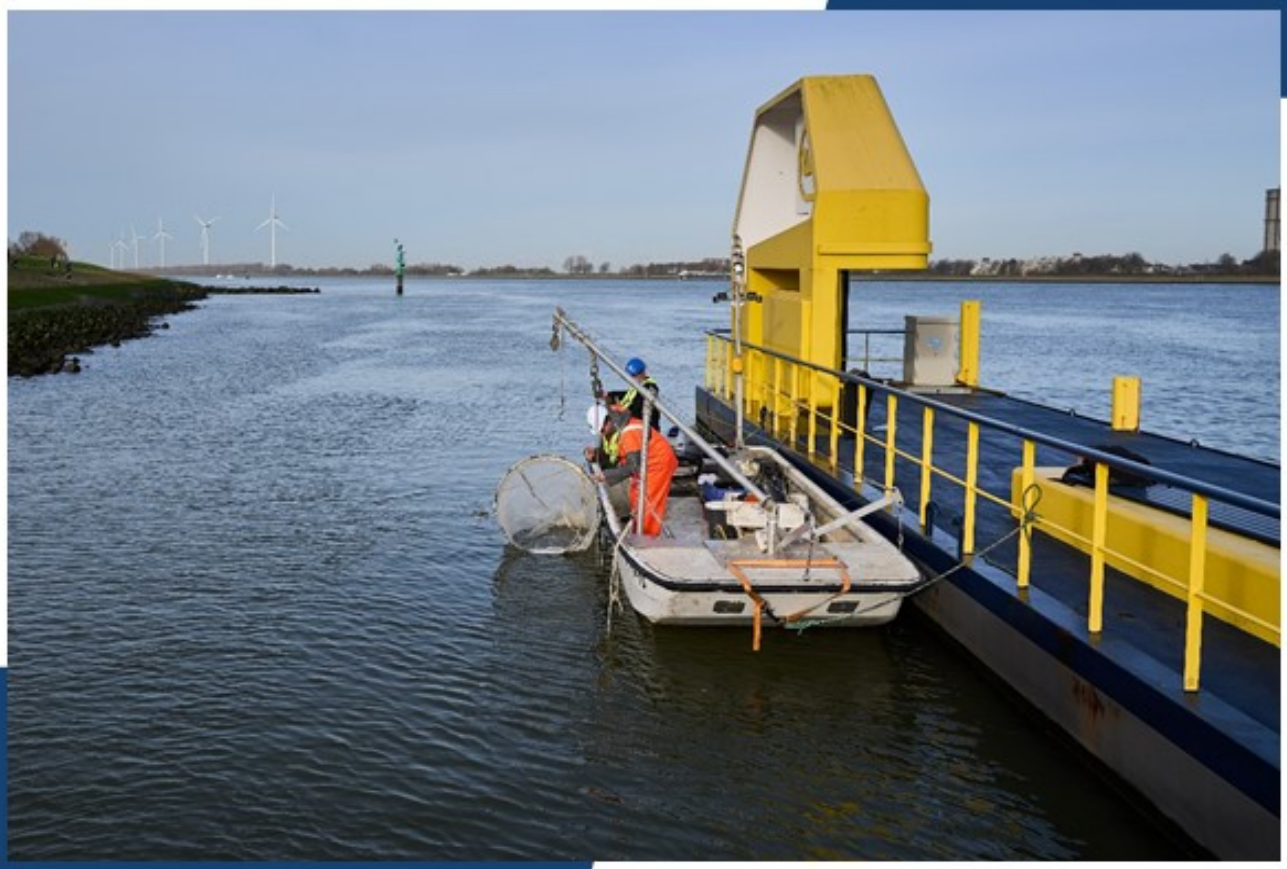
Interreg
Euregio Meuse-Rhine

LIVES litter free rivers and streams

EUROPEAN UNION
European Regional Development Fund



Synthesis Report LIVES Workpackage 1: Inventory & Data Sharing

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

1. Executive summary

The goal of the Litter Free Rivers and Stream (LIVES) project is to work towards litter free rivers and streams in the Euregio Meuse-Rhine. LIVES supports environmentally friendly cross-border cooperation by bringing together ten project partners in the Netherlands, Belgium and Germany throughout the Euregion Meuse-Rhine.

A common understanding among the LIVES partners is that monitoring is needed to aid the design effective measures aimed at reducing the presence of litter pollution and its negative effects in the Euregio Meuse-Rhine.

This report synthesizes the steps that were made in Working Package 1 (WP1) of the EU Interreg LIVES project. The LIVES project had the aim of providing the knowledge, tools, and methods to gain this common understanding among international project partners in the Netherlands, Belgium and Germany.

WP1 focused on creating a common understanding among project partners on the following monitoring aspects in the river Meuse:

- What, when and where are hotspots of litter?
- How to model litter in streams?
- How to gather data? How to build a dataset?
- What are best practices of monitoring litter?
- How to monitor litter effectively?
- What are the next steps in monitoring litter in 2022-2027?

To effectively reach a common understanding of the magnitude of the problem litter in the Meuse basin, and what to effectively monitor and manage it, WP1 was subdivided into several building blocks:

1. **Cross border hotspot map** – Creating a map with points of interest for monitoring, including previously identified hotspots and monitoring locations, locations where litter is already removed, and potential locations for future monitoring.
2. **STORM Project** – An analysis of the possible sources, transport routes, and effects of litter in Euregio Meuse-Rhine.
3. **Open access data system** – Creating a data system in which all monitoring data gathered within the LIVES project can be stored and be accessed by all partners.
4. **Inventory of best practices** – Creating an overview of best practices in monitoring of riverine litter, and how the process can be improved in the future.
5. **Cross border dataset** – Harmonizing the monitoring data gathered by the LIVES partners and integrating it in the open access data system.
6. **Monitoring water column** – Development and application of method to monitor litter in the water column of the river Meuse.
7. **Monitoring strategy 2022-2027** – Using the insights gained in the previous building blocks to design a strategy that the LIVES partners can use to set up long term monitoring of litter in the Meuse river system.

These building block together serve three main purposes, these being 1) Creating an inventory of knowledge. 2) Effective data sharing, 3) Future monitoring.

Creating an inventory of knowledge

Creating an inventory of knowledge was done in threefold. First, A hotspot map was made with monitoring data that previously been collected by the LIVES partners (building block 1). This map also includes other location that may be interesting for monitoring such as current clean-up and removal locations, and potential future monitoring locations. Second, the LIVES partners created a common understanding of what the system boundaries are

to the LIVES project, identified possible sources and pathways of litter in this system, and to identified important knowledge gaps (building block 2). Besides, an inventory of best practices was made, both for monitoring and project management (building block 4). From this inventory of knowledge it was found that monitoring methods for litter in the water column of rivers were relatively underdeveloped. Pilot projects were therefore executed for the development of these methods (building block 6). Together these building blocks created a foundation on which the other building blocks could be built.

Effective data sharing

In a large scale and cross-border project like LIVES it is key to effectively share data, methods, and insights with each other. To ensure this the LIVES Open Access Data System (LOADS) was created (building block 3) and relevant monitoring data was integrated in this data system (building block 5). With LOADS, all LIVES partners have an effective place to store, handle, and share data with each other. This database can also be used as a starting point for deciding upon harmonized data formats for future monitoring.

Future monitoring

The insights gained from building blocks 1-6 were used to help the design of a future monitoring strategy (building block 7). As current monitoring efforts are now often sporadic it was advised to use the Roadmap for long-term monitoring[1] to transition towards long-term and integrated monitoring in the Euregio Meuse-Rhine.

The Roadmap can be used by the LIVES partners to design a monitoring strategy by following the following steps:

1. Decide on the goals for monitoring litter in the Euregio Meuse-Rhine (e.g. policy development, knowledge development, operations and maintenance, solution design)
2. Decide on relevant research questions related to these goals
3. Design routes to answers using the Roadmap (what river compartments should be monitored, what levels in the Roadmap should be passed to answer research questions?)
4. Execute projects along the route to answers (start with the relevant level in the Roadmap for each river compartment) until the desired level is achieved.
5. Evaluate research goals and questions, start new cycle (at step 1)

Following this stepwise approach allows for standardized methods to be developed for each river compartment, to gather harmonized baseline data for the rivers and streams in the Euregio Meuse-Rhine, and to eventually gather long term data that can be used to guide litter intervention strategies.

Concluding remarks

With the conclusion of the 7 building blocks set out in WP1 of the LIVES project the first efforts have been made for setting up a cross-border and harmonized monitoring strategy of litter in the Euregio Meuse-Rhine. The LIVES project was the first of its kind and therefore the creation of the monitoring strategy was an iterative process: first an inventory was made of current knowledge on monitoring by the LIVES partners, an open-access data system was made for the effective storing and sharing of data, best practices for monitoring, project management and data handling were identified, and finally a monitoring strategy was suggested.

[1] van Emmerik, T., Vriend, P., Copius Peereboom, E. (2022). Roadmap for long-term macroplastic monitoring in rivers. *Frontiers in Environmental Science*, 9:802245.

It is important to highlight that there is no one-size-fits-all monitoring strategy. Instead a monitoring strategy is highly dependent on monitoring goals, the research questions that follow from these goals, the available resources, and the political willingness to implement the strategy. It is therefore key for the LIVES partners to keep the dialogue open on further development of the monitoring strategy and on the implementation of this strategy. Only then monitoring can be harmonized and a cross-border understanding of problem of litter in Euregio Meuse-Rhine can be gained. Such understanding can be used to design effective measures to reduce litter in the rivers and streams in the Meuse basin.

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2. Introduction to Working package 1 of the LIVES Project

Litter pollution – How did we get here?

The past 70 years have seen a worldwide exponential increase in the production and consumption of products.[2] New materials such as plastic revolutionized our way of living. However, these materials and products also have a down side: a large portion of these materials and products have ended up in the environment through improper waste disposal and littering. This so called litter pollution is now everywhere: large amounts of plastics have accumulated in our oceans (also known as the 'plastic soup'), in our rivers, and on land. We even find microplastics, which mainly stem from plastic litter that is broken down in the environment, in the food we consume and the water we drink.

Litter in rivers – A serious problem

Litter pollution is produced on land through mismanagement of waste and littering. A small fraction of litter pollution ends up in the 'plastic soup' in seas and oceans. Most litter is (temporarily) retained in rivers.[3] Here it has a range of negative effects on nature and fauna, it can increase flood risk due to blockage of drainage systems, and cause economic damage.[4] Due to the longevity of the materials in our waste streams, the ubiquity and large quantities of it, litter pollution has become one of the most significant and challenging environmental problems of our times.

Key knowledge required to effectively tackle the litter problem through policies and waste management operations, is currently lacking. For example, very little is known about the sources of litter pollution, how much litter is exactly in our rivers, where hotspots of litter can be found, and knowledge about bioaccumulation and toxic levels is lacking. Such knowledge is key for the design of effective litter reduction, mitigation, and removal strategies. This knowledge can only be gained through effective monitoring of litter in our rivers.

Rivers run cross-border, litter pollution therefore is a cross-border problem and it requires international cooperation to solve. Monitoring is one of the areas where international cooperation is needed the most. International standardized methods to monitor riverine litter are currently lacking. This leads to data gathered by different countries to often be incomparable with each other, hindering the design of effective solutions to the litter problem.

The LIVES project – Cross border cooperation to reduce litter pollution

The Litter Free Rivers and Streams (LIVES) project is an EU Interreg project and a cross-border initiative with the aim of reducing the presence of litter in the catchment of the Meuse river through international cooperation. This project unites governments, water managers, citizens, and scientists from Germany, Belgium, and the Netherlands to jointly tackle the litter pollution. This is done on three levels: 1) creating a shared understanding of the litter pollution problem through cross-border monitoring and data sharing, 2) implementation of measures aimed at reducing litter, and 3) creating institutional arrangements to anchor these changes in future policy.

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[2] For example, plastic production increased from 2 to 381 million tons worldwide per year over this period of time, Geyer et al. (2017). *Science Advances*, 3, 7.
[3] van Emmerik et al. (2022). Rivers as plastic reservoirs. *Frontiers in Water, Environmental Water Quality*
[4] van Emmerik & Schwarz (2020). Plastic debris in rivers. *Wiley interdisciplinary reviews in Water*, 7,1. ; Deloitte – The price tag of plastic pollution

This report provides an overview of the results that have been achieved during the LIVES project towards goal 1 – creating a shared understanding of the litter pollution problem through cross-border monitoring and data sharing.

Structure of the LIVES project

To achieve the multitude of goals within the LIVES project it was decided to create a working package (WP) for each goal (Figure 1). This report is presenting the progress that has been made on WP1 – Inventory & Data sharing. WP1 was managed by Rijkswaterstaat Zuid-Nederland (RWS).

LIVES was a one of a kind project when it was created. A project with a diverse group of international stakeholders aimed at reducing litter in rivers and streams had not been undertaken at such a scale before. The project could not rely on a backlog of knowledge generated in previous projects or prior experience in terms of time, money and organizational structures required to achieve this knowledge. The LIVES partners had to pioneer through trial and error, and had to adjust their goals to what proved feasible within the term. The same applies for WP1. To make WP1 more manageable it was decided to break down WP1 in several building blocks. The aim of these building blocks was to first get an inventory of knowledge on monitoring of riverine litter already present within the LIVES partners' organisations. This knowledge would then be extended through implementing monitoring projects within the Euregio Meuse-Rhine and effectively sharing the gathered data as well as the best practices with each other. Last, the insights gained through monitoring and data sharing would be used to create a long-term monitoring strategy that can be used by the LIVES partners, either individually or jointly, after the project had finished.

With these goals in mind, the following building blocks were decided to be executed in WP1 (Figure 1):

1. **STORM Project** – An analysis of the possible sources, transport routes, and effects of litter in Euregio Meuse-Rhine (key factors).
2. **Cross border hotspot map** – Creating a map with points of interest for monitoring, including previously identified hotspots and monitoring locations, locations where litter is already removed, and potential locations for future monitoring.
3. **Open access data system** – Creating a data system in which all monitoring data gathered within the LIVES project can be stored and access by all partners.
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6. **Monitoring Water Column** – Development and application of method to monitor litter in the water column of the river Meuse.
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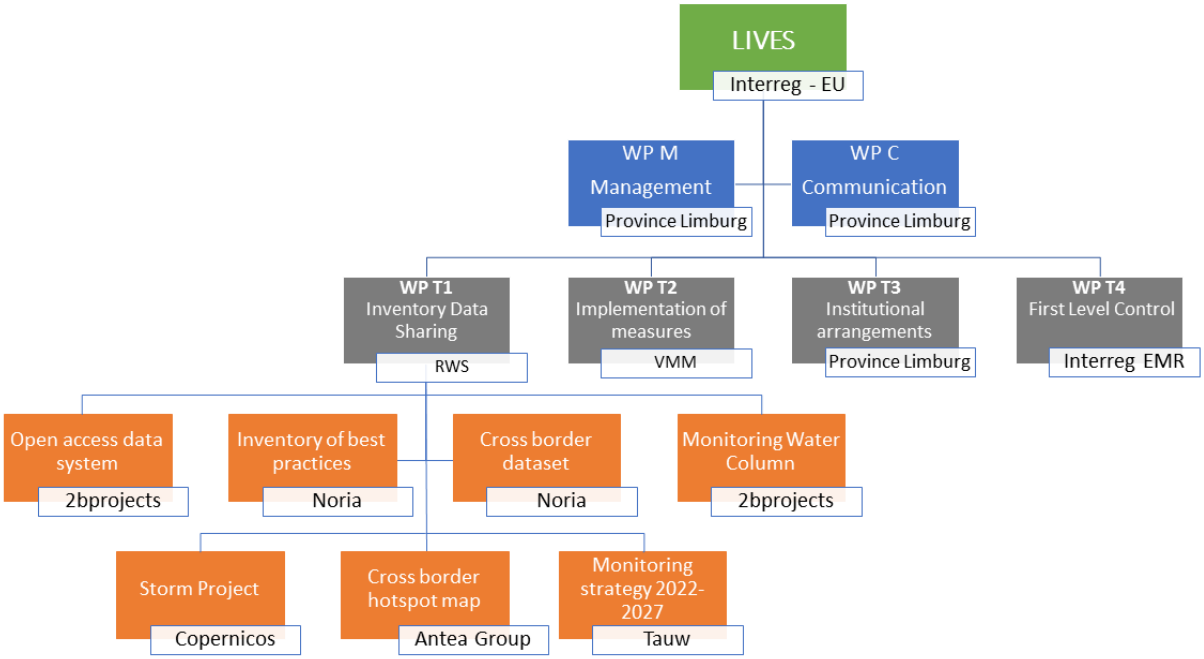


Figure 1 - Structure of the LIVES project, the building blocks of WP1 in orange, and the organizations that executed the work for each project in white.

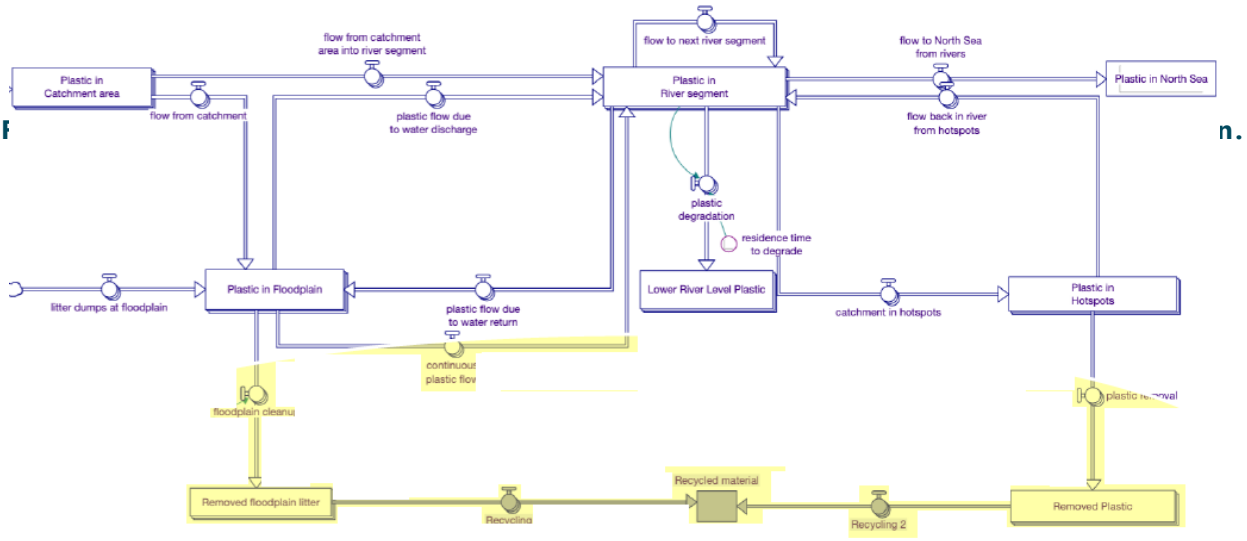
3. Results of LIVES Working Package 1

This chapter will provide a synthesis of the results each building block. For the full reports we refer to annex I – VI.

Building block 1 – STORM Project

To effectively monitor litter in the Euregio Meuse-Rhine it is key to first have a common understanding on what should be monitored and why. Building block 1 was therefore used to organize a STORM session with the LIVES partners to set these parameters (Annex I). In a STORM session the participants jointly look at the potential value of an innovation and the chances of its success. Once these key factors are identified the participants search together for actions that might increase the potential value and the chances of success for said innovation.

The central innovation in the LIVES STORM session was the monitoring of litter in the Euregio Meuse-Rhine. To increase the chances of success for the monitoring of litter it was found that it is important to understand what the system boundaries are to the LIVES partners, to identify possible sources and pathways of litter in this system, and to identify important knowledge gaps. To this end, the LIVES members jointly made a model of litter in the Meuse basin (Figure 3). This model includes the sources of litter, the transport routes, degradation processes of macroplastics into microplastics, and opportunities for removal and recycling. This knowledge was used as the basis for monitoring efforts in WP1 of LIVES.



Building block 2 – Creating a cross border hotspot map

Creating a hotspot map was a key step in WP1 since it provided the LIVES partners with a first overview of the current state of knowledge of litter pollution in the Interreg Euregio Meuse-Rhine. Using the STORM method (building block 1), the LIVES partners had previously selected the relevant key factors. The LIVES partners shared their available data related to these key factors as inputs for the hotspot map. This data included insights on litter monitoring activities, as well as clean-up, removal, and potential future monitoring locations. These data were then bundled and visualized in a map (Figure 2, for more detailed maps we refer to annex II).

Several conclusions can be made based on this hotspot map:

- Valuable information has already been gathered by LIVES partners, including monitoring data, but also data on removal of litter from the river system.
- Monitoring data on litter had mainly been gathered for the Meuse river, not the streams.
- Methods used to gather these data differ greatly. This complicates effective comparison of data from different sources. Harmonization of monitoring methods would solve this.
- A large part of the data has been gathered through citizen science projects in commission of the LIVES partners. This involvement allows for rapid data gathering on broad temporal and spatial scales but requires further research on how this can be included in operational plans of water management authorities.

The insights provided by the hotspot map was subsequently used as input for the other building blocks within WP1 of the LIVES project.

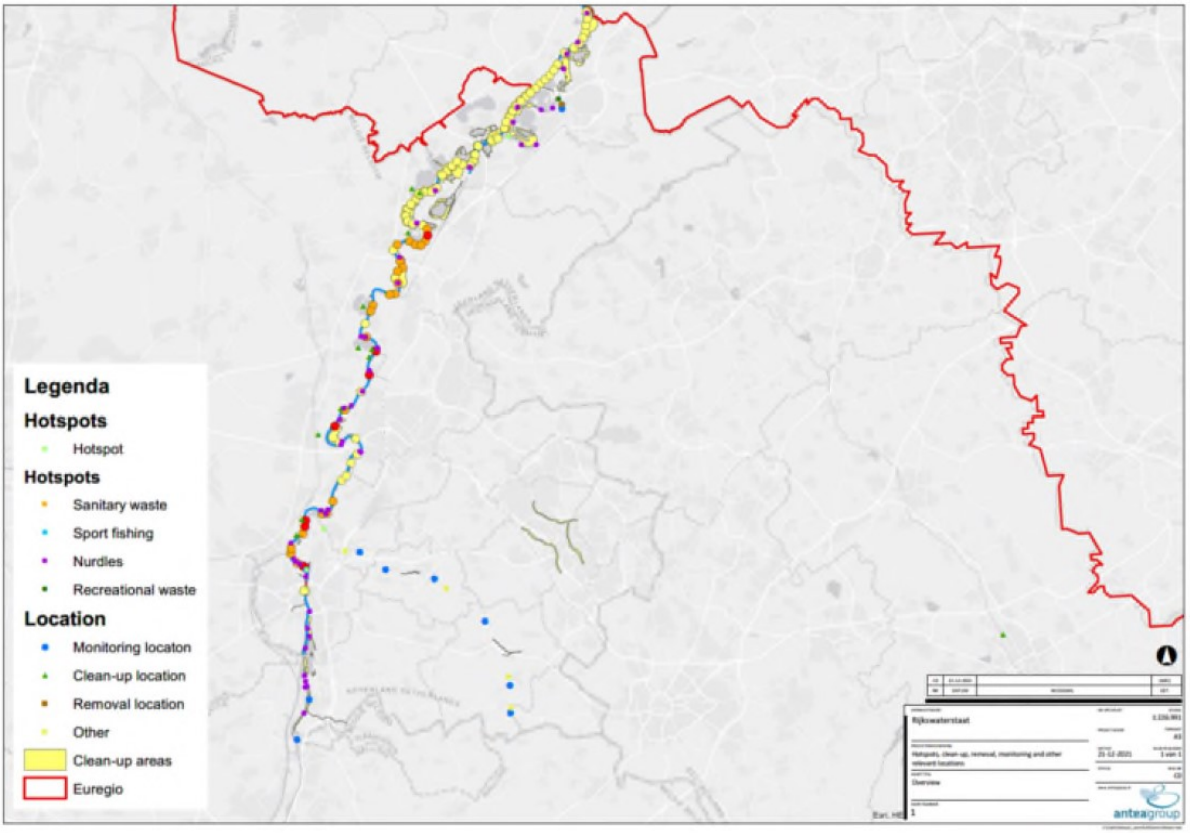


Figure 3 - Overview of the hotspot map for litter monitoring in the Interreg Euregio Meuse-Rhine.

Building block 3 – Creating an open access data system

To gain a cross-border understanding of litter pollution in the Euregio Meuse-Rhine it is crucial to effectively share monitoring data gathered by the partners with each other. The sharing of these data allow for a first cross-border analysis to be executed of litter pollution in the Meuse river system. Building block 3 was therefore focused on creating a proof of concept of an open access data system which can be used by all LIVES partners to store, share, and retrieve monitoring data (Annex III). The data system that was created is called LOADS (LIVES Open Access Data System).

Steps to take to realize LOADS
The LIVES partners are diverse, ranging from water managers, to scientific institutes. This variety of partners also leads to a diversity in the goals and uses for monitoring data. To effectively store and use all the relevant data on macro litter pollution the aim was to development an open access data system LOADS. This was set up with a set of premises that will need to be met for future use:

- Optimal processing (storage and use) of data play a central role when designing a monitoring strategy for the LIVES partners. To make data comparable to each other, agreements have to be made beforehand on the goals that the data will be used for, what the format needs to be to meet these goals, and how monitoring methods can be designed in such a way that these data formats are met. These agreements will create a common language that will ensure that data are uniform, consistent and reliable.
- It is important to log a wide range of metadata when gathering and storing monitoring data of macro litter. Metadata is data that provides information on how to main monitoring data was gathered data. For example, metadata for monitoring litter may include environmental conditions when the measurements were performed, who executed the monitoring, and other that might be relevant to reaching the monitoring goals. Logging metadata ensures that quality control can be performed on monitoring data.
- The implementation of this open data system can be supported by an authority, that ensures that data is of high quality, consistent, and intercomparable. This will not be possible within the current LIVES project. It is advisable that one of the former project partner organisations takes the lead and responsibility in this.

Building block 4 – Inventory of best practices

The LIVES project was a first of a kind effort to monitor plastic in rivers on a cross-border scale with active participation of partners from multiple countries. The pioneering character of the project has made LIVES an iterative project. To better understand what went well during the project and to identify areas that can be further improved, building block 4 was used to make an inventory of best practices regarding monitoring and project management (Annex IV).

7 key main messages regarding best practices were distilled from interviews with the LIVES partners. These key messages can be grouped in 3 categories: 1) Political Agenda & Priorities, 2) Project Management & Collaboration, and 3) Future Innovative Methods & Knowledge.

Political Agenda & Priorities

I. *Take political, linguistic, and cultural differences seriously*

Cross border-cooperation as seen in the LIVES project highlights differences between the LIVES partners. Differences include the way water management is organized in each country, the height of the topic of litter pollution on the political agenda, and language barriers. A best practice is to be aware of these differences and to accommodate each other, if necessary with the help of a regional interpreter,

II. *Removal of litter should contribute to preventative measures*

Little data is available on the sources and pathways of litter through the environment. Such knowledge is key to effectively prevent litter. Currently a large amount of the litter removed from the Meuse is not analysed. This could be low hanging fruit for gaining insight in sources and pathways of litter. It is therefore a best practice to start monitoring the removal of litter as well.

Project Management & Collaboration

III. *Collaboration is essential for successful joint activities and measures*

Collaboration is key for reaching the goals set out within the LIVES project. Collaboration on monitoring in particular, includes partners such as water managers, area managers, scientific institutions and citizen scientists; some of these are already involved in LIVES as partners and associated partners. Other have to yet join. A best practice here is to encourage such collaboration in future efforts.

IV. *Information management is crucial to make cross-border datasets useful, transparent, and comparable*

Data management is crucial to reaching the goals set out in the LIVES project. Several best practices can help improve this process in the future: 1) agree on common desired monitoring objectives, current state of knowledge, and methods for information exchange at the beginning of the project, 2) Establish standardized methods for monitoring to ensure comparable results, and 3) Ensure data is reproducible and transparent.

V. *Project Manager or Project Leader are two important roles that should be explicitly given to a separate person*

It should be clear to all partners who the project manager and project leader is on a certain project. These persons should ensure that the project timeline is long enough and aligned with the stated objectives, safeguard knowledge during the project, and make work more

manageable by creating smaller working groups. The LIVES project created a solid foundation, but a best practice would be to put more focus on this in the future.

Future Innovative Methods & Knowledge

VI. *Future knowledge about the behaviour of litter in rivers and streams is essential*

Fundamental knowledge on the behaviour of litter in water systems is key to improving monitoring efforts. However, this knowledge is currently lacking. It is therefore a good practice to invest in research to better understand this behaviour.

VII. *New or innovative technologies can help automating and simplifying monitoring efforts*

New or innovative technologies such as using cameras and artificial intelligence to detect and quantify litter, or using Unmanned Aerial Vehicles (UAV's), can potentially automate and simplify monitoring, give more data, and reduce costs and time required for monitoring Several LIVES partners are already experimenting with these technologies. It is a good practice to further explore the possibilities of these technologies for monitoring of riverine litter.

Building block 5 – Cross-border dataset

Building block 5 was used to gather monitoring data gathered by the LIVES partners, to process these data to make sure it fits in LOADS created in building block 3, and to provide suggestion on how to effectively use LOADS (Annex IV). The data were processed and imported in LOADS. In this section the best practices for the cross-border dataset are provided.

I. *Shared data should be reliable, useful, and the associated methods for data collection should be standardized among the LIVES partners*

What types of data are gathered and how they are registered should be decided on before monitoring commences. Similarly, data formats used to log data in the field should be harmonized. This ensures that data is reliable, comparable, and reproducible.

II. *Data inconsistencies can be overcome by introducing unified methodologies and safety layers*

It is important to ensure that data is of high quality before it is entered in LOADS. This can be done by introducing unified and standardized methods as well as by doing a quality control processing of the data before they are entered in LOADS.

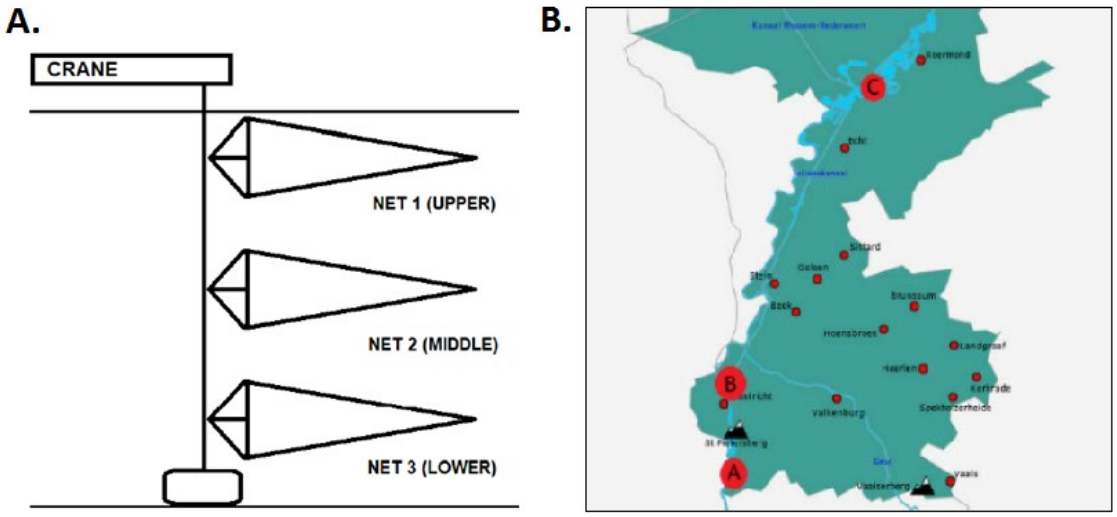
III. *Measuring factors that may potentially influence the presence of litter may be as important as monitoring litter itself*

Several external factors may influence the presence of litter at a particular location, including time, geographic location, precipitation, wind, and discharge of a river. To ensure that monitoring data can be used to determine the effects of these factors these metadata should be logged and combined with the monitoring data in LOADS.

Building block 6 – Monitoring Water Column

The inventory of knowledge made in previous building blocks showed that monitoring methods for litter in the water column of rivers were underdeveloped compared to other river compartments (e.g. floating litter and litter on the riverbanks). Building block 6 was therefore used for an innovative pilot to further develop these methods (Annex V).

During the pilot a new monitoring method was tested that utilizes nets at different heights in the water column (Figure 4A). These nets were lowered from a ship using a crane, left in the water for 45 minutes or until the nets were clogged while flow velocity was monitored, and the caught samples were analysed in a lab using the river-OSPAR categorization method. The most frequently found items found in the samples included unidentifiable small pieces of soft and hard plastic (0-2.5 cm). The efforts in the building block have proven that this monitoring concept is applicable in the river Meuse and can be used in future monitoring strategies by the LIVES partners.



the monitoring of litter in the water column of the Meuse, and B. Locations (A,B,C) at which the monitoring was tested.

Building block 7 – Monitoring strategy 2022-2027

Previous building blocks have made an inventory of monitoring data, identified best practices, and set out guidelines for data storing and sharing. Building block 7 was used to combine all the lessons learned in the previous building blocks to create a plan that can be used to set up cross-border monitoring strategy of litter in the Euregio Meuse-Rhine for the period 2022-2027(Annex VI).

Monitoring efforts by the LIVES partners are now often of short-term and use different methodologies. Interviews were executed with the LIVES partners to create an inventory of in-house knowledge on monitoring. From these interviews the gaps in monitoring were identified. Based on these knowledge gaps it was suggested to utilize the Roadmap for long-term macroplastic monitoring in rivers[5] for the rivers and streams in the Euregio area as well. Rijkswaterstaat already uses this roadmap for the development of their national monitoring strategy for riverine litter.

The Roadmap can help accelerate the process of achieving structural monitoring through providing a stepwise approach which links monitoring goals and research questions to the data and methods required to answer them (Figure 5). 12 important research questions that can be answered through monitoring are given in the Roadmap. However, questions can be added and removed when the LIVES partners identify other research questions that are important. The Roadmap consists of three levels: (1) method development, (2) baseline assessment, and (3) long-term monitoring. At each level, specific questions can only be answered if the level is achieved for specific river compartments. For questions at higher levels, the previous levels need to be unlocked first. This creates a clear stepwise approach to solve open challenges.

The Roadmap can be used by the LIVES partners to design a monitoring strategy by following the following steps:

1) Decide on the goals for monitoring litter in the Euregio Meuse-Rhine (e.g. policy development, knowledge development, operations and maintenance, solution design)
2) Decide on relevant research questions related to these goals
3) Design routes to answers using the Roadmap (what river compartments should be monitored, what levels in the Roadmap should be passed to answer research questions?)
4) Execute projects along the route to answers (start with the relevant level in the Roadmap for each river compartment) until the desired level is achieved.
5) Evaluate research goals and questions, start new cycle (at step 1)

Following this stepwise approach allows for standardized methods to be developed for each river compartment, to gather harmonized baseline data for the rivers and streams in the Euregio Meuse-Rhine, and to eventually gather long term data that can be used to guide litter intervention strategies.

[5] van Emmerik, T., Vriend, P., Copius Peereboom, E. (2022). Roadmap for long-term macroplastic monitoring in rivers. *Frontiers in Environmental Science*, 9:802245.

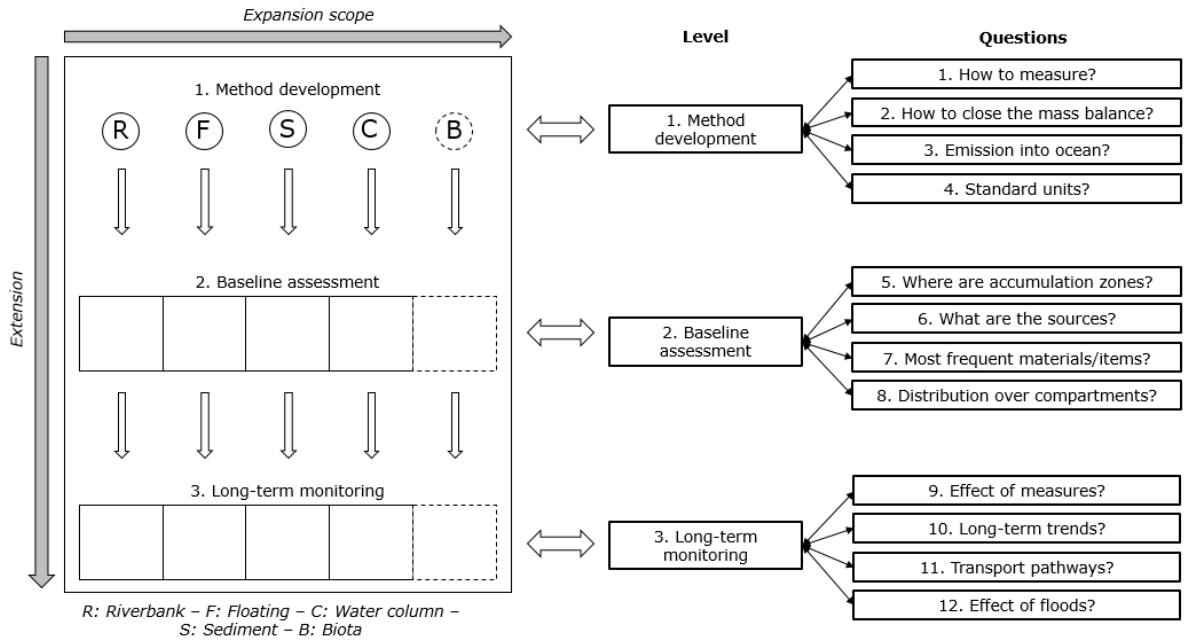


Figure 5- Overview of the Roadmap with 3 development levels (Method development, Baseline assessment, Long-term monitoring) for each river compartment (R = Riverbank, F = Floating, S = Sediment, C = Water column, B = Biota) the level of questions that can be answered for each development level, and the option to expand the scope of monitoring by adding river compartments (dotted line around Biota). Source: van Emmerik et al. (2022).

4. Concluding remarks

With the conclusion of the 7 building blocks set out in WP1 of the LIVES project the first efforts have been made for setting up a cross-border and harmonized monitoring strategy of litter in the Euregio Meuse-Rhine. As mentioned in the introduction, the LIVES project was the first of its kind and therefore the creation of the monitoring strategy was an iterative process. First an inventory was made of current knowledge on monitoring by the LIVES partners. This was done by producing a Meuse flow scheme (STORM), and creating a hotspot map. Next, effective data storing and sharing was facilitated through creating an open-access data system (LOADS) and through identifying best practices for monitoring, data storage, data handling, and project management. Last, a monitoring strategy for the coming years was suggested.

It is important to highlight that there is no one-size-fits-all monitoring strategy. Instead a monitoring strategy is highly dependent on monitoring goals, the policy, operational, and research questions that follow from these goals, the available resources, possibilities for cooperation and the political willingness to implement the strategy. It is therefore key for the LIVES partners to keep the dialogue open on further development of the monitoring strategy and on the implementation of this strategy. Only then monitoring (methods, protocols and datasets) can be harmonized and a cross-border understanding of problem of litter in Euregio Meuse-Rhine can be gained. Such understanding can be used to design effective measures to reduce litter in the rivers and streams in the Meuse basin.