Mekong River Commission
For Sustainable Development

PROTOCOL FOR RIVERINE MACROPLASTICS MONITORING

Long-term and cost-effective monitoring of riverine plastic debris pollution in the Lower Mekong River

Protocol for Riverine Macroplastics Monitoring:

A detailed methodology for long-term and cost-effective monitoring of riverine plastic debris pollution in the Lower Mekong River

November 2023

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Mekong River Commission
Documentation and Learning Centre
184 Fa Ngoum Road, Unit 18, Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR
Telephone: +856-21 263 263 | E-mail: mrcs@mrcmekong.org | www.mrcmekong.org

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Authors

Management
Mr Phetsamone Khanophet, Director of Environmental Management Division, Mekong River Commission Secretariat

Technical Expert and Author
Mr Satoshi Sasakura, Riverine Plastic Management and Monitoring Expert, IDEA Consultants, Inc.

Technical Experts and Editor
Dr Kongmeng Ly, Water Quality Officer, Environmental Management Division, Mekong River Commission Secretariat
Dr So Nam, Former Chief Environment Officer, Environmental Management Division, Mekong River Commission Secretariat

Contributors
National Mekong Committee Secretariats of Cambodia, Lao PDR, Thailand, and Viet Nam; Department of Hydrology and River Works, Ministry of Water Resources and Meteorology, Cambodia; Natural Resources and Environment Research Institute, Ministry of Natural Resources and Environment, Lao PDR; Faculty of Environment and Resource Studies, Mahidol University, Thailand; Southern Institute of Ecology, Ministry of Natural Resources and Environment, Viet Nam

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1. Background and rationale

1.1 Background

The Mekong River Commission (MRC) was established by the 1995 Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin, between the Governments of Cambodia, Lao PDR, Thailand and Viet Nam. The role of the MRC is to coordinate and promote cooperation in all fields of sustainable development, and on the utilization, management, and conservation of the water and related resources of the Mekong River Basin.

The MRC Secretariat (MRCS) is the operational arm of the MRC. It provides technical and administrative services to the Joint Committee and the Council to achieve the MRC's mission.

The Environmental Management Division (ED) is responsible for environmental monitoring, assessment, planning, and management to support basin planning management and development for the sustainable development of the Mekong River.

The Mekong River Basin is one of the largest and most biodiverse river basins in the world, spreading over more than 795,000 km2 and extending over 5,000 km through six different countries. and providing a home to more than 70 million people alone in its lower reaches (Lower Mekong Basin). However, the Mekong River is also one of the 10 major contributors to marine plastic pollution. Collectively, these major contributors discharge about 95% of the plastic strangling the world's oceans.

In 2019, the United Nations Environmental Assembly agreed on measures aiming at curtailing global plastic pollution and leakage into the world's oceans with the commitment of 180 countries including the MRC Member Countries. The main aim is to reduce the use of single-use plastic products. However, it is known that this will not be enough to effectively address the magnitude of plastic waste that pollutes our freshwater waterways and our oceans.

The MRC has six river basin management core functions, including assessments and analysis, monitoring of environmental status and trends, and the implementation of MRC procedures. Among the five MRC procedures are the Procedures for Water Quality (PWQ) and the Procedures for Data and Information Exchange and Sharing (PDIES). One of the key monitoring functions of the MRC core is the continuous assessment and identification of basin changes of five different areas: (i) hydrology and hydraulics; (ii) sediment and discharge; (iii) water quality; (iv) aquatic ecology; and (v) fisheries. The MRC has long-lasting experience with environment and fisheries monitoring of key disciplines. The MRC Water Quality Monitoring (WQM) activity dates back to 2003, and to date, 48 WQM sites have been established throughout the mainstream and major tributaries in the Lower Mekong Basin (LMB). The MRC Fisheries monitoring began in 1994 and consists of three types of the monitoring: (i) fish abundance and diversity monitoring (FADM); (ii) fish larvae and juvenile drift monitoring (FLDM); and (iii) Dai (bag net) fishery monitoring. FADM has been implemented by implementing agencies in the four Member Countries for about 10 years with 38 monitoring stations in the LMB. FLDM was implemented by Cambodia in 2000, Lao PDR in 2019, and Viet Nam in 1999. The monitoring stations are located in two sites in Cambodia (Mekong and Tonle Sap Rivers), Viet Nam (Mekong and Bassac Rivers), and Lao PDR (Mekong and Sekong Rivers). Since 1995, Dai fishery monitoring has been implemented only at Tonle Sap River in Cambodia. It is located in the lower section of the Tonle Sap River, spanning more than 30 km across the municipality of Phnom Penh and Kandal Province. Due to its transboundary nature, only FADM and FLDM were included in the Joint Environmental Monitoring (JEM) Programme for the Mekong mainstream hydropower projects. These procedures and monitoring activities lay the groundwork for this assignment.

The MRC and the United Nations Environment Programme (UNEP) signed a Memorandum of Understanding (MoU) to, among others, work on water quality monitoring including plastic waste leakage into the Mekong River system. Under this partnership arrangement in 2019, the MRC supported the first phase of the UNEP project on Promotion of Countermeasures against Marine Plastic Litter in Southeast Asia" (CounterMEASURE) funded by the Government of Japan, which includes regional workshops, capacity mapping for plastic pollution in the Mekong Basin and support to the pilot projects in the four MRC Member Countries, i.e. Cambodia, Lao PDR, Thailand and Viet Nam.

To build on the initial efforts under the first phase of the CounterMEASURE project, the MRC and UNEP agreed on several areas of cooperation including the identification of sources of plastic waste leakage and the development of a standardized methodology for plastic waste assessment and monitoring in the Mekong River. The goal is to provide timely data and information on transboundary plastic waste pollution status and trends, and to report on these status and trends to inform policy decision-making processes.

To achieve this, the MRC planned two key activities for 2020: to carry out a review of the status and trends of plastic waste management in Lower Mekong Countries; and to develop a concept note for a long-term and cost-effective assessment and monitoring methodology of riverine plastic debris pollution in the Mekong River. After completion, and upon the availability of funds for the MRC Annual Work Plan 2021, it was planned to develop and finalize a detailed methodology for the long-term and cost-effective assessment and monitoring of plastic waste in the Mekong Basin, followed by national and regional capacity building to implement this methodology in collaboration with UNEP through the CounterMEASURE project. The methodology consists of three monitoring protocols – for riverine macroplastics, riverine microplastics and microplastics in fish.

Based on the protocols, MRC will plan and implement the MRC riverine plastic debris pollution monitoring programme.

For management purposes, it is important to know the quantities and types of plastic waste in a river to be able to identify the sources and to prioritize management measures. For more reliable information, longer-term monitoring and analysis would be recommended on more sampling sites in a river to determine if there are seasonal changes (possibly related to different uses throughout the year), whether concentrations of plastics differ at different locations, and how this can be related to their sources, as well as to observe how the variability in weather influences quantities of plastic waste in a river.

1.2 Rationale

Today, marine plastic debris is a worldwide issue, and all countries must take urgent action accordingly. Rivers are known as the main contributors in transporting most of the plastic debris into the sea. Schmidt et al. (2017) estimated that the world's 10 largest contributing rivers, including the Mekong River, account for 88–95% of transportation of the global load.

Riverine/marine plastic debris has diverse sources of leakage from land. Macroplastic, i.e. plastic debris larger than 5 mm in diameter, is considered to mainly leak from illegal dumping sites, uncontrolled open dumpsites, and citizens' littering activities. Microplastic, smaller than 5 mm in diameter, is considered to mainly leak from consumer products such as toothpaste and skin care products, industrial sources using plastic resin pellets, and the disintegration of macroplastics debris. However, the actual behaviour of plastic debris is yet to be clarified, including its leakage sources and transportation in water.

To solve these issues, several organizations have established a working plan on monitoring riverine and/or marine plastic debris, such as the Association of Southeast Asian Nations (ASEAN) Regional Action Plan. Still, LMB does not have regular monitoring programmes nor a standardized method for monitoring riverine plastic debris which would enable a precise analysis and comparison of data over areas and time. Therefore, this protocol shall provide the region with the appropriate and harmonized method for monitoring riverine plastic debris to support efficient policymaking for the reduction of plastic debris.

2. Goal and scope

2.1 Goal and scope of riverine macroplastics monitoring

The goal of riverine macroplastics monitoring is to understand riverine plastic pollution levels, trends, and their distribution throughout LMB, with a view to preventing impacts on human health and ecosystems. Being different from microplastics, the abundance of macroplastics in a river is lower and thus requires a longer sampling time. For example, one piece of a polyethylene terephthalate (PET) bottle is usually equivalent to 200,000 pieces of microplastics, assuming that the weight of a PET bottle is around 20 g and that of a microplastic, 0.1 mg. In order to understand the current condition of riverine macroplastics pollution, we recommend three sampling methods, as described below (Detailed sampling methods are described in Sections 4, 5, and 6).

(A) Sampling by fishing net at the community level

Plastics caught by any fisher during fishing activities are collected and counted. A collection box at fishery community offices should be provided where fishers must place the collected plastic debris, which must be counted them periodically. With this sampling method, it is difficult to ensure quantitative data reliability because plastics are collected by various fishing methods, nevertheless, this sampling method provides us with a basin-wide overview of long-term trends (amount and type) of riverine plastics. When it is carried out in many communities and the results are plotted in a map, plastic polluted areas can be identified. This also contributes to river clean-up and awareness raising, especially when a ghost fishing net is collected by a fisher. Cooperation mechanisms with fishers need to be established.

This method is suitable for large floating plastic that can be caught in fishing nets, since the mesh size of the fishing net is generally greater than 10 mm. The target size will be macro (25 mm – 1 m) and mega (> 1 m) plastic.

(B) Sampling at artificial barriers (e.g. ports, dams, hydropower plants)

The number and volume of plastic debris that is drifted or piled against artificial barriers are monitored. The method allows to know the volume of plastics drifted or accumulated at artificial barriers and to estimate riverine plastic flux at a fixed location. Plastic flux are estimated based on the consideration of the barrier's configuration, the collected frequency, and trap ratio, etc. The method requires collaboration with several stakeholders; thus, collaboration mechanisms with the administrators of ports, rivers and hydropower plants (HPPs) need to be considered.

This method is suitable for relatively larger accumulated plastic that can be caught by installed artificial barriers. The target size will be macro (25 mm – 1 m) and mega (> 1 m) plastic.

(C) Sampling by towing a net from a boat

Floating macroplastics are collected by a plankton net from a boat. Sampling from boats is the most common plastic sampling method in the open ocean. Accordingly, it is also recommended to collect riverine macroplastics samples by casting a net from a boat on the Mekong River. The greatest advantage of using boats is that it is possible to sample floating plastics at any safe location on a river and to estimate the riverine plastic flux, and without being limited to suitable bridges.

This method is suitable for smaller floating plastic that can be caught by a plankton net since the width of the plankton net usually smaller than 1 m.

2.2 Targets and definitions of macroplastics in this Protocol

(1) Size of macroplastics

In the field of marine debris monitoring, the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) introduces the following size range categories of plastic marine debris:

- Megaplastics (>1 m);
- Macroplastics (25 mm – 1 m);
- Mesoplastics (5–25 mm);
- Microplastics (<5 mm).

Regarding riverine debris monitoring, United Nations Environment Programme (UNEP) defines the same debris size range categories as the GESAMP ones above.

Therefore, it is recommended that the size of the riverine macroplastics to be monitored in the Lower Mekong River should be > 25 mm. The materials of macroplastics > 25 mm may be more easily identified by visual observation without using spectral optical instruments such as Fourier transform infrared spectroscopy (FTIR).

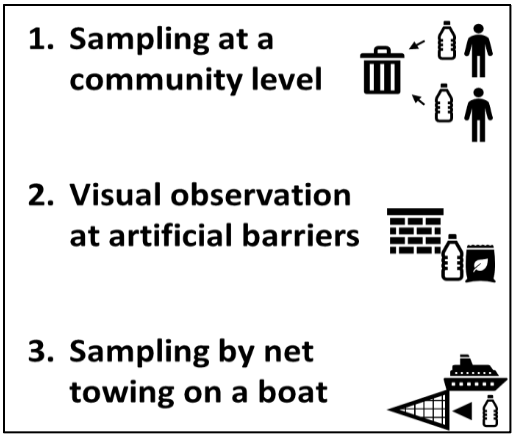
(2) Plastic product items

In order to obtain information about the sources, travel paths, potential sinks, consumer behaviour and waste management of plastics in freshwater systems, it is important to identify the composition of plastics. Plastics come in many different polymer types, such as polyethylene (PE), polypropylene (PP), polyester (PES), polyethylene terephthalate (PET), and polyvinyl chloride (PVC), etc. It is usually difficult to identify the composition of plastics from their polymer types with the naked eye in the field. Therefore, in this Protocol, it is recommended to identify the composition of plastics from their applications by product items, which is described in Section 4.3.

3. Summary of three survey methods

Protocol for monitoring riverine macroplastics consists of three survey methods, namely,

1. **Sampling at the community level:** The fishers collect the plastic debris that was captured during the daily fishing activities.
2. **Visual observation at artificial barriers:** The accumulation of debris at the fixed location (e.g. artificial barrier at ports/piers) is monitored by visual observation.
3. **Sampling by net towing on a boat:** The debris flowing in the river is sampled by towing a net on a vessel in the river.



Sampling by net towing on a boat

Below is a summary of the three sampling methods and of the respective equipment; each is detailed in the corresponding chapters: Chapter 4. *Sampling using a fishnet at the community level*, Chapter 5. *Visual observation at artificial barriers* (ports, dams, hydropower plants, etc.), and Chapter 6. *Sampling by net towing on a boat*.

Riverine macroplastics

(1) Sampling at the community level

Planning (see Chapter 4.1 Survey plan)

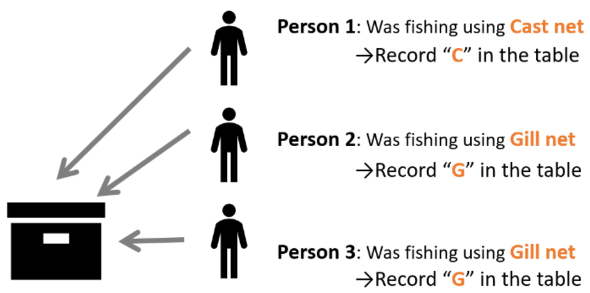
Timing and frequency	Once a month
Survey locations	To be decided in consultation with the fishery community

Sampling (see Chapter 4.2 Sampling method)

Collecting samples by fishers

- Collect the plastic debris that was captured in the daily fishing activity.
- Put the plastic debris into the collection box.
- On the field sampling datasheet, record the fishing gear in which the debris was captured, as shown on the right.

Example: on 9th September 2021



Date	Number of collected times and fishing method			No. of collected times
9th	C	G	G	3
①	②			③

Reporting (see Chapter 4.3 Summary of sample data)

Sample measuring by responsible line agencies

- At the end of the month, dry the samples collected in the box.
- Sort the collected debris into the group shown in the record form.
- Weigh and count the debris, and record these numbers in the reporting form.

No	Plastic Product Item	Total Piece (pieces)	Total Weight (kg)
MOST LIKELY FIND ITEMS:			
1	Food Wrappers (candy, chips, etc..)		
2	Take Out/Away Containers (Plastics)		
3	Take Out/Away Containers (Foam)		
4	Bottle Caps & Lids		

Necessary equipment

Items in Table 3.1 will allow for an efficient implementation of the survey.

Table 3.1 List of necessary equipment for riverine macroplastics sampling at the community level

Category	Group	Item
Sampling	Collection	Macroplastics collection box
	Sorting	Manual waste sorting equipment and apparatus (e.g. tongs)
	Weighing	Weighing scale (500 g)
		Weighing scale (1 kg)
	Storing	Large heavy duty plastic bags for storing and transporting collected macroplastics to disposal facilities
	Safety	Personal safety equipment (safety hats, goggles, a life vests, waterproof boots)
Recording	Sanitation	Hygienic supplies
		Plastic gloves
	Stationary	Pen
		Pencil

Riverine macroplastics

(2) Sampling at artificial barriers

Planning (see Chapter 5.1 Survey plan)

Timing and frequency Once a month

Survey locations

- To be decided in consultation with the port authorities, fishery communities, or river managers.

- Select an area where visual observation from a safe place is possible.
- Select a structure in the area that allows constant accumulation of debris (i.e. its structure does not change over time, the accumulated debris does not drift by departure and arrival of ships, etc.)

Measurement (see Chapter 5.2 Measurement method)

Measurement at artificial barriers

- **1st observation**: Take a photo of the structure to be observed. Record the location and characteristics for future reference.
- **2nd observation:** Return to the area that was selected in the 1st observation, since it is important to conduct monitoring at the same location. If this is not possible, choose another location and proceed as in the "1st observation" above.
- Measure the volume of accumulation by either (i) virtually filling up the garbage bags; or (ii) comparing it with benchmark photos.
- When virtually filling up the 20 L garbage bags, compare the accumulation with the benchmark photos in the protocol, which show the actual amount collected in a 20 L garbage bag. Then, estimate the total volume.
- Compare the density of the accumulated plastic debris with the benchmark photos in the protocol. Then, calculate the total volume using the proportional relationship.

Reporting (see Chapter 5.3 Summary of sample data)

- Estimate the rough number of debris for each type, and record it in the record form.

No	Plastic Product Item	Total Piece (pieces)
MOST LIKELY FIND ITEMS:		
1	Food Wrappers (candy, chips, etc..)	
2	Take Out/Away Containers (Plastics)	
3	Take Out/Away Containers (Foam)	
4	Bottle Caps & Lids	

Necessary equipment

- Items in Table 3.2 will allow for an efficient implementation of the survey.

Table 3.2 List of necessary equipment for riverine macroplastics sampling at artificial barriers

Category	Group	Item
Sampling	Safety	Personal safety equipment (one unit include: safety hat, google, life vest, water boot)
Recording	Measuring	Measuring tape (up to 100 m)
	Sanitation	Personal hygienic supplies
		Gloves
	Stationary	Logbook preparation and binding (one per type of fish gear)
		Pen
		Pencil

Riverine macroplastics

(3) Sampling by towing a net

Planning (see Chapter 5.1 Survey plan)

Timing and frequency

- Once in during the wet season and once during the dry season, avoiding events such as festivals.

Survey locations

- Select the location near the stations of ongoing monitoring programmes by the MRC.
- Select the locations according to the purpose of the monitoring.

Sampling (see Chapter 5.2 Sampling method)

Preparation (the day before sampling)

- Confirm that all the necessary equipment functions appropriately. Most importantly, mesh size of the net should be 4–5 mm.
- Make a final decision regarding the survey implementation day based on weather, and the availability of manpower and equipment.
- Conduct the safety check.

Equipping the net and the vessel

- Fasten a flowmeter to the lower net frame. Set the reading at 0.
- Attach the floaters to the side of the net.
- Fix the net to the pipe.

Towing a net

- Record the necessary data before, during, and after the towing.
- Start towing as close to the centre of the river as possible, considering safety as the priority.
- Make sure that the flow velocity is 0.5–1.5 m/s; if any faster, stop the boat with anchors and then start towing again.
- For neuston nets, less than 90% of the net should be immersed in the water (e.g. 50%, 75%).
- Keep the net submerged for the planned tow duration (time estimated to be required to collect 100 pieces of debris, or 20 minutes if there is no precedent survey).

Sample collection

- Haul the net slowly and lift it up. During and at the end of this process, wash the net from the outside to wash down the particles inside to the cod-end.
- Transfer the particles collected in the cod-end to the sample container by opening the outlet of the cod-end.
- Seal and store the container.
- Transfer the container to the laboratory.

Analysis (see Chapter 5.3 Analysis method)

Pre-treatment

- Sieve the sample with a stainless steel sieve (mesh size 22.4 mm).
- Isolate the possible macroplastic, then dry.
- Weigh and count according to the record form.

Reporting (see Chapter 5.4 Summary of sample data)

Metadata

- Make sure that all the necessary data are entered into the datasheet.

Record form

- Weigh and count the collected debris, and record the numbers in the reporting form.

Necessary equipment

Table 3.3 Necessary survey equipment for riverine macroplastics sampling by towing net

Category	Group	Item
Sampling	Ship equipment	4–5 mm mesh macroplastics tow net built in accordance with the specifications described in Toolbox 5 (x2)
		Floater (multiples)
		Sinker (multiples)
		Water pump (1)
		Nets
		Pipes for rigging the nets
		Ropes for pulling up the nets
	Measuring	Flowmeter (x2)
		GPS receiver (1)
	Storing	Sample container (multiple)
		Heavy duty bags
	Safety	Personal safety equipment (1 per staff taking part in the pilot)
	Sanitation	Plastic gloves and personal hygienic supply
	Stationary	Office supplies (logbook, printing paper, pen, etc.) and printing
		Cameras that can take photographs and videos (recommended).
Analysis	Analysis	Large stainless steel bowl (4)
		Stainless steel sieve with mesh size of 22.4 mm (4)
		Glass beaker (500 mL)
		Glass beaker (1,000 mL)
		Petri dish (diameter of 15 cm)
		Petri dish (diameter of 30 cm)
		Tweezers (2)
		Washing bottle (distilled water)
		Distilled water
	Safety	Personal safety equipment (1 per staff taking part in the pilot)
	Sanitation	Plastic gloves and personal hygienic supply
	Stationary	Office supplies (logbook, printing paper, pen, etc.) and printing.

- Items in Table 3.3 will enable the efficient implementation of the survey.

Sampling by fishing net at the community level

Plastics caught by fishers during fishing activities are counted. Provide the fishery community office with a collection box. Fishers need only put the collected plastic debris in the collection box and count them periodically. Plastics are collected through the several fishing methods and thus it is difficult to secure quantitative results in this method and to show the scientific validity for plastic pollution; however, the method allows to fully understand the basin-wide big-picture as long-term trends of riverine plastics. If this is carried out in many communities and the results shown in a map, it will be possible to identify plastic polluted areas. This would also contribute to river clean-up and awareness raising, especially if a ghost fishing net is collected by a fisher. Collecting plastic debris from the river can help clean it up, reduce the amount of plastics in the fish (products). Consumers can understand the safety of the fishery and the efforts of the fishers.

Any nets used by fishers at the community level can be used for collecting plastic samples. A community is selected as the sampling site. Collection boxes are placed at the community centre or the pier where fishers moor their boats. Fishers are requested to recover all plastic debris that is trapped by their fishing nets and put it into the collection boxes.

A record book is used for recording the number of fishers who put the plastics into the collection boxes.

The number and weight of plastic debris by product item in the collection boxes are counted and weighed once in a month.

The main stakeholders involved in the sampling by fishing nets may be the responsible line agencies, fishery communities, and local government.

The riverine macroplastics monitoring by fishing nets at the community level is conducted according to the following steps – planning, sampling, and reporting, as shown in Figure 4.1.

Planning (see Chapter 4.1 Survey plan)
✓ Timing and frequency
✓ Survey locations

Sampling (see Chapter 4.2 Sampling method)
✓ Collecting samples by fishers
✓ Measuring samples by the responsible line agency

Reporting (see Chapter 4.3 Summary of sample data)

Figure 3.1 Steps in riverine macroplastics monitoring using fishing nets, at the community

3.1 The objectives of the MRC Riverine Plastic Debris Pollution Monitoring Programme

The objectives of the MRC Riverine Plastic Debris Pollution Monitoring Programme are to assess the Basin-wide status and trends of plastic pollution, including both macroplastics (plastic debris larger than 5 mm in diameter) and microplastics (plastic debris smaller than 5 mm in diameter). The Programme also aims to gather information and knowledge to inform decision-making for effective and efficient management of riverine plastic pollution in the LMB as part of the MRC Water Quality Monitoring Network (WQMN).

The **MRC Riverine Plastic Debris Pollution Monitoring Programme** should cover riverine macroplastics, riverine microplastics and microplastics in fish, and will be developed based on the following approaches:

- **Pillar 1:** The protocol for riverine macroplastics monitoring should be undertaken annually at selected monitoring stations along the Mekong mainstream and its major tributaries in the four Member Countries by the relevant national research institutes or line ministries.
- **Pillar 2:** The protocol for riverine microplastics monitoring should be undertaken every five years at a smaller number of selected monitoring stations along the Mekong mainstream and its major tributaries in the four Member Countries by (i) relevant national research institutes or line ministries of the four Member Countries for sample collection in the field; and (ii) a qualified national laboratory in one of the Member Countries for laboratory analysis.
- **Pillar 3:** The protocol for microplastics monitoring in fish should be conducted every five years at a smaller number of selected monitoring stations along the Mekong mainstream and its major tributaries in the four Member Countries by (i) relevant national research institutes or line ministries of the four Member Countries for sample collection in the field; and (ii) a qualified national laboratory in one of the Member Countries for laboratory analysis.

Figure 4.2 provides an overview of the scope of the monitoring programme and monitoring protocols.

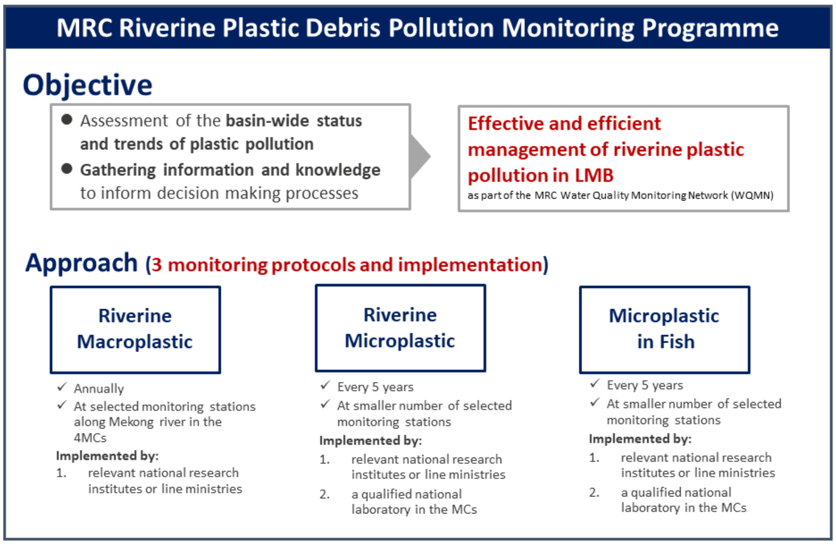


Figure 3.2 The scope of the monitoring programme and monitoring protocols

3.2 Survey plan

(1) Timing and frequency

Riverine plastic abundances can be highly variable over time due to river flow, inhomogeneous and /or random distribution or human activities. Thus, it is recommended that the plastic debris in the collection boxes be counted and weighed once a month in order to identify the fluctuation of the plastic abundance.

(2) Survey locations

The survey location should be selected in consultation with the fishery communities who are working cooperatively for the FADM programme. Although the fishery community may be selected following discussions with MRC fishery monitoring expert, potential criteria for choosing the survey location are as follows:

- two to three communities in each country (a larger fishing community would be better to collect enough samples);
- upstream, midstream and downstream in each country.

3.3 Sampling method

The following procedures describe how to collect a set of plastic samples by using a fishing net.

(A) The collection of samples by fishers

1) Cast a net. Any type of fishing net can be used.
2) Collect all plastic debris trapped in the net during fishing activities. Other natural substances such as wood chips and water weeds need not be collected.
3) After returning to the pier, transport the plastic debris and put all of it into the collection boxes.
4) Check in the record book as sample collector.

(B) The measuring of samples by the responsible line agencies

1) Measure the weight of the total plastic collected in a collection box. The weight should be the dry weight. If the samples are wet, wipe them as much as possible and note down that they are wet.
2) Separate the collected plastics by product item based on the record form (Table 4.2) described in following section.
3) Count the pieces and weigh each one.

3.4 Summary of sample data

(A) Field record book

Fishers use a riverine plastic debris record book (Table 4.1) to enter the date when they put the plastic debris larger than 25 mm into the collection boxes. At this time, the fisher is requested to write down the fishing net codes. The number of fishers who enter information into the record book could provide an indication of sampling effort. The cells in yellow must be filled in, but not necessarily are all the cells used in "Number of collection times and fishing method". For this method (sampling using a fishing net at the community level), more than one fisher can be engaged at each fishing community to support the sampling of riverine macroplastics during their routine fishing activities. In filling in the riverine plastic debris record book (Table 4.1), each fisher must fill out one code of fishing method per day, regardless of how many fishing events are carried out during the day. For example, if a fisher conducts a fishing activity in the morning and afternoon, he or she is required to enter data in the riverine plastic debris record book only once including the code of the fishing method for that day. However, if the fisher uses multiple fishing methods (e.g. a cast net in the morning and then a lift net in the afternoon), then he/she is required to enter data in the riverine plastic debris record book multiple times with codes corresponding to the fishing method used

Code	C	D	G	L	P	S
Fishing method	Cast net	Dai (bag net)	Gillnet	Lift net	Push net	Seine net

Table 3.4 The riverine plastic debris record book

Survey profile		Examples	Input
Name of community		Tokyo, Japan	
Location of the fishery community	**Latitude:**	35.6895	
	Longitude:	139.69171	
Survey date	**From:**	2021/11/16	
	To:	2021/11/21	

Survey results																		
Date	**Number of collection times and fishing method**																	**No. of collection times**
1st																		
2nd																		
3rd																		
4th																		
5th																		
6th																		
7th																		
8th																		
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19th																		
20th																		
21st																		
22nd																		
23rd																		
24th																		
25th																		
26th																		
27th																		
28th																		
29th																		
30th																		
31st																		
Total number of collection times (monthly frequency)																		0

(2) Summary of sample data

The responsible line agency counts and weighs the plastic samples collected in the collection boxes once a month, and then records the data, as described below. in order to obtain information about the composition of the plastic samples, it is recommended to identify them with the naked eye by their product items.

This method is affected by fishing efforts, so it is recommended to collect basic information on the fishing communities to facilitate the interpretation of the results. This basic information includes the number of fishers belonging to the community, the fishing area, and the total monthly fish catch, etc.

1) Summary of the data recorded by the responsible line agency

In order to obtain information on the composition of plastic samples, it is recommended to identify the samples by their product items, as described in Table 4.2. In addition, the total pieces and total weight of the samples by product item will be recorded.

Table 3.5 Record form on plastic product items, number and weight

No.	Plastic product item	Total number of pieces	Total weight (kg)
Most common items			
1	Food wrappers (candy, chips, etc.)		
2	Takeout/away containers (plastic)		
3	Takeout/away containers (foam)		
4	Bottle caps and lids		
5	Straws/stirrers		
6	Forks, knives and spoons		
7	Beverage bottles (plastic)		
8	Grocery bags (plastic)		
9	Plastic woven bags		
10	Other plastic bags		
11	Cups and plates (plastic)		
12	Cups and plates (foam)		
Packaging materials			
13	4-/6-pack holders		
14	Other plastic or foam packaging		
15	Other plastic bottles (oil, bleach, etc.)		
16	Strapping bands		
Fishing gear			
17	Fishing buoys, pots and traps		
18	Fishing net and pieces		
19	Fishing line (1 yard/metre = 1 piece)		
20	Rope (1 yard/metre = 1 piece)		
Other trash			
21	Appliances (refrigerators, washers, etc.)		
22	E-waste		
23	Cigarette butts/tips		
24	Construction materials		

25	Fireworks		
26	Tires		
27	Other plastic material (specify:)		
Personal hygiene			
28	Condoms		
29	Diapers		
30	Medical items (e.g. syringes)		
31	Tampons/tampon applicators		
32	Cotton bud sticks		
Very small trash less than 2.5cm			
33	Foam pieces		
34	Plastic pieces		

4. Visual observation at artificial barriers (ports, dams, hydropower plants, etc.)

The number and volume of plastic debris that drifted to or piled against artificial barriers are monitored. This method allows to understand the volume and item of plastics drifted to or pilled against artificial barriers and to estimate riverine plastic flux at a fixed location. Plastic flux is estimated by considering the configuration of the barrier, collection frequency, and trap ratio, etc. The method requires collaboration with several stakeholders, hence collaboration mechanisms with administrators of port, river, and hydropower plants (HPPs) need to be considered.

The major stakeholders engaged in visual observation at artificial barriers may include responsible line agencies, municipalities, irrigation departments, the port authorities, marine departments, private sectors (port operation), and local governments.

Riverine macroplastics monitoring by visual observation at artificial barriers is conducted according to the following steps of planning, sampling, and reporting, as shown in Figure 5.1.

Planning (see Chapter 5.1 Survey plan)
✓Timing and frequency
✓Survey locations

Sampling (see Chapter 5.2 Observation method)
✓Visual observation at artificial barriers

Reporting (see Chapter 5.3 Summary of sample data)
✓Record form
✓Estimating the total annual riverine macroplastics flux

Figure 4.1 Flow of riverine macroplastics monitoring by sampling at artificial barriers

4.1 Survey plan

(1) Timing and frequency

The survey is conducted in line with the periodical clean-up activities carried out by the manager of each target structure. In order to fully understand the area and volume change of plastics, it is recommended to conduct continuous surveys throughout the entire monitoring period.

(2) Survey locations

It is highly recommended to select the locations where periodical clean-up activities are conducted since the collection of accumulated debris at an artificial barrier is challenging.

Potential criteria to select locations of artificial barriers are as follows:

- two to three operational commercial and/or passenger ports that have permanent landing structures and/or other artificial barriers in each country;
- located near or in close proximity to the location of the MRC environmental monitoring stations (water quality, hydrological, sediment, fisheries, or/and ecological health) and have the potential to be considered as future monitoring stations;
- upstream, midstream, and downstream in each country;
- dams, dykes, weirs, water gates, and flood gates, which extend along the entire cross-section of the river would be preferable in order to effectively to collect plastics;
- artificial barriers whose maintenance and clean-up activities are carried out by irrigation departments or river managers.

According to the *Assessment of Plastic Waste Leakage/Accumulation at Ports/Piers and their Effects on Freshwater Fauna of the Mekong River Basin: A Research Plan* (MRC, 2021) the 12 most suitable ports/piers (three in each Member Countries) were selected as the study sites for assessing plastic waste leakage/accumulation. These 12 ports/piers can be selected as candidate monitoring locations in this protocol (Table 5.1). It should be noted that for long-term monitoring, the selected location will need to be properly surveyed in order to ensure that data collection through visual inspection can be carried out without any obstruction and/or hindrance in both the wet and dry season.

Ideal monitoring location

the ideal locations must meet the following criteria:

- ✓ a location where visual observation from a safe place is possible;
- ✓ a location that has a structure in the area that allows constant accumulation of debris (i.e. its structure does not change over time, the accumulated debris does not drift by departure and arrival of ships).

Figure 4.2 Example of structure that allows constant accumulation

By monitoring at these locations, it will be possible to monitor the change in the volume of accumulation over time. It can also help calculate the flux of riverine plastic debris.

Table 4.1 A summary of the 12 ports/piers selected as potential monitoring locations

No	Ports	Location	Stakeholder	Scheduled clean-up activities	Remarks
Lao PDR					
1	Pak Beng Port	172 km from a central market in Oudomxay Province	N/A	N/A	The port has a 5-tonne lifting truck. Most cargo operations are carried out using manual labour. It is used for importing and exporting agriculture products as well as passengers and tourist services.
2	Luang Prabang Port	702 km from Jinghong port (PRC) and 357 km from Chiang Saen Port (Thailand).	N/A	N/A	New port with concrete embankment
3	Vientiane – Laksi Port	In Vientiane Capital	N/A	N/A	The main types of cargo are: construction materials, agricultural products, and timber.
Thailand					
1	Chiang Saen Port	On the bank of the Mekong River in Chiang Saen District	(1) Port authority (2) Private contractor	Daily routine clean-up Bi-annual. event-based clean-up	The port has one mobile crane with a capacity of 50 tonnes and a conveyor belt for loading/discharging cargo to and from ships. It provides both cargo and passenger services.
2	Nakorn Phanom	On the bank of the Mekong River at the City of Nakhon Phanom about 6 km downstream of Lao-Thai Friendship Bridge 3	(1) Municipality (2) Private contractor	Twice daily routine clean-up Yearly event-based clean-up Monthly unscheduled clean-up	Prior to the completion of the Lao-Thai Friendship Bridge #3, the pier was for both cargo and passenger transport to and from Thakhek, Lao PDR. Now it is used mainly by tourists for sightseeing.
3	Chiang Kong Port	Serves small ships and ferries from Lao PDR	(1) Port Authority (2) Municipality	N/A	No facilities to load or discharges vessels but equipped with a quayside terminal (24 m x 108 m).

Cambodia					
1	Phnom Penh Passenger Port	Sisowath Quay Boulevard, at the riverfront	(1) Municipality (2) Seth Bo Cruise	N/A	There are two floating pontoons of 15 m x 45 m.
2	Kratie Port	220 km upstream from Phnom Penh	N/A	N/A	35-m long pontoon, used only in the rainy season.
3	Kompong Cham Port (Tonlé Bet)	Located in Kompong Cham province, a 10-m long pontoon for barges	N/A	N/A	There is also a warehouse with a covered area of 550 m2, has a capacity of about 600 tonnes.
Viet Nam					
1	Dong Thap Port	Located on the Mekong River near Cao Lanh City	(1)Tan Cang Waterway Transport JSC – Dong Thap Branch (2) Urban Environment Limited Company	Weekly event-based collection	A river port handling containers and general cargo. There is a bulk terminal in the northern port. Equipped with a 70-m long wharf and can handle vessels of 3,000 DWT. The total ground area of the port is over 2.7 ha, including warehouses and container yards.
2	Can Tho City Port	Situated 6 km downstream of the new bridge of Can Tho	(1) Can Tho Port Joint Stock Company (2) Urban Environment Limited Company	Daily routine collection	The port area is 400 m x 300 m with two warehouses and an administration building.
3	My Tho Port	Located in the Mekong River in the City of My Tho, Tien Giang Province.	(1) My Tho Port Joint Stock Company (2) Urban Environment Limited Company	N/A	The port provides commercial and tourist services.

4.2 Observation method

This observation method mainly consists of three steps:

- finding a barrier to monitor;
- estimating and recording the amount of accumulation, either by (a) virtually filling up the garbage bags, or (b) comparing with benchmark photos);
- recording the rough composition.

Finding an object to monitor

When there are no precedent surveys, i.e. it is the first time of the monitoring at the artificial barrier:

- take photos of the structure to be observed;
- record the location and characteristics, and save the photos for future reference in the datasheet. Also, sketch the object that was observed (Table 5.2). The cells in yellow must be filled in.

Table 4.2 Form for recording the location and characteristics of the barrier

	20 L bag	Benchmark photos
Name of artificial barrier		
Agency responsible for maintenance/clean-up		
Last cleaning was conducted on _______________		
Location of barrier (latitude)		
Location of barrier (longitude)		
Date		
Time		
Characteristics of the barrier		
Total accumulation volume [L] (This is automatically calculated after entering the necessary data in other forms.)		
Sketch of the observed area (photo of hand-drawn sketch, PPT file, etc.)		
Photos (at least 3 from various directions)		

Source: MRC (2021)

For the second observation:

- find the area that was established in the 1st observation since it is important to conduct monitoring at the same location to see changes over time. If this is not possible, choose another location and follow the steps of the "First observation" above;
- take photos of the structure to be observed;
- record the location and characteristics for future reference in the datasheet. The cells in yellow must be filled in.

Estimating the amount of accumulation

a) Visually filling up the 20 L garbage bags
b) Using sample photographs and tables showing the examples, determine the amount of plastic debris that fits into one 20 L capacity garbage bag (Figure 5.3 and Figure 5.4, and Table 5.3).

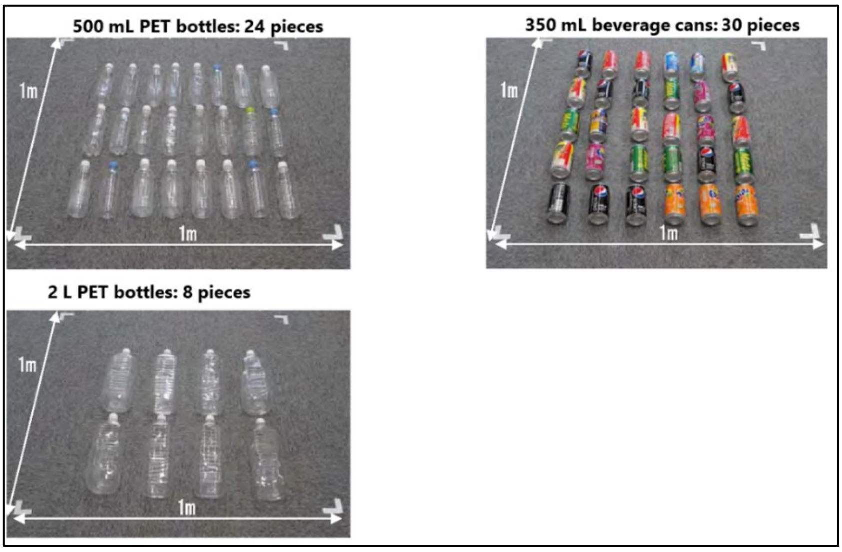


Figure 4.3 Example of debris that can be contained in a 20 L garbage bag
Source: Japanese Ministry of Land, Infrastructure, Transport and Tourism (2012)

Figure 4.4 Example of debris that was collected in a 20 L garbage bag
Source: Japanese Ministry of Land, Infrastructure Transport and Tourism (2012)

Table 4.3 Example of contents in garbage bags

Number of 20-L garbage bags [piece]	Example of contents	Volume [L]
0	No debris	0
0.25	Two 2 L PET bottles	5
0.5	Four 2 L PET bottled or Fifteen 350 mL beverage cans	10
1	Eight 2 L PET bottles or Thirty350 mL beverage can	20
2	Sixteen 2 L PET bottled	40
4	Thirty-two 2 L PET bottles or Three boxes of cardboard boxes	80
8	Amount of a steel drum for containing oil	160
64	Amount in almost 1 m (1 m in length, width, and height)	1,280
128	Amount in a mini-sized truck	2,560

Source: Japanese Ministry of Land, Infrastructure Transport and Tourism (2012)

a. Count the plastic debris in a part of the accumulated volume (if possible, all of it) and then calculate the number of 20-L garbage bags that it could fit into. Record this number in the "Number of 20 L garbage bags" in the record form (Table 4.4).

Table 4.4 Record form based on the visual filling up of 20-L garbage bags

	Value	Accumulation volume [L]
Number of 20-L garbage bags	3	60
Percentage of the area observed [%]	10%	-
Total accumulation volume [L]		**600**

b. Examine the accumulation at the barrier from one end to the other and record the percentage of the total volume counted under "Percentage of the area observed" in the record form (Table 4.4).
c. By entering the number and the percentages in a and b, the total amount of plastic accumulation is automatically calculated (Table 4.4).

2) Comparison with the benchmark photos

a. Observe the site and rank the "level of plastic accumulation", which will provide the rough density of plastic debris in accumulation. This can be achieved by comparing the benchmark photos that show the examples (Figure 5.5) and the actual accumulation. If the level of plastic accumulation differs within the site, divide the site into several transects.

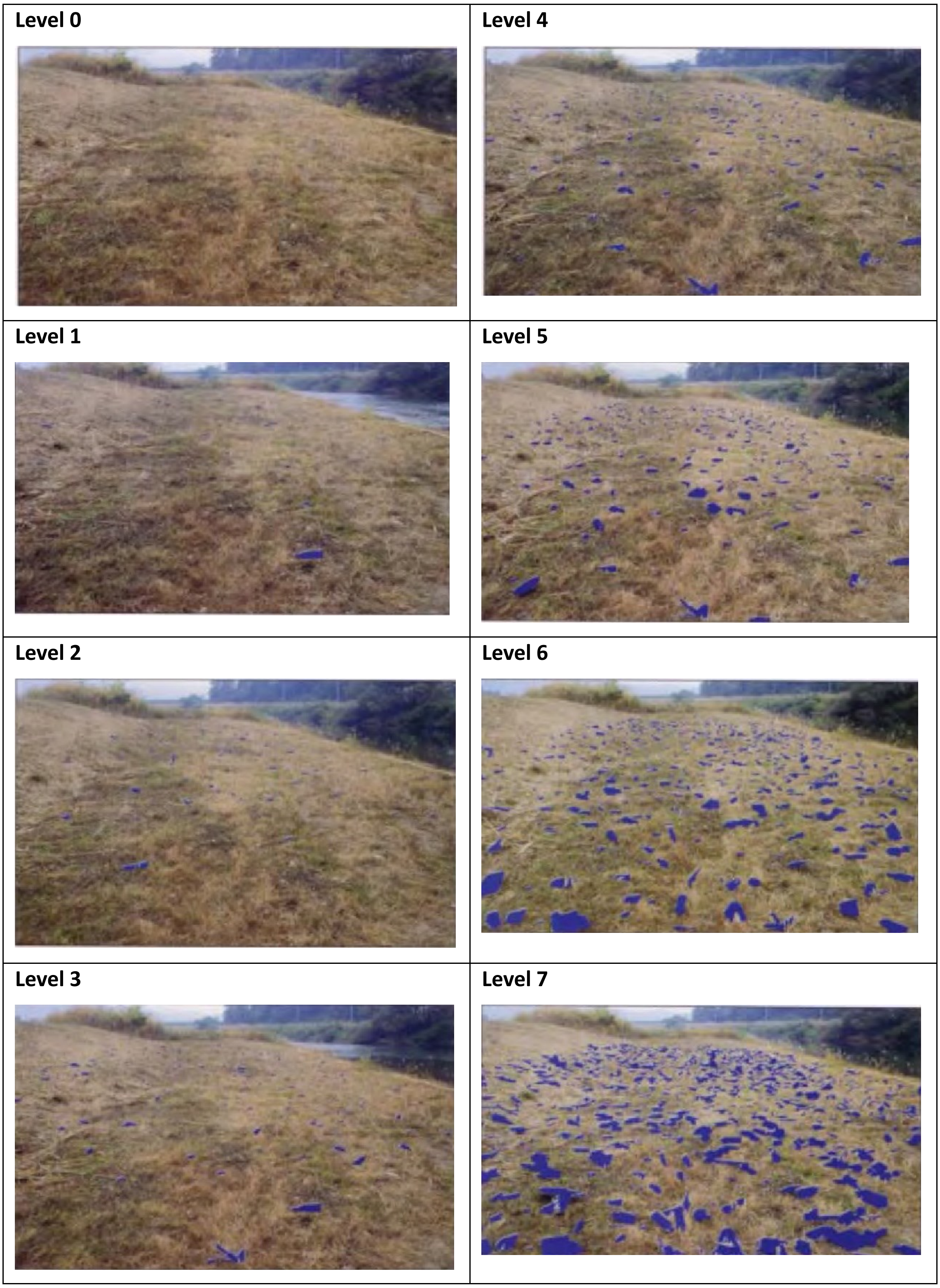


Figure 4.5 Benchmark photos for recording the level of plastic accumulation

Note: Items in blue represent plastic accumulation
Source: Japanese Ministry of Land, Infrastructure Transport and Tourism (2012)

b. For each transect, record the level of plastic accumulation and the corresponding area for each transect under "level of plastic accumulation" and "area of accumulation" in the yellow cells of the record form (Table 5.5). Transect IDs are automatically inserted in the record form, and the accumulated volume each transect and their sum are automatically calculated.

Table 4.5 Record form for comparing with benchmark photos

Transect ID (For the convenience in counting, you can split the area)	**Level of plastic accumulation**	**Area of accumulation [m^2]**	**Accumulation volume [L]**
1	1	1	0.05
2	2	1	0.1
SUM [L]			**0.15**
Percentage of the area observed [%]			**10%**
Total accumulation volume [L]			**1.5**

c. Observe the overall accumulation of the object from one end to the other, and record the percentage of the total volume estimated under "Percentage of the area observed" in the record form (Table 5.5).

Recording the rough composition

In the yellow cells of the record form, record the approximate number of the plastic debris. Unlike other method of monitoring riverine macroplastics, it is not necessary to weigh the debris.

Table 4.6 Record form for the composition of plastic items (partial)

No.	Plastic product item	Total piece (pieces)
MOST LIKELY TO FIND ITEMS:		
1	Food Wrappers (candy, chips, etc.)	
2	Take Out/Away Containers (plastic)	
3	Take Out/Away Containers (foam)	
4	Bottle Caps and Lids	
5	Straws/ Stirrers	
6	Forks, Knives, Spoons	
7	Beverage Bottles (Plastic)	
8	Grocery Bags (Plastic)	
9	Plastic woven bags	
10	Other Plastic Bags	
11	Cups and Plates (Plastic)	
12	Cups and Plates (Foam)	
PACKING MATERIALS:		
13	Other Plastic/Foam Packaging	
14	Other Plastic Bottles (oil, bleach, etc.)	
15	Strapping Bands	

5. Sampling by net towing on a boat

This section describes how to collect floating macroplastics samples by a plankton net from a boat.

Sampling from boats is the most common plastic sampling method in the open ocean. Hence, it is recommended to collect riverine macroplastics samples by deploying a net from a boat on the Mekong River. The greatest advantage of using boats is to be able to sample actual floating plastics at any safe locations on a river and to estimate riverine plastic flux, and without being limited to suitable bridges.

The main stakeholders engaged with sampling by net towing may include responsible line agencies, fishers, and analytical institutions.

Riverine macroplastics monitoring by net towing is conducted according to the steps of planning, sampling, analysis and reporting, as shown in Figure 6.1.

Planning (see Chapter 6.1 Survey plan)
✓Timing and frequency
✓Survey locations

Sampling (see Chapter 6.2 Sampling method)
✓Outline
✓Equipment used for sampling
✓Preparation
✓Towing a net
✓Sample collection

Analysis (see Chapter 6.3 Analysis method)
✓Pre-treatment
✓Obtaining information

Reporting (see Chapter 6.4 Summary of sample data)

Figure 5.1 Steps of riverine macroplastics monitoring by net towing

5.1 Survey plan

(1) Timing and frequency

Riverine plastic abundances can be highly variable over time due to river flow, inhomogeneous/random distribution, or human activities (Figure 6.2). Thus, it is recommended to focus on relatively frequent and long-term monitoring as follows:

- Both in rainy and dry seasons indicating the average river conditions for each, conduct monitoring more than once in each season per year.
- If the purpose is to fully understand the pollution trend, monitoring should be conducted every year.

- Monitoring during events such as festivals should be avoided, because there may be increased littering around the riverside.
- At the beginning of the rainy season, a larger amount of riverine debris than usual may be observed since the wastes accumulated on the riverbanks during the dry season may be washed away and run off.
- It may be more efficient to combine with other methods introduced in Chapters 3 and 4, or to conduct frequent surveys (at least once a month) in the first year (or in a pilot survey) to fully understand the seasonal trend of riverine debris in a year. The seasonal trend is useful to decide an appropriate survey time and frequency in order to fully understand the peak/base of macroplastics leakage.

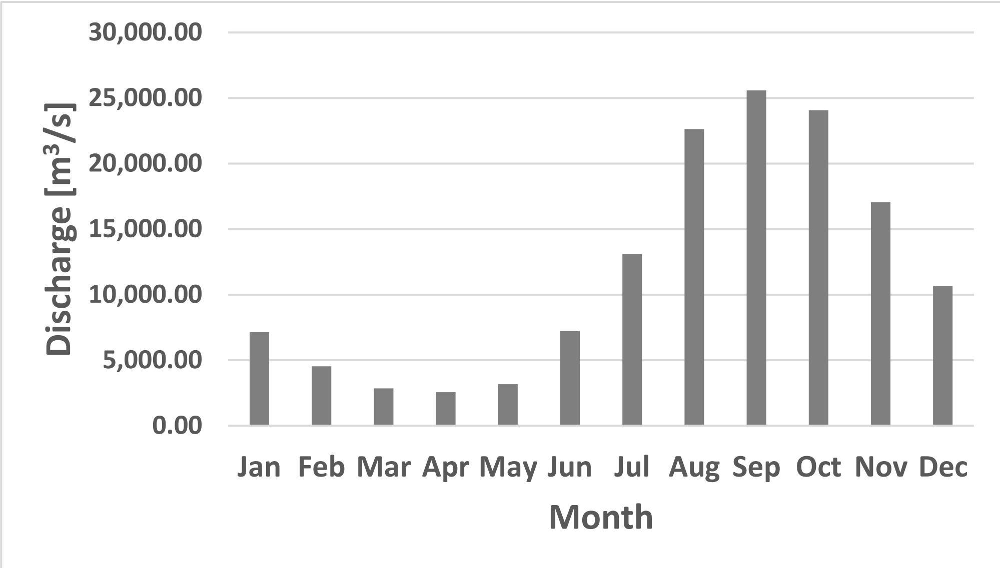


Figure 5.2 Mean monthly discharge at Than Chau (Mekong) and Chau Doc (Bassac) in Viet Nam

(2) Survey locations

Survey locations should be chosen according to the purpose of the monitoring. Survey locations are recommended to be selected among ongoing MRC monitoring programmes, including WQMN monitoring (Figure 6.3). Also, it is recommended to select the same points at which other riverine plastic debris pollution monitoring programmes are implemented. This allows efficient use of resources and available metadata (e. g. water quality, river discharge, fish populations).

Potential selection criteria are as follows:

- located upstream, midstream, and downstream in each country;
- presence of nearby water intake for municipal water supply or industrial supply;
- a major fishing location;
- upstream of confluence points;
- downstream of confluence points (i.e. the location where mainstream water and tributary water are well mixed);
- downstream of major cities or industrial areas;
- key tributaries of the Mekong River to facilitate the identification of leakage sources;
- upstream of diversion points;

- the centre of the river stream (river current near riverbank tends to slow down and thus macroplastics tend to be accumulated and settled);
- in the estuary area, the sample should be taken at ebb or low tide. Estuaries are subject to complex flow dynamics, as they are influenced by both the tide and the freshwater discharge, which in turn influence plastic transport and export into the ocean. It is recommended to take into account the complex dynamics in the estuaries. It is also recommended to select a location upstream of the deltaic section of the river.

From the areas that meet the above criteria, survey locations should be chosen according to the survey objectives such as:

- To fully understand the pollution source: downstream of major cities and industrial areas should be chosen.
- To evaluate impact on water quality and fish species: upstream of water intake and at fishing location should be chosen.
- To estimate plastic flux with transboundary impact: upstream, midstream, and downstream in each country, and near the confluence and diversion points should be chosen.

In riverine macroplastics monitoring, survey sites shall be selected from "upstream of water intake" sites as per the MRC monitoring programmes, with a view to preventing impacts on human health and ecosystems. To be specific, based on the results of water quality surveys, sites where pollution is of particular concern and sites where analysis of riverine microplastics and microplastics in fish will be facilitated should be chosen.

Where in the survey location must sampling be carried out?
On selected survey locations, the tow starting point should be chosen as near the centre of the river as possible to collect the data that represent its regional characteristics.

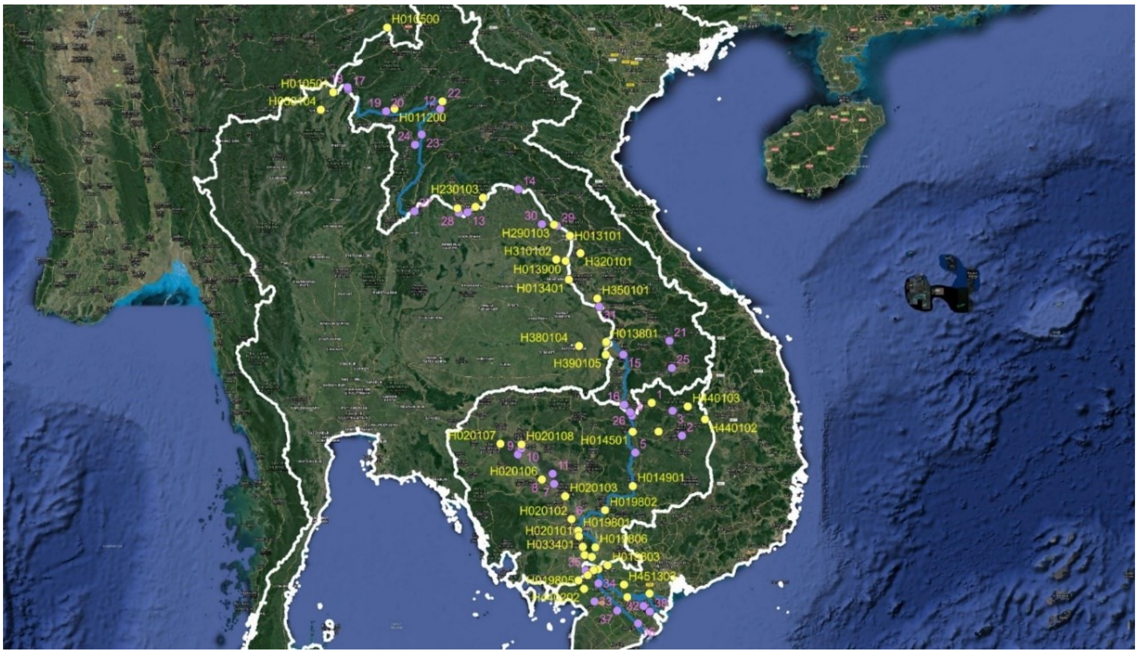


Figure 5.3 Monitoring stations and locations in the Mekong River
Note: The selected monitoring location for the tow net method should be surveyed and investigated prior to long-term monitoring for year-round representation, accessibility, and safety.

5.2 Sampling method

This chapter discusses the following five sampling components:

- **the outline of the sampling procedures,** which summarizes the overall procedures to be followed on the vessel, and how to measure the collected samples;
- the equipment necessary for sampling that are to be prepared before the survey;
- the preparation of equipment and the safety check;
- the towing process to be followed on the vessel; and
- the process of collecting samples from the towed net and transferring them to the laboratories.

Outline of sampling procedures

The following two points, (1) collecting samples and (2) measuring samples, explain the general outline of procedures in collecting samples on the boat, and measuring samples after collection.

(1) Collecting samples

The following procedures describe how to collect one set of plastic samples by deploying a net from a boat.

The tow starting point should be chosen as near the centre of the river as possible to collect the data that represent its regional characteristics.

1) Fasten a flowmeter to the lower net frame (Figure 6.4). Set the reading of the flowmeter at 0.

Flowmeter (RIGO No. 5571)

Neuston net with flowmeter

Figure 5.4 A flowmeter (left) and a net with a flowmeter and floaters (right)

2) Attach the net to the floaters.
3) Fix the net to the pipes.
4) Lower the net until the upper net frame submerges under the river surface. After the

net submerges, record the sampling start time.
5) Keep the net submerged for the planned tow duration (i.e. estimated time required to collect 100 pieces of debris, or 20 minutes if there is no precedent survey).
6) Lift up the net and record the sampling end time. Record the readings of the flowmeter.
7) Collect all debris from the net and separate the debris into plastic samples and non-plastic debris manually.

(*Note: If it is difficult to separate plastic samples from non-plastic debris manually by visual observation, it is recommended to conduct density separation with solutions in a laboratory.*)

8) Put the plastic samples in a container.

(2) Measuring samples

1) Pieces of plastics
Count all numbers of plastic samples by plastic product item shown in Table 4.2 and record the data.
2) Total weight of plastics
Measure the total weight of the dried plastic samples by plastic product item shown Table 4.2 and record the data.

Equipment

(1) Sampling vessel

A sampling vessel should have a device to equip a net at the bow. This is to avoid any disturbances from undertows from the boat. When using a boat other than a research vessel, such as a fishing boat, some outfitting is required to equip a net at the bow (Figure 6.5)

The sampling vessel must be able to continue towing stably at the speed of 1–2 knots in the intended direction despite any load potentially caused by net clogging. *(Also, vessel speed may be adjusted accordingly when towing from the downstream side to the upstream side against the river flow.)*

Furthermore, when multiple collections are conducted continuously with one net or it is deemed inadequate to continue the collection due to net clogging during towing, the boat should have a workspace for washing the net and collecting samples.

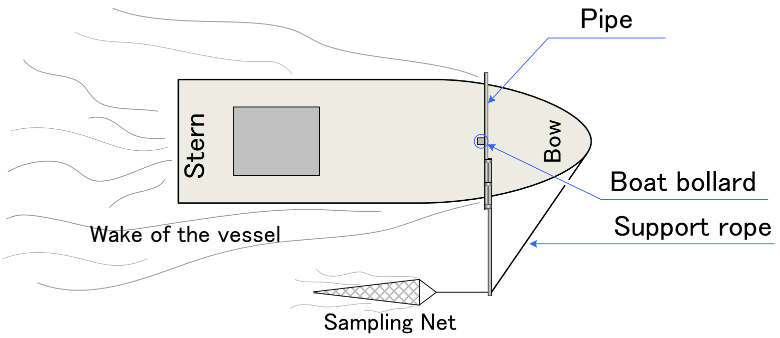


Figure 5.5 Towing a net from a boat

For a small fishing boat requiring outfitting, the following points should be noted to avoid damaging the boom when towing a net from the side:

a) Set an adequate length of the outfitting pipe to keep the net close to the body of the vessel. Also, in order to avoid impact from undertows, the pipe equipped on the side should be as close as possible to the bow. This is also effective for prevention of contamination.
b) The pipe should be fixed at a safe and stable location where the vessel strength is high such as boat bollards.
c) In order to prevent damage to the mounting hardware, stabilize the edges of the pipe by tension using support ropes.

Figure 5.6 Towing a net from boat in survey on plastic waste in the Ayeyarwady

Source: Survey on Plastic Waste in the Ayeyarwady, 2018–2019

(2) Sampling nets

a) Net size

It is recommended to use a suitable net (not exceeding 1 m in height or width), taking into consideration of vessel/boat size. Small nets may simplify the work on board a ship but will require more trawling time in order to filtrate the necessary amount of water. Also, longer trawling time means more clogging, which would lead to more net washing during trawling. As such, it is necessary to choose a net of adequate size according to the conditions of the sampling sites as well as the size of the survey boats used.

Note

Net dimensions are crucial variables that influence results. This includes the height and depth of the frame, how deeply the frame is submerged, net length and net mesh size. Height and depth determine the sampling area of the net, which in turn determines the maximum size of the debris that can be sampled. Choosing a net opening is always a balance between sample size and the effort required to operate the net (Figure 6.7). Generally, macroplastics sampling nets tend not to exceed 1 m in height or width. Examples of nets used include 1.0 m^2 x 0.5 m^2 (Saigon, Viet Nam; van Emmerik et al., 2018), 0.67 m^2 x 0.5 m^2 (Jakarta waterways, Indonesia; van Emmerik et al., 2019), 0.6 m^2 x 0.3 m^2 and 0.6 m^2 x 0.6 m^2 (the Danube, Austria; Hohenblum et al., 2015), 0.5 m^2 x 0.15 m^2 (the River Tamar, United Kingdom; Sadri and Thompson, 2014), and 0.27 m^2 x 0.105 m^2 (Chilean rivers; Rech et al., 2014) (UNEP).

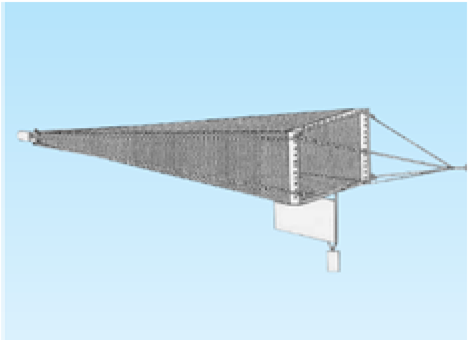


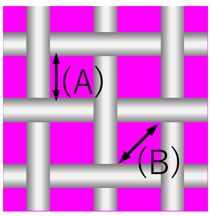
Figure 5.7 An example of a Neuston net

Source: Rigo (2020)

b) Mesh openings

It is recommended to use mesh openings of 4 mm to 5 mm since this influences the lower size limit of items that can be collected. Mesh sizes used for macroplastics debris reported in the literature range between 300 µm (Sadri and Thompson, 2014) and 4 cm (van Emmerik et al., 2018) Choosing the best mesh size, as in the case of other variables, is an iterative process. Harmonization of the mesh sizes used is recommended, although there are often practical reasons to select another size. It is most important that the mesh size used is clearly reported, so that the results can be interpreted consistently (UNEP, 2020).

The mesh opening as used in this protocol is expressed as the side length of a quadrangle separated by mesh thread and through which water passes – i.e. (A) in the figure below. However, in some cases, the length of the diagonal line – i.e. (B) in the figure below – is used as the mesh opening. The researcher should confirm and record the type of mesh opening before the survey.



(3) Flowmeter

Macroplastics abundance is reported as particle number or weight per unit water volume or unit surface area.

The plastic concentration Cp (kg/m^3) can be calculated using:

$$C_P = \frac{M_P}{V}$$

$$V = Q \cdot t = A_n \cdot u \cdot t$$

with collected plastic mass Mp (kg), sampled water volume V (m^3), river discharge at sampling net Q (m^3/s), sampling net opening An (m^2), flow velocity u (m/s) and sampling duration t (s) (UNEP).

Filtered water volume or area is obtained by multiplying the tow distance by the filtered area (net width x net immersion depth). It is advisable to use a flowmeter for calculating tow distances.

When using a flowmeter, it is necessary to select a model that can accurately measure the filtered water distances at different towing speeds. In addition, it is important to ensure that the measurement can be conducted accurately at the towing speeds which were planned before the towing.

(4) Cleaning equipment

After towing, smaller samples in the net should be washed down to the cod-end using water from outside. A pump would make this process easier (Figure 6.8).

If a pump is not available, it would be effective to use a bucket or tub that is large enough in which to put the net from its cod-end to the net mouth. Soak the net from the cod-end side to the net mouth and push the collected samples down to the cod-end using water from outside as the net is raised slowly.

Figure 5.8 Net washing (left) and pump (right)

(5) Sample collection containers

In order to prevent pollution, it is advisable to use sample collection containers made of non-plastic materials. If plastic containers must be used, it is recommended to use new ones because old ones may be damaged by deterioration and could contaminate the samples. The sampling location, sampling date, and the serial number of the sample should be written on the container with a waterproof method before conducting sampling (Figure 6.9). When the mouth of the container is smaller than the outlet of the cod-end, a funnel with the inlet larger than the outlet of the cod-end should be used in order to avoid dissipation of samples.

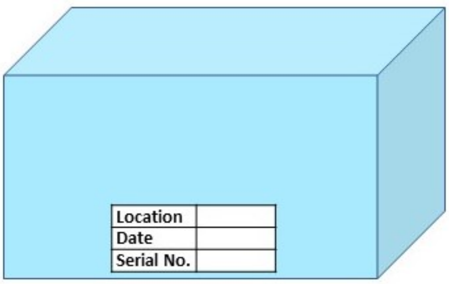


Figure 5.9 A label attached at a sample collection container

(6) GPS receiver

The start and the end point during towing are the most primary information obtained through a survey. Whether or not the amount of filtered water is measured as the distance recorded by a flowmeter or as the total tow distance obtained from the vessel speed relative to the ground speed, a GPS receiver will be necessary to record these two points during towing.

Preparation

(1) Preparing equipment

The day before sampling, all sampling equipment should be in place and their functions checked. Table 6.1 lists the major equipment to prepare.

Table 5.1 Major equipment used for sampling by net towing on a boat

No.	Major Equipment	Piece	Note
1	Net	2	
2	Floater	Multiple	For stabilizing immersed net
3	Sinker	Multiple	For stabilizing immersed net
4	Flowmeter	2	
5	Pump	1	
6	Sample container	Multiple	
7	GPS receiver	1	
8			
9			
10			

For the nets, particular attention should be paid to detect any tear in the texture and damage to the net mouth and the cod-end.

Any equipment such as nets and sample containers that may come in contact with the samples collected should be washed thoroughly and stored, avoiding any contamination.

Every item of the equipment used shall be assigned a serial number, which should be displayed on the equipment.

(2) Final decision on the day of survey

Consideration must be made on whether the survey may go ahead based on the forecast of weather and river conditions on the sampling day. In addition, the full availability of manpower and equipment should be confirmed, before deciding to proceed with the sampling.

(3) Safety check

Before boarding, the conditions of safety equipment such as life jackets and helmets should be checked, and the schedule for the day should be communicated to all onboard.

Safety guidelines in Standard Sampling Procedures for Fish Abundance and Diversity Monitoring in the Lower Mekong Basin (Ngor et al., 2016)

(1) Boats

The boat safety checklist should to be completed prior to departure for sampling. In particular and as for all small-boat use:

- ✓ No smoking is allowed on the boat.
- ✓ All personnel must wear full lifejackets at all times.
- ✓ Boat drivers must be briefed on safety issues and requested not to smoke, to be considerate of other people on the water and to watch out for submerged nets and obstructions.
- ✓ All crew must watch for overhanging branches and inform others when there is any possibility of injury.
- ✓ The driver must avoid rapid acceleration or deceleration while setting nets.
- ✓ No more than one extra person (e.g. observer) may be on board while sampling, and this person must be briefed by the supervisor, must wear the safety equipment, and must stay near the rear of the boat.

(2) Protective clothing

- ✓ All personnel must wear safety boots or shoes to protect their feet from any dropped nets, containers, or other items.
- ✓ All personnel must wear hard-hats to protect against tree branches
- ✓ All personnel must wear sunglasses to reduce the effect of surface glare on the water and also to protect against branches and net-handles.
- ✓ Personnel may wear gloves if required.

(3) First Aid

- ✓ At least one person in the sampling team must have completed First Aid and CPR training.
- ✓ There must be a full First Aid Kit on the boat.

Towing a net

The following method explains net towing by boat. It is recommended to use a boat moored by anchors at a fixed location if towing is difficult.

(1) Towing steps

The tow starting point should be chosen as near the centre of the river as possible in order to collect the data which represent its regional characteristics.

Upon reaching the tow starting point, the serial numbers of the net used for towing, and the flowmeter and other equipment should be recorded in the field book.

Towing should begin by dropping the net gently on the water surface. Gradually increase the vessel speed while making sure that the towing is smooth by checking that the alignment is orderly from the net's mouth to the cod-end and that the net immersion depth is stable at the pre-determined depth. Upon reaching a pre-determined vessel speed, continue to tow at a certain speed and monitor the floating substances in the net and on the water surface.

What if the net is clogged?

When the net gets clogged during towing, find its cause lifting it up, and either collect the samples, or change the net and resume the towing.

Once the planned towing duration has been reached (excluding the disruption time), lift up the net slowly.

What If the net rotates?

Install floats of appropriate size on both sides of the net opening and weights of appropriate size at the bottom of the net opening.

Also, it can be assumed that the towing speed is high. Tow the net at a speed of about 1.5 m/s relative to the river water.

(2) Towing speed/duration

Measure the flow velocity before towing the net. If the speed of the current is up to about 2 m/s, stop the boat and start sampling. If the current speed is higher than this, consider changing the sampling location. It is suggested by the literature on marine surveys that towing should be conducted at the speed of 0.5–1.5 m/s; if any faster, the water is not properly filtered and may flow backwards through the net mouth.

Keep the net submerged for the planned tow duration (i.e. estimated time required to collect 100 pieces of debris, or 20 minutes if there is no precedent survey).

Options in deciding on the sampling duration

The appropriate sampling duration may be chosen depending on the purpose of the assessment. Typical deployment durations vary between a few minutes and 24 hours, but this depends on the mode of operation. The deployment duration of nets depends on the debris loading of both plastics and other components, such as organic material and suspended sediment. Deployment times must be sufficiently long to capture material, but must be short enough to avoid full clogging or blocking of the net opening (UNEP, 2020).

(3) Towing positions

Most macroplastics monitoring efforts focus on floating and suspended plastic debris in the upper 1.5 m of the water column. Data on and understanding of the vertical distribution of plastic debris are lacking. The distribution of plastic in the water column is related to the buoyancy, shape, and degree of degradation of the plastic, river morphological characteristics, and the hydrological regime. However, it is difficult to predict the vertical profile of plastic debris for a given river without in situ data. One of the few efforts to quantify a profile along the water column demonstrated that 66–79% of the total plastic transport may be below a depth of 1.5 m (Hohenblum et al., 2015. Recently, sampling of plastic in the upper 1.3 m showed that, in the upper layer, most of the debris (88 per cent) was transported in the upper 0.5 m (van Emmerik et al., 2019. Sampling at deeper layers requires more costly and labour-intensive methods (UNEP, 2020).

(4) Net immersion depth

The Manta net is usually designed to match the height of the net mouth so that the upper end of the net mouth can catch the water surface.

The Neuston net is commonly used for towing at 1/2 to 3/4 of the height of the net mouth. However, in river areas abundant with floating substances, the immersion depth gradually increases due to net clogging.

In order to reach the pre-determined immersion depth, place sinkers and buoys of adequate weight and make adjustments to the length of the towing net. During towing, observe the condition of the net mouth regularly to record immersion depth.

If the net is clogged and immersion depth cannot be kept at a certain level, either haul the net to collect the samples, or change the net before continuing the towing.

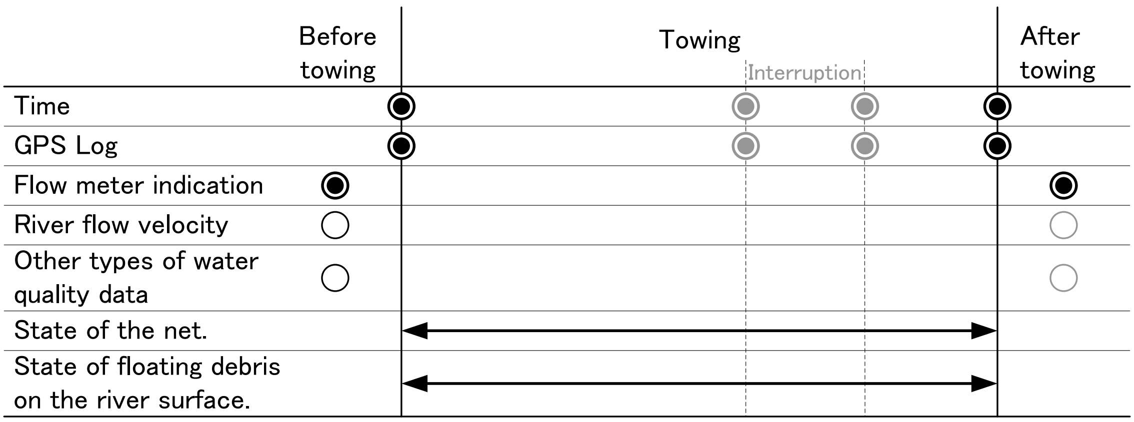
> **Note**
> Deployment depth and the depth to which the frame is submerged also influence the sampling results. More submerged plastic can be sampled when nets are installed at greater depths. However, in some case, it is crucial to allow some space between the water surface and the top of the net. In rivers with large amounts of floating plastics, such as polyethylene terephthalate (PET) bottles and expanded polystyrene (EPS) foams, a net that is too deep will be unable to capture them (UNEP).

(5) Collection of relevant data

Conduct various observations to obtain and record relevant data before, during and after towing.

A time chart for relevant data observations is shown in Figure 6.10.

If a flowmeter is not available and the filtered volume is calculated from the current speed or GPS log, record results from consecutive measurements taken at a certain interval during towing.



◉, ◀▶ Items for which an observation is compulsory.

○ Items for which an observation is recommended in order to quantify microplastics concentration

◉ , ○ Items to be observed when towing is interrupted or when the post-towing condition changed greatly from the pre-towing condition.

Figure 5.10 Time chart for relevant data observations

Sample collection

(1) Net cleaning/sample collection

When towing is finished, haul the net slowly with the mouth side up at all times (Figure 6.11). During and at the end of this process, the net is washed with water from the outside to wash down the particles inside to the cod-end while particles on the outside are washed away. The water can be drawn from the river by a pump or a bucket.

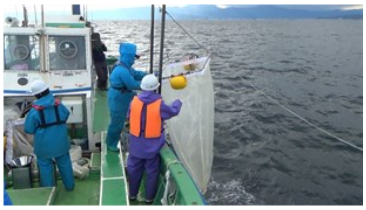


Figure 5.11 Net washing

When it is difficult for all the particles to be collected in the sample container due to large pieces of rubbish inside the net, larger items that are clearly not plastic particles should be removed first. Before removing, wash them carefully inside the net to separate the small plastic particles attached. Separated particles will be funnelled into the cod-end.

The sampling positions and serial numbers shown on the containers should be checked for accuracy.

Particles piled up in the cod-end will be transferred to the sample container by opening the outlet of the cod-end over it when the outlet of the cod-end if smaller; however, should it be larger, then the container, a funnel larger than the outlet of the cod-end, should be used over the container. Here, organic debris (branches, leaves, wood chips, etc.) will be removed.

(2) Transfer to laboratories

Samples should be transferred to a laboratory swiftly and should be protected to avoid damage to the container.

5.3 Analysis method

Figure 6.12 shows the steps to follow in analysing riverine macroplastics sampled by net towing.

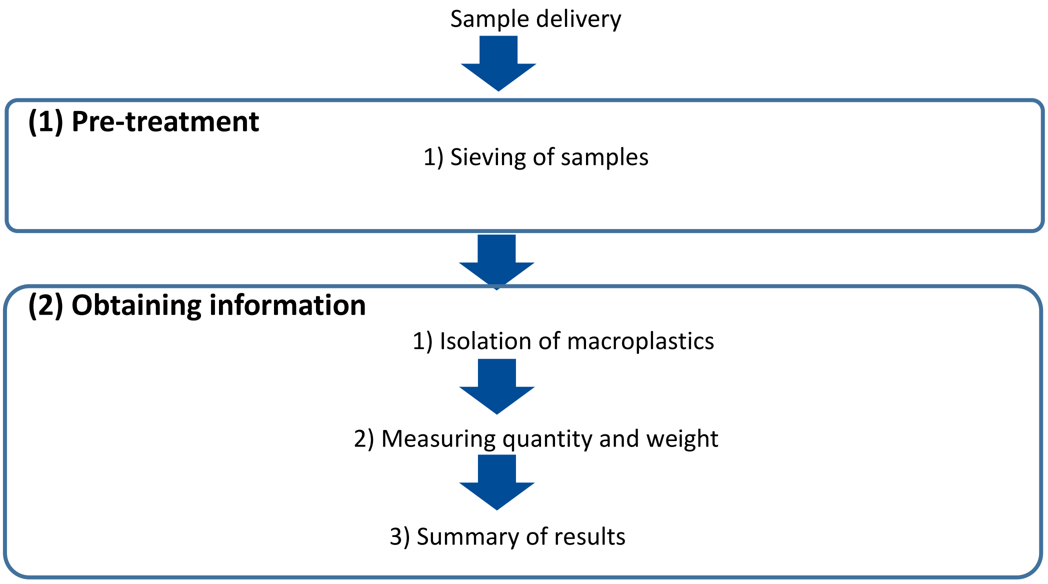


Figure 5.15. Steps for measuring and analysing macroplastics samples

(1) Pre-treatment
A) Sieving of samples

Samples are sieved using sieves with a mesh size of 22.4mm.

Equipment

- Stainless steel basin
- Glass beaker (between 500 ml and 1,000 ml); the size can be changed according to the volume of samples)
- Petri dish (diameter between 15 cm and 30 cm)
- Stainless steel sieve (mesh size 22.4 mm)
- Water (it is possible to use tap water, purified water, or distilled water).

Procedures

a) Place sieves (upper mesh 22.4 mm) over a stainless steel basin and sieve the samples through. Return the filtered water to the sample container (to serve as a sample backup).
b) Among the samples on the sieve, wash thoroughly larger substances such as wood chips, leaves and jellyfish. Return the washed substances to the container (to serve as a sample backup). If any large pieces of plastic such as those from a plastic bag or a pet bottle were mixed in at this time, wash them thoroughly with water and keep them separate before adding them as macroplastics.
c) Wash the remaining samples in the container with water and sieve through the 0.1 mm or larger sieve. The filtered water can be discarded.
d) Wash the samples on the 22.4 mm sieve with water and transfer all samples to a petri dish.

(B) Obtaining information

1) Isolation of macroplastics

Isolate possible macroplastics in the samples on the petri dishes by visual inspection.

Equipment

- Glass petri dish
- Precision tweezers (2 pairs)
- Washing bottle (distilled water)

Procedures

a) Isolate possible macroplastics from the samples on a petri dish with a precision tweezer by visual inspection. The petri dish should be soaked in the water to prevent the particles from sticking to the tweezers due to static electricity when dry.
b) Classify the particles by types of macroplastics according to Table 4.2, as described in 4.4 *Summary of sample data*.
c) Mix the large plastic fragments that were separated during (a), with the particles, classified in (b) above.

2) Measuring quantity and weight of macroplastics

The MRC Riverine Plastic Debris Pollution Monitoring Programme focuses on plastics. Thus, the target items of this protocol exclude non-plastic items, such as organic waste, paper water, rubber, and grasses. The number of pieces and the weight of macroplastics are recorded using Table 4.2, described in Chapter *4.4 Summary of sample data*.

5.4 Summary of sample data

(1) Meta data

Many factors influence the abundance of debris in the river at a given time and location. Therefore, it is critical to provide information about the monitoring conditions to facilitate the interpretation of the results. Metadata to be reported together with the monitoring data should therefore be agreed upon and be reported together with the real debris data.

The following types of data (metadata) are helpful for the interpretation and use of monitoring data on riverine debris fluxes:

- geographic location of the sampling site (WGS 84);
- wind direction during and before the sampling;
- current and historical precipitation data upstream in the watershed;
- current and historical discharge data;
- water level of the river;
- depth and flow velocity profiles of the river section.

Table 5.2 Record form for the survey summary

Items				Results input	Unit
Sampling date and location	Sample name/ ID				-
	Enter time difference from GMT				-
	Sampling date				-
	Sampling time (initial)				-
	Sampling time (final)				-
	Season				-
	Sampling location (name)				-
	GPS Log	● Input style			-
		● GPS Log (initial position)	- Latitude		N
			- Longitude		E
		● GPS Log (final position)	- Latitude		N
			- Longitude		E
Sampling equipment	Classification of net frame	● Type of net frame			-
		● Model number and manufacturer			-
	Net aperture	● Shape of net aperture			-
		● Size of net aperture	- Width		m
			- Height		m
			- Area		m^2
	Length of net				m
	Mesh	● Openings			mm
					-
		● Model number and manufacturer			-

Tow Parameter	Tow distance	● Distance		m
		● Calculation method		-
		● Calculation formula	Distance=	-
	Trawl sweep area	● Sweep area		m^2
		● Calculation formula	Area=	-
	Filtered water volume	● Water volume		m^3
		● Calculation formula	Volume=	
	Tow duration			min
	Vessel speed			m/s
	Tow position			
	Distance from vessel			m
	Net immersion	● Net immersion depth		m
		● Percentage of net immersion depth to size of net frame		%
		● Whether or not there was any change in the immersion depth during tow		-
	Tow direction		Current → Wind →	-
	Blank tests	● Whether or not blank tests were conducted		-
		● Results		particles/ sample

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Mekong River Commission Secretariat

P. O. Box 6101, 184 Fa Ngoum Road, Unit 18 Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR

Tel: +856 21 263 263| Fax: +856 21 263 264 www.mrcmekong.org