LIVES WP1

Monitoring strategy 2022-2027

Monitoring Strategy for The Litter Free Rivers and Streams (LIVES)

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Photo front cover:
Part of the yield of hard macroplastics in the river bank monitoring of the Rhine at Spijk (NL), early 2019 in the Schone Rivieren project. (photograph taken by Michiel Wilhelm).

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1 Summary

This report presents the monitoring strategy for the monitoring of litter in the river basin of the Meuse, offered by TAUW to the LIVES partners and all who are interested. This strategy is the result of interviews with the LIVES partners and desk research, and provides a handle to the partners to expand their monitoring ventures and to keep that up to date in the coming 5 years.

It has come forward in the interviews that all partners have some kind of basis in monitoring litter, ranging from incidental clean-up actions to years of monitoring that already have been completed. Our advice to the partners is to expand that basis of monitoring according to the Dutch Roadmap for plastic monitoring in rivers by Rijkswaterstaat. Moreover, our advice is that the LIVES partners do set up a monitoring program to monitor the structural amount of litter in their part of the Meuse river basin, in order to gain insight into its size. This relates to both the flux as well as the litter that accumulates on the river banks. When that information is known, then based on this information the choice can be made whether or not to try to tackle that flow of plastic. Continuous monitoring of this flow is advised, to keep informed about possible changes in the size and composition of the flow.

The agreements that the LIVES partners at least need to make to come to an integrated plan for monitoring litter in the Meuse are:

- Agree on the Roadmap to use as a guide for future monitoring projects.
- Agree on a water system-wide monitoring approach that all LIVES partners will implement.
- Store all data in LOADS
- Store all metadata in LOADS

This Roadmap contains both a linear element (in three levels) as well as a circular element. First the three levels are gone through.
At **Level 1** the choice for the river compartment where monitoring will take place is made (River bank, Floating, Water Column, Sediment or Biota), as well as the decision on the monitoring technique to use. The type of question that can be answered in this level is: How can we measure litter?
Connected to this level are choices regarding for example the units and metrics, and the location where to monitor in the river. In choosing the monitoring technique in level 1, information is available regarding which technique is best suitable in different situations. Rivers differ for example in terms of their discharge rate or the amount of ships that pass through. For those situations has TAUW provided an overview which can be helpful. In case a method is not available, level 1 can be used to develop a suitable method.
Level 2 of the Roadmap presents the baseline measurement, which is the result of the first full monitoring cycle. The type of question that can be answered in this level is: What is a first indication of the amount of litter in the system?

This level brings information regarding for example the distribution of macroplastic, as well as the performance of the chosen monitoring technique.
Level 3 presents long-term monitoring, where the monitoring cycles developed in level 1 and 2 are repeated on the agreed upon interval. Repeating the monitoring each time brings the information about long-term trends that most LIVES partners wanted to know when they signed up for LIVES: Where does the litter come from? What are the effects of specific prevention and reduction measures? What are transportation pathways of plastic pollution through rivers? Etcetera. This is the kind of knowledge that the LIVES partners are most interested in, but this means that first level 1 and 2 of the Roadmap need to be completed.
The circular element of the Roadmap is that when level 3 has been reached, then the evaluation of the monitoring techniques can take place and the methods can be renewed or altered if possible.

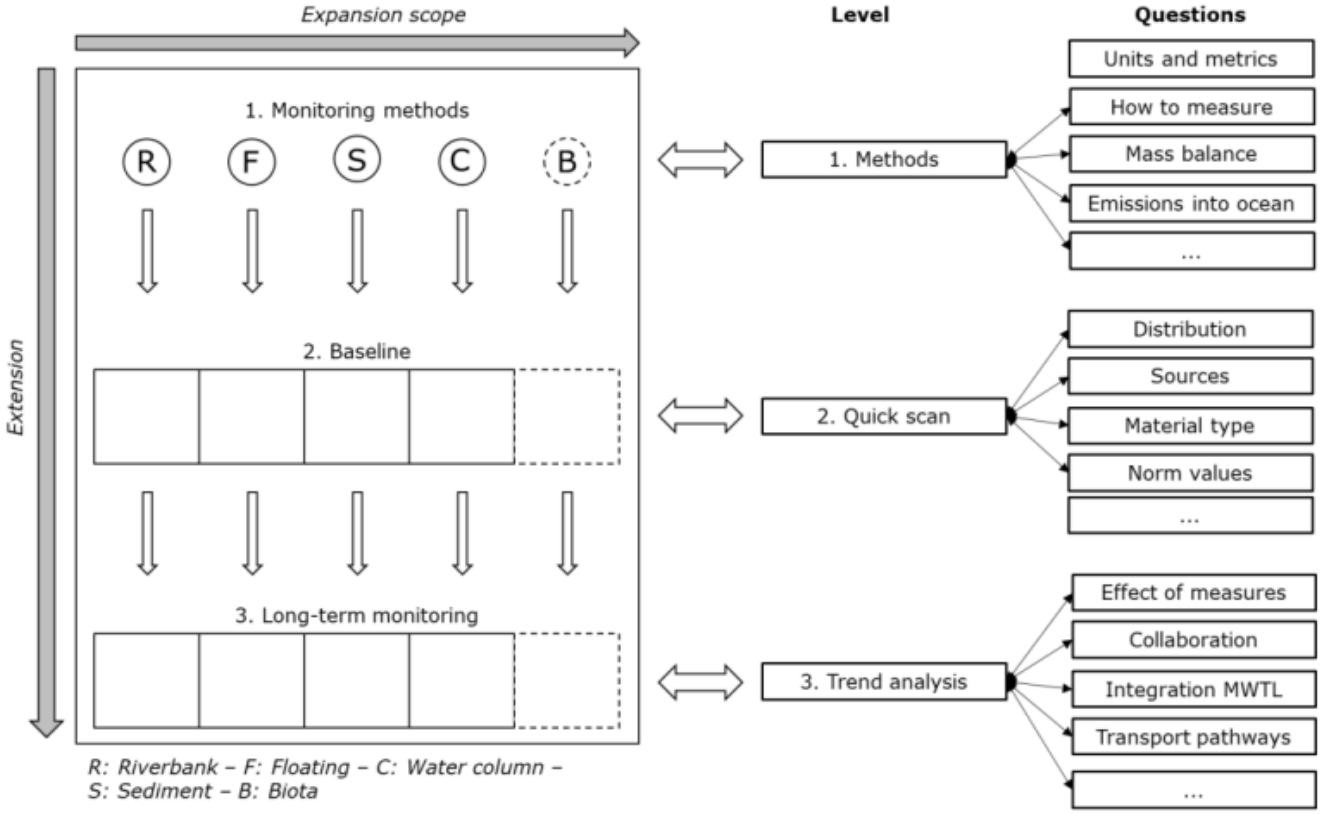


Figure 1.1 Roadmap for plastic monitoring in Dutch rivers (Rijkswaterstaat, Netherlands)

Next to the Roadmap, which provides a handle for all partners to base their monitoring ventures on, are other aspects important as well for the monitoring of litter a success.

Agreements on data need to be made. The units of the yielded data needs to be uniform. This ensures the possibility for comparing data from different LIVES partners. The goal eventually is to be able to analyze the macroplastic littering across the entire river basin of the Meuse. To ensure that these analyses are possible all data and metadata need to be stored in a central location

which is openly accessible for everyone. LOADS (Lives Open Access Data System), created by contracted company 2bprojects in building block 2 of WP 1 is created for that purpose.

Furthermore, it is wise for the LIVES partners to strive for a cross-border collaboration that is as open as possible. Information about successes or lessons from monitoring should not be kept within the organizations but shared, and partners are encouraged to start projects together as much as possible. The partners have indicated that they would like a better collaboration, which helps them in more effectively tackling the plastic issue. Lessons learned can be shared, and partners can help each other in setting up monitoring projects, with knowledge or maybe even money. For this to happen, it is advised that the partners actively seek collaboration and try to not let the bureaucratic barriers of their own organization get in the way. This will be very important to make water system-wide monitoring a success.

2 Introduction

2.1 Litter pollution – How did we get here?

The past 70 years have seen a worldwide exponential increase in the production and consumption of products . New materials such as plastic revolutionized our way of living. However, this leap forward also has a shadow side to it: a large portion of these 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 litter that is broken down in the environment, in the food we consume and the water we drink.

2.2 Litter in rivers – A serious problem

Litter pollution is produced on land through mismanagement of waste and littering. Only a small fraction of litter pollution ends up in the famous 'plastic soup' in seas and oceans. Most litter is (temporarily) retained in rivers. 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. Due to the longevity of the materials in our waste streams, the ubiquity and large volume 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 is currently lacking. For example, very little is known about the sources of litter pollution, how much litter is exactly in our rivers, and where hotspots of litter can be found. 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 as well which 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.

2.3 The LIVES project – Cross border cooperation to reduce litter pollution

The Litter Free Rivers and Streams (LIVES) project is 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, and scientists from Germany, Belgium, and the Netherlands to jointly tackle the litter pollution. This is done on three fronts: 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.

2.4 Structure of the LIVES project

The LIVES project follows a layer-based approach, whereby the first two layers comprises six different work packages, namely: Management (WP M), Communication (WP C), Inventory Data Sharing (WP T1), Implementation of Measures (WP T2), Institutional Arrangements (WP T3) and First Level Control (WP T4). This report is part of WP T1. WP T1 consists of five building blocks which each block having their own deliverables. This report focuses on the 'Monitoring strategy 2022-2027' (most right orange box, Figure 2.1). The main objective is to give insight in the type and density of future cross border litter monitoring projects.

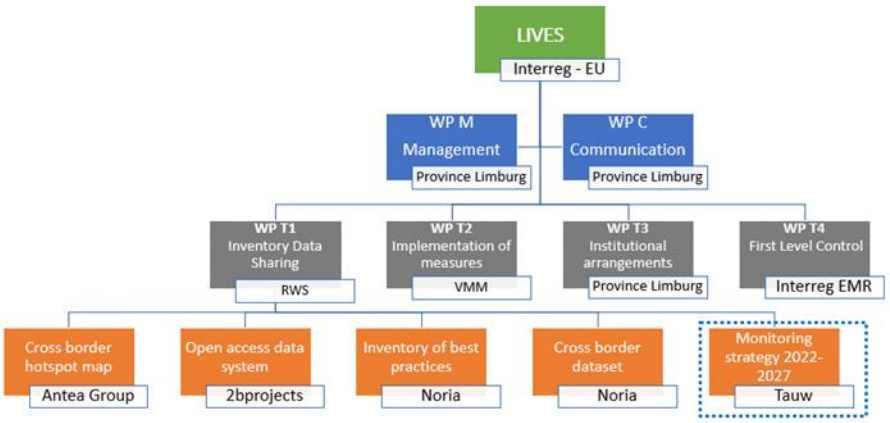


Figure 2.1 Structure of the LIVES project (Noria, Netherlands)

2.5 Creation of the strategy advice 2022-2027

From these activities, the monitoring strategy in chapter 2 is the result. It is a combination of input provided within the interviews, TAUW's own expertise in the field of litter monitoring and the knowledge available in the roadmap of Rijkswaterstaat..

2.6 Reading guide

The next chapter, chapter 3, presents the main recommendations that are advised to the LIVES partners for the development of their own litter monitoring projects. The main guide for setting up monitoring, the Roadmap, will be explained. The goals that can be achieved by monitoring litter will be discussed as well. Furthermore, recommendations are made regarding the storage of the data that will be the result of the monitoring. Chapter 0 discusses the research that has been conducted by TAUW in order to reach the recommendations made in chapter 3. The progress that the LIVES partners have made will be discussed, how this progress can be expanded, which are the lessons learned and the recommendations we collected from the partners to keep monitoring successfully. Additionally the internal knowledge of TAUW regarding monitoring techniques and the applicability of those techniques is discussed, as well as the conditions of a river which need to be researched in order to select a proper technique.

3 Monitoring strategy 2022-2027

3.1 Main conclusion

Our advice to the LIVES partners is to set up their monitoring program in the following years according to the roadmap of plastic litter monitoring in Dutch rivers by RWS. This roadmap can be seen in Figure 3.1 (van Emmerik et al, 2021).

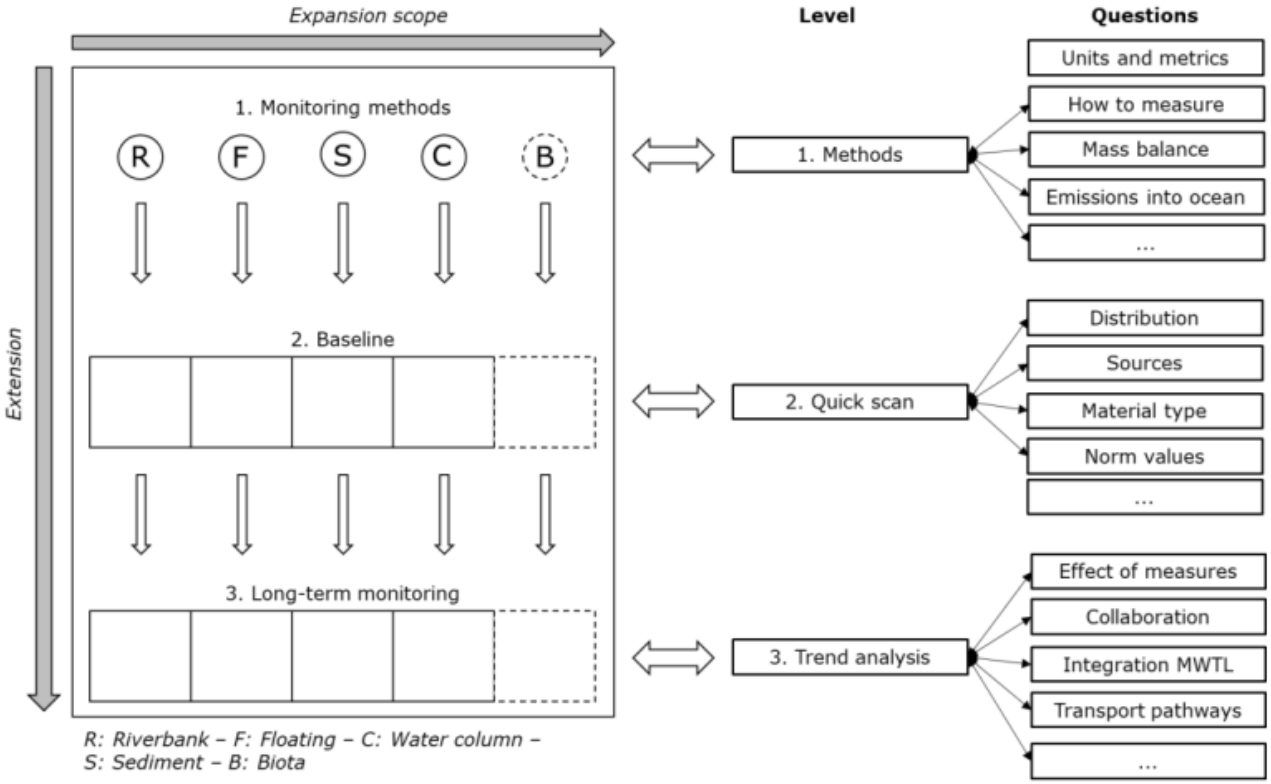


Figure 3.1 Roadmap for plastic monitoring in Dutch rivers (Rijkswaterstaat, Netherlands)

The roadmap shows how certain goals of waste policy and watermanagement can be achieved. Four goals are defined within the roadmap: policy development, knowledge development, operations and maintenance, and solutions.

3.1.1 Monitoring to answer main questions

During the interviews, certain questions arose on which the LIVES partner would like to have an answer. For example where the litter came from or what good monitoring locations were. The above presented roadmap enables LIVES partners to set up a monitoring strategy that answers those questions, and the following questions as well:

- How can litter be monitored in each river compartment?
- How to determine the plastic mass balance in rivers?
- What are the emissions of litter from rivers into the ocean?

- What are standard measuring units for each river compartment?
- Where are litter accumulation zones in rivers?
- What are the sources of riverine macroplastic?
- What are the most abundant macroplastic polymers and items?
- How is litter distributed over the river compartments?
- What are the effects of specific prevention and reduction measures?
- What are the long term trends of riverine macroplastic transport?
- What are transport pathways of plastic pollution through river systems?
- What is the role of floods on macroplastic transport in rivers?
- When can microplastic litter be measured optimally with respect to the dynamics of the water?
- The amount of organic material, especially during high water events in the Meuse, sometimes makes it difficult to monitor in a larger whole of wet litter

3.1.2 Levels (extension scope) should be met

Through different levels of the Roadmap, each of the above questions relate to data. The first level is the development of the monitoring method, the second level is the measurement of a baseline (a t=0 measurement), and the third level refers to long-term monitoring.

The first level, the development of the monitoring method, specifies several areas where the monitoring can take place. Many of the current monitoring is only done at the riverbanks as a result of cleanup actions, but monitoring in the water column or floating macroplastic is also important since that will partially end up in the ocean.

The research questions that are posted in the previous paragraphs are each linked to the different levels in the Roadmap. For example if one would like to know the effects of specific prevention and reduction measures, then all three levels have to be met for the relevant river compartments in order to obtain that information. If one for example would like to know the distribution at a certain moment of macroplastic in certain river compartments then only level one and two have to be met.

3.1.3 Choices in monitoring strategy are crucial

For the LIVES partners, it is important that in the first two years – where level 1 and 2 of the Roadmap are being completed - of setting up a monitoring strategy for the next five years where the first long-term results will become known, some choices are made. One of those choices, which is part of the first level of the Roadmap, is on which compartment of a river (river bank, floating, water column, sediment, biota) the litter should be monitored. Preferably all 5 of the river compartments are monitored, but it is not realistic to set up monitoring for all 5 of the compartments within the next 5 years. This will cost too much time and money, focusing first on one compartment is likely to yield better results. So compartments which are assumed to bring the largest effect or the highest amount of added knowledge should be chosen. For example the riverbank can be chosen since that is the easiest compartment to monitor, or the water column if it is expected that the most litter will be present there.
Then the standardized methods should be decided on or developed. Once research method have been established (level 1), a baseline measurement should be performed. A baseline

measurement is the result of the first fully completed monitoring cycle. This corresponds with the second level of the Roadmap.

This baseline provides the starting point of the long-term analysis of macroplastic behavioural trends. It has become clear in the interviews with the LIVES-partners that there is a desire to know what the sources and the pathways of the litter are, whose responsibility the macroplastic is and who to target in an anti-littering campaign, through either stimulation or penalizing. These are desires that can be achieved through long-term trend analysis. In order to be able to obtain such knowledge, the first two steps of the roadmap – determination of the monitoring method and the performance of a baseline measurement – are necessary to take first. If one would immediately start with the goals that are part of the long-term trend analysis part, it is more likely that mistakes are made.

> *"What we would like to know is who we need to address when we find a high amount of a specific kind of plastic. For example if we consistently find plastic with the logo of a fast food chain on it, then we can address either the chain or its customers in a campaign."*
>
> *Regional water authority*

3.2 Development of a monitoring strategy through the Roadmap

This paragraph discusses an example of the development of a monitoring strategy through the Roadmap. Because of the usage of the Roadmap, fundamental choices come to light such as the location of the monitoring points.

3.2.1 Level 1

Let's say for example that the LIVES partners are interested in knowing the transportation pathways of macroplastics through the water column: where does it come from, and where does it end up. The water column is one of the five possible areas of monitoring that can be specified in the first level of the Roadmap. In this first level, choices have to be made regarding the monitoring method.

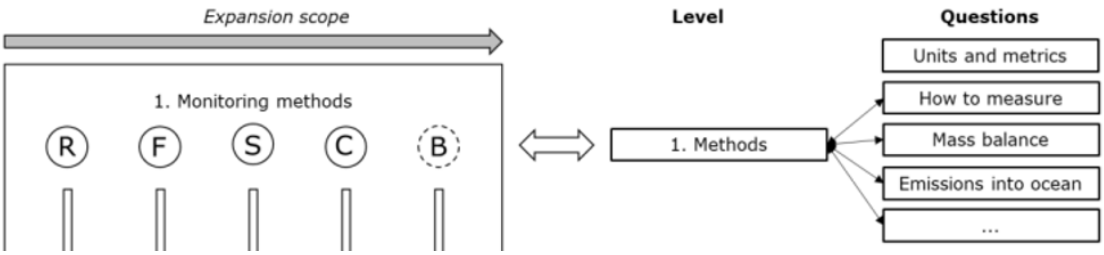


Figure 3.2 First level Roadmap for plastic monitoring in Dutch rivers

- **Units and metrics**
  Do you measure in kg/day or tons/month? Or another unit?
  It is recommended that the units and metrics are agreed upon by the LIVES partners for all monitoring ventures. This allows for easy comparison and analysis of data.
- **How and where to measure**
  For monitoring in the water column, there are several techniques available. A net across points in the river is possible, as well as litter traps that do not capture all plastic during the measurement but a sample. One of the LIVES partners as chosen to make use of the

infrastructure that is present in the water system; macroplastic that travels through the water column will eventually be intercepted by a waste fence in front of a watermill. Monitoring the macroplastic at such a fence, tells you about the amount of plastic that came into the river in that particular segment.

- **Where to store the information**
  Before the monitoring takes place, it should be clear where the information that will be obtained through the monitoring will be stored. Our recommendation is the LIVES Open Access Data System (LOADS), which will be elaborated further on in this report, and which is created by 2bprojects, one of the other contracted companies for WP1.

3.2.2 Level 2

With these choices made, you can move down to the second level of the Roadmap and perform a baseline measurement.

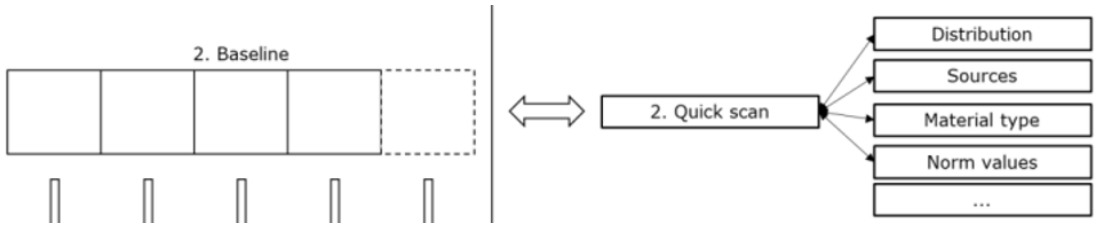


Figure 3.3 Second Level Roadmap for plastic monitoring in Dutch rivers

This measurement represents the first full cycle of your monitoring activities. What constitutes a full cycle depends on the agreed upon monitoring frequency: do you monitor over a full year, or each June, or every Sunday for three months for example.
The baseline measurement is the result of the first fully completed monitoring cycle. This will give answers to the following questions:

- **What is the distribution of litter?**
  The baseline measurement will tell you what the distribution of the litter (and macroplastic as part of the total amount of litter) is in the first cycle of monitoring. This information does not yet provide a handle for actions; actions can only be taken when the following monitoring cycles prove that litter is distributed in a certain way. This information does give an insight in where maybe added monitoring may be needed in the following years, or areas of high interest such as nature conservation areas.
- **What are possible sources of litter?**
  Following the distribution of the litter, an inventory of possible sources can be made. For example if a lot of litter with the logo of a certain company on it is found, then that company or its customers are possible sources. Again, this first has to be confirmed in the following measurement cycles before actions can be taken.
- **What is the composition of the monitored litter?**
  The composition, such as certain logo's as mentioned in the previous points, but also the size and shape of the litter provides extra information. This information can be used to enhance the monitoring techniques, or to add extra monitoring points in areas with high interest.

- **What are possible norm values?**
  The baseline measurement gives a first insight into the possible norm values. Can it be clear from this first measurement whether the measured amount of litter poses a risk for natural values in that particular segment? If yes, than a norm below the found results can be set that can be enforced in the future. If no, then perhaps simply the current measurement can serve as a norm, with the goal to get the amount of litter below this threshold. During the following monitoring cycles, when knowledge on the subject increases, these norms can be adjusted if necessary. It is again recommended that the norms are uniformly agreed upon by the LIVES partners.

3.2.3 Level 3

With this information, the monitoring cycles can be repeated over and over again, and improved if necessary. With these cyclic results, the long-term analyses that are part of the third level of the Roadmap can be performed.

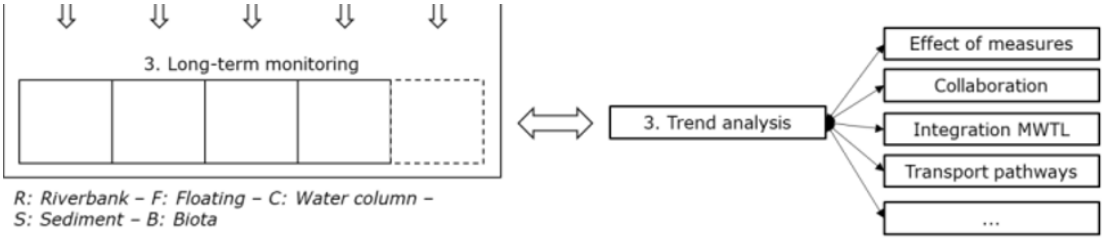


Figure 3.4 Second Level Roadmap for plastic monitoring in Dutch rivers

Examples of long-term analyses that can be performed are:

- **Effect of measures**
  A certain measure can be taken to combat littering, such as a social campaign. The effect of such measures can be seen in the monitoring cycles over the years.
- **Collaboration**
  Enhanced collaboration with other partners can diminish the amount of plastic in the system, as well as a better understanding of the water system as a whole. New monitoring techniques or insights can be the result of such collaboration.
- **Transport pathways**
  The route that litter travels can be analysed through the monitoring. It should be noted that for a thorough understanding of the transportation pathways of litter, not a single area such as the water column should be monitored. The plastic can wash up the river banks, or sink to the bottom for example. So for a complete picture, monitoring in more areas is needed.

Furthermore, the Roadmap has a cyclic element, which can be seen in Figure 3.5. After level 3 has been met, the program is evaluated to see if monitoring goals are met and if new monitoring goals and/ or additional monitoring projects are necessary (which may trigger a new cycle of improved monitoring).

Figure 3.5 Cyclic element of the Roadmap (Rijkswaterstaat, Netherlands)

The steps in this cycle are explained below:

- Decide which goals you have for monitoring
- Decide which question stem from these goals (which you provide before)
- Routes to answers (so the 3 levels in the roadmap)
- Execute these project and cluster the ones which are most important
- After everything has been performed you have new results, new insights, and the monitoring goals can be re-evaluated (are they still relevant, do we need different questions?)
- Cycle starts again

3.3 Data storage

Next to the Roadmap, which presents a guide to set up a monitoring program, should the data from this monitoring be stored somewhere. Our advice is to store it in the LIVES Open Access Data System (LOADS), which is mentioned before. In such a system the data and metadata of the monitoring can be stored and viewed by each of the LIVES partners. The report of contracted company 2bprojects elaborated on this.

We think that this is necessary because the fact that every partner sets up their monitoring strategy according to the Roadmap, does not guarantee that the data that is produced is uniform. This asks for agreements among the partners, and LOADS can help in checking that the data is uniform. So our advice is to not just come to agreements about monitoring protocols, but also about data storage. Data storage and -management should be included in the development of the monitoring method (level 1 of the Roadmap) to ensure homogenous data. If there are no agreements made then the risk is that data produced by partners can't be used by other partners for analysis. Then everyone is still operating on their own.

Along with the data, the metadata should also be stored in LOADS. Metadata presents information on how the monitoring data were obtained. This helps in placing the results in reality, and a nuance for numbers that may seem excessive at first sight, or very small.

These recommendations regarding data- and metadata storage have to do with the fact that the different LIVES partners have different approaches and responsibilities towards plastic monitoring. For example data can be collected through volunteer initiatives that collect litter and dispose of it while other parties may search only for responsible parties of illegal dumpings, or only collect data when after a calamity the waste is removed. Such different motivations and methods will have different results and the resulting data is either difficult or impossible to compare. That is why it is important to determine and share the meta-data, so that the figures can be put into context. Furthermore we advise that all LIVES partners agree on certain standard monitoring techniques that are applied everywhere in the Meuse water system (Which is level 1 of the Roadmap). Doing so provides a broad basis for the long-term analysis that can be able to answer most of the research questions that the LIVES partners have. Working together through homogenous data collection, storage and presentation can help combat both structural littering as illegal dumpings, and serve both instances through the same methods.

Concluding, what should be the agreements that the LIVES partners at least need to make to come to an integrated solution for monitoring macroplastic in the Meuse:

- Agree on the Roadmap to use as a guide for future monitoring projects.
- Agree on a water system-wide monitoring approach that all LIVES partners will implement.
- Store all data in LOADS
- Store all metadata in LOADS

4 Setting up a monitoring program

This roadmap is suggested because this research has shown that there are many opportunities to move towards a structural monitoring strategy for the long-term. This will be explained further in the following paragraphs

There is an opportunity to expand the present basis into a structural program of monitoring. From the conducted interviews it became clear that all partners have done something that fits a monitoring strategy. This ranges from incidental cleaning actions with volunteers to a completed first monitoring cycle (resembling level 2 of the roadmap).. The partners however do not call it monitoring themselves, since there is no monitoring plan that underlies the actions that they undertake. They simply call it clean up actions, for example. However, as long as the information that is obtained through such actions is noted and stored, then this can be considered some form of monitoring. We noticed that spread over the LIVES partners there are a lot of initiatives in inquiring plastics/ litter. We mention a few:

- student research with an own built litter catching system
- student research on debris collected at a power station
- student research with daily collection litter during six weeks on a river bank
- combining recording data by pied pipers (muskrat catchers)
- providing volunteers in litter collection with a registration form
- inventory of litter after floodings
- drone images of effects of floodings in a reservoir

What these initiatives have in common is that each of them have used different methods of collecting and recording data and that data hardly can be found afterwards. Therefore the next step is to expand such actions into full monitoring programs.

Next to just incidental removal, it is wise to set up a monitoring program to assess the size of the structural litter transport at average discharges, through the part of the water system for which the LIVES partners are responsible. The reason for this is that when the size of the structural flow is known, based on indicators, then the choice can be made to:

- Focus on removing the structural flow of litter
- Go back to focusing on calamities,
- Take policy measures and/or operational management measures
- Continue monitoring insights into the status quo and the trends within that
- Do a combination of the above mentioned points

It is important that this choice is made after a monitoring program is created, because then the LIVES partners can make a decision based on facts. Otherwise the structural flow of litter may be unfairly underestimated due to inattention, and the choice for measures is still partially a guess since the partners then don't have the numbers to back their choices up.

In order to move from the base that is present towards a good-functioning monitoring program according to the Roadmap, the best practices of the other LIVES partners should be learned from. At this moment the furthest developed monitoring strategies are based in the Netherlands. This is

not only because the advised Roadmap is a Dutch product, but the actual projects of litter monitoring that yielded the most results were carried out by Dutch LIVES partners. The advice that is presented in this report is based on the lessons and opportunities that these programs have yielded. Other LIVES partners can use this advantage to speed up relatively easy. This way the monitoring of plastic can move from a national Roadmap to an Euregio Roadmap. The steps to be taken can be seen in Figure 4.1.

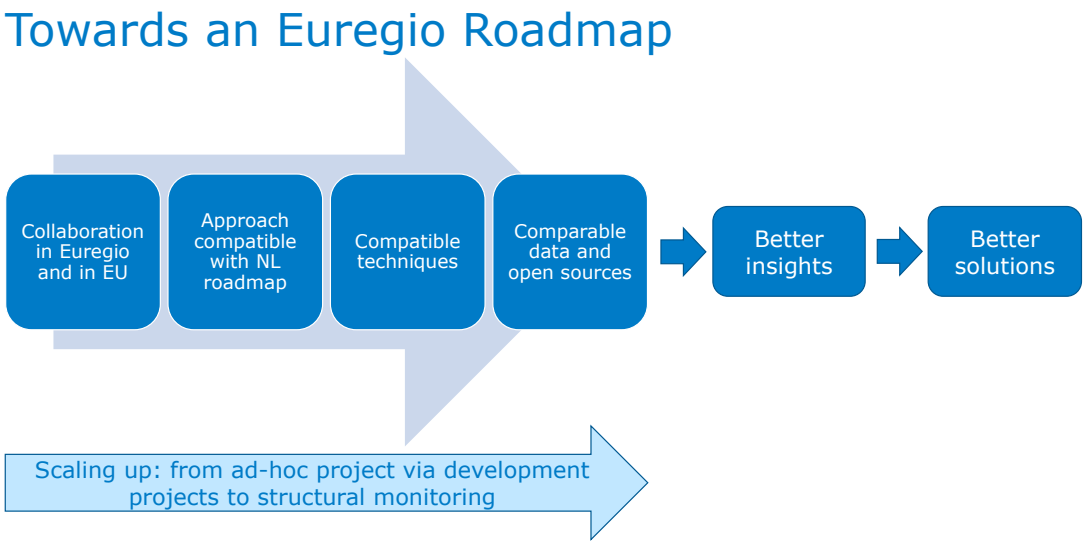


Figure 4.1: from a national Roadmap to an Euregio Roadmap (Rijkswaterstaat, Netherlands)

4.1 Reasons to use the Roadmap

In the following paragraphs it will be discussed why we think that this roadmap is a good tool to use to set up a monitoring program.

4.1.1 The partners who have used this roadmap to set up their monitoring project had successes

As mentioned before, there are some differences in the progress that is made by the several LIVES partners in setting up a monitoring program, even though every partner has at least done something. The partners are the furthest, have made plans that fit in the ideology of the Roadmap. In Figure 4.2 we give an overview of the degree of progress that has been made on parts of the monitoring strategy carried out by the LIVES partners, based on the interviews we had in November and December 2021.

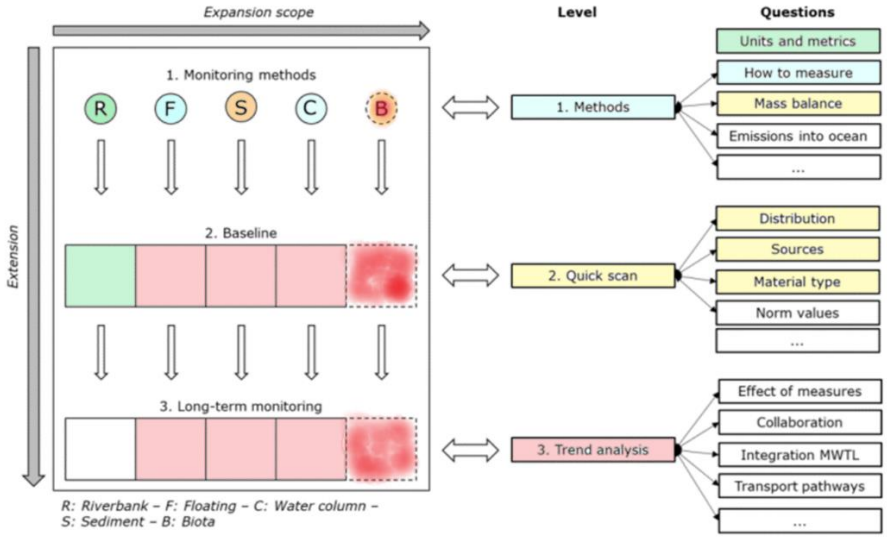


Figure 4.2 Briefly overview of progress on parts of the Roadmap by the LIVES partners. Green: good developed over at least two members; Blue: starting initiatives over at least two members; Yellow: some kind of development over the members; Red: poor developed.

The river bank compartment is coloured green because this compartment has been developed well and monitoring has been executed by at least two of the LIVES partners. Floating litter and litter in the water column are blue, because they may not be as well developed as the river bank, but initiatives by at least two partners were carried out and some results have been collected as well. Sediment and Biota are both underdeveloped, with no partners monitoring in those compartments yet and no sign that monitoring in those compartments is desired in the near future. Finally some of the boxes are yellow as well, this means that there is some development, but it has a lot of room for expansion and improvement.

For the partners that are the furthest in monitoring, the green and blue parts of Figure 4.2, this means that:

- A choice is made for an area of monitoring; some monitored in the water column and floating litter, some cleaned up the riverbanks.
- The monitoring method is adjusted to suit that area. This means that the location of the monitoring points and the size of the segments that the river has been divided in, was dependent on the present infrastructure in the system. Figure 4.3 displays a picture of one of those monitoring locations. Furthermore, specific plastic items that can be traced back to possible sources in the surroundings are documented.
- A baseline measurement has been performed.
  For example for one of the partners this has been a monthly monitoring program, over the course of one whole year from September 2020 until August 2021. The found litter has been categorized and monitored through a tally list.

Figure 4.3 One of the monitoring locations that was chosen based on the present infrastructure.

The results from the measurements that have been performed by the LIVES partners that were the furthest are suitable to use as a baseline measurement. This means that with the litter yield at the monitoring locations, a first insight into the distribution of the plastic is gained, as well as the composition. Furthermore some lessons have been learned which are:

- Smaller monitoring segments may be needed to capture macroplastic that may get stuck or decompose into microplastic before it is caught. One of the partners experienced that their segments were too big, which resulted in litter getting stuck behind branches. Furthermore they suspected that the plastic disintegrated before it ended up at the monitoring location.
- Riverbank monitoring is at the moment advisable to implement, since it has the most developed methods.
- Monitoring floating litter still has techniques in development, and is quite labour intensive. Monitoring in the water column is relatively expensive, and its techniques are also still in development. Sediment and Biota are not advised to undertake at this moment, since those methods are relatively difficult and expensive to implement.
- The data should be stored central and easy to access. That way the knowledge is accessible for everyone and an integrated monitoring strategy across borders is easier to create. This is solved with the creation of LOADS.
- It is impossible to monitor all plastic that ends up in the main river or streams. Some of it will break down into microplastic, or some will get stuck in the vegetation. Furthermore, the monitoring developments are not 100% foolproof and weather events might disrupt monitoring.
- It is advisable to select the monitoring technique which is most likely to monitor the highest amount of litter, and which is relatively easy to implement. The easiest to implement is riverbank monitoring, since you do not need to get into the water and the river can be split into manageable segments. Also water column monitoring can be easy if there is already infrastructure present in the system that can be combined with monitoring. For example a weed rack at a water mill stops litter that is transported through the water column and can be monitored at that location.

> *"During high water events the excess water is diverted around the mill. On that side there is no rack to stop the plastic so during high water not everything is registered."*
>
> - *Regional water authority*

For the next cycles of monitoring, all LIVES partners are advised to note these best practices and to learn from them.
The ideal size of river segments that are monitored should be determined. For example if a LIVES partner simply wants to monitor the water column, then the size of the river segments depends on the behaviour of the water: across what distance does litter wash up the riverbank? How fast does macroplastic disintegrate into microplastic? Our advice is to cooperate with scientific institutes that have knowledge on hydrology and the disintegration of plastic particles. It is the wish of at least one LIVES-partner to increase cooperation with these kinds of institutes. There are two scientific institutes who are LIVES partners (Open Universiteit and Hogeschool Zuyd) which means that more cooperation between the partners can provide such knowledge relatively easy.
All data should be stored in LOADS and the partners should accept that the monitoring still only captures a sample of the plastic that is present in the water system. Measures and long-term analyses can help determine whether the entire population of litter that is sampled by the monitoring decreases. This should determine whether or not a measure is a success.
It is advisable to perform some kind of quick scan of the amount of litter in each compartment to assess which compartment of a river (bank/ water column/ etc) it is best to monitor. Which compartment yields the best results should be the main indicator for this decision, costs and labour intensity can be additional indicators.

4.1.2 Every partner using the same system benefits the sharing of information

If every partner uses the Roadmap as a basis for their monitoring, and adheres to the made agreements about storing the data and using the same units of measurement, then the chance of the monitoring projects to be a success increases. This is because then the monitoring ventures of the LIVES partners can be read and analyzed by other partners as well, and analyses regarding the long-term can be carried out for a larger area then when each LIVES partner stays on their island. For example research into the possible upstream sources of litter in the streams that end up in the Meuse, which is one of the wishes of some of the partners, can only be carried out if the data of the downstream and upstream organizations is compatible. If other methods and classifications of the litter are used, then it is very difficult to prove where it has come from. Furthermore, homogeneity in plans makes the different plans easier to interpret for other LIVES partners, and the recognizability towards the public increases.

From the interviews with the LIVES partners it became clear that there is a desire to work better together, so this is a great opportunity to become more tied together. What is important for the sharing of information is an understanding of the organizational structure of the government organizations in the Euregio countries. Figures which represent the structure of Flemish, Walloon and German governments compared to the Dutch structure can be found in the appendix.
Having this knowledge increases the chance of the information ending up at the right person, and a better cooperation between countries. For example one of the LIVES partners – a regional government – advocated for a better cross-borders cooperation, not just in knowledge but also in financially helping other organizations in setting up a monitoring program. Monitoring (and perhaps extracting the plastic from the water as part of that monitoring) plastic upstream and gaining insight in the distribution may work better in tackling the issue than monitoring and cleaning up at the end, where the plastic could have come from anywhere. This added efficiency can cause the downstream organizations to save money. Since they do benefit from this added efficiency, it may be justified to help out financially in that upstream project. However, this is at the moment not yet a possibility due to the institutional barriers that are experienced, such as financial bureaucracy to spend money somewhere else than in the partners' own area, or other issues that disturb the start of a joint monitoring project.

> *"A better international and interregional cooperation helps us in tackling the microplastic issue at the root of the problem. Funding a plastic monitoring project across the border can eventually save money here because of the added efficiency. However, cross-border project funding is at this moment not realisable."*
>
> - *Dutch waterway manager*

4.1.3 Desk research into internal knowledge at TAUW comes to the same recommendations

At TAUW, there are several initiatives to enhance the monitoring of plastic and to solve the issue of litter in rivers. There is an internal task force which has the aim of sharing knowledge, and recently (Intven et al, 2019) a strategy has been developed for the monitoring of litter in Dutch rivers. While this does focus on the Dutch rivers, can it also be applied (perhaps with some small adjustments) to rivers and streams across the border that are part of the Meuse river basin.
The strategy that has been developed by TAUW shows similarities with the Roadmap. It concerns a separation of the areas of monitoring (water column/ river bank/ etc), and a list of techniques that are good to use in those different areas. Just as the advice that we have given in the previous paragraph does this strategy encourage the adaptive development of monitoring strategies based on the actions that are already being taken.

Additional to the Roadmap, does TAUW advise that the hydrological aspects of the river are explicitly considered in the development of a monitoring method (level 1 of the Roadmap). In the Roadmap this part does not come forward very clear, and our advice is to make it more visible. The aspects that should be considered are the following:

- Discharge rate and
- Velocity of the waterflow
- Influence of wind
- Internal turbulence in the water

- Influx of a small river into the main river and its influence on the composition of the water
- Land use: recreational areas, influx sewage treatment plant, industrial activity

These hydrological aspects of a river influence which monitoring methods are possible to apply. For example, in a river with a high discharge rate, using a net to monitor in the water column may not be a good choice, since the high discharge rate can drag the net away or tear it if plastic and other particles get stuck behind it.

Furthermore, are not all monitoring techniques applicable to all river compartments. TAUW has created an overview of which techniques are applicable to which compartment. This overview can be seen in Table 4.1. Note that the fifth compartment of the Roadmap (Sediment) is not listed in this table. This is because the TAUW strategy has only considered these four compartments.

Table 4.1 applicability of monitoring techniques in the different river compartments. X = this technique is applicable in this compartment.

Method / River compartment	Floating barriers	Use of infra-structure present	Visual counting	Dragging net/ Mantra trawl	Sensors	Cameras	Submerged drone	Satellite	Bubble screen	(autom.) Skimmer boat	Manual collection
Floating	X	X	X	X	X	X	X	X	X	X	
Water column				X	X		X		X	X	
River bank			X			X		X			X
Biota				X			X		X		

Furthermore, does each monitoring technique have properties that make it more or less suitable in different situations. For example in a river with a high amount of shipping, are floating barriers not a good monitoring option because of the obstruction for ships that this presents. Table 4.2 presents information on the suitability of monitoring techniques in for different indicators.

Table 4.2 Suitability of monitoring techniques for different indicators. + = suitable, 0 = suitable, but with restrictions, - = not suitable.

Method	Floating barriers	Use of infra-structure present	Visual counting	Dragging net/ Mantra trawl	Sensors	Cameras	Submerge d drone	Satellite	Bubble screen	(autom.) Skimmer boat	Manual collection
Weather independent	-	+	-	-	+	0	-	+	0	0	+
Selfsufficient	0	0	-	-	+	+	-	+	0	-	-
High water velocity	-	+	-	0	+	+	-	-	-	0	+
Measuring frequency	0	0	-	-	+	+	-	0	0	-	-
Fish safety	+	+	+	-	+	+	+	+	0	0	+
Shipping	-	+	+	-	+	+	+	+	0	0	+
Level of detail	+	0	-	+	-	0	0	-	+	+	+
Removing litter	+	+	-	+	-	-	-	-	+	+	+
Technology Readiness Level	+	+	+	+	-	0	0	0	+	+	+
Costs	+	+	+	+	-	+	+	+	+	-	+

Using these tables in addition to the Roadmap, helps the LIVES partners in selecting a monitoring technique in level 1 of the Roadmap that fits their personal goals and that is well suitable for their

situation, both with the properties of the river and streams in the partners' area and their own goals and budget for litter monitoring.

4.2 Why LOADS?

Is needed because using the same strategy and methods does not guarantee the same data output. Motivation for choices made on data-related subjects is to be found in the reports of 2bprojects en Antea.

5 References

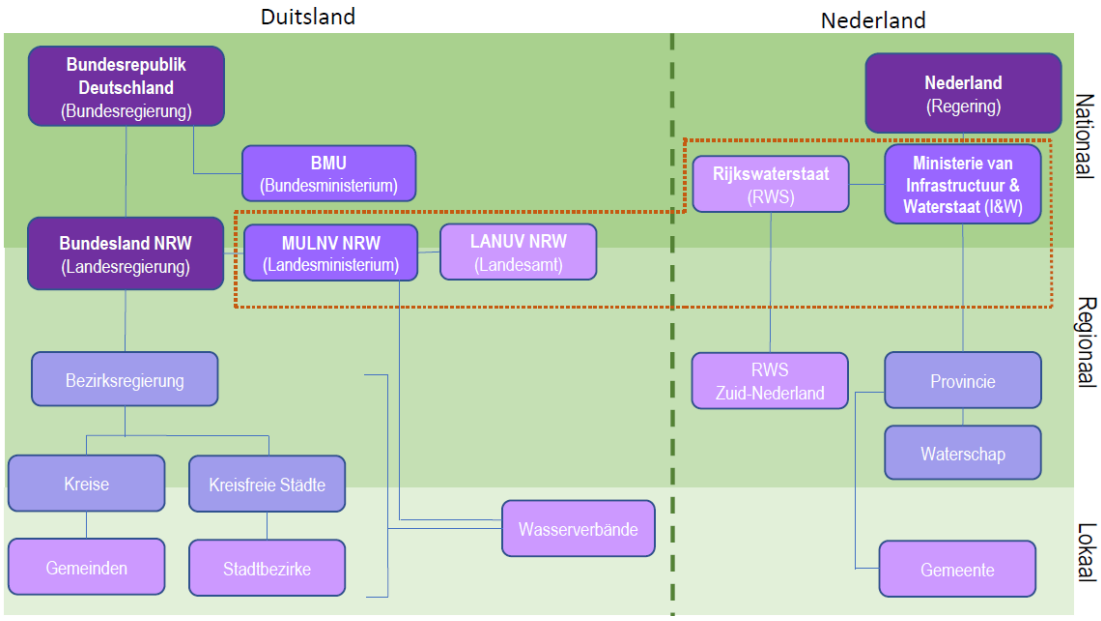
- Oswald, S.B.; Collas, F.P.L.; Schoor, M.M.; Buschman, F.; Leuven, R.S.E.W. (2020) Abundance and composition of macro- and mesoplastic in the Waal river, the Netherlands. Reeks verslagen Dierecologie en Fysiologie 2020-5, Radboud Universiteit Nijmegen.
- Van Emmerik, T.; Vriend, P.; Copius Peereboom, E. (in press, 2021). Roadmap for long-term macroplastic monitoring in rivers.
- Intven, M., M. Wilhelm & S. Spieksma (2019). Ontwikkeling Plan van Aanpak voor monitoring van (macroplastic) zwerfafval in de Nederlandse hoofdrivieren. In opdracht van Rijkswaterstaat. TAUW rapport 1266257.

Appendix 1 Dates interviews LIVES partners

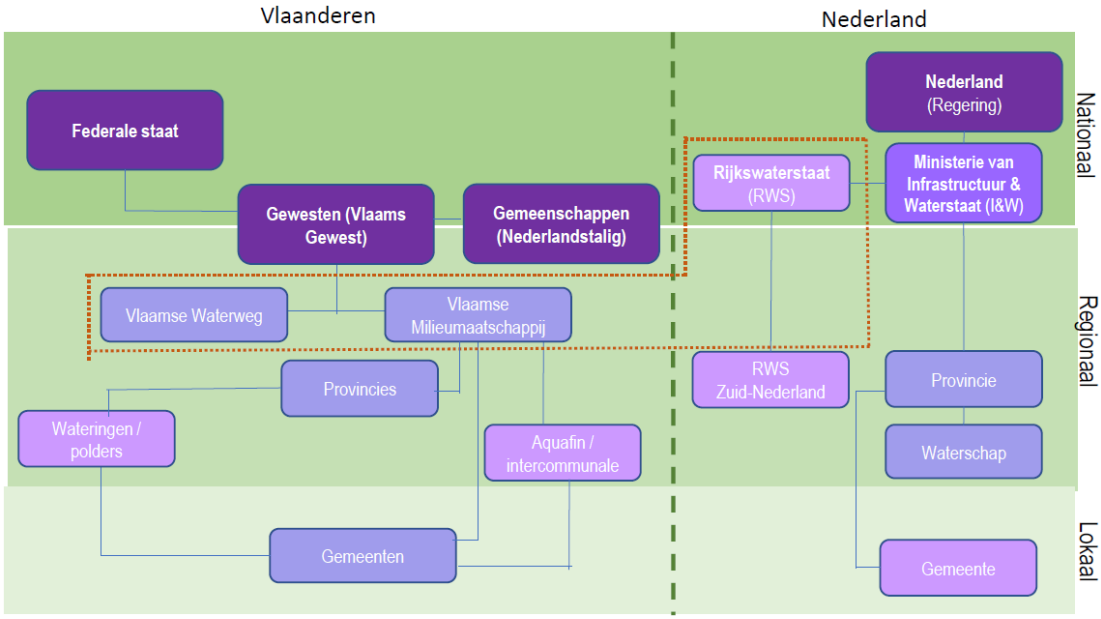
LIVES partner	Date interview (2021)
Rijkswaterstaat Zuid Nederland	November 16
Waterschap Limburg	November 30
Provincie Limburg	December 7
Vlaamse Milieumaatschappij	December 21
Vlaamse Waterweg	No interview
OVAM	November 24
Wasserverband Eifel-Ruhr	December 3
RWTH Aachen	No interview
Hogeschool Zuyd	November 23
Open Universiteit Heerlen	December 2

Appendix 2 Organizational structure of Belgian and German government organizations

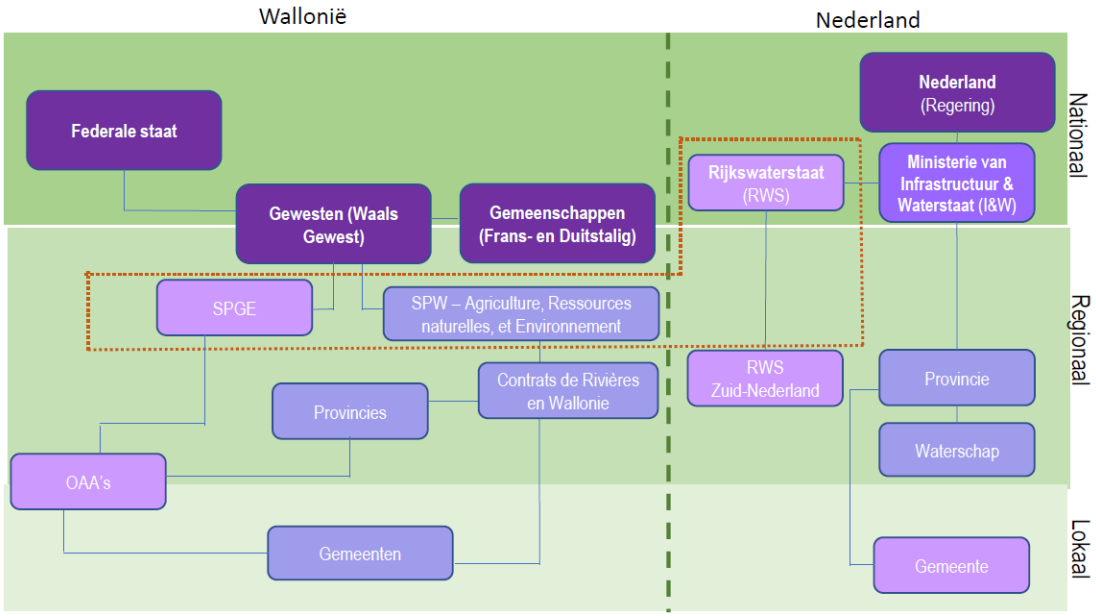
These figures were obtained with the courtesy of the contracted company Noria.



Organizational hierarchy of German government organizations, compared to the Netherlands



Organizational hierarchy of Flemish government organizations, compared to the Netherlands



Organizational hierarchy of Walloon government organizations, compared to the Netherlands

Appendix 3 Results Litter monitoring on the rivers Geul en Roer 2020-2021