caused by the spinning of the propeller (Photo: © Christos Ioakeimidis, UNEP/MAP).

5.2.1 <u>Trawl net dimensions:</u>

43. This includes the height and depth of the trawl frame; depth of submergence of the frame; the net length; and net mesh size. The deployment depth, and the depth to which the frame is submerged influence the sampling results.

44. A trawl used to sample the upper 40 cm of the water column should have dimensions consisting of (H67 × W50 cm), with 2 m long nets attached. However other dimensions are also used in the literature (e.g., 1.0 x 0.5 m^2 Saigon River in Viet Nam (van Emmerik et al. 2018); 0.6 x 0.3 m^2 and 0.6 x 0.6 m Danube River in Austria (Hohenblum et al. 2015); 0.5 x 0.15 m^2 in the River Tamar, United Kingdom (Sadri and Thompson 2014); and 0.27 x 0.105 m^2 in Chilean rivers; (Rech et al. 2014)).

45. The net length determines the drag force on the net and the maximum litter collection capacity. For rivers with high litter concentrations and/or high flow velocities, it is recommended to use smaller net length, especially if the nets are deployed from bridges without additional equipment. This implies that the duration of sampling should be shorter, as the maximum capacity will be reached more quickly. Longer nets are advised when sampling duration is longer and when, for example, cranes or a larger number of people are available to retrieve the nets.

5.2.2 Mesh size:

46. The mesh size influences the lower size limit of items that can be collected. During periods of high flow velocity, a too small mesh size can result in a backwater curve in front of the net opening; therefore, the litter may divert away from the net, and the sample becomes less representative. A mesh size of 2.5 cm is advisable within MSFD framework as floating macro litter monitoring refers to items >2.5 cm. However, an optimization between the desired size fraction of plastic and the adaptability of the trawl to the drag forces without affecting the sample must also be considered. To avoid the net dragging inside the water and to increase buoyance and stability, horizontal buoys should be attached on each side of the frame of the net.

5.2.3 Sampling duration and frequency:

47. Close to the river mouth, the flow dynamics are influenced by both freshwater discharge and the tide, this may lead to changes in flow velocity and direction multiple times per day. In the case of strong hourly variations, it is recommended to take samples under different flow conditions and plan several high frequency sampling sessions, for example, hourly measurements during a full tidal cycle.

48. The deployment duration must be adjusted for each individual sampling location, flow velocity and plastic loads variations. The deployment time must be sufficiently long to capture material, while short enough to avoid total clogging or blocking of the net opening.

5.2.4 Designing a monitoring campaign

49. The design of sampling monitoring campaign requires the definition of the optimal deployment location, which should be as close as possible to the river mouth considering the safety and feasible conditions to perform the sampling.

50. Plastic transportation and export into the marine environment can change on hourly time scale; therefore, high-frequency monitoring during targeted time periods should be considered.

5.2.5 Data collection:

51. The trawls can be deployed by two or more people holding on each side of the trawl. The trawls can also be placed in lifting cranes, lowered on bridges, riverbanks or by boats. The deployment method strongly depends on the availability of safe deployment sites on bridges or accessible riverbanks (Rech et al. 2015). The sampling volume and mass are also limited by the maximum load the nets can handle, which is generally in the order of several kilograms for flow velocities.

52. To categorize the observed items, the common agreed list for beach marine litter items (IMAP Common Indicator 22) could be used after possible adaptation (Annex I).

53. The river surface flow velocity must be measured every time that a section is sampled. The assessment of the river water surface (e.g., turbulence and presence of natural foam), wind direction and intensity, cloud/rain, light conditions (e.g., reflections, direction of the sun and shades), tidal conditions and visibility (e.g., fog) must be recorded.

54. For each trawl the GPS coordinates (grades and thousandths, GG°, GGGGG) must be recorded in WGS 84 UTM 32.

6. Use of smartphone applications

55. The Joint Research Centre (JRC) of the European Commission undertook an exploratory research project titled RIMMEL (Nov. 2015 – Oct. 2017). In the framework of the RIMMEL project, the RIMMEL floating litter monitoring application was developed having a target to quantify floating macro litter loads through rivers to marine waters, through the collection of existing data and the development of a European observation network.

56. Additionally, the project developed the RiverLitterCam methodology which provided an innovating tool for the monitoring and the assessment of litter in freshwater/estuarine environments. The RIMMEL project aims in bringing a better understanding on litter dynamics from freshwater to marine environments, contributing to source identification and quantification, thus supporting policy makers for improvement of management options.

57. To start, the App allows selection of “sea” or “river” litter monitoring modes. When selecting the river monitoring mode, a metadata settings menu is accessed, where specific information about the observation set-up must be added.

58. A list of floating macro litter items is available on a menu, organized by materials. This list is based on the “Master List of Categories of Litter Items” from the “Guidance on Monitoring of Marine Litter in the European Seas” (EC JRC, 2013), and includes all items that have been described as floating litter. But It is also possible to create a list of favorite items that will allow faster access to the common items found in the monitoring area. Furthermore, a section of sizes ranges classes is also provided. All information is registered along with the GPS position and time, into a data file previously set with the observer’s name and institution.

59. In the end of the observation/sampling the data is saved in an individual “.csv” file formats and are stored in the tablet computer memory and the information can be send directly from the App to a mailbox or copied to a computer. The use of a simple harmonized data format allows importation of the data directly into the project database.

60. The App (version 2.0) has been developed for tablet computers with an Android operating system. The tablet computer must have GPS functionality to allow position tracking.

7. Advanced tracking methods

61. Scaling up visual observations may be facilitated using automated monitoring tools. Unmanned aerial vehicles (UAVs) based methods have recently been used to monitor rivers and demonstrated that variations in time and space can be well quantified from UAV-based camera imagery (Geraeds et al 2019). Research has also been focusing on the use of UAVs for long-term data collection, with the use of cameras for automated plastic monitoring (van Lieshout et al 2020, Counter Measure Project).

62. UAV-based monitoring is a promising alternative to the currently available techniques and approaches for monitoring riverine inputs of marine litter, especially in remote and inaccessible areas (Geraeds et al 2019). However, it still requires further development in order to become a practical standard for monitoring programs (EC JRC, 2013).

8. Sampling sediment in rivers

63. The steel grab is a tool commonly used to sample sediment in order to analyze organic/inorganic contaminants, as well as for the collection of microplastics.

64. The flow dynamic of the rivers is the main driving force affecting the accumulation of meso- and micro-litter on riverbanks and river shores; also depending on the margin characteristics (e.g., when sand, vegetation exists less marine litter is found on the rocks) and the hydrological conditions. The present methodology is very similar to the approaches used for monitoring microplastic on beaches and in shallow sediment at sea.

8.1 Sediment sampling

65. There are different sampling methods that can be chosen depending on the purpose of sampling, location and characteristics of sediment. The sampling device used to collect meso and microplastic should be designed to obtain specific volume and surface area, specific depth of stream and very important, should shield the sample from outside contamination, preferably not made of plastic.

66. Sediment sampling can be done using gravity corers (Naidoo et al., 2015) and grabs (Castañeda et al. 2014) (Figures 4 and 5), and the collected samples consist of meso- and micro-litter. The main difference of the two devices is the material of construction, the extraction method and the depth of deployment for the collection of the sample.

67. Rod-operated or cable-operated Ekman grabs are typically extract 15 cm long. They can provide a large amount of sample material in a single step. Grabs can cause disturbance to the sediment surface. As a result, the exact depth of the grab can be difficult to determine.

68. Alternatively, gravity coring can be used for sediment sampling. Gravity corers come in various diameters. Naidoo et al 2015, used 50 mm diameter and 10 cm long. Corers are typically made of clear plastic polymers such as polyvinyl chloride (PVC) which can contaminate the sample, and therefore are not advisable. Stainless steel hand corers have become recently available and should be considered when collecting microplastic samples.

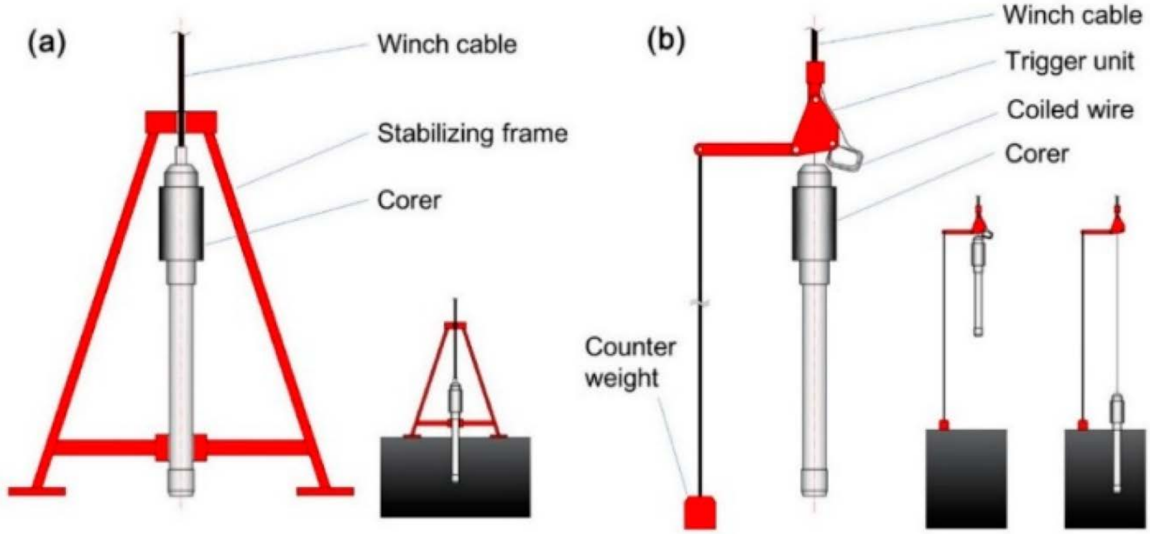

Figure 4: Structure and function schemes of the conventional corers with (a) a stabilizing frame and (b) an overhanging trigger system; the radial sizes (150–600 cm) of these corers are far larger in diameter than can enable access to hot-water drilled boreholes (10–60 cm) (Adapted by Gong et al., 2019[4]).

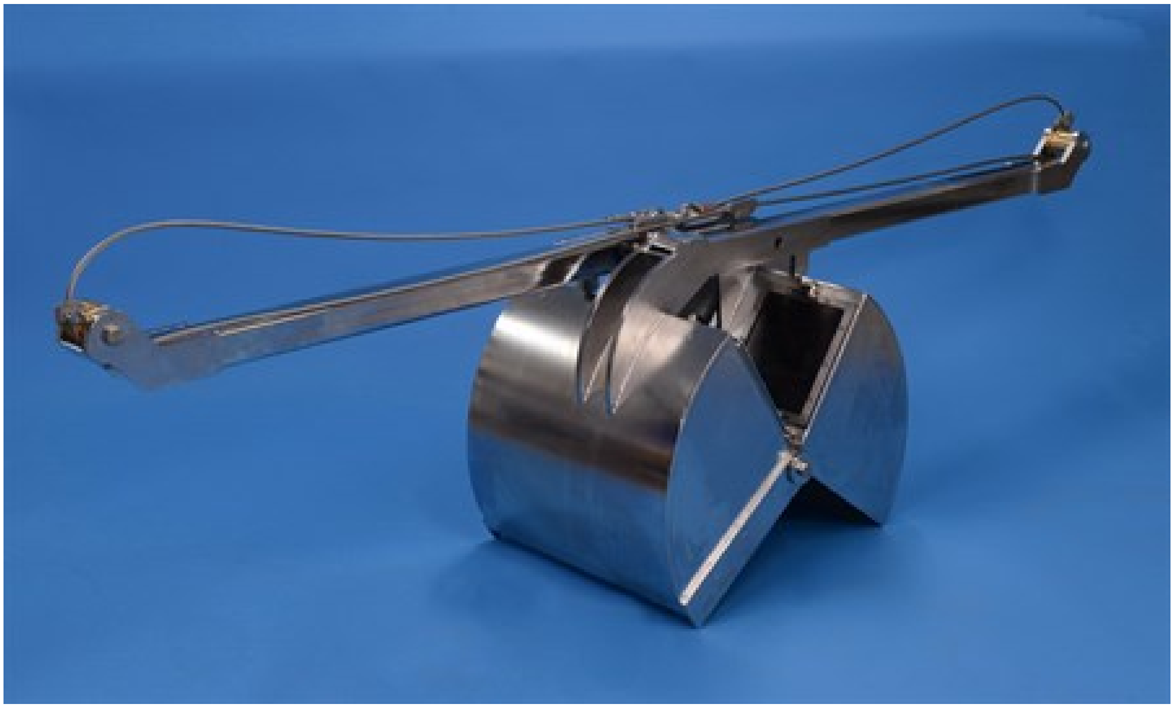

Figure 4: Grab for the collection of samples for collecting bottom sediments for biological, hydrological and environmental studies[5].

[4] Gong, Da, Xiaopeng Fan, Yazhou Li, Bing Li, Nan Zhang, Raphael Gromig, Emma C. Smith, Wolf Dummann, Sophie Berger, Olaf Eisen, Jan Tell, Boris K. Biskaborn, Nikola Koglin, Frank Wilhelms, Benjamin Broy, Yunchen Liu, Yang Yang, Xingchen Li, An Liu, and Pavel Talalay. 2019. "Coring of Antarctic Subglacial Sediments" Journal of Marine Science and Engineering 7, no. 6: 194. https://doi.org/10.3390/jmse7060194

[5] https://www.kc-denmark.dk/products/sediment-samplers/van-veen-grab/van-veen-grab-2500-cm%C2%B2.aspx

8.2 Designing a monitoring campaign

69. The monitoring of items deposited on the sediments is often based on transects of the shore covering a determined distance in parallel to the shoreline, e.g., sampling site of 10-15 meters where a number of sampling areas must be chosen randomly (e.g., 40). The device used to collect the samples gives the area of the samples collected and their depth, for example 30 cm^2, and 2 cm deep (Worch and Knepper, 2015). The length, width, and depth of the transect are important factors.

70. Once collected, all samples must be assembled and homogenized to obtain a sample of approximately the same weight. Assessment of the status of the river water (e.g., turbulence and presence of natural foam), wind, cloud/rain, light conditions (e.g., reflections, direction of the sun and shades) and visibility (e.g., fog) should be also considered for record.

71. For each sample collection, the GPS coordinates (grades and thousandths, GG°, GGGGG) must be recorded in WGS 84 UTM 32.

9. Sample preparation for microplastics analysis

72. The preparation of the samples requires the organizations of the material that will be used during the sampling a priory in the lad. Several aspects should be also taken into consideration, including the clothes that the lab staff will be wearing during the samples analysis to avoid potential contamination. It is advisable to use cotton to avoid any possibility of contamination with microplastic particles. The material that will be used to store the samples should be made of steel or glass and rinsed with distillate water before the sampling and covered to avoid contamination with any plastic material.

9.1 Water samples

73. Once water samples are collected, it is important that they are not allowed to dry. The samples must be rinsed with distillated water in stainless steel sieve with the mesh sizes already defined in the monitoring protocol. To prepare the samples for the microplastic analyzes, at first, the particles > 500 µm should be sorted either manually or by use of a stereo microscope. With the remaining particles, it is recommended to portion the sample using a mesh size of 500 µm and to divide into sub-samples, and then to apply the enzymatic purification protocol, which is the safest way to obtain representative microplastic samples (Löder et al., 2017). Depending on the sampling composition, the procedure should be adapted (Löder et al. 2017, supplementary information).

74. The removal of organic compounds can also be achieved using acids, bases and oxidants (Devriese et al. 2015, Cole et al. 2014, Tagg et al. 2017). However, it is important to not destroy the polymer fibers and fragments using strong reagents.

75. Following the enzymatic purification and depending on the number of plastic particles in the sample, density separation should be applied. The density separation solution can be prepared using concentrate or saturated salt solutions. The use of sodium chloride (NaCl) is currently recommended by the Marine Strategy Framework Directive (MSFD) and other researchers (Galgani et al., 2013; Rødland et al., 2020), as it is a non-toxic solution, safe and widely available (UNEP, 2020). However, only light polymers can be reliably retrieved.

9.2 Sediment samples

76. Generally, sediment samples present a significant ratio of natural and inorganic particles. Therefore, density separation is required by using concentrated or saturated salt solutions. As stated above, the use of sodium chloride (NaCl) is a widely favorable and recommended option.

77. Size fractionation of the samples is required, especially when dealing with mass-based microplastic, by using wet sieving prior to the density separation. A certain sequence of mesh sizes can be established as follows: 500 µm, 100 µm, 50 µm, 10 µm (Braun et al. 2018; UNEP, 2020). Stainless steel sieves should be used for the preparation of the microplastics sampling to avoid potential contamination.

78. Other salt solutions, because of the cost and hazardous waste constraints would require for filtration recycling through pore sizes smaller than the microplastic particles as well as density adjustment (e.g. by evaporation) (UNEP 2020, Prata et al., 2019). Alternative density separation methods have been developed by different authors, such as suction density separation (Worch and Knepper 2015; Coppock et al., 2017), and a device designed for plastic sediment separation (Imhoff et al., 2012).

79. The use of oils to separate microplastics has also been studied as an alternative to dense salt solutions. The lipophilic characteristics of plastics makes them preferentially move into the oil phase. The use of Castor oil (Mani et al., 2019) showed that a thick layer of oil surrounded the microplastics, facilitating its recovery for subsequent analysis, while canola oil produces an infrared spectrogram which later can limit the detection and identification of the microplastic (Crichton et al., 2017).

9.3 Size and morphology categories

80. The analysis of the samples consists of physical and chemical characterization. Plastics larger than 5mm are considered macro-plastics while micro- and meso-plastics are separated into different size classes.

81. The morphology and state of fragmentation or disintegration of plastic debris are important indicators of their origins. Larger particles often can be recognized according to their original shape (e.g., bottles, plastic bags, cups, straws, etc.). The identification of macro-plastic can be made during the samplings/observations in line with the UNEP/MAP category for beach marine litter (Annex I). This list should be used as basis to commence the monitoring of the selected areas and could be further adapted and possibly shortened with the items most commonly found in the sampled areas. Such a modification will facilitate the long-term collection of data.

82. Smaller particles of meso- and micro-plastics can be identified according to their morphologies (e.g., fragments, fibers, filaments, beads, spheres, foams sheets and pellets). Relevant categories for meso- and micro-plastic categories are provided hereunder under Table 1.

Table 1: *Categorization of plastic marine litter (Adapted from UNEP 2020 and Lusher et al., 2017).*

Microplastic Characteristics	Classes	Description
Size	Mega	> 1 m
	Macro	25 mm-1 m
	Meso	5 mm-25 mm
	Micro	< 5 mm
Morphology	Fragments	Irregularly shaped particles, crystals, fluff, powder, granules, shavings
	Fibres	Filaments, microfibres, strands, threads
	Beads/spheres	Grains, spherical microbeads, microspheres
	Films/sheets	Polystyrene, expanded polystyrene
	Pellets	resin pellets, nurdles, pre-production pellets, nibs

83. The dimensions of plastic debris can be determined using a gravelometer, which is designed to measure stone sizes (Figure 3).

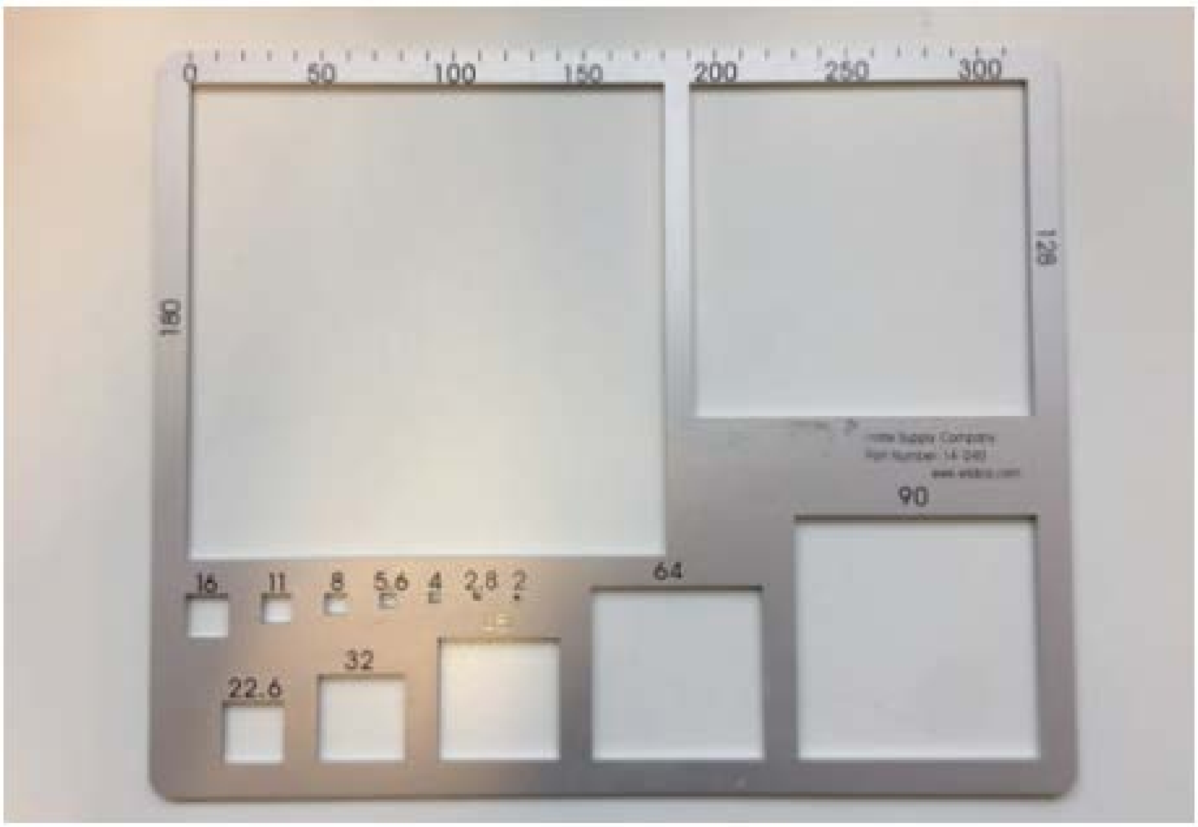

Figure 3: Gravelometer (Adapted from UNEP 2020 - ©Corinna Völkner, UFZ)

9.4 Polymer types

84. Plastics consist of different polymer types with specific characteristics and chemical compounds. Table 2 presents the most common polymer types, their minimum and maximum densities, and applications. Important note is that particles higher than 1g/cm^3 are likely to sink (Schwarz et al. 2019, Borneman 2019, Plastic Europe). The identification of the composition of plastics provides important information about sources, pathways, retention, potential sins, consumer behavior and waste management practices.

Table 2: *Most common polymer types and applications (Adapted by UNEP 2020).*

Polymer	Abbreviation	Main Application
Polyethylene	PE	Packaging
Polypropylene	PP	Many applications, but mainly packaging
Polyester	PES	Textiles
Polyethylene terephthalate	PET	Packaging
Polystyrene	PS	Packaging
Expanded polystyrene	EPS	Food packaging, construction material
Ethylene Vinyl Acetate	EVA	Equipment for various sports
Alkyd	Al	Paints, fibres
Polyvinyl chloride	PVC	Building and Construction
Polymethyl methacrylate	PMMA	Electronics (e.g., touch screens)
Polyamide (nylon)	PA	Automotive, textiles
Polyacrylonitrile	PAN	Textiles
Polyvinyl alcohol	PVA, PVOH	Textiles
Acrylonitrile butadiene styrene	ABS	Electronics
Polyurethane	PUR	Building and construction

9.5 Plastic-particle identification

9.5.1 Plastic-based:

85. The most widely used methods to identify plastic particle-based polymer is the Fourier-transform infrared spectroscopy with Attenuated Total Reflectance accessory (FTIR-ATR) and Raman spectroscopy. It is a non-destructive method that produces a spectrum based on the interaction with light and presumptive polymer molecules. However, it is recommended that before applying this method, a portion of the samples should be tested for the assurance of the polymer type that will be tested.

86. Regarding microplastics, all particles in sizes ranging from 20-100 µm should be analyzed in addition to at least 10 percent of particles ranging from 100-5,000 µm. However, the extrapolation to the total particle number remains considered uncertain (JRC 2013).

87. The use of low-cost methods such as hot needle or staining the particles with dyes can be applied in the pre-selection of particles for analyzed (UNEP, 2020). Nile Red staining can be used with weathered plastics and provides high recovery rates for plastics which allows subsequent spectroscopy for confirmation (Maes et al. 2017).

9.5.2 Chemical analysis:

88. The analysis of chemicals in plastic polymers requires a database of known polymers for reference[6].

89. Recently, a freeware for quick identification based on FTIR spectra (Raman spectra in development) has been provided by Aalborg University, Denmark, in collaboration with the Alfred Wegener Institute in Germany (https://simple-plastics.eu/). siMPle is a freeware for the fast detection of microplatic materials in environmental samples. Its algorithm compares the IR spectra of the sample with each reference spectra in the database, then assigns a material to them along with a probability score.

[6] UNEP/MAP Monitoring Guidelines/Protocols for Floating Microplastics. Meeting of the Ecosystem Approach Correspondence Group on Marine Litter Monitoring (CORMON Marine Litter). 30 March 2021

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Annex I
MED POL List for Beach Marine Litter Items

Annex I: MED POL List for Beach Marine Litter Items[7]

Value	Description	Macro-Category
G1	4/6-pack yokes, six-pack rings	Plastic/Polystyrene
G3	Shopping bags incl. pieces	Plastic/Polystyrene
G4	Small plastic bags (e.g. freezer bags incl. pieces)	Plastic/Polystyrene
G5	The part that remains from rip-off plastic bags	Plastic/Polystyrene
G7/G8	Drink bottles	Plastic/Polystyrene
G9	Cleaner bottles & containers	Plastic/Polystyrene
G10	Food containers incl. fast food containers	Plastic/Polystyrene
G11	Beach use related cosmetic bottles and containers (e.g., Sunblocks)	Plastic/Polystyrene
G13	Other bottles, drums and containers	Plastic/Polystyrene
G14	Engine oil bottles & containers <50 cm	Plastic/Polystyrene
G15	Engine oil bottles & containers >50 cm	Plastic/Polystyrene
G16	Jerry cans (square plastic containers with handle)	Plastic/Polystyrene
G17	Injection gun containers (including nozzles)	Plastic/Polystyrene
G18	Crates and containers / baskets (excluding fish boxes)	Plastic/Polystyrene
G19	Vehicle parts (made of artificial polymer or fiber glass	Plastic/Polystyrene
G21/24	Plastic caps and lids (including rings from bottle caps/lids)	Plastic/Polystyrene
G26	Cigarette lighters	Plastic/Polystyrene
G27	Cigarette butts and filters	Plastic/Polystyrene
G28	Pens and pen lids	Plastic/Polystyrene
G29	Combs / hairbrushes / sunglasses	Plastic/Polystyrene
G30/31	Crisps packets/sweets wrappers/Lolly sticks	Plastic/Polystyrene
G32	Toys and party poppers	Plastic/Polystyrene
G33	Cups and cup lids	Plastic/Polystyrene
G34	Cutlery, plates and trays	Plastic/Polystyrene
G35	Straws and stirrers	Plastic/Polystyrene
G36	Heavy duty sacks (e.g., fertilizer or animal feed sacks)	Plastic/Polystyrene
G37	Mesh bags (e.g., vegetables, fruits and other products) excluding aquaculture mesh bags	Plastic/Polystyrene
G40	Gloves (washing up)	Plastic/Polystyrene
G41	Gloves (industrial/professional rubber gloves)	Plastic/Polystyrene
G42	Crab/lobster pots and tops	Plastic/Polystyrene
G43	Tags (fishing and industry)	Plastic/Polystyrene
G44	Octopus pots	Plastic/Polystyrene
G45	Mesh bags (e.g., mussels nets, net sacks, oyster nets including pieces and plastic stoppers from mussel lines)	Plastic/Polystyrene
G46	Oyster trays (round from oyster cultures)	Plastic/Polystyrene
G47	Plastic sheeting from mussel culture (Tahitians)	Plastic/Polystyrene
G49	Rope (diameter more than 1cm)	Plastic/Polystyrene
G50	String and cord (diameter less than 1 cm)	Plastic/Polystyrene

[7] UNEP/MED WG.490/6: Addendum to the MED POL Beach Marine Litter Item List and their Data Standards and Data Dictionaries to include Two New COVID-19 Related Items (Single-Use Plastic Masks & Gloves). Meeting of the Ecosystem Approach Correspondence Group on Marine Litter Monitoring (CORMON Marine Litter). Videoconference, 30 March 2021).

Value	**Description**	**Macro-Category**
G53	Nets and pieces of net < 50 cm	Plastic/Polystyrene
G54	Nets and pieces of net > 50 cm	Plastic/Polystyrene
G56	Tangled nets/cord	Plastic/Polystyrene
G57/G58	Fish boxes	Plastic/Polystyrene
G59	Fishing line (tangled and not tangled)	Plastic/Polystyrene
G60	Light sticks (tubes with fluid) incl. Packaging	Plastic/Polystyrene
G62/G63	Buoys (e.g. marking fishing gear, shipping routes, mooring boats etc.)	Plastic/Polystyrene
G65	Buckets	Plastic/Polystyrene
G66	Strapping bands	Plastic/Polystyrene
G67	Sheets, industrial packaging, plastic sheeting (i.e. non-food packaging/transport packaging) excluding agriculture and greenhouse sheeting[8]	Plastic/Polystyrene
G68	Fiberglass items and fragments	Plastic/Polystyrene
G69	Hard hats/Helmets	Plastic/Polystyrene
G70	Shotgun cartridges	Plastic/Polystyrene
G71	Shoes and sandals made of artificial polymeric material	Plastic/Polystyrene
G73	Foam sponge items (i.e. matrices, sponge, etc.)	Plastic/Polystyrene
G75	Plastic/polystyrene pieces 0 - 2.5 cm	Plastic/Polystyrene
G76	Plastic/polystyrene pieces 2.5 cm > < 50 cm	Plastic/Polystyrene
G77	Plastic/polystyrene pieces > 50 cm	Plastic/Polystyrene
G91	Biomass holder from sewage treatment plants and aquaculture	Plastic/Polystyrene
G253	Single-use plastic masks (e.g. used for protection from COVID-19)	Plastic/Polystyrene
G254	Single-use plastic gloves (e.g. used for protection from COVID-19)	Plastic/Polystyrene
G124	Other plastic/polystyrene items (identifiable) including fragments	Plastic/Polystyrene
	Please specify the items included in G124	Plastic/Polystyrene
G125	Balloons, balloon ribbons, strings, plastic valves and balloon sticks	Rubber
G127	Rubber boots	Rubber
G128	Tyres and belts	Rubber
G134	Other rubber pieces	Rubber
	Please specify the items included in G134	Rubber
G137	Clothing / rags (e.g., clothing, hats, towels)	Cloth
G138	Shoes and sandals (e.g., Leather, cloth)	Cloth
G141	Carpet & furnishing	Cloth
G140	Sacking (hessian)	Cloth
G145	Other textiles (including pieces of cloths, rags, etc.)	Cloth
	Please specify the items included in G145	Cloth
G147	Paper bags	Paper/Cardboard
G148	Cardboard (boxes & fragments)	Paper/Cardboard
G150	Cartons/Tetrapack Milk	Paper/Cardboard
G151	Cartons/Tetrapack (non-milk)	Paper/Cardboard
G152	Cigarette packets (including transparent covering of the cigarette packet)	Paper/Cardboard

[8] Meeting requested to consider defining separate categories for greenhouse for agriculture and greenhouse sheeting; polystyrene and irrigation pipes

Value	Description	Macro-Category
G153	Cups, food trays, food wrappers, drink containers	Paper/Cardboard
G154	Newspapers & magazines	Paper/Cardboard
G158	Other paper items (including non-recognizable fragments)	Paper/Cardboard
	Please specify the items included in G158	Paper/Cardboard
G159	Corks	Paper/Cardboard
G160/161	Pallets / Processed timber	Processed/Worked Wood
G162	Crates and containers / baskets (not fish boxes)	Processed/Worked Wood
G163	Crab/lobster pots	Processed/Worked Wood
G164	Fish boxes	Processed/Worked Wood
G165	Ice-cream sticks, chip forks, chopsticks, toothpicks	Processed/Worked Wood
G166	Paint brushes	Processed/Worked Wood
G171	Other wood < 50 cm	Processed/Worked Wood
	Please specify the items included in G171	Processed/Worked Wood
G172	Other wood > 50 cm	Processed/Worked Wood
	Please specify the items included in G172	Processed/Worked Wood
G174	Aerosol/Spray cans industry	Metal
G175	Cans (beverage)	Metal
G176	Cans (food)	Metal
G177	Foil wrappers, aluminium foil	Metal
G178	Bottle caps, lids & pull tabs	Metal
G179	Disposable BBQ's	Metal
G180	Appliances (refrigerators, washers, etc.)	Metal
G182	Fishing related (weights, sinkers, lures, hooks)	Metal
G184	Lobster/crab pots	Metal
G186	Industrial scrap	Metal
G187	Drums and barrels (e.g., oil, chemicals)	Metal
G190	Paint tins	Metal
G191	Wire, wire mesh, barbed wire	Metal
G198	Other metal pieces < 50 cm	Metal
	Please specify the items included in G198	Metal
G199	Other metal pieces > 50 cm	Metal
	Please specify the items included in G199	Metal
G200	Bottles (including identifiable fragments)	Glass
G202	Light bulbs	Glass
G208a	Glass fragments >2.5cm	Glass
G210a	Other glass items	Glass
	Please specify the items included in G210a	Glass
G204	Construction material (brick, cement, pipes)	Ceramics
G207	Octopus pots	Ceramics
G208b	Ceramic fragments >2.5cm	Ceramics
G210b	Other ceramic/pottery items	Ceramics
	Please specify the items included in G210b	Ceramics
G95	Cotton bud sticks	Sanitary Waste
G96	Sanitary towels/panty liners/backing strips	Sanitary Waste
G97	Toilet fresheners	Sanitary Waste
G98	Diapers/nappies	Sanitary Waste

Value	Description	Macro-Category
G133	Condoms (including packaging)	Sanitary Waste
G144	Tampons and tampon applicators	Sanitary Waste
G--	Other sanitary waste	Sanitary Waste
	Please specify the other sanitary items	Sanitary Waste
G99	Syringes/needles	Medical Waste
G100	Medical/ Pharmaceutical containers/ tubes	Medical Waste
G211	Other medical items (swabs, bandaging, adhesive plaster etc.)	Medical Waste
	Please specify the items included in G211	Medical Waste
G101	Dog faeces bag	Faeces
G213	Paraffin/Wax	Paraffin/Wax
Presence of pellets	Please say Y or N	
Presence of oil tars	Please say Y or N	
Number Items	Number of items in the category expressed as number of objects / 100m	