

Roadmap for the Implementation of Monitoring and Sampling of Riverine Litter in South Baltic Sea Rivers

A Practical Framework for City-Level Monitoring,
Data Harmonisation and Mitigation Planning

Report

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Report on harmonised monitoring and sampling of riverine litter in South Baltic cities

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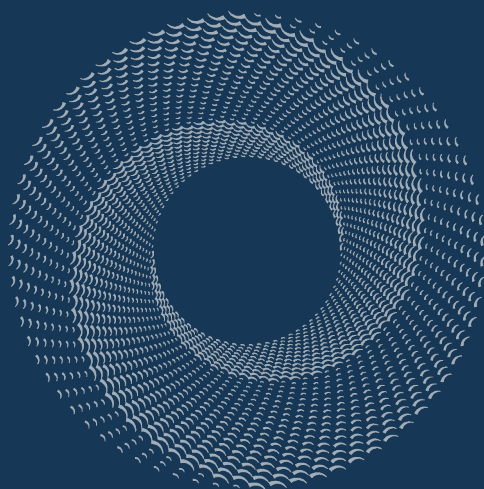


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1. Introduction



1. Introduction

Riverine litter refers to litter found in rivers and along riverbanks. Rivers can collect litter from runoff and direct inputs, transport it towards the sea, or temporarily retain it within the catchment before later release or degradation (González et al., 2016). Rivers are therefore a dominant pathway of (plastic) pollution into the marine environment. In addition, rivers can act as sinks that accumulate litter from multiple sources (Winton et al., 2020). In urban coastal regions, this role is particularly important because rivers connect densely used city areas, stormwater systems, harbours, recreational waterfronts and estuaries with the marine environment. This makes cities located at river mouths especially relevant for the monitoring and management of litter inputs to the sea (EEA, 2023; Tasseron et al., 2023; van Emmerik and Schwarz, 2020).

Although some monitoring such as for beach litter is comparatively well established in many European monitoring frameworks, particularly through MSFD-related guidance and harmonised European data infrastructures (EMODnet, 2026; MSFD TSG ML, 2023), riverine litter monitoring is still less consistently implemented (González et al., 2016). Many cities already support clean-up activities, citizen-science initiatives or local waste prevention campaigns. However, these activities are often not linked to standardised monitoring protocols, harmonised litter categories, quality assurance procedures or long-term data management. As a result, locally collected information may be useful for awareness raising, but less suitable for comparison across cities, countries or regional sea areas (Corbau et al., 2025).

For cities that want to go beyond clean-ups and collect pollution data in a standardised and harmonised way, a city-level roadmap is therefore needed. It helps to translate existing marine litter monitoring principles into practical implementation steps for urban river systems. Such a roadmap should not only describe individual monitoring methods, but also define:

- how monitoring stations are selected,
- how local actors are trained,
- how data are checked,
- how responsibilities are distributed and
- how results are used for mitigation.

Monitoring should be understood as part of a full management cycle, linking field observation, data validation, source identification, targeted measures and follow-up assessment.

The overall aim of this roadmap is to provide practical guidance for South Baltic cities to establish

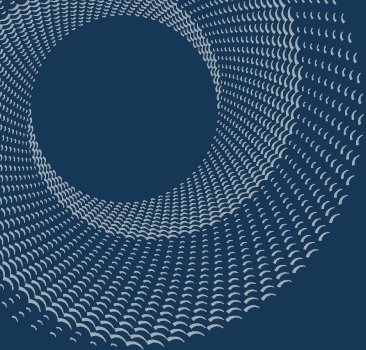
harmonised, quality-assured and policy-relevant monitoring of riverine macro-litter (> 25 mm). The focus is on monitoring approaches that can be implemented by municipalities, local environmental authorities, NGOs, schools, universities and other local actors, while still producing data that are compatible with broader national and European monitoring needs.

The roadmap focuses primarily on macro-litter, especially floating litter on the river surface and deposited litter along riverbanks. These fractions are particularly relevant for city-level monitoring because they are visible, can be recorded with relatively simple methods and are directly linked to local mitigation measures. The two methods recommended are:

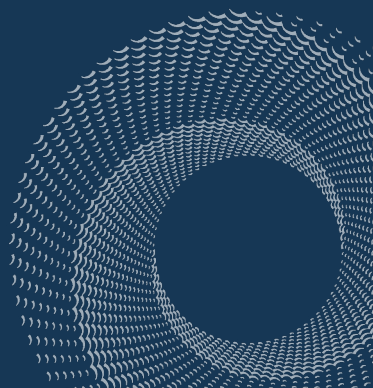
- Visual surveys of Riverine Floating Macro-Litter (RFML)
- Riverbank surveys of Macro-Litter

The roadmap also places strong emphasis on governance and data flow. Reliable monitoring requires more than field surveys. Local monitoring teams, such as schools, NGOs or citizen-science groups, need protocols, training and support. However, monitoring can already start before a formal local, regional or national coordination structure is fully established. In the initial phase, one responsible person or institution should temporarily coordinate survey dates, field sheets, data storage and basic data checks. As the monitoring programme develops, this role can be formalised through a local or regional coordinator, while a national coordinator or designated technical institution can later provide templates, organise intercalibration, validate submitted data, apply QA/QC procedures and support long-term data storage or reporting.

By combining practical field methods with clear institutional responsibilities, digital tools, QA/QC procedures and a stepwise implementation plan, this roadmap aims to support cities in moving from isolated clean-up activities towards long-term, harmonised riverine litter monitoring. The final objective is to generate reliable data that can help cities identify litter hotspots, understand dominant litter item categories and sources, evaluate mitigation measures and contribute to wider regional efforts to reduce litter inputs to the South Baltic Sea.



2. Policy and Data Framework



2. Policy and Data Framework

Riverine litter monitoring in South Baltic Sea cities should be designed in a way that supports local management needs while remaining compatible with wider European monitoring and reporting frameworks. The most relevant policy and data framework is the Marine Strategy Framework Directive (MSFD 2008/56/EC, 2008). For reporting, data should be collected in a way that fits the requirements of the Marine Water Information System for Europe (WISE Marine), and the European Marine Observation and Data Network (EMODnet).

For city-level implementation, the aim is not to create a completely new monitoring system, but to translate existing European principles into practical methods, data flows and quality assurance procedures for urban river systems.

2.1 Key Reference Documents and Practical Inputs for the Roadmap

The roadmap is based on existing European and regional policy frameworks, technical guidance documents and harmonised classification systems for marine and riverine litter monitoring. In addition, practical experience from the Circular Ocean-bound Plastic (COP) project contributed to the development of this roadmap. This includes experiences from city-level monitoring activities, stakeholder exchange and discussions. The most relevant reference documents and practical inputs are summarised in Table 1.

Table 1: Key policy frameworks, technical guidance documents, data infrastructures and practical project inputs used as the basis for this roadmap.

Reference document / practical input	Relevance for this roadmap
Circular Ocean-bound Plastic (COP) project documents, experience and stakeholder workshops	Provides practical input from city-level riverine litter monitoring, mitigation activities and stakeholder exchange in the South Baltic Sea region. The roadmap builds on previous COP project outputs, including the report: A feasible method for riverine macro-litter monitoring - A case study of the Warnow River (Haseler, 2026), as well as experiences from workshops and exchanges with municipalities and local actors. These inputs helped shape the roadmap as a practical, easy-to-implement framework for cities.
Marine Strategy Framework Directive MSFD 2008/56/EC (2008)	Provides the overarching European policy framework for the protection of the marine environment. Under Descriptor 10, it defines marine litter as a key pressure and sets the objective that the properties and quantities of marine litter should not cause harm to the coastal and marine environment.
Guidance on the Monitoring of Marine Litter in European Seas MSFD TSG ML (2023)	Provides updated guidance for harmonised marine litter monitoring under the MSFD. It is relevant for this roadmap because it defines general monitoring principles, methodological consistency, metadata requirements and QA/QC procedures that can inform riverine macro-litter monitoring.
A Joint List of Litter Categories for Marine Macro-litter Monitoring by Fleet et al. (2021)	Provides the harmonised classification system for marine macro-litter monitoring. It supports the selection of litter categories and litter item codes, helping ensure that riverine macro-litter data remain compatible with established European marine litter monitoring categories.

Riverine Litter Monitoring - Options and Recommendations by González et al. (2016)	Provides specific technical guidance for monitoring litter in rivers, including methodological options for different river compartments. It is a key reference for visual surveys of Riverine Floating Macro-Litter and for the general design of riverine litter monitoring approaches.
Identifying Sources of Marine Litter by Veiga et al. (2016)	Provides practical guidance for identifying likely sources and pathways of marine litter. The report introduces source attribution approaches, including a likelihood-based Matrix Scoring Technique adapted from Tudor and Williams (2004). It is relevant for this roadmap because riverine litter monitoring results should not only quantify litter, but also support the identification of likely sources and pathways for targeted mitigation.
Guidelines for Monitoring Riverine Inputs of Marine Litter by UNEP/MED (2023)	Provides regional guidance for monitoring riverine inputs of marine litter within the UNEP/MAP Mediterranean framework. It is relevant because it addresses riverine litter inputs as part of a structured monitoring approach and can support the design of harmonised protocols and data flows.
Report on the evaluation of the UNEP/MED guidelines for monitoring riverine inputs of litter by HELCOM (2025)	Provides a Baltic Sea regional perspective on the applicability of UNEP/MED riverine litter monitoring guidance. It is particularly relevant for assessing how riverine litter monitoring approaches can be adapted to the Baltic Sea context.
Workshop on Riverine Litter - Summary Record by OSPAR Commission (2025)	Provides insights from regional expert discussions on riverine litter monitoring in the OSPAR context. It is relevant for understanding current discussions, practical challenges and possible steps towards more harmonised riverine litter monitoring in European regional seas.
WISE Marine	Provides the European reporting framework for marine environmental information under the MSFD. It is relevant because riverine litter data should be structured in a way that can support national and European reporting needs where applicable.
EMODnet	Provides European marine data infrastructure and harmonised marine litter data products. For this roadmap, EMODnet is used as a reference for data compatibility, metadata completeness, QA/QC and future integration of harmonised litter datasets.

2.2 The Marine Strategy Framework Directive

The MSFD provides the central European policy framework for the assessment and management of marine litter. Under the MSFD, marine litter is addressed through Descriptor 10, which states that good environmental status is achieved when: “Properties and quantities of marine litter do not cause harm to the coastal and marine environment (MSFD 2008/56/EC, 2008).” Although the MSFD focuses on marine waters, riverine litter monitoring is directly relevant because rivers can act as major pathways through which land-based litter is transported to coastal and marine areas (EEA, 2023; González-Fernández and Hanke, 2017).

For this roadmap, the MSFD is used as the main policy and harmonisation reference. Riverine macro-litter data collected by cities should therefore, wherever possible, follow MSFD-compatible principles, including harmonised litter item categories, a clear macro-litter size threshold, standardised metadata and transparent QA/QC procedures. This allows local monitoring data to support city-level management while remaining suitable for wider comparison.

2.3 The Marine Strategy Framework Directive

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2.4 Data and Reporting Framework: WISE Marine and EMODnet

For monitoring data to be useful beyond local awareness raising, they should be collected and stored in a way that supports harmonised reporting and future data exchange. WISE Marine and EMODnet provide relevant European reference frameworks for marine environmental information, data management and marine litter data products. For riverine macro-litter, direct integration into existing European marine litter datasets may still require further development. Therefore, this roadmap uses the term “EMODnet-compatible” in a practical sense. Data should be collected using harmonised litter item categories, standardised metadata fields, clear method descriptions and QA/QC information, so that they can later be aggregated nationally, compared regionally or adapted for future European data systems.

2.5 Harmonisation Requirements for City-level Monitoring

To ensure that city-level monitoring data are comparable and reusable, a minimum set of harmonisation requirements should be applied from the beginning of the monitoring programme. Monitoring stations should have a unique station ID, GPS coordinates, photographs, access information and a clear description of the observation or survey area.

Methods should be standardised and kept stable over time. RFML surveys should use fixed observation points, defined observation durations and consistent rules for recording floating macro-litter. Riverbank surveys should use fixed survey sections or transects and clearly defined rules for recording litter.

Litter classification should follow harmonised litter item categories wherever possible. The Joint List of Litter Categories for Marine Macro-litter Monitoring provides a suitable basis for litter item classification (Fleet et al., 2021). For data recording, this roadmap distinguishes between counted litter pieces and litter item categories. A litter piece is one individual object recorded in the field, while a litter item category refers to the harmonised category or litter type used for classification, preferably based on the Joint List. Monitoring results should therefore report both the total number of litter pieces and the piece counts assigned to each litter item category.

Field teams can also use the online photo catalogue of the Joint List of Litter Categories by the European Commission (2026) to support the identification and assignment of litter pieces to harmonised litter item categories.

Download Link:

<https://mcc.jrc.ec.europa.eu/main/photocatalogue.py?N=41&O=457&cat=all>

The Joint List of Litter is also available for download and can be used as a practical basis for field sheets, digital forms or local monitoring databases. Using the downloadable Joint List supports harmonised data entry and helps ensure that litter pieces are assigned consistently to comparable litter item categories.

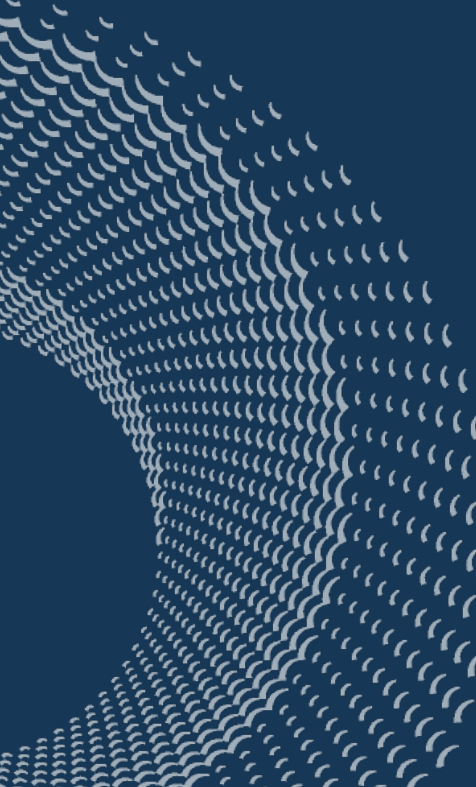
Download Link:

<https://mcc.jrc.ec.europa.eu/main/dev.py?N=41&O=459>

A consistent macro-litter size threshold should also be applied. For this roadmap, macro-litter is defined as anthropogenic litter pieces larger than 25 mm in the longest dimension, with no set upper limit (MSFD TSG ML, 2023).

In addition, each survey should record essential metadata, including date, time, station, method, survey duration, survey team, weather conditions, visibility, observed width or surveyed area, total litter pieces recorded, litter item categories, piece counts per litter item category and QA/QC status.

In summary, harmonised riverine litter monitoring should combine practical field methods, standardised litter item categories, complete metadata, clear QA/QC procedures and a structured data flow. This allows cities to start quickly while still producing data that can support long-term monitoring, mitigation planning and wider regional comparison.



3.

Monitoring Objectives and Core Indicators

3. Monitoring Objectives and Core Indicators

The design of a riverine litter monitoring programme should be guided by clear monitoring objectives. In general, monitoring programmes should collect information on the amount, distribution, composition, sources and input rates of litter, as well as their spatial and temporal variation and potential impact (MSFD TSG ML, 2023). At city level, monitoring should provide practical information on where, when, how much and what types of litter are present or transported. This information is needed to understand urban rivers as litter pathways, identify hotspots, support local management and evaluate whether mitigation measures are effective over time.

This roadmap follows the general logic proposed by van Emmerik et al. (2022), linking monitoring goals, research questions, river compartments and method development levels. For practical city-level implementation, the focus is placed on two accessible compartments: floating macro-litter on the river surface and deposited macro-litter along riverbanks.

3.1 Monitoring Goals

Riverine macro-litter monitoring should support four overarching goals: policy development, knowledge development, operations and maintenance, and solution design and evaluation.

Monitoring supports policy development by providing evidence on litter abundance, dominant litter item categories and priority areas for action. It supports knowledge development by improving the understanding of local sources, pathways and environmental drivers such as rainfall, discharge, wind or seasonal use of waterfront areas. It supports operations and maintenance by helping municipalities, harbour operators and waterway managers identify areas that require regular cleaning or targeted management. Finally, it supports solution design and evaluation by providing the data needed to plan mitigation measures and assess whether they reduce litter abundance over time.

3.2 Development Levels of Monitoring

The roadmap is designed as a practical starting point for cities and should not require municipalities or local actors to first carry out a complex method-selection process. Several riverine macro-litter monitoring methods have already been tested (González et al., 2016; Haseler, 2026; Schreyers et al., 2021; Tasseron et al., 2024). Therefore, cities should begin with methods that are scientifically useful, cost-efficient, safe and suitable for repeated implementation by trained local actors. This roadmap recommends starting with cost-efficient methods that have a comparatively high Technological Readiness Level (TRL) (Falk-Andersson et al., 2025), and are suitable for immediate or near-term implementation at city level.

The recommended starting methods are:

- Visual surveys of Riverine Floating Macro-Litter (RFML);
- Riverbank surveys of Macro-Litter

These methods are suitable for establishing an initial baseline and can later be continued as long-term monitoring methods. More technical approaches, such as river surface net sampling, hotspot mapping using Unmanned Aerial Vehicles (UAVs), fixed cameras, water column sampling or riverbed sampling, may be added later if specific management or research questions require them.

Monitoring should develop stepwise. First, cities establish a baseline using fixed stations and sections. Second, they continue long-term monitoring using stable methods, litter item categories and metadata fields. Third, they improve or expand the monitoring system where additional information is needed.

This stepwise approach allows cities to start quickly with suitable and relatively mature methods, while keeping the monitoring system flexible enough to incorporate new technologies, additional river compartments or improved protocols over time.

3.3 Core Monitoring Questions

During the baseline phase, which ideally lasts 12 months, the monitoring programme should answer the following questions:

How much riverine macro-litter is present or transported at selected monitoring stations?

- Which litter item categories and material groups are most frequent?
- Where are the main accumulation zones and hotspots?
- Which local sources and pathways are likely responsible?
- How does litter occurrence differ between river surface and riverbanks?
- Which stations, methods and survey frequencies are suitable for long-term implementation?

During long-term monitoring, the focus shifts towards temporal patterns and evaluation:

- How does riverine litter occurrence change over time?
- Are there seasonal, rainfall-related, discharge-related or event-related patterns?
- Do mitigation measures implemented or adjusted after the baseline assessment reduce total litter abundance or specific litter item categories over time?
- Are hotspots stable, increasing, decreasing or shifting over time?
- Can the data support city-level management, national reporting and regional comparison?
- Are additional methods needed to answer specific management or research questions?

In this context, mitigation measures primarily refer to actions introduced or adjusted after the baseline assessment, based on identified hotspots, dominant litter item categories and likely sources or pathways. Existing measures can also be evaluated during long-term monitoring if their location, timing, maintenance routines and responsibilities are documented.

3.4 Core Indicators

The roadmap recommends a simple core indicator set that can be applied by cities without requiring complex modelling or highly specialised equipment. The indicators should be easy to calculate, compatible with harmonised data structures and useful for local management.

For RFML surveys, the core indicators are:

- total number of floating macro-litter pieces per observation;
- number of floating macro-litter pieces per hour;
- number of litter pieces per litter item category;
- material composition;
- share of single-use plastic pieces;
- top 10 most frequent litter item categories; number of uncertain or unclassified litter pieces.

For riverbank surveys, the core indicators are:

- total number of litter pieces per survey section;
- number of litter pieces per meter of riverbank;
- number of litter pieces per square meter;
- number of litter pieces per litter item category;
- material composition;
- share of single-use plastic pieces;
- top 10 most frequent litter item categories;
- location and intensity of hotspots;
- cleaning status of the riverbank section.

Riverbank indicators should be interpreted as indicators of deposited or accumulated litter, not as direct measurements of floating litter transport. RFML indicators provide information on floating litter transport but do not capture submerged, stranded or riverbed litter. The two methods should therefore be interpreted together.

3.5 Minimum Data Package

Each survey should collect a minimum set of information to ensure that monitoring data are comparable and reusable. The minimum data package should be included in field sheets, digital forms or app-based tools.

The minimum data package should include:

- country, city and river name;
- station ID and GPS coordinates;
- monitoring method;
- date and start/end time;
- survey duration;
- name of surveyor or monitoring team;
- local or regional coordinator;
- observation width, or surveyed riverbank area;
- total river width, where relevant;
- litter item categories and piece counts;
- material group, where possible;
- weather conditions during the survey;
- wind direction and wind speed during the survey, where available;
- rainfall during the survey and recent rainfall before the survey, where known;
- water level, discharge or flow conditions, where available and relevant;
- visibility conditions;
- cleaning status of the riverbank section, where relevant;
- photo documentation of uncertain litter pieces or hotspots;
- comments on unusual events, uncertainties or disturbances;
- QA/QC status.

The minimum data package should remain simple enough for routine use, but complete enough to allow interpretation of the results. Missing metadata can strongly reduce the value of monitoring data, especially when results are compared between stations, seasons or cities. For example, an unusually high number of floating litter pieces may be linked to rainfall, high discharge, public events, or wind conditions. Without such contextual information, it is difficult to interpret whether observed differences reflect real pollution patterns or short-term conditions.

3.6 Use of Indicators for City-level Management

The indicators should be directly linked to city-level management and mitigation planning. Monitoring should not end with data collection, but should support decisions on where action is needed, which litter item categories should be targeted and whether implemented measures are effective.

For RFML surveys, pieces per hour, dominant litter item categories and top 10 litter item categories can show whether floating litter pressure changes over time or increases after rainfall, high discharge or public events. For riverbank surveys, pieces per meter, hotspot locations and cleaning status can guide local clean-ups, improved waste infrastructure, awareness campaigns and cooperation with harbour operators or waterfront businesses.

The indicators should therefore be used in a monitoring-to-mitigation cycle:

1. collect standardised monitoring data;
2. check and validate the data;
3. identify dominant litter item categories, hotspots and likely sources;
4. discuss results with local stakeholders;
5. implement targeted mitigation measures;
6. repeat monitoring to evaluate whether the measures were effective.

For a more structured interpretation of likely sources, cities may apply a simple likelihood-based source assessment to the most frequent litter item categories. This should not be carried out during the field survey itself, but as an analytical step by the local or regional coordinator, ideally together with relevant stakeholders. The assessment uses dominant litter item categories, hotspot locations, site characteristics, nearby activities, land use, infrastructure and local knowledge to assign likely sources and pathways (see Chapter 12.1). This helps translate monitoring results into more targeted mitigation priorities.

This cycle is essential for turning riverine litter monitoring into a practical management tool. It allows cities to move from general clean-up activities towards evidence-based prevention, targeted removal and long-term reduction of litter inputs to the Baltic Sea.

3.7 Recommended Core Indicator Set

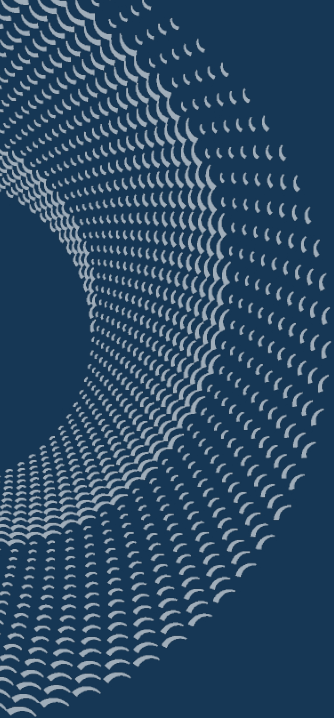
For harmonised implementation across South Baltic cities, the roadmap recommends a compact core indicator set. The indicators should be applied during the baseline phase and then maintained during long-term monitoring to avoid breaks in the time series. The recommended core indicator set

for city-level riverine macro-litter monitoring is summarised in Table 2.

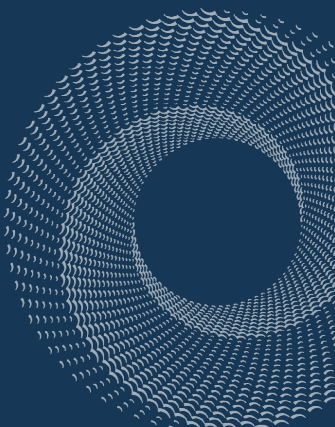
Table 2: Recommended core indicators for city-level riverine macro-litter monitoring.

Monitoring component	Core indicators	Main purpose
Visual surveys of Riverine Floating Macro-Litter (RFML)	Pieces per observation, pieces per hour, pieces per litter item category, material composition, top 10 litter item categories	Quantification of floating macro-litter and temporal comparison
Riverbank surveys	Pieces per meter or square meter, pieces per litter item category, material composition, top 10 litter item categories, hotspot locations	Hotspot identification, source assessment and local mitigation planning

This indicator set provides a practical balance between feasibility and policy relevance. Additional indicators, such as floating litter flux, polymer composition, water column items or riverbed litter, can be added later if specific management or research questions require them.



4. Governance and Institutional Set-up



4. Governance and Institutional Set-up

A city-level riverine litter monitoring programme requires a clear governance structure. Monitoring cannot rely only on individual clean-up activities or short-term project initiatives. To generate comparable and quality-assured data over time, responsibilities need to be clearly distributed between local monitoring teams, local or regional coordinators, national coordinators and municipal decision-makers.

The proposed governance structure follows a simple data and responsibility chain:

Local monitoring teams → Local or regional coordinator → National coordinator → Database and reporting system → Municipal action and mitigation

However, this full structure does not need to be in place before monitoring can start. Cities can begin with a minimum operational structure consisting of trained local monitoring teams, one local or regional coordinator, fixed monitoring stations or sections, standardised field sheets or digital forms and simple local data storage. If harmonised litter item categories, metadata fields and QA/QC flags are used from the beginning, the data can later be transferred to national or regional systems once these are available.

The guiding principle is: start locally, harmonise from the beginning and connect nationally later.

4.1 Local Monitoring Teams

Local monitoring teams carry out the field surveys. They may include schools, NGOs, citizen-science groups, universities, local environmental initiatives, harbour actors or trained municipal staff. Their main tasks are to conduct surveys according to the agreed protocol, count litter pieces, classify them into litter item categories, record metadata, document uncertain litter pieces or hotspots and submit the data to the local or regional coordinator.

All teams should receive basic training before monitoring starts. Training should cover the survey method, litter item classification, field sheets or apps, safety procedures and the documentation of uncertain litter pieces.

4.2 Local or Regional Coordinator

The local or regional coordinator is the operational centre of the monitoring programme. This role can be taken by a municipality, environmental office, university, NGO coordinator, regional project partner or waste management authority.

The coordinator selects and maintains monitoring stations, organises survey dates and teams, provides field sheets or digital forms, checks submitted data, stores local backup copies and communicates results to municipalities and local stakeholders. The coordinator should also ensure that the monitoring schedule remains realistic and can be maintained over several years.

4.3 National Coordinator

A national coordinator or designated data centre can support harmonisation, validation and long-term data storage. This role may be taken by a national environmental agency, research institute, national marine litter monitoring body or technical data centre.

In the start-up phase, such a structure may not yet be available for riverine litter monitoring. In that case, cities should still collect and store data in a harmonised local format so that they can later be transferred for national validation, storage or reporting. Once available, the national coordinator can provide templates, organise training or intercalibration, validate datasets, apply QA/QC procedures and support national or regional reporting.

4.4 Role of Municipalities and Local Authorities

Municipalities are key users of the monitoring results. They should use the data to identify hotspots, improve waste bin placement and cleaning routines, address dominant litter item categories, improve event-related waste management, support awareness campaigns and cooperate with harbour operators, waterfront businesses and local stakeholders.

For municipal use, results should be communicated in a practical format. Annual summaries, hotspot maps, top litter items list and short management recommendations are often more useful for decision-making than complex datasets alone.

4.5 Data Flow and Responsibility Chain

A clear data flow is essential for quality assurance, but it can be developed stepwise. In the start-up phase, field data can be collected by local monitoring teams, checked by the local or regional coordinator and stored in a structured local database or spreadsheet.

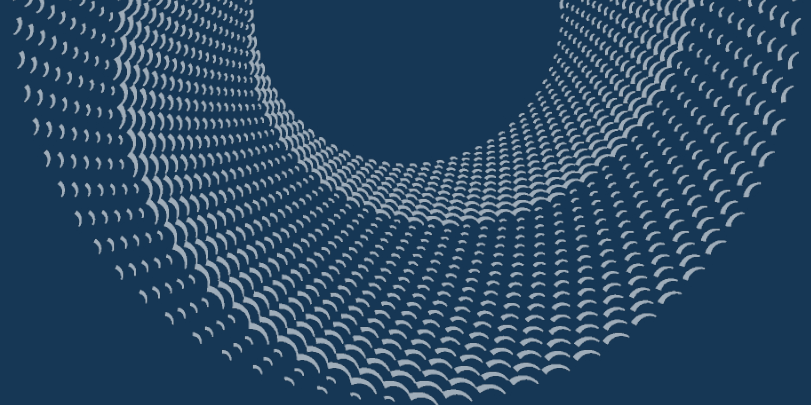
Once a national coordinator, data centre or reporting pathway is available, the locally stored data can be transferred for further validation, long-term storage and wider reporting. This stepwise data flow allows cities to start monitoring without waiting for all national or regional structures to be fully operational.

4.6 Recommended Governance Model for Cities

For South Baltic cities, the governance model should be simple, scalable and easy to maintain. Monitoring can start with one local or regional coordinator, trained monitoring teams, fixed stations or sections, a realistic survey schedule and structured local data storage.

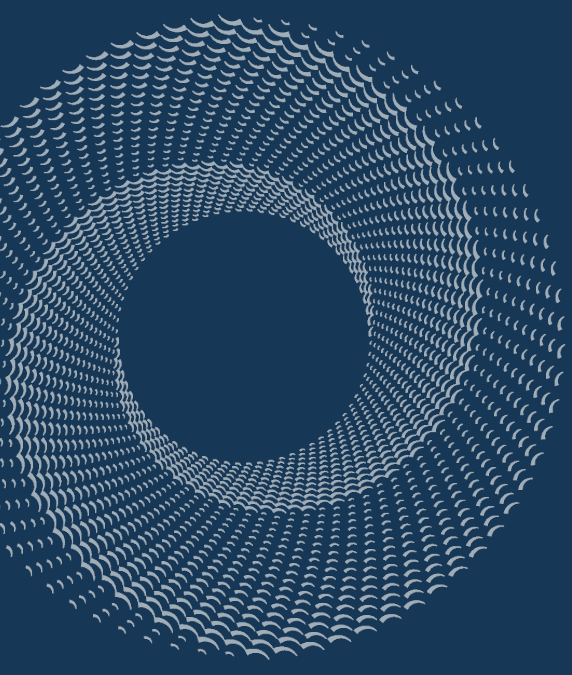
During the baseline phase, this minimum structure should be tested and improved. Once monitoring moves into long-term implementation, responsibilities can be formalised and the data flow can be extended to national-level QA/QC, data storage and reporting.

This approach allows cities to start quickly while still creating the basis for long-term, harmonised and policy-relevant monitoring.



5.

Monitoring Methods and Technical Readiness



5. Monitoring Methods and Technical Readiness

Monitoring methods should not only be scientifically sound, but also practical, cost-efficient, safe and suitable for repeated implementation by trained local actors.

This roadmap therefore recommends a focused method package for city-level riverine macro-litter monitoring based on two core methods:

- Visual surveys of Riverine Floating Macro-Litter (RFML)
- Riverbank surveys of Macro-Litter

Together, these methods cover the two most accessible and management-relevant compartments: floating litter transported on the river surface and deposited litter along riverbanks. RFML surveys provide information on floating macro-litter transport, while riverbank surveys identify accumulation zones, hotspots and potential local sources.

Both methods can be implemented with limited equipment, standardised field sheets or app-based tools and trained local monitoring teams.

5.1 Visual Surveys of Riverine Floating Macro-Litter (RFML)

Visual surveys of Riverine Floating Macro-Litter (RFML) are the recommended core method for monitoring floating macro-litter in urban river systems. The method is based on direct observation, counting and classification of floating litter pieces from a fixed observation point, such as a bridge, quay, harbour structure, pier or accessible riverbank. It follows the general principles developed for harmonised floating macro-litter monitoring in rivers, including the JRC/RIMMEL approach and the recommendations provided by González et al. (2016) and González-Fernández and Hanke (2017). RFML surveys are useful for assessing how much floating macro-litter is transported at selected stations, which litter item categories dominate and whether litter occurrence changes between seasons, after rainfall events, during public events or after mitigation measures. For this roadmap, RFML surveys should record all visible floating litter pieces larger than 25 mm. Natural material should not be recorded as litter, but large amounts of leaves, branches or drift material may be documented because they can influence visibility and litter transport.

5.1.1 Station Selection

RFML surveys should be carried out at fixed monitoring stations. Fixed stations are essential because they allow results to be compared over time. Suitable locations should provide a clear and safe view of the river surface, stable access throughout the year and, where possible, an elevated observation position. The observation point should be high enough to provide a clear overview of the defined

observation area, but should preferably not be located more than 10 m above the water surface. Greater observation height can make smaller macro-litter pieces difficult to detect and classify reliably. If a higher observation point has to be used, this should be documented in the station metadata and considered when interpreting the results.

Preferred locations include bridges, quays, piers, harbour structures or safe riverbank locations. Where feasible, at least one RFML station should be located close to the river mouth or harbour area, because this provides information on floating litter that may enter coastal waters. However, the station should ideally be located upstream of strong seawater, tidal or backwater influence. If this is not possible, the distance between the observation point and the river mouth should be documented, together with potential additional litter sources between the station and the sea.

Additional upstream stations may be added to identify urban input areas, compare different river sections or assess the effect of local mitigation measures. Where possible, RFML stations should be aligned with existing water quality or hydrological monitoring stations. This can improve access to discharge, water level and other contextual data that are useful for interpreting temporal variation in floating litter observations.

Each station should be documented with a station ID, GPS coordinates, photographs, observation direction, observed track width, total river width where possible, access information and safety notes. The observation track width should remain stable throughout the monitoring programme. Where feasible, the observation track should cover at least half of the river width or, preferably, the full river width. If only part of the river can be observed, the observed track width and total river width should always be recorded to support data interpretation and, where relevant, later extrapolation.

The suggested RFML observation set-up, including observation direction, observation track width and total river width, is illustrated in Figure 1.

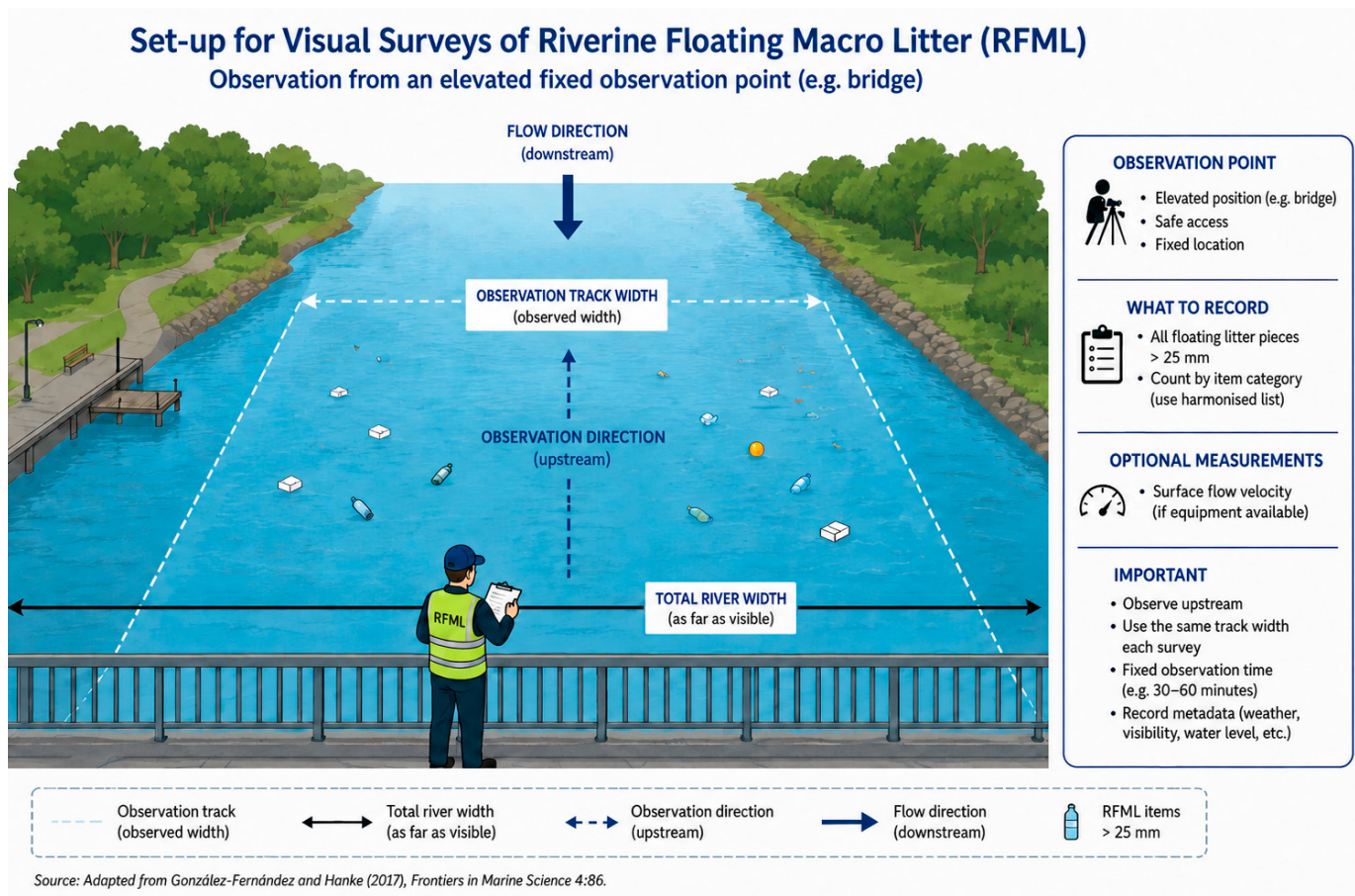


Fig. 1: Suggested set-up for visual surveys of Riverine Floating Macro-Litter (RFML) from an elevated fixed observation point, showing observation direction, observation track width and total river width. Where feasible, the observation track should cover at least half of the river width or preferably the full river width. Concept based on González-Fernández and Hanke (2017); final illustration generated with the help of AI and revised by the authors.

5.1.2 Survey Design, Frequency and Timing

Each RFML survey should follow a standardised observation protocol. The observation duration should be fixed for each station and remain consistent over time. Based on existing RFML guidance, observation sessions of 30–60 minutes are suitable for routine monitoring. For city-level monitoring, 60 minutes is recommended where feasible, while 30 minutes may be used when resources are limited or surveys are repeated more frequently.

The recommended survey frequency depends on available resources and monitoring objectives. Weekly or bi-weekly surveys provide better information on short-term variability and are recommended where sufficient capacity exists. For this roadmap, monthly surveys are proposed as a practical standard for city-level baseline monitoring, while seasonal surveys represent the minimum option where resources are limited. Additional event-based surveys can be added after rainfall, high discharge, public events or known litter inputs.

The recommended RFML survey frequency for different monitoring levels is summarised in Table 3.

Monitoring level	Recommended frequency	Purpose
Minimum baseline	Four surveys per year, one per season	Basic seasonal overview where resources are very limited
Standard baseline	Monthly surveys for at least one full year	Recommended starting point for most cities
Enhanced baseline	Weekly or bi-weekly surveys at selected stations	Better detection of short-term, rainfall-related and event-related variability
Long-term monitoring	Monthly surveys, or at minimum seasonal surveys	Trend assessment and evaluation of mitigation measures
Event-based surveys	Additional surveys after rainfall, high discharge, public events or known litter inputs	Identification of input pulses and management-relevant events

Table 3: Recommended RFML survey frequency for city-level monitoring.

Surveys should be carried out during daylight and under safe conditions. Strong glare, fog, darkness, heavy rain, unsafe wind conditions, ice cover, rough water surfaces or intense boat traffic can reduce visibility and data quality. Such conditions should be documented, and surveys should be postponed where safety or data quality are compromised.

5.1.3 Field Procedure and Data Recording

Before each survey, the observer or monitoring team should confirm that the correct station is used, access is safe and the observation area is clearly visible. During the fixed observation period, all visible floating litter pieces larger than 25 mm should be counted when they pass the defined observation line or observation area. Binoculars may be used to support the detection and identification of litter pieces, especially where the observation track is wide or visibility is limited. Their use should be documented and, where possible, kept consistent between repeated surveys at the same station. Litter pieces should be assigned to harmonised litter item categories, preferably using the Joint List of Litter Categories for Marine Macro-litter Monitoring. The online photo catalogue of the Joint List can be used as an additional field or training aid to support consistent identification of litter pieces. Uncertain litter pieces should be recorded in a broader category and documented with comments or photographs where possible.

Each RFML survey should record the minimum data package described in Chapter 3.5. Method-specific RFML field-sheet requirements are provided in Annex 1. RFML Field Sheet.

Where available, the JRC Floating Litter Monitoring Application can be used to support RFML surveys. However, the app should not be a precondition for starting monitoring. Cities may also use paper field sheets, spreadsheets or other digital forms, provided that they record the same station information, metadata, litter item categories and QA/QC information. The main field steps for RFML surveys, from station check to indicator calculation and reporting, are summarised in Figure 2.

RFML field workflow

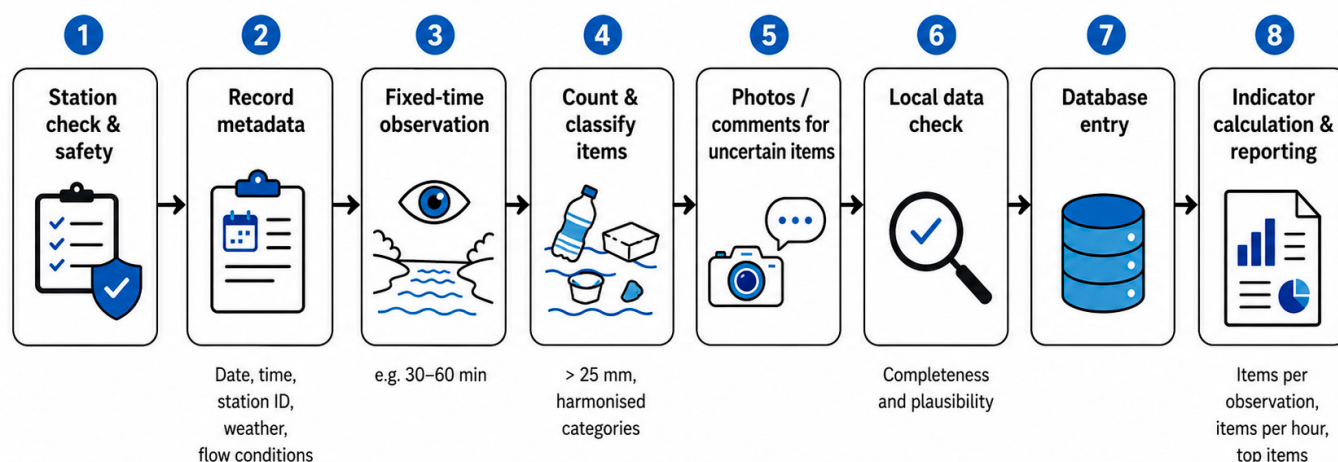


Fig. 2: RFML field workflow from station check to indicator calculation and reporting.

The figure illustrates the main steps of a standardised RFML survey, including safety and station checks, metadata recording, fixed-time observation, piece counting and classification, documentation of uncertain litter pieces, local data checking, database entry and the calculation of monitoring indicators such as litter pieces per observation, litter pieces per hour and top litter item categories.

Final illustration generated with the help of AI and revised by the authors.

5.1.4 Indicators, QA/QC and Outputs

The recommended core indicators for RFML surveys are total litter pieces per observation, litter pieces per hour, litter pieces per litter item category, material composition, top 10 litter item categories and uncertain or unclassified litter pieces. Litter pieces per hour should be used as the main standardised metric because it allows comparison between surveys if observation durations differ.

More advanced estimates, such as floating litter flux, may be added later if reliable information on observation width, total river width, flow velocity or discharge is available. For most cities starting a monitoring programme, pieces per observation and pieces per hour are more practical and robust.

Quality assurance should focus on training, consistent station use, complete metadata, documentation of uncertain litter pieces and local data checks by the local or regional coordinator. Duplicate observations or intercalibration exercises may be added where resources allow. Detailed QA/QC checks are provided in Annex 4. QA/QC Checklist.

RFML results should be summarised in practical outputs such as monthly or seasonal abundance, annual station summaries, top litter items list, plastic share, event-related peaks and short interpretations of likely sources or management implications. An example monitoring calendar for a baseline year, including routine surveys, event-based surveys, QA/QC and indicator calculation, is shown in Figure 3.

Example RFML Monitoring Calendar for City-Level Monitoring

Illustrative annual schedule for a monitoring station

OBJECTIVE Capture seasonal and event-driven variation in RFML loads. SURVEY DURATION 30–60 minutes (minimum recommended: 30 minutes) OBSERVATION METHOD Visual observation from a fixed elevated point (e.g. bridge) ITEMS RECORDED All floating litter pieces > 25 mm within the observation track width													
MONITORING ELEMENT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NOTES / PURPOSE
Routine surveys (baseline monitoring)	●	●	●	●	●	●	●	●	●	●	●	●	At least 8–10 surveys per year. Monthly or bi-weekly surveys recommended.
Event-based surveys (after high flow / heavy rain)			▲		▲		▲		▲		▲		Conduct additional surveys within 24–72 h after major rainfall or flood events.
Seasonal coverage (all seasons)			■			■			■			■	Ensure at least one survey in each season.
Winter conditions (ice / low flow)	❄	❄										❄	Adjust for safety and access conditions.
Data check & QA/QC (local level)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Check completeness and consistency after each survey.
Data submission (city / national database)			↑			↑			↑			↑	Submit validated data regularly (e.g. quarterly).
Indicator calculation (e.g. items/hour, items/km/day)			★			★			★			★	Calculate indicators and track temporal trends.
● Routine survey (monthly / bi-weekly) ▲ Event-based survey (after rainfall / flood) ■ Seasonal coverage (at least once per season) ❄ Winter conditions (adjusted frequency) ✓ QA/QC (after each survey) ↑ Data submission (e.g. quarterly) ★ Indicator calculation (e.g. quarterly)													
NOTES - The calendar is illustrative and should be adapted to local conditions, resources and risk of high-flow events. - Increase survey frequency during rainy seasons or periods with expected high litter inputs. - Maintain consistent observation time (30–60 min), location and observation track width. - Document all metadata (weather, flow, visibility) for interpretation of temporal trends.													

Fig. 3: Example RFML monitoring calendar for city-level monitoring, illustrating a baseline year with routine surveys, optional event-based surveys, seasonal coverage, local QA/QC, regular data submission and periodic indicator calculation.
Final illustration generated with the help of AI and revised by the authors.

5.1.5 Strengths, Limitations and Recommended Package

RFML surveys are low-cost, non-invasive, easy to repeat and suitable for implementation by trained local actors. They can generate comparable time series and are useful for communicating floating litter patterns to municipalities and stakeholders.

However, the method records only litter visible on the river surface. Submerged, stranded or riverbed litter is not captured. Detection can be affected by glare, poor visibility, wind, waves, turbidity, boat traffic, darkness, ice cover and observer fatigue. These limitations should be addressed through standardised protocols, training, complete metadata and cautious interpretation.

RFML surveys should therefore be interpreted as a practical indicator of floating macro-litter occurrence and temporal variation, rather than as a full quantification of total riverine litter flux. More robust flux estimates require additional information on river width, observation width, flow velocity, discharge and, where feasible, complementary sampling or retention data.

For South Baltic cities, the recommended RFML package includes one or more fixed stations, a fixed observation duration, monthly surveys during the baseline year where feasible, seasonal surveys as

a minimum, additional event-based surveys where useful, local QA/QC and an annual summary of indicators and management-relevant findings.

5.2 Riverbank Surveys of Macro-litter

Riverbank surveys of macro-litter are the second core method for city-level riverine litter monitoring. While RFML surveys focus on floating litter transported on the river surface, riverbank surveys record litter deposited along riverbanks, riparian vegetation, embankments, access points, recreational areas and other accumulation zones.

The method is particularly relevant for municipalities because riverbank litter is directly linked to local management, public use, clean-up activities, stormwater inputs, harbour areas and waste infrastructure. It provides information on deposited litter, dominant litter item categories, hotspots, possible source areas and the effectiveness of mitigation measures.

For this roadmap, riverbank surveys should record all visible macro-litter pieces larger than 25 mm within the defined survey section. Natural material should not be recorded as litter, but vegetation density, driftwood, flood deposits or other natural accumulation features should be documented if they influence litter retention or survey visibility.

5.2.1 Selection of Riverbank Survey Sections

Riverbank surveys should be carried out at fixed survey sections. Fixed sections are essential because they allow results to be compared between seasons, years and mitigation phases. Survey sections should represent relevant riverbank types and management contexts within the city, such as urban waterfronts, parks, harbour or marina areas, stormwater outlet areas, reed belts, vegetated accumulation zones or reference sections with lower expected pressure.

Riverbank sections may include natural, semi-natural and artificial surfaces, including sand, grass, pebbles, boulders, riprap, embankments, quays, paved waterfronts or other modified riverbank structures. The selected surface type should be documented because it can influence litter accumulation, detectability and comparability between sites.

Where the monitoring objective is long-term comparison, riverbank sections should be as representative and stable as possible and should not be strongly affected by irregular clean-up activities. Additional hotspot sections may be included for management purposes, but they should be clearly labelled as hotspot monitoring sites and interpreted separately from representative monitoring sections.

Each survey section should be documented with a section ID, start and end point, GPS coordinates, photographs, survey length, surveyed width or area, riverbank type, land-use context, access information, safety notes and cleaning status where available. The same section boundaries should be used throughout the monitoring programme.

Where possible, a 100 m riverbank section is recommended. If site conditions do not allow this, shorter fixed sections may be used, for example 50 m or 10 m, but the exact length must be recorded and kept stable over time. The surveyed width should be clearly defined, for example from the waterline to the upper riverbank boundary, path, wall, vegetation edge or another fixed feature. If unsafe conditions prevent surveyors from reaching the waterline, the surveyed area should be limited to the safely accessible part and this limitation should be documented. An example set-up for a fixed riverbank macro-litter survey section is shown in Figure 4.

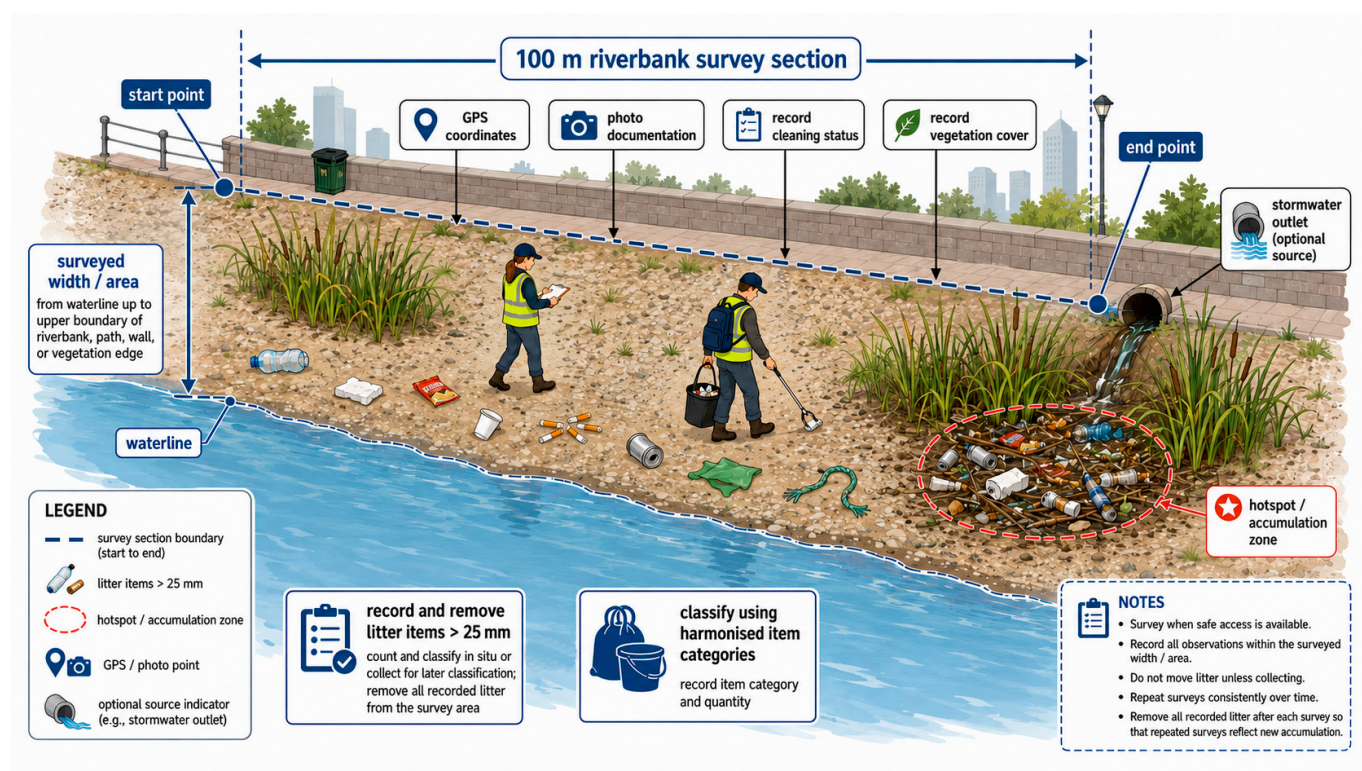


Fig. 4: Suggested set-up for riverbank macro-litter surveys, showing an example fixed survey section, start and end points, surveyed width or area, waterline, GPS and photo documentation points, cleaning and vegetation metadata, and the removal and classification of litter pieces larger than 25 mm using harmonised litter item categories. Survey sections may be 100 m where feasible or shorter fixed sections where site conditions require this. Final illustration generated with the help of AI and revised by the authors.

5.2.2 Survey Design, Frequency and Timing

For a baseline assessment, cities should aim to survey selected riverbank sections over at least one full year. Monthly surveys are recommended where resources allow this. If monthly surveys are not feasible, seasonal surveys should be used as a minimum. Additional event-based surveys are useful

after high water, flooding, heavy rainfall, public events or known litter inputs.

Riverbank surveys should ideally be carried out before routine cleaning takes place or after a clearly documented accumulation period. Before regular monitoring starts, the selected riverbank section should preferably be cleared once of all visible macro-litter. This initial clean-up should be documented, so that subsequent surveys can be interpreted as litter accumulation during a defined period. If no initial clean-up is carried out, the first survey should be treated as a standing-stock survey, as the recorded litter may have accumulated over months or years and should not be directly compared with later routine surveys. If cleaning occurs before a survey, this must be recorded because it strongly affects litter abundance. Recent flooding, vegetation cutting, construction work or access restrictions should also be documented. The recommended riverbank survey frequency for different monitoring levels is summarised in Table 4.

Table 4: Recommended riverbank survey frequency for city-level monitoring.

Monitoring level	Recommended frequency	Purpose
Minimum baseline	Four surveys per year, one per season	Basic seasonal overview where resources are very limited
Standard baseline	Monthly surveys for at least one full year	Recommended starting point for most cities
Enhanced baseline	Monthly surveys plus event-based surveys	Detection of flood-, rainfall- or event-related litter inputs
Long-term monitoring	Monthly or seasonal surveys at fixed sections	Trend assessment and evaluation of mitigation measures
Before-after monitoring	One survey before and one or more surveys after a mitigation measure	Evaluation of clean-ups, bin placement, awareness campaigns or technical measures

5.2.3 Field Procedure and Data Recording

Before each survey, the monitoring team should confirm the correct section, check access and safety, and identify the start and end points. The section should then be surveyed systematically from start to end. All visible macro-litter pieces larger than 25 mm should be recorded, counted and collected from the survey section.

Litter pieces should be assigned to harmonised litter item categories. The online photo catalogue of the Joint List can be used as an additional field or training aid to support consistent identification of litter pieces. If the litter item classification is uncertain, the piece should be recorded in a broader category and flagged as uncertain. Photographs should be taken for uncertain litter pieces, hotspots or relevant source indicators.

The minimum data recorded during each riverbank survey should include section ID, start and end points, date, survey team, survey length, surveyed width or area, riverbank type, weather, recent rainfall or flooding, vegetation cover, cleaning status, litter item categories, piece counts, hotspots, comments and QA/QC status. Detailed field-sheet requirements are provided in Annex 2. Riverbank Survey Field Sheet. The main field steps for riverbank macro-litter surveys, from section check to data entry and indicator calculation, are summarised in Figure 5.

Riverbank macro-litter field workflow

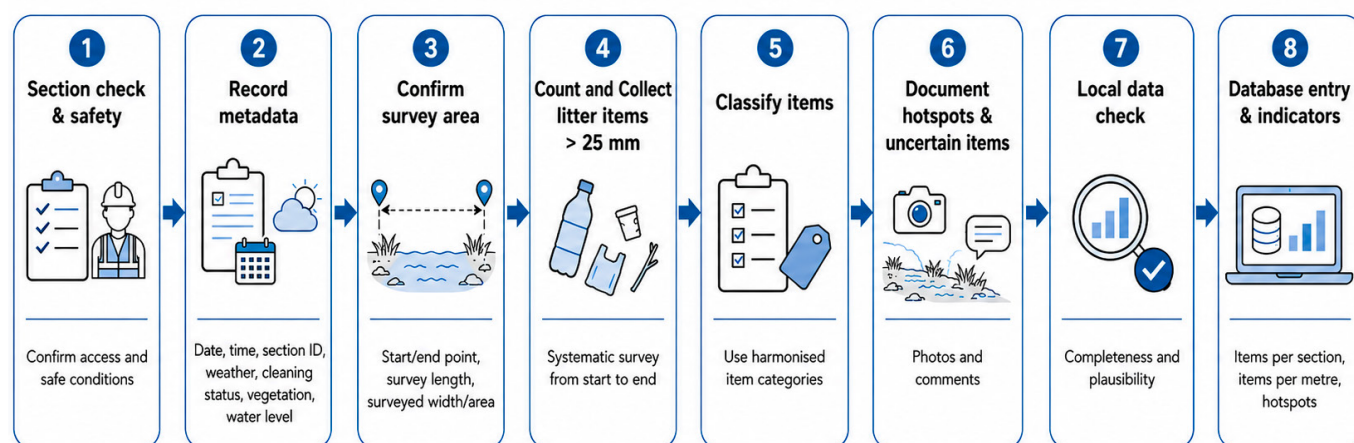


Fig. 5: Riverbank macro-litter field workflow from section check to database entry and indicator calculation. The figure illustrates the main steps of a standardised riverbank survey, including safety checks, metadata recording, confirmation of the survey area, systematic counting and collection of litter pieces larger than 25 mm, classification using harmonised litter item categories, documentation of hotspots and uncertain litter pieces, local data checking and indicator calculation. Final illustration generated with the help of AI and revised by the authors.

5.2.4 Indicators, QA/QC and Outputs

The recommended core indicators for riverbank surveys are total litter pieces per section, litter pieces per meter, litter pieces per square meter where the surveyed area is available, litter pieces per litter item category, material composition, top 10 litter item categories, hotspot locations and uncertain or unclassified litter pieces. Cleaning status should always be documented because it strongly affects interpretation. When interpreting riverbank survey results, it is important to distinguish between standing stock and accumulation. A first survey without prior cleaning represents the visible litter stock present at the site and may include material accumulated over a long and unknown period. In contrast, surveys carried out after an initial clean-up and a defined accumulation period provide more comparable information on new litter inputs and accumulation rates.

Where 100 m sections are used, results can also be reported as pieces per 100 meter to improve compatibility with UNEP/MED riverbank monitoring guidance. Pieces per meter remain useful for comparing sections of different lengths, while pieces per square meter can be used where the

surveyed area is clearly defined.

Special pollution indicators, such as industrial pellets, paraffin wax, oil residues or other chemical pollution indicators, should be recorded where observed. Even if these categories do not dominate total piece counts, they can provide important information on specific sources or pollution events. Quality assurance should focus on training, fixed section boundaries, complete metadata, documentation of cleaning status, photo documentation of hotspots and local data checks by the local or regional coordinator. Intercalibration or duplicate surveys may be added where resources allow. Detailed QA/QC checks are provided in Annex 4. QA/QC Checklist.

Riverbank survey results should be summarised in practical outputs, including seasonal or annual abundance per section, comparison between sections, top litter items list, hotspot maps, likely source areas and recommendations for local management actions. An example riverbank macro-litter monitoring calendar for a baseline year is shown in Figure 6.

Example Riverbank Monitoring Calendar for City-Level Monitoring

Illustrative annual schedule for a monitoring section

OBJECTIVE		SURVEY DURATION		OBSERVATION METHOD		ITEMS RECORDED								
 Capture seasonal and event-driven accumulation on riverbanks.		 Depending on section size and litter load (e.g. 30–120 minutes)		 Repeated survey of a fixed riverbank section (e.g. 100 m section)		 All macro-litter pieces > 25 mm within the surveyed section / area								
MONITORING ELEMENT		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NOTES / PURPOSE
 Routine surveys (baseline monitoring)		●	●	●	●	●	●	●	●	●	●	●	●	Monthly surveys recommended during the baseline year.
 Event-based surveys (after high flow / flooding / public events)				▲		▲		▲		▲		▲		Conduct additional surveys after high-flow events, flooding or major public-use events where relevant.
 Seasonal coverage (all seasons)				■			■			■			■	Ensure at least one survey in each season.
 Winter or high-water conditions		❄	❄										❄	Adjust timing for safety, access and water-level conditions.
 Data check & QA/QC (local level)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Check completeness, plausibility and section consistency after each survey.
 Data submission (city / national database)				⬆			⬆			⬆			⬆	Submit validated data regularly (e.g. quarterly).
 Indicator calculation (e.g. pieces/section, pieces/metre, pieces/m ²)				★			★			★			★	Calculate indicators and assess spatial and temporal accumulation patterns.

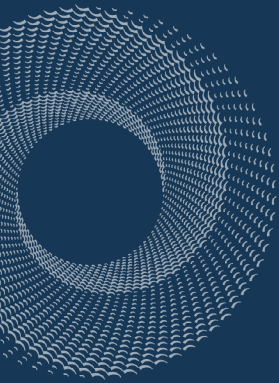
5.2.5 Strengths, Limitations and Recommended Package

Riverbank surveys are low-cost, easy to repeat and suitable for trained local actors, including municipalities, NGOs, schools, universities and citizen-science groups. They provide direct information on visible litter pollution, local hotspots and dominant litter item categories, and can be linked directly to management actions.

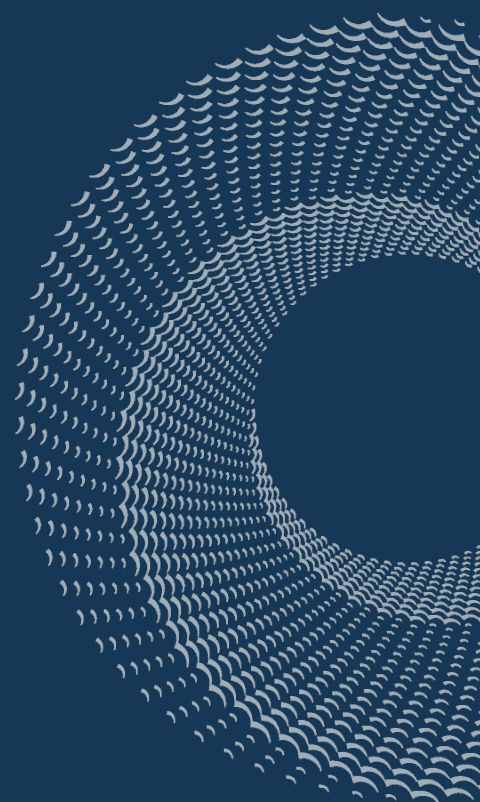
However, riverbank litter does not directly represent floating litter transport or total riverine litter loads. Results can be influenced by cleaning frequency, flooding, wind, vegetation, access restrictions, recreational use and seasonal maintenance. Litter may also be hidden in dense vegetation or removed before surveys take place.

Riverbank surveys provide information on deposited and retained litter, but they should not be interpreted as direct measurements of total riverine litter transport. Their value lies mainly in hotspot identification, source interpretation and the evaluation of local management measures. These limitations should be addressed through fixed sections, standardised protocols, complete metadata, documentation of cleaning status and cautious interpretation.

For South Baltic cities, the recommended riverbank package includes a small number of fixed survey sections, a standard section length of 100 m where feasible, clearly defined survey width or area, monthly surveys during the baseline year where possible, seasonal surveys as a minimum, event-based surveys where useful, local QA/QC and an annual summary of indicators, hotspots and management-relevant findings.



6. Digital Tools and App-supported Litter Identification



6. Digital Tools and App-supported Litter Identification

Digital tools can support city-level riverine litter monitoring by standardising data collection, reducing missing information and improving data flow between field teams, local coordinators and wider reporting systems. They are particularly useful when several teams, schools, NGOs, municipalities or citizen-science groups monitor different stations or sections.

However, digital tools should support the monitoring protocol, not replace it. Cities should be able to start with paper field sheets or spreadsheet-based forms if app-based tools are not yet available. The key requirement is that all tools record fixed station or section IDs, harmonised litter item categories, mandatory metadata, comments on uncertain litter pieces, photo documentation where useful and QA/QC status.

6.1 Digital Tools for RFML Surveys

For RFML surveys, the JRC Floating Litter Monitoring Application provides a useful digital tool. The app was developed for visual observations of floating macro-litter in rivers, lakes and marine waters from observation points such as bridges or ships. It allows users to record metadata, GPS position and floating litter pieces during monitoring sessions. Its litter item-category list is harmonised with the EU Joint List of Litter Categories for Marine Macro-litter Monitoring, which makes it relevant for MSFD-compatible RFML data collection.

Where available, the app can therefore support RFML surveys in South Baltic cities, especially when several observers or institutions contribute to the same monitoring programme. At the same time, the use of the app should not be a precondition for starting monitoring. Paper field sheets, spreadsheets or locally developed digital forms can also be used if they follow the same methodological principles and record the required metadata, litter item categories and QA/QC information. An example of the JRC Floating Litter Monitoring Application is shown in Figure 7.

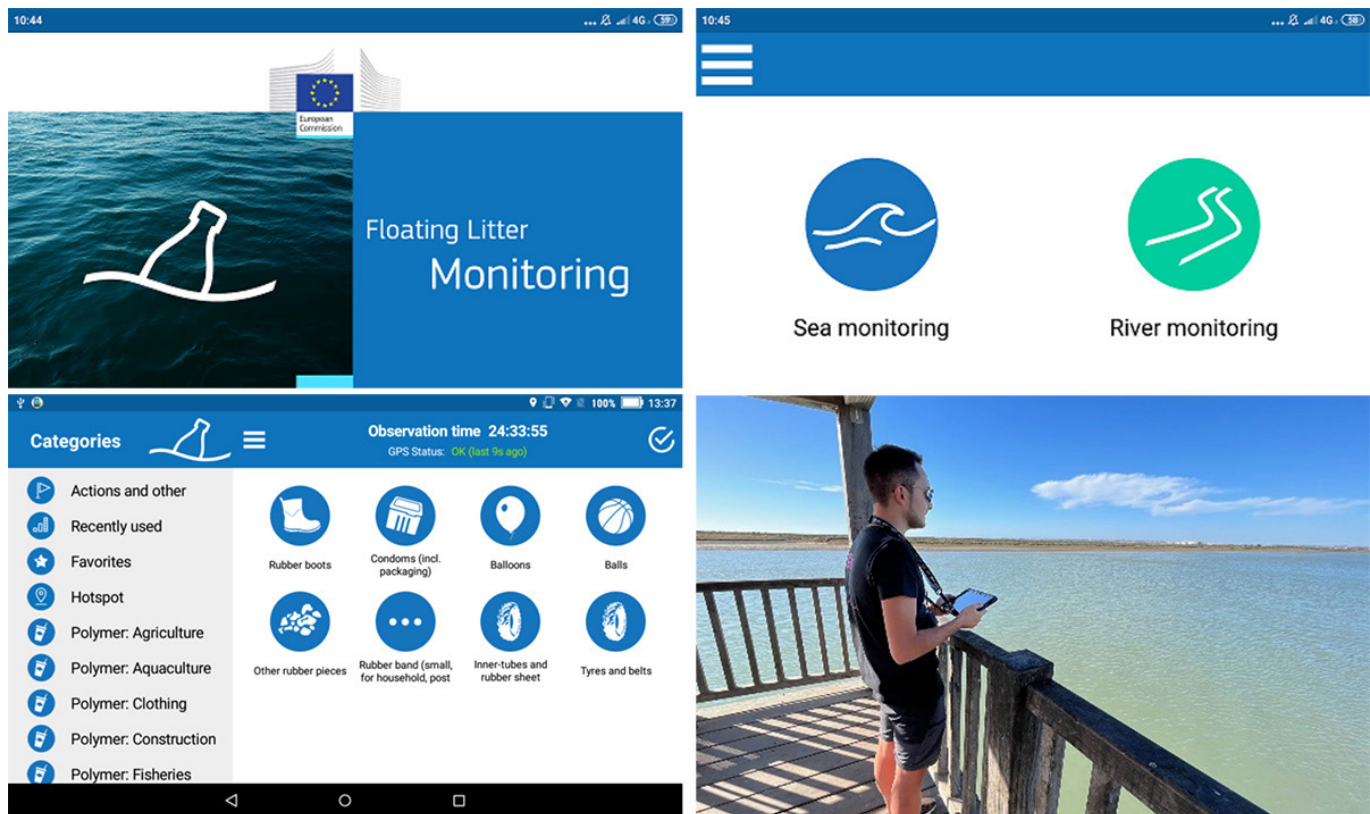


Fig. 7: JRC Floating Litter Monitoring Application for app-supported visual monitoring of floating macro-litter in rivers and marine waters. The application allows users to record metadata, GPS position and floating litter pieces during monitoring sessions, using harmonised litter item categories based on the EU Joint List of Litter Categories for Marine Macro-litter Monitoring. Source: INSPIRE Europe / JRC Floating Litter Monitoring App.

Further information and access to the JRC Floating Litter Monitoring system are available through the official JRC Floating Litter Monitoring website. The mobile application is available via Google Play, and uploaded surveys can be managed through the associated web application.

6.2 Digital Forms for Riverbank Surveys

For riverbank macro-litter surveys, digital forms can also be useful, especially when several fixed sections are monitored repeatedly. A digital form can guide survey teams through the required steps and help ensure that section ID, survey area, cleaning status, vegetation cover, piece counts, hotspot information and photographs are recorded consistently.

There is no single mandatory app for riverbank surveys. Cities may therefore use simple digital forms, spreadsheets, GIS-based survey tools or locally adapted apps. The important point is that the data structure remains harmonised and exportable.

6.3 Minimum Requirements and Data Export

Any digital tool used for riverine litter monitoring should be simple enough for trained local actors to use in the field, but structured enough to produce comparable data. As a minimum, it should include

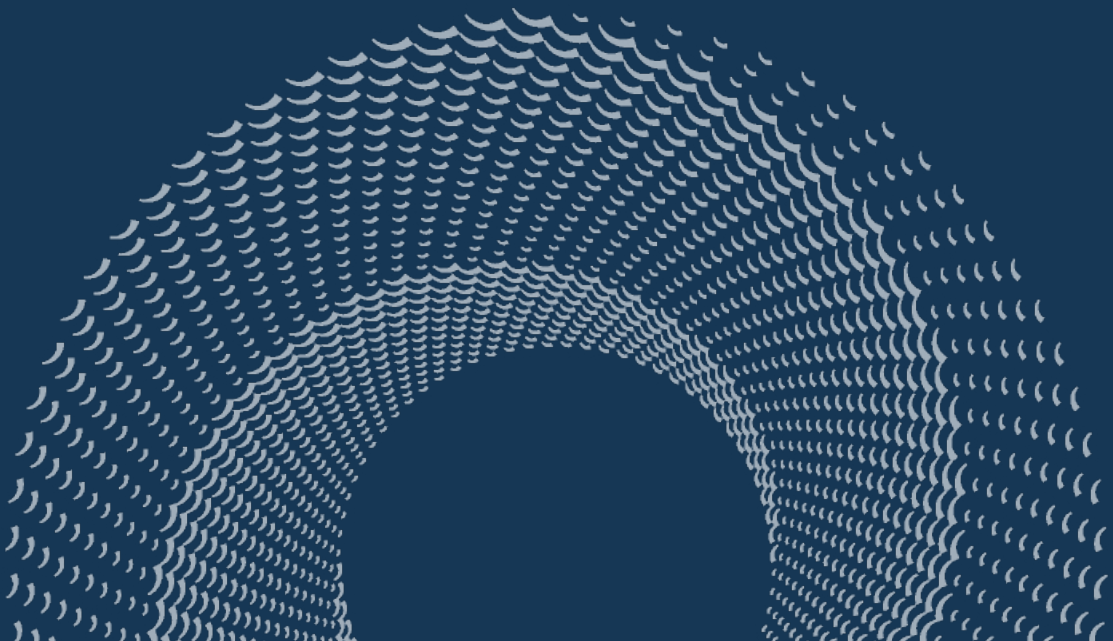
station or section IDs, GPS coordinates, date and time, observer or team, method type, mandatory metadata fields, harmonised litter item categories, photo and comment options, QA/QC status and an exportable data format.

Data should be stored locally in a structured spreadsheet or database and backed up regularly. If a national coordinator, data centre or reporting pathway becomes available later, locally stored data can then be transferred more easily. This is particularly important for cities that start monitoring before a national riverine litter database is fully established.

The key principle is that the monitoring protocol defines the data, not the tool. A simple paper form that follows the protocol is more useful than a digital app that omits essential metadata.

7.

Emerging and Near-future Technologies



7. Emerging and Near-future Technologies

Emerging and near-future technologies can complement city-level riverine litter monitoring, but they should not be required as starting methods. The core monitoring package of this roadmap is based on RFML visual surveys and riverbank surveys because these methods are practical, low-cost and ready for immediate implementation. More technical approaches can be added later once baseline monitoring is established and specific management or research questions have been identified.

UAVs, or drones, can support the mapping of riverbank litter hotspots, inaccessible accumulation zones, reed belts, harbour basins and stormwater outlet areas. They are useful for visual documentation before and after clean-ups or mitigation measures, but require trained operators, suitable weather conditions, permits and image interpretation. They should therefore be used as complementary tools rather than replacements for standardised field surveys.

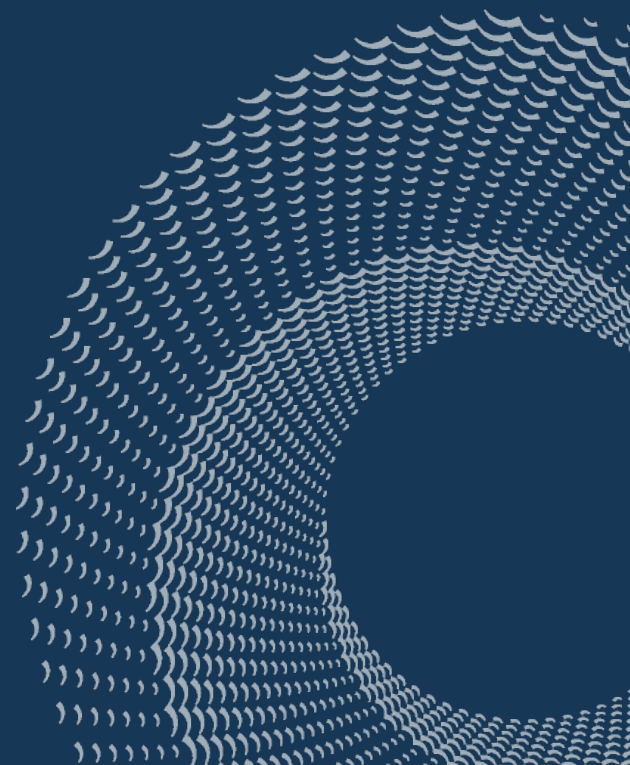
Fixed cameras and AI-supported detection systems are promising for repeated observations of floating litter at bridges, river mouths or harbour structures. They may help detect short-term litter pulses after rainfall, high discharge or public events. However, they should currently be considered pilot tools because they require installation, power supply, data storage, calibration and validation against manual observations.

Technical retention systems, such as litter traps, booms, port bins or surface collectors, can provide additional information when collected litter is counted and classified systematically. However, these data are not directly comparable to RFML or riverbank survey data because capture efficiency depends on design, location, hydrology, wind, maintenance and operation time.

For South Baltic cities, emerging technologies should therefore be introduced stepwise and only where they provide clear added value. Their main role is to support hotspot mapping, event-based monitoring and the evaluation of mitigation measures. The key principle is that emerging technologies should support the monitoring strategy, not define it.

8.

Recommended Monitoring Package for South Baltic Cities



8. Recommended Monitoring Package for South Baltic Cities

The recommended monitoring package for South Baltic cities follows a stepwise approach. Cities should be able to start with a simple and realistic monitoring design, while still producing harmonised and reusable data. The core package combines two complementary methods: visual surveys of Riverine Floating Macro-Litter (RFML) and riverbank surveys of macro-litter.

RFML surveys provide information on floating macro-litter transported on the river surface, while riverbank surveys provide information on deposited litter, accumulation zones, hotspots and potential local sources. Together, both methods create a practical city-level picture of riverine macro-litter pressure.

8.1 Monitoring Package Levels

Not all cities have the same resources, staff capacity or monitoring experience. Therefore, this roadmap recommends three implementation levels: a minimum package, a standard package and an advanced package. These packages are summarised in Table 5. The minimum package allows cities to start quickly, the standard package is recommended for most cities, and the advanced package can be used where additional capacity or specific management questions exist.

Table 5: Recommended monitoring packages for city-level riverine macro-litter monitoring.

Package level	Main components	Recommended frequency	Purpose
Minimum package	One RFML station; one or more fixed riverbank sections; local data storage	Four surveys per year, one per season	Basic seasonal overview and first baseline information
Standard package	One or more RFML stations; several fixed riverbank sections; local QA/QC; annual summary	Monthly surveys for at least one baseline year; seasonal or monthly continuation	Recommended package for baseline and long-term monitoring
Advanced package	Standard package plus event-based surveys and site-specific extensions	Monthly surveys plus event-based or site-specific extensions	Detailed hotspot assessment, mitigation evaluation and research-oriented questions

8.2 Recommended Standard Package

For most South Baltic cities, the standard package is recommended. It provides a realistic balance between scientific value and practical feasibility. The standard package should include at least one fixed RFML station and several fixed riverbank survey sections. Where possible, one RFML station should be located close to the river mouth or harbour area, because this provides information on

floating litter that may enter coastal waters.

Riverbank survey sections should represent the main urban riverbank types in the city, such as recreational waterfronts, harbour areas, parks, stormwater outlet areas, vegetated accumulation zones and reference sections with lower expected litter pressure. The number of sections should remain realistic. It is better to monitor a small number of well-documented sections over several years than to start with too many sites that cannot be maintained.

During the baseline phase, monthly surveys over at least one full year are recommended where resources allow this. If monthly surveys are not feasible, seasonal surveys should be used as a minimum. Additional event-based surveys can be added after heavy rainfall, high water, public events or known litter inputs.

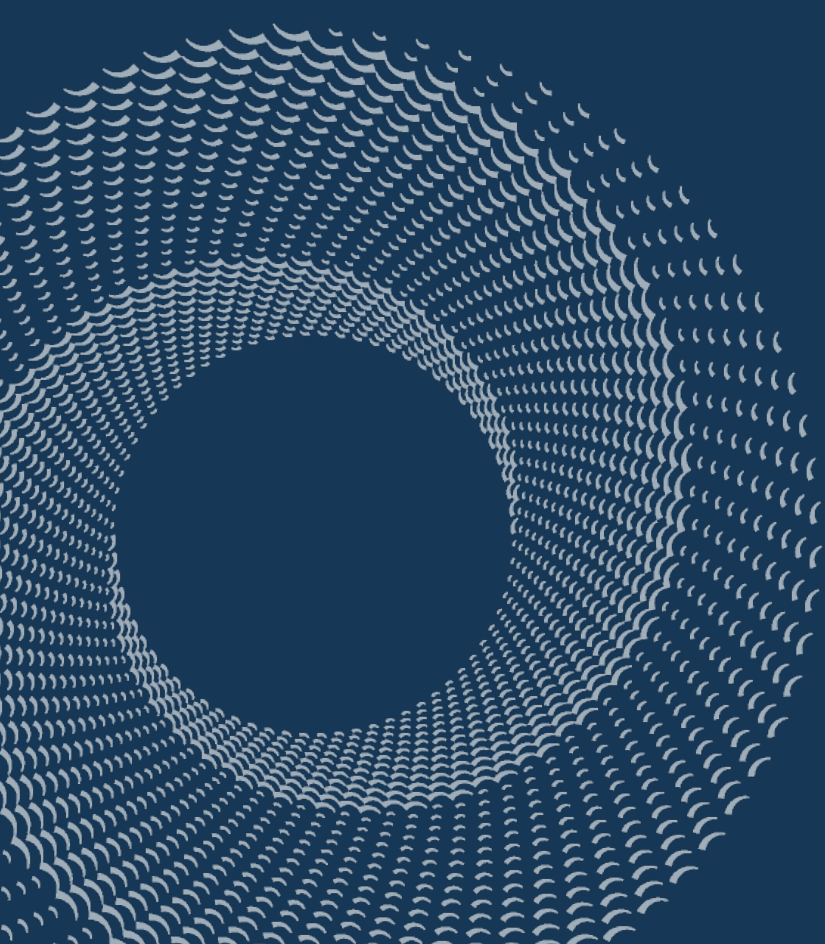
8.3 Linking Methods, Outputs and Management Needs

The selected monitoring package should reflect the main questions of the city. RFML surveys are most suitable when the focus is on floating macro-litter transport and temporal patterns. Riverbank surveys are most suitable when the focus is on local hotspots, deposited litter, accumulation zones and management actions. For most city-level programmes, both methods should be combined because they provide complementary information.

Regardless of the selected package level, all cities should apply the same basic requirements from the beginning: fixed stations or sections, unique IDs, GPS coordinates, photo documentation, a clear survey duration or surveyed area, the macro-litter threshold of >25 mm, complete metadata, local QA/QC and structured local data storage.

Monitoring results should be translated into practical outputs for municipalities and local stakeholders. Recommended outputs include annual summaries, hotspot maps, top litter items list, seasonal comparisons and short recommendations for mitigation measures. For RFML surveys, the main outputs are litter pieces per observation, litter pieces per hour, dominant floating litter item categories and temporal patterns. For riverbank surveys, the main outputs are litter pieces per meter and/or square meter, hotspot locations, dominant riverbank litter item categories, cleaning status and likely source areas.

The key recommendation is to start with a monitoring design that can be maintained over time. A simple, stable and well-documented monitoring programme is more valuable than a complex design that cannot be continued after the initial project phase.



9. QA/QC, Data Management and Reporting

9. QA/QC, Data Management and Reporting

Quality assurance and quality control are essential to ensure that city-level riverine litter data are comparable, reliable and useful for long-term monitoring. QA/QC should be applied from the beginning, even if the monitoring programme starts with a simple local structure. This ensures that early data remain useful when they are later transferred to a national coordinator, database or wider reporting system. For city-level monitoring, QA/QC should remain simple and practical. It mainly means that survey teams are trained, methods are applied consistently, metadata are complete, uncertain observations are documented, and data are checked before they are used for reporting or management decisions.

After each survey, the local or regional coordinator should check the submitted data for completeness and plausibility. This includes checking station or section IDs, survey duration or surveyed area, piece counts, mandatory metadata, cleaning status where relevant, uncertain litter pieces and unusual observations. Errors should be corrected as soon as possible after the survey.

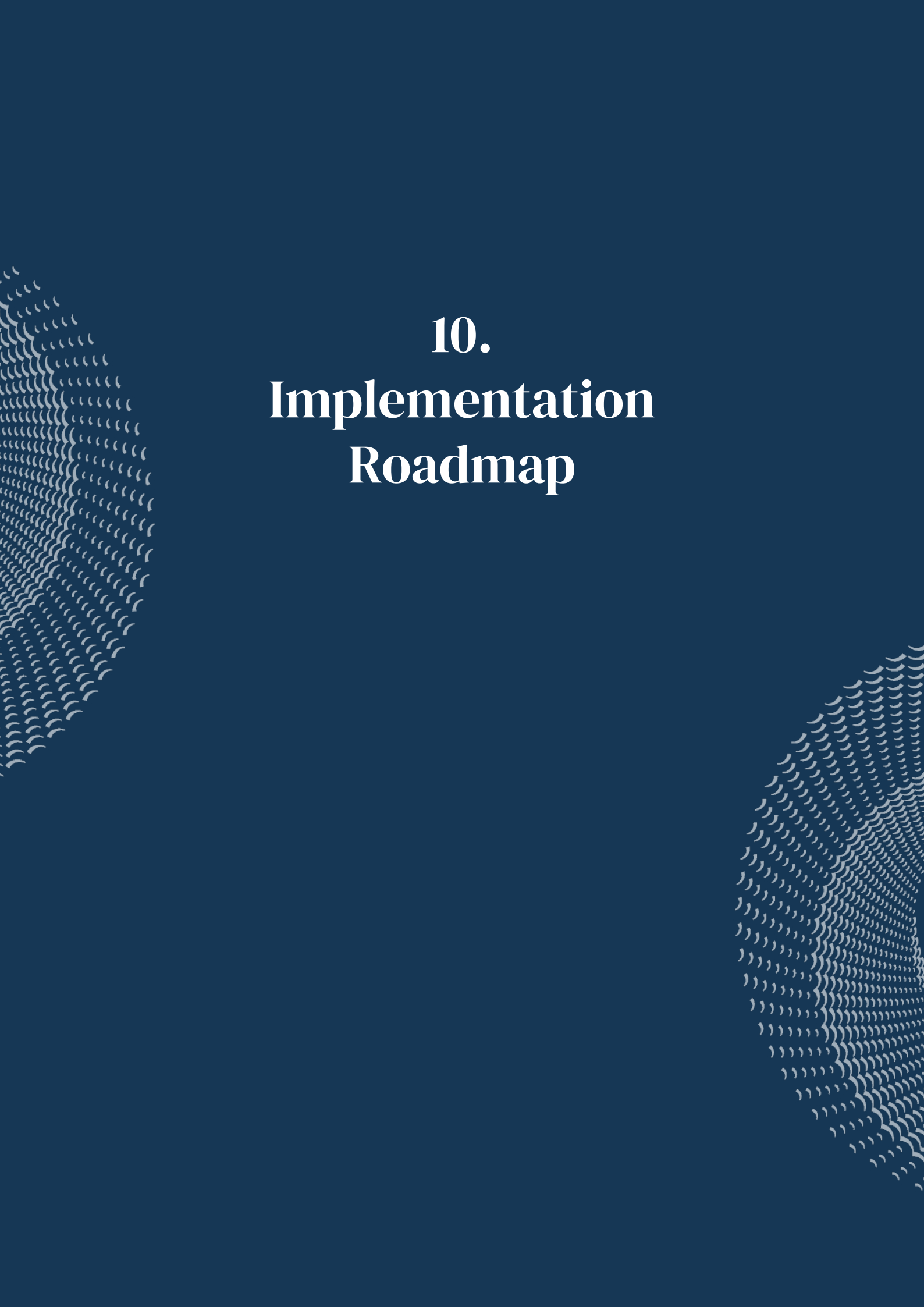
Each dataset should receive a simple QA/QC status. Recommended QA/QC status categories are provided in Table 6.

Table 6: Recommended QA/QC status categories for riverine macro-litter monitoring.

QA/QC status	Meaning
Raw data	Data submitted by the field team, not yet checked.
Locally checked data	Data checked by the local or regional coordinator.
Corrected data	Data corrected after clarification with the survey team.
Validated data	Data accepted for analysis, reporting or transfer.
Excluded data	Data not used because essential information is missing or survey conditions were unsuitable.

All monitoring data should be stored in a structured local spreadsheet or database. The database should include the method, station or section ID, date, survey duration or surveyed area, litter item category, piece count, key metadata and QA/QC status. If paper field sheets are used, they should be scanned or photographed and archived together with the digital data. Detailed metadata requirements and QA/QC checklists are provided in Annex 3. Minimum Metadata Requirements and Annex 4. QA/QC Checklist.

Reporting should translate monitoring results into practical outputs for municipalities and local stakeholders. An annual summary is recommended and should include monitored sites, number of surveys, data quality, main indicators, dominant litter item categories, hotspot locations, seasonal or event-related patterns and recommendations for mitigation measures. Maps, figures, top litter items list and short management summaries are often more useful for local decision-makers than complex datasets alone.



10.

Implementation Roadmap



10. Implementation Roadmap

The implementation of city-level riverine litter monitoring should follow a stepwise approach. Cities do not need to establish a complete monitoring and reporting system before they start. Instead, they should begin with a simple, harmonised and realistic monitoring design that can later be expanded and connected to national or regional structures.

The roadmap follows four implementation phases:

1. preparation,
2. baseline assessment,
3. long-term monitoring and
4. improvement or extension.

These phases can be adapted to local capacity, but the overall logic should remain the same: start with fixed stations and clear responsibilities, collect baseline data, continue monitoring with stable methods and use the results to improve mitigation.

10.1 Phase 1: Preparation

The preparation phase establishes the minimum structure required to start monitoring. This includes selecting a local or regional coordinator, identifying monitoring teams, choosing RFML stations and riverbank survey sections, preparing field sheets or digital forms and agreeing on local data storage.

Monitoring stations and sections should be documented with GPS coordinates, photographs, IDs and short descriptions. Safety issues, access permissions, responsibilities and training needs should be clarified before the first field survey. A national database or formal reporting pathway is not required at this stage, but methods, litter item categories and metadata fields should be harmonised from the beginning.

10.2 Phase 2: Baseline Assessment

The baseline assessment should provide the first structured overview of riverine macro-litter in the city. It should include both RFML surveys and riverbank surveys at fixed stations and sections. Where possible, monthly surveys over one full year are recommended; where resources are limited, seasonal surveys should be used as a minimum.

The baseline phase should identify litter abundance, dominant litter item categories, hotspots, seasonal or event-related patterns and the suitability of the selected monitoring stations and

methods. At the end of this phase, the local or regional coordinator should prepare a short baseline report with key findings and first recommendations.

10.3 Phase 3: Long-term monitoring

After the baseline phase, the monitoring programme should move into long-term implementation. The main aim is to maintain stable methods, fixed stations, harmonised categories and consistent metadata over several years. This allows cities to detect changes over time and evaluate whether mitigation measures are effective.

Long-term monitoring should remain realistic. A smaller number of well-maintained stations and sections is preferable to a large network that cannot be continued. The monitoring frequency can be adjusted after the baseline phase, but any changes should be documented clearly. Results should be summarised annually and communicated to municipalities, harbour authorities, waste managers, NGOs, schools and other local stakeholders.

10.4 Phase 4: Improvement, Extension and Mitigation Feedback

Once the core monitoring programme is established, cities can improve or extend it based on the results. Additional stations or riverbank sections may be added if important hotspots are identified. Event-based surveys can be introduced after rainfall, high water or public events. Complementary tools, such as UAV mapping, fixed cameras or data from technical retention systems, may be added where they provide clear added value.

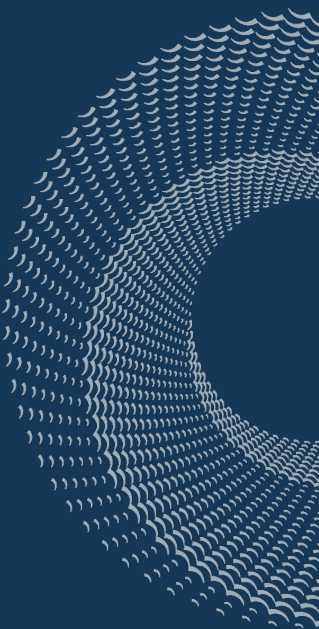
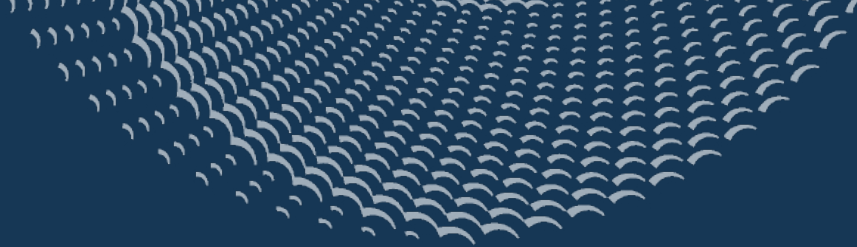
Monitoring results should also be used to evaluate mitigation measures. If waste bins are added, cleaning schedules changed, awareness campaigns implemented or technical retention systems installed, before-after monitoring should be used to assess whether litter abundance, hotspots or specific litter item categories decrease.

The implementation roadmap should therefore be understood as a continuous cycle: plan, monitor, assess, mitigate and improve. The four implementation phases and their expected outputs are summarised in Table 7.

Table 7: Implementation roadmap for city-level riverine macro-litter monitoring

Phase	Main actions	Expected output
Phase 1: Preparation	Define coordinator, teams, stations, sections, field sheets, data storage and training	Monitoring structure ready to start
Phase 2: Baseline assessment	Conduct RFML and riverbank surveys for at least one year where feasible	Baseline dataset and first city-level assessment

Phase 3: Long-term monitoring	Continue surveys using stable methods, stations and metadata	Time series, annual summaries and trend information
Phase 4: Improvement and extension	Add event-based surveys, additional sites or complementary tools where needed	Improved monitoring design and stronger mitigation feedback



11.

Application to South Baltic City Contexts



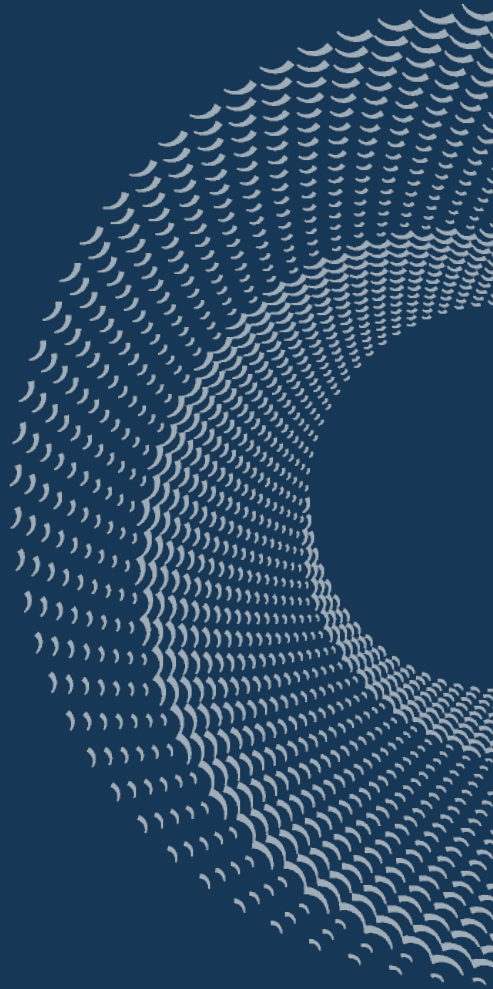
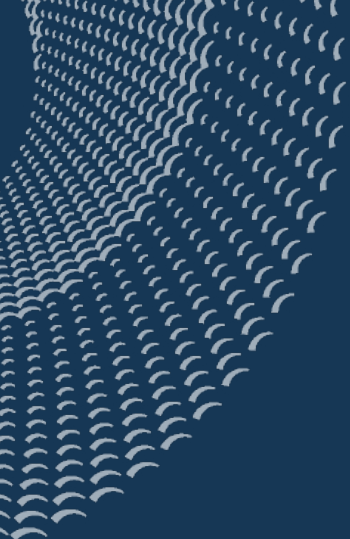
11. Application to South Baltic City Contexts

The roadmap is designed to be flexible and applicable to different South Baltic city contexts. Cities in the region differ in river size, harbour infrastructure, waterfront use, stormwater systems, cleaning routines, existing clean-up activities and available monitoring capacity. Therefore, the monitoring design should be adapted locally while keeping the same core principles: fixed RFML stations, fixed riverbank sections, harmonised litter item categories, complete metadata and local QA/QC.

In cities with urban river-mouth or harbour areas, RFML surveys can help assess floating macro-litter transport towards coastal waters, while riverbank surveys can identify local accumulation zones, recreational hotspots and areas influenced by urban use, stormwater inputs or harbour infrastructure. In larger urban river systems, several riverbank sections may be needed to cover different waterfront types, canals, vegetated banks, harbour-related areas and recreational spaces.

Where technical retention systems, litter traps, port bins or organised clean-up activities are already in place, monitoring data from RFML surveys and riverbank sections can be combined with information from these measures. This can help cities better understand temporal patterns, dominant litter item categories, hotspot development and mitigation effectiveness. A good example of such a retention system is installed in Aarhus, Denmark (Haseler and Mihut, 2025).

The roadmap should therefore not be understood as a fixed sampling scheme, but as a practical framework that can be adapted to local conditions while still producing comparable and policy-relevant data. The key requirement is that all local adaptations are clearly documented, so that monitoring results remain interpretable and suitable for long-term comparison.



12. From Monitoring to Mitigation

12. From Monitoring to Mitigation

Riverine litter monitoring should not end with data collection. Its main purpose is to generate information that supports practical mitigation. Monitoring results should help cities understand where litter occurs, which litter item categories dominate, when inputs are highest and which local activities or pathways may contribute to the problem.

The most direct use of monitoring data is hotspot identification. Riverbank surveys can show where litter accumulates repeatedly, while RFML surveys can indicate periods with increased floating litter transport. These results can help municipalities prioritise clean-ups, improve waste bin placement, adjust cleaning schedules or focus awareness campaigns on specific locations.

Top litter items lists are another important output. If cigarette butts, food packaging, plastic bags, bottles, cups or other single-use item categories dominate, mitigation can be targeted towards these categories. Dominant litter item categories should be interpreted together with potential sources and pathways, such as recreational waterfront use, outdoor gastronomy and events, smoking at waiting areas, construction or maintenance activities, sewage- or stormwater-related inputs, recreational shipping, fishing or angling, agricultural activities and illegal dumping.

Monitoring can also support event-based management. Increased litter after rainfall, high discharge, public events or tourist periods can indicate specific input pathways. In these cases, cities may need temporary cleaning measures, additional bins, improved stormwater management or targeted communication before and after events.

Before-after monitoring should be used to evaluate whether mitigation measures work. If a city installs additional bins, changes cleaning routines, implements awareness campaigns or tests a technical retention system, the same monitoring stations and sections should be surveyed before and after implementation.

Monitoring results should therefore be communicated in a management-oriented way. Annual summaries, hotspot maps, top litter items list, seasonal comparisons and short recommendations are useful formats for local decision-makers. The aim is to create a feedback loop in which monitoring informs mitigation, mitigation is evaluated through monitoring, and the monitoring design is improved over time.

12.1 Sources of litter

Monitoring results can support mitigation only if they are interpreted in relation to likely sources and pathways. Source identification should therefore be treated as an analytical step between data evaluation and measure selection. It should be based on dominant litter item categories, hotspot locations, temporal patterns, site observations and stakeholder knowledge.

For this roadmap, a simplified likelihood-based Matrix Scoring Technique can be used for selected dominant or management-relevant litter item categories (Table 8). The approach is adapted from the source attribution method described by Veiga et al. (2016), which builds on the Matrix Scoring Technique developed by Tudor and Williams (2004). The method is not a field survey method, but a post-survey assessment tool. It uses monitoring results and local knowledge to assess how likely it is that specific litter item categories originate from different potential sources.

The Matrix Scoring Technique is applied as a tabular source-attribution approach. Each litter item category is assessed against a predefined set of potential sources. Qualitative likelihoods, such as very likely, likely, possible, unlikely or very unlikely, are assigned to each item-source combination and then translated into numerical scores. These scores are used to allocate the recorded litter items across the plausible sources and to derive an indicative source profile for the site or city. The resulting source profile should be interpreted as an assessment of likely source contributions, not as proof of origin.

Table 8: Suggested likelihood scoring system (System E) for identifying potential sources of litter, adapted from Veiga et al. (2016), Table 4, based on Tudor and Williams (2004).

Phase	Main actions	Expected output
Phase 1: Preparation	Define coordinator, teams, stations, sections, field sheets, data storage and training	Monitoring structure ready to start
Phase 2: Baseline assessment	Conduct RFML and riverbank surveys for at least one year where feasible	Baseline dataset and first city-level assessment
Phase 3: Long-term monitoring	Continue surveys using stable methods, stations and metadata	Time series, annual summaries and trend information
Phase 4: Improvement and extension	Add event-based surveys, additional sites or complementary tools where needed	Improved monitoring design and stronger mitigation feedback

Before the scoring is applied, a list of potential local sources and pathways should be defined for the city or river section. For South Baltic urban river systems, relevant source categories may include public recreation, outdoor gastronomy and events, smoking-related littering, waste management infrastructure, harbour and boating activities, fishing or angling, construction activities, littering and

illegal dumping. Relevant pathways or transport contexts may include wind transport, stormwater runoff, drainage systems, flooding, river transport and upstream catchment inputs.

This distinction is important because rivers should not be treated as sources of litter in themselves. They are pathways or transport mechanisms that move litter from different land-based or water-based sources through the catchment towards downstream areas, harbour basins or coastal waters. Therefore, the assessment should aim to identify both the likely source activity and the pathway by which litter reaches the river system.

To keep the approach simple and reduce workload, the scoring can be applied only to the dominant or management-relevant litter item categories, such as the top 20–25 items recorded during RFML or riverbank surveys. For each item category, the local or regional coordinator and relevant stakeholders assess how likely it is that the item originates from each potential source.

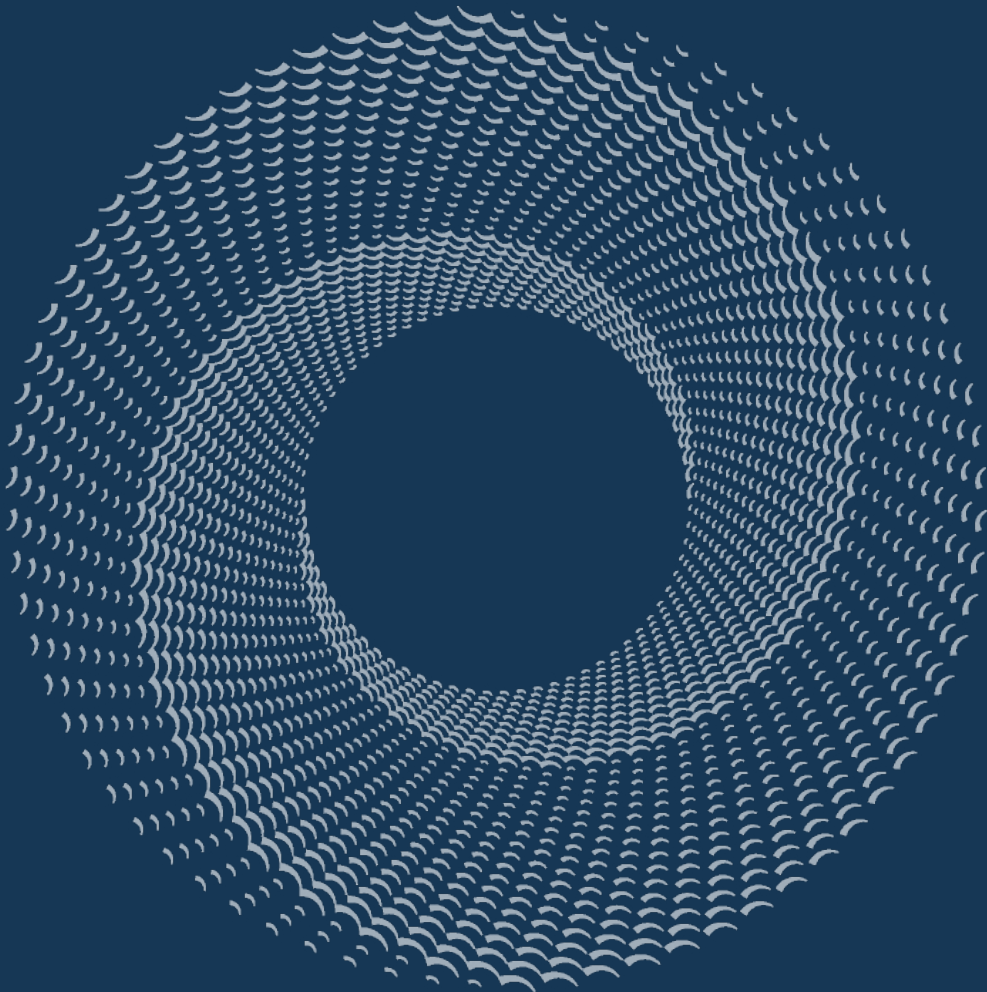
The results should be used to support mitigation planning. For example, if food packaging, cups and lids are mainly linked to waterfront events or outdoor gastronomy, measures should focus on event waste management, reusable systems, bin placement and targeted communication. If cigarette butts are linked to ferry stops, benches or waiting areas, ashtrays and smoking-related awareness may be more appropriate. If litter is linked to stormwater or wind transport from adjacent public spaces, pathway-related measures and cleaning routines may be needed.

The results should always be interpreted with caution. Many litter item categories can originate from several sources, and the same item may have different sources in different local contexts. Source scoring should therefore be combined with site observations, stakeholder knowledge and, where possible, supporting information on land use, events, cleaning routines, stormwater infrastructure, harbour activities and weather conditions. The reasoning behind each score should be documented to make the assessment transparent, repeatable and useful for later comparison.

Overall, the source assessment provides a practical bridge between monitoring and mitigation. It helps cities move from knowing which litter item categories are most common towards understanding which activities, locations or pathways should be addressed by targeted measures

13.

Conclusions and Key Recommendations



13. Conclusions and Key Recommendations

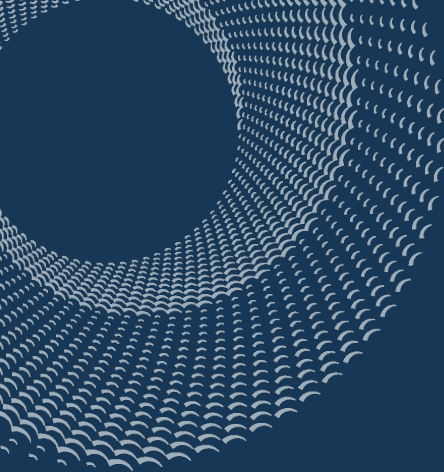
This roadmap provides a practical framework for the implementation of city-level riverine macro-litter monitoring in South Baltic cities. It focuses on methods that are scientifically useful, technically ready and feasible for local actors. The recommended core package combines visual surveys of Riverine Floating Macro-Litter (RFML) with riverbank surveys of macro-litter.

The roadmap follows a stepwise approach. Cities can start locally with trained monitoring teams, fixed stations and sections, harmonised litter item categories, complete metadata and simple local data storage. A fully developed national coordinator, database or reporting system does not need to be in place before monitoring starts. The key principle is to start locally, harmonise from the beginning and connect nationally later.

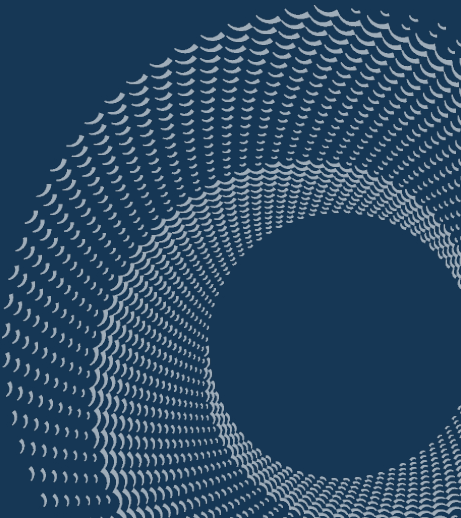
The most important recommendations are:

- start with a simple and realistic monitoring design;
- combine RFML surveys and riverbank surveys;
- use fixed stations and fixed riverbank sections;
- focus on macro-litter >25 mm;
- record complete metadata and QA/QC status;
- train monitoring teams before field work starts;
- store data in a structured local database;
- prepare annual summaries for municipalities and local stakeholders;
- use monitoring results to identify hotspots, dominant litter item categories and mitigation priorities;
- expand the monitoring programme only when the core methods are working.

A simple, stable and harmonised monitoring programme is more valuable than a complex design that cannot be maintained. By combining practical field methods, stepwise governance, digital tools, QA/QC and a clear link to mitigation, South Baltic cities can generate data that support both local action and wider regional comparison.



14. References





14. References

Corbau, C., Lazarou, A., Bajt, O., Filipović Marijić, V., Simčič, T., Coltorti, M., Pignoni, E., Simeoni, U., 2025. Citizen Science for Monitoring Plastic Pollution from Source to Sea: A Systematic Review of Methodologies, Best Practices, and Challenges. *Water* 17, 2668. <https://doi.org/10.3390/w17182668>.

EEA, 2023. From rivers to the sea — the pathways and the outcome. <https://www.eea.europa.eu/en/analysis/publications/from-source-to-sea-the-untold-story-of-marine-litter/from-rivers-to-the-sea-the-pathways-and-the-outcome> (accessed 4 June 2026).

EMODnet, 2026. European beach litter aggregated datasets 2001/2023 v2025: Product catalogue. <https://emodnet.ec.europa.eu/geonetwork/srv/ger/catalog.search#/metadata/23f2c658-6880-4429-8809-07a512dc2b00> (accessed 4 June 2026).

European Commission, 2026. Online Photo Catalogue of the Joint List of Litter Categories: Example images to support the monitoring of macro litter in different environmental matrices. <https://mcc.jrc.ec.europa.eu/main/photocatalogue.py?N=41&O=457&cat=pl> (accessed 22 March 2025).

Falk-Andersson, J., Hurley, R., Lusher, A.L., 2025. Including decision makers in development of cost-efficient litter monitoring - A three step process. *Environmental pollution* (Barking, Essex : 1987) 373, 126104. <https://doi.org/10.1016/j.envpol.2025.126104>.

Fleet, D., Vlachogianni, T., Hanke, G., 2021. A Joint List of Litter Categories for Marine Macrolitter Monitoring: Manual for the application of the classification system. EUR 30348 EN, Publications Office of the European Union, Luxembourg, 2021. <https://doi.org/10.2760/127473>.

González, D., Hanke, G., Tweehuysen, G., Bellert, B., Holzhauer, M., Palatinus, A., Hohenblum, P., Oosterbaan, L., 2016. Riverine Litter Monitoring - Options and Recommendations: MSFD GES TG Marine Litter - Thematic Report. JRC Technical report EUR 28307, 52 pp.

González-Fernández, D., Hanke, G., 2017. Toward a Harmonized Approach for Monitoring of Riverine Floating Macro Litter Inputs to the Marine Environment. *Front. Mar. Sci.* 4. <https://doi.org/10.3389/fmars.2017.00086>.

Haseler, M., 2026. A feasible method for riverine macro litter monitoring: A case study of the Warnow River.

Haseler, M., Mihut, G., 2025. Two years of daily monitoring of floating macro-litter at the River-Sea interface: Aarhus River, Denmark. *Mar. Pollut. Bull.* 222, 118913. <https://doi.org/10.1016/j.marpolbul.2025.118913>.

HELCOM, 2025. HELCOM Report on the evaluation of the UNEP/MED guidelines for monitoring riverine inputs of litter.

MSFD 2008/56/EC, 2008. Marine Strategy Framework Directive DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive): MSFD. Official Journal of the European Union.

MSFD TSG ML, 2023. Guidance on the Monitoring of Marine Litter in European Seas: An update to improve the harmonised monitoring of marine litter under the Marine Strategy Framework Directive. Publications Office of the European Union. <https://doi.org/10.2760/59137>.

OSPAR Commission, 2025. Workshop on Riverine litter – Summary record.

Schreyers, L., van Emmerik, T., Nguyen, T.L., Phung, N.-A., Kieu-Le, T.-C., Castrop, E., Bui, T.-K., Strady, E., Kosten, S., Biermann, L., van den Berg, S., van der Ploeg, M., 2021. A field guide for monitoring riverine macroplastic entrapment in water hyacinths, 18 pp.

Tasseron, P., Begemann, F., Joosse, N., van der Ploeg, M., van Driel, J., van Emmerik, T., 2023. Amsterdam urban water system as entry point of river plastic pollution. *Environ Sci Pollut Res* 30, 73590–73599. <https://doi.org/10.1007/s11356-023-26566-5>.

Tasseron, P.F., van Emmerik, T.H.M., Winter, W. de, Vriend, P., van der Ploeg, M., 2024. Riverbank plastic distributions and how to sample them. *Micropl.&Nanopl.* 4. <https://doi.org/10.1186/s43591-024-00100-x>.

Tudor, D.T., Williams, A.T., 2004. Development of a 'Matrix Scoring Technique' to determine litter sources at a Bristol Channel beach. *Journal of Coastal Conservation*.

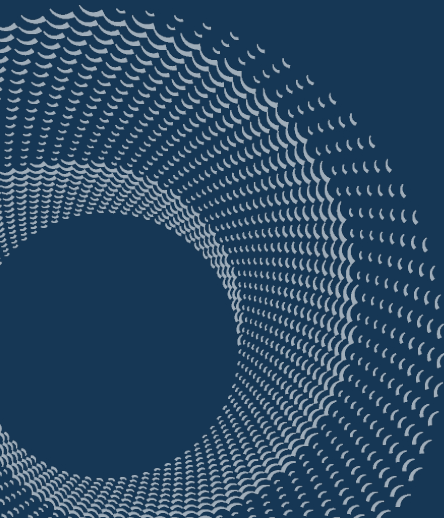
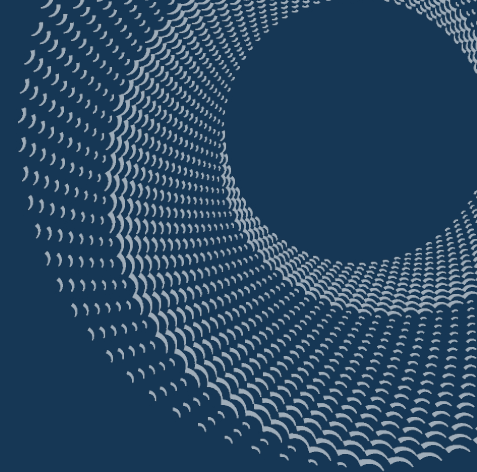
UNEP/MED, 2023. WG.550/14 Guidelines for Monitoring Riverine inputs of Marine Litter: Integrated Meeting of the Ecosystem Approach Correspondence Groups (CORMONs) Athens, Greece, 27-28 June 2023 Agenda Item 1.C.iv: Marine Litter CORMON.

van Emmerik, T., Schwarz, A., 2020. Plastic debris in rivers. WIREs Water 7, e1398. <https://doi.org/10.1002/wat2.1398>.

van Emmerik, T., Vriend, P., Copius Peereboom, E., 2022. Roadmap for Long-Term Macroplastic Monitoring in Rivers. Front. Environ. Sci. 9, 802245. <https://doi.org/10.3389/fenvs.2021.802245>.

Veiga, J.M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., Galgani, F., Thompson, R.C., Dagevos, J., Gago, J., Sobral, P., Cronin, R., 2016. Identifying Sources of Marine Litter: MSFD GES TG Marine Litter - Thematic Report. Thematic Report; JRC Technical Report;

Winton, D.J., Anderson, L.G., Roccliffe, S., Loiselle, S., 2020. Macroplastic pollution in freshwater environments: Focusing public and policy action. The Science of the total environment 704, 135242. <https://doi.org/10.1016/j.scitotenv.2019.135242>.



15.

Annexes for Riverine Macro-litter Monitoring

15. Annexes for Riverine Macro-litter Monitoring

These annexes provide practical templates for RFML surveys, riverbank surveys, minimum metadata requirements and QA/QC checks. They can be used as paper forms, digital forms or as a basis for app-supported data collection.

15.1 Annex 1. RFML Field Sheet

Field sheet for visual surveys of Riverine Floating Macro-litter (RFML)

This field sheet is intended for standardised visual observations of floating macro-litter from fixed observation points such as bridges, quays, harbour structures or accessible riverbanks. It can be used as a paper form, digital form or basis for app-based data collection. Litter pieces should be classified into harmonised litter item categories. Where possible, the EU Joint List of Litter Categories for Marine Macro-litter Monitoring should be used as the reference classification system (Fleet et al., 2021).

Reference: Fleet, D., Vlachogianni, T. and Hanke, G. (2021). A Joint List of Litter Categories for Marine Macro-litter Monitoring. EUR 30348 EN, Publications Office of the European Union, Luxembourg. DOI: 10.2760/127473. Available at: <https://publications.jrc.ec.europa.eu/repository/handle/JRC121708>

A1.1 Station Information

Field	Entry
Country	
City	
River	
Station ID	
GPS coordinates	
Observation point type	Bridge / quay / harbour structure / riverbank / other
Observation direction	Upstream / downstream / other
Observed track width	
Total river width, where possible	
Observation height above water, where possible	
Access notes	
Safety notes	

A1.2 Survey Metadata

Field	Entry
Date	
Start time	
End time	
Observation duration	
Observer/team	
Local/regional coordinator	
Field sheet / app version	
Survey type	Routine / event-based / other
Reason for event-based survey, where relevant	Rainfall / high discharge / public event / other

A1.3 Observation Conditions

Field	Entry
Weather conditions	
Visibility	Good / moderate / poor
Light conditions	Good / glare / low light / other
Wind direction and strength, where available	
Rainfall during survey	No / light / moderate / heavy
Rainfall before survey, where known	
Water level / discharge, where available	
Flow condition	Clear downstream flow / slow flow / backwater / unclear
Boat traffic	None / low / moderate / high
Other disturbances	

A1.4 Litter Recording

All visible floating litter pieces larger than 25 mm should be counted when they pass the defined observation line or observation area. Litter pieces should be assigned to harmonised litter item categories. Use the Joint List and, where useful, the online photo catalogue of the Joint List to support item identification.

Litter category (J-code)	item group	M a t e r i a l	Piece count	Uncertain?	Photo/comment
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	
				Yes / No	

A1.5 Comments and QA/QC

Field	Entry
Unusual observations	
Possible sources or input pathways	
Survey limitations	
Photos taken?	Yes / No
Data checked by local coordinator?	Yes / No
QA/QC status	Raw / locally checked / corrected / validated / excluded
QA/QC comments	



15.2 Annex 2. Riverbank Survey Field Sheet

Field sheet for riverbank macro-litter surveys

This field sheet is intended for standardised surveys of macro-litter deposited along fixed riverbank sections. It can be used for routine surveys, baseline assessments, hotspot monitoring or before-after assessment of mitigation measures. Litter pieces should be classified into harmonised litter item categories. The EU Joint List of Litter Categories for Marine Macro-litter Monitoring should be used as the main reference system where possible (Fleet et al., 2021).

Reference: Fleet, D., Vlachogianni, T. and Hanke, G. (2021). A Joint List of Litter Categories for Marine Macro-litter Monitoring. EUR 30348 EN, Publications Office of the European Union, Luxembourg. DOI: 10.2760/127473. Available at: <https://publications.jrc.ec.europa.eu/repository/handle/JRC121708>

A2.1 Section Information

Field	Entry
Country	
City	
River	
Section ID	
Start point GPS coordinates	
End point GPS coordinates	
Survey length	
Surveyed width	
Surveyed area, where calculated	
Riverbank type	Natural / modified / quay / harbour / park / reed belt / other
Land-use context	Recreational / harbour / residential / industrial / mixed / other
Access notes	
Safety notes	

A2.2 Survey Metadata

Field	Entry
Date	
Start time	
End time	
Survey team	
Local/regional coordinator	
Survey type	Routine / event-based / before-after / other

Reason for event-based survey, where relevant	High water / flooding / rainfall / public event / other
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A2.3 Site and Environmental Conditions

Field	Entry
Weather conditions	
Visibility	Good / moderate / poor
Vegetation cover	Low / moderate / dense
Access restrictions	No / yes, specify
Recent rainfall, where known	
Recent high water or flooding	No / yes / unknown
Water level or discharge, where available	
Evidence of recent cleaning	No / yes / unknown
Date of last known cleaning	
Cleaning operator, where known	
Other relevant conditions	

A2.4 Litter Recording

All visible macro-litter pieces larger than 25 mm within the defined survey section should be counted or collected. Litter pieces should be assigned to harmonised litter item categories. Use the Joint List and, where useful, the online photo catalogue of the Joint List to support item identification.

Litter item category (J-Code)	Material group	Piece count	Collected?	Uncertain?	Photo/comment
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	
			Yes / No	Yes / No	

A2.5 Hotspots, Comments and QA/QC

Field	Entry
Hotspots observed?	Yes / No
Hotspot location or description	
Possible sources or pathways	
Unusual observations	
Special pollution observed?	Industrial pellets / paraffin wax / oil residues / other / none
Survey limitations	
Photos taken?	Yes / No
Data checked by local coordinator?	Yes / No
QA/QC status	Raw / locally checked / corrected / validated / excluded
QA/QC comments	

15.3 Annex 3. Minimum Metadata Requirements

This annex summarises the minimum metadata that should be recorded for RFML surveys and riverbank surveys. Complete metadata are essential for interpreting monitoring results and for making data suitable for long-term comparison, QA/QC and later reporting.

For each fixed monitoring station or riverbank section, a short site context description should be prepared during station set-up and updated if conditions change. This should include river use, riverbank type, channel morphology, nearby stormwater outlets, harbour or recreational use, land use in the surrounding area, known cleaning activities and relevant hydrological information where available. Where possible, monitoring stations should be linked to existing water quality or hydrological monitoring stations to improve interpretation of discharge, water level and event-related variability.

Metadata field	RFML surveys	Riverbank surveys	Comment
Country, city and river	Required	Required	Basic location information
Station or section ID	Required	Required	Must remain stable over time
GPS coordinates	Required	Required	Station point for RFML; start/end points for riverbank sections
Site context description	Required	Required	River use, bank type, channel morphology, land use, nearby sources and hydrological context
Date	Required	Required	Survey date
Start and end time	Required	Required	Required for RFML observation duration
Observation duration	Required	Recommended	Fixed duration, e.g. 30 or 60 minutes
Survey length	Not applicable	Required	Fixed section length, e.g. 100 m where feasible
Surveyed width or area	Required	Required	Needed for pieces per square meter
Observer or survey team	Required	Required	Important for QA/QC
Local/regional coordinator	Required	Required	Responsible for local data check

Method type	Required	Required	RFML or riverbank survey
Observation point type	Required	Not applicable	Bridge, quay, riverbank, harbour structure etc.
Riverbank type and surface type	Not applicable	Required	Natural, modified, quay, riprap, boulders, reed belt, paved surface etc.
Riverbank type	Not applicable	Required	Natural, modified, quay, reed belt, park etc.
Weather conditions	Required	Required	Important for data interpretation
Visibility	Required	Recommended	Especially important for RFML
Wind conditions	Recommended	Optional	Relevant for floating and stranded litter
Rainfall before/ during survey	Recommended	Recommended	Relevant for event-related inputs
Water level/ discharge	Recommended where available	Recommended where available	Supports interpretation of transport and deposition
Cleaning status	Not applicable	Required	Essential for interpreting riverbank data
Vegetation cover	Not applicable	Required	Affects detectability and accumulation
Litter item categories	Required	Required	Harmonised categories should be used
Piece counts	Required	Required	Core monitoring data
Material group	Recommended	Recommended	Supports plastic share and source interpretation
Uncertain litter pieces	Required where relevant	Required where relevant	Should be flagged and documented
Special pollution indicators	Optional	Recommended	Industrial pellets, paraffin wax, oil residues or other chemical pollution indicators
Photo documentation	Recommended	Recommended	Especially for uncertain litter pieces and hotspots
Comments	Recommended	Recommended	For unusual events, limitations or sources
QA/QC status	Required	Required	Raw, checked, corrected, validated or excluded

Litter item categories should follow a harmonised classification system. The EU Joint List of Litter Categories for Marine Macro-litter Monitoring is recommended as the reference list for macro-litter item classification (Fleet et al., 2021).

The minimum metadata should be included in all field sheets, digital forms and app-based tools. If a field is not available, it should be marked as “not available” or “unknown” rather than left blank.

15.4 Annex 4. QA/QC Checklist

This checklist is intended for local or regional coordinators. It should be used after each survey to check whether submitted data are complete, plausible and suitable for storage, analysis or later reporting. It also supports checking whether litter item categories are compatible with the Joint List.

A4.1 General QA/QC Checklist

Check	Yes/No	Comment
Correct station or section ID used?		
Date recorded?		
Start and end time recorded where required?		
Observer or survey team recorded?		
Method type clearly stated?		
Required metadata complete?		
Litter item categories recorded?		
Piece counts plausible?		
Uncertain litter pieces documented?		
Photos included where needed?		
Comments added for unusual observations?		
Survey limitations documented?		
QA/QC status assigned?		

A4.2 Additional Checks for RFML Surveys

Check	Yes/No	Comment
Observation duration recorded?		
Observation direction recorded?		
Observed track width recorded?		
Total river width recorded where possible?		
Visibility conditions recorded?		
Flow condition or water level recorded where available?		
Boat traffic or other disturbances documented?		

Survey conditions suitable for visual observation?		
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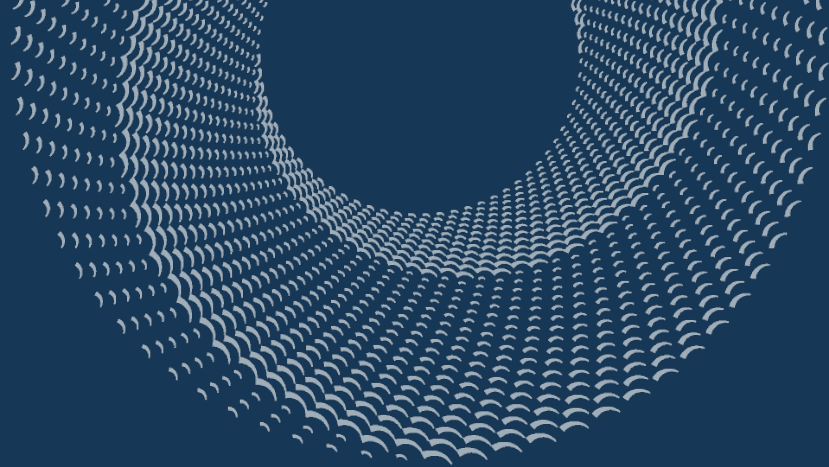
A4.3 Additional Checks for Riverbank Surveys

Check	Yes/No	Comment
Start and end points confirmed?		
Survey length recorded?		
Surveyed width or area recorded?		
Cleaning status recorded?		
Vegetation cover recorded?		
Recent flooding or high water documented where relevant?		
Hotspots documented where present?		
Access or safety limitations documented?		

A4.4 QA/QC Decision

QA/QC status	Select one	Comment
Raw data		
Locally checked data		
Corrected data		
Validated data		
Excluded data		

If data are corrected or excluded, the reason should be documented clearly. Excluded data should not be deleted, but stored with an explanation so that the data history remains transparent.



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