Interreg Euregio Meuse-Rhine

LIVES litter free rivers and streams

EUROPEAN UNION European Regional Development Fund

waterschap limburg

Benchmarking of litter removal systems in a cross-border pilot

Work package T2.3

NORIA SUSTAINABLE INNOVATORS

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Management Summary

Nederlandse samenvatting

Het LIVES-project richt zich op de vermindering van zwerfvuil in de Maas en de daarin uitmondende beken. Een belangrijke doelstelling van de EUREGIO Maas-Rijn (EMR) is het ontwikkelen van een gezonde en aantrekkelijke omgeving om in te wonen, werken en te recreëren. Dit rapport is het resultaat van interviews die zijn gehouden met vijf partners die zwerfafval afvangsystemen hebben getest. Die interviews gingen over het tweede werkpakket 'Implementatie van maatregelen' met een specifieke focus op 'Benchmarking drijfvuil-afvangtechnieken' in de Maas en de daarin uitmondende beken.
In het algemeen kunnen twee belangrijke conclusies worden getrokken uit het LIVES-project. Beide zullen hieronder worden genoemd en beschreven, gevolgd door hun belangrijkste argumenten.

Conclusie 1:
Er zijn veel waardevolle inzichten gegenereerd met betrekking tot de keuze en installatie van zwerfafval afvangsystemen in de wateren. Het is van groot belang deze opgedane kennis toe te passen in toekomstige vervolgprojecten en deze te delen met andere (water)beheer autoriteiten.

De eerste conclusie is het resultaat van twee belangrijke inzichten die uit de interviews naar voren zijn gekomen.
Ten eerste hebben alle partners in totaal een veelheid aan drijfvuil-afvangtechnieken geïmplementeerd binnen de Interreg EUREGIO Maas-Rijn. Deze systemen varieerden van drijvende barrières, veiligheidsnetten voor rioolafvoer, speciale schoppen voor duikers, personen in boten, zwerfafval opruimers bij watermolens en veiligheidsnetten op boten.
De meeste partners gaven aan dat het LIVES-project een kickstart was voor hun inspanningen om drijfvuil-afvangtechnieken in het stroomgebied van de Maas te installeren. De uitvoering leverde veel waardevolle inzichten op, over welke systemen er op de markt zijn, in hoeverre ze werken onder verschillende omstandigheden en hoe ze kunnen worden geïmplementeerd. Al met al hebben de partners de intentie om hun inspanningen voor het verwijderen van plastic in de Maas verder op te voeren.

Conclusie 2:
Er is een eerste basis gelegd voor een benchmark voor afvalverwijderingssystemen binnen het LIVES-project. Dit zou moeten worden voortgezet door een nieuwe benchmarking-regeling die van toepassing is in het gehele gebied.

De tweede conclusie werd voornamelijk getrokken uit de volgende inzichten:
Er zijn primaire stappen vastgelegd voor de benchmarking van drijfvuil-afvangtechnieken in het LIVES-project. Dit heeft geresulteerd in een goed overzicht van bestaande technieken. Om in de toekomst de afzonderlijke drijfvuil-afvangtechnieken voor rivieren uitgebreider te kunnen vergelijken, zou het aantal criteria moeten worden uitgebreid.
Om methodologieën te harmoniseren en resultaten nog beter vergelijkbaar te maken, moeten afspraken tussen de partners over de selectiecriteria van variabelen en doelstellingen van drijfvuil-afvangtechnieken meer verfijnd worden en aan het begin van een project worden vastgelegd.

In het algemeen geeft het LIVES-project waardevolle inzichten met betrekking tot de aspecten die nodig zijn om in de toekomst een gemakkelijker toepasbare benchmark te creëren. Niettemin is het belangrijkste aspect van een goede benchmark de gegevensverzameling die nodig is voor de vergelijkbaarheid van afvalverwijderingssystemen. Daarom moet nu en in de toekomst de nadruk worden gelegd op het verzamelen van gegevens, zodat een benchmark kan worden vastgesteld.

English summary

The LIVES project focuses on the reduction of plastic waste in the river Meuse and the streams debouching in it. An important objective of the EUREGIO Meuse-Rhine (EMR) is to develop a healthy and attractive environment in which to live, work and recreate. This report is a result of interviews that were held with five partners. Those interviews were about the second work package 'Implementation of measures' with a specific focus on 'Benchmarking floating litter trapping techniques' in the river Meuse and the streams debouching in it.
Overall, two main conclusions could be drawn from the LIVES project. Both will be mentioned and described below, followed by their main arguments.

Conclusion 1:
Many valuable insights have been generated regarding the choice and installation of systems in the waters. It is very important to apply this gained knowledge in future follow-up projects and it should be shared with other (water) managing authorities.

The first conclusion is the result of two important insights that emerged from the interviews. Firstly, all partners have implemented a multitude of floating debris capture techniques within the Interreg EUREGIO Maas-Rhine. These systems ranged from floating barriers, safety nets for sewage outlets, special shovels for divers, persons in boats, trash rack cleaners at water mills and safety nets on boats.
Most partners indicated that the LIVES project kickstarted their efforts to install floating litter removal systems in the catchment of the Meuse. The implementation provided many valuable insights into what systems are on the market, to what extent they work under different conditions and how they can be implemented. All in all, the partners intend to further intensify their efforts to remove plastic in the river Meuse and the streams debouching in it.

Conclusion 2:
A solid foundation for a benchmark for litter removal systems could be established. This should be followed/continued by a new benchmarking scheme that is applicable in the entire Interreg area.

The second conclusion was mainly drawn from the following insights:
Firstly, the primary steps for the benchmarking of litter removal systems have been set in the LIVES project. This resulted in a good overview of existing techniques. To compare individual river litter trapping techniques more extensively in the future, the number of criteria should be expanded.
To harmonize methodologies and make results more comparable, agreements amongst the partners should be made with respect to what information is important to compare different techniques.

Overall, the LIVES project gave valuable insights regarding the aspects that are needed for creating a more easily applicable benchmark in the future. Nevertheless, the most important aspect of a good benchmark is the data collection that is needed for the comparability of litter removal systems. Therefore, in the future the focus should be on the addition of new benchmark-specific data to the existing of data, such that a benchmark can be established.

Deutsche Zusammenfassung

Das LIVES-Projekt konzentriert sich auf die Verringerung des Mülls in der Maas und den in sie einmündenden Bächen. Ein wichtiges Ziel der EUREGIO Maas-Rhein (EMR) ist die Entwicklung einer gesunden und attraktiven Umwelt, in der man leben, arbeiten und sich erholen kann. Der vorliegende Bericht konzentriert sich auf das zweite Arbeitspaket "Umsetzung von Maßnahmen" mit besonderem Schwerpunkt auf dem "Benchmarking von Techniken zum Fang von schwimmendem Abfall" von fünf beteiligten Partnern.
Insgesamt lassen sich zwei wesentliche Schlussfolgerungen aus dem LIVES-Projekt ziehen. Beide werden im Folgenden erwähnt und beschrieben, gefolgt von ihren Hauptargumenten.

Schlussfolgerung 1:
Es wurden viele wertvolle Erkenntnisse über die Auswahl und Installation von Systemen in den Gewässern gewonnen. Es ist sehr wichtig, dieses gewonnene Wissen in zukünftigen Folgeprojekten anzuwenden und es sollte mit anderen (Wasser-)Verwaltungsbehörden geteilt werden.

Die erste Schlussfolgerung ergab sich hauptsächlich aus zwei wichtigen Erkenntnissen aus den gehaltenen Interviews. Die folgenden Argumente unterstützen diese erste Hauptschlussfolgerung.
Erstens: Insgesamt haben alle Partner innerhalb der Interreg EUREGIO Maas-Rhein eine Vielzahl von Abfallbeseitigungssystemen implementiert. Diese Systeme reichten von schwimmenden Barrieren, Sicherheitsnetzen für die Kanalisation, speziellen Schaufeln für Taucher, Personen in Booten, Rechenreinigungsanlagen an Wassermühlen und Sicherheitsnetzen auf Booten.

Die meisten Partner gaben an, dass das LIVES-Projekt den Anstoß zu ihren Bemühungen gab, Systeme zur Abfallbeseitigung im Einzugsgebiet der Maas zu installieren. Die Umsetzung brachte viele wertvolle Erkenntnisse darüber, welche Systeme es auf dem Markt gibt, inwieweit sie unter verschiedenen Umständen funktionieren und wie sie eingesetzt werden können. Insgesamt haben die Partner die Absicht, ihre Bemühungen, hinsichtlich der Beseitigung von Plastik im Einzugsgebiet der Maas weiterhin zu intensivieren.

Schlussfolgerung 2:
Es könnte eine solide Grundlage für ein Benchmarking für Abfallbeseitigungssysteme geschaffen werden. Darauf sollte ein neues Benchmarking-System folgen, das im gesamten Interreg-Gebiet anwendbar ist.

Die zweite Schlussfolgerung wurde hauptsächlich aus den folgenden Erkenntnissen gezogen:
Erstens wurden im Rahmen des LIVES-Projekts die wichtigsten Schritte für das Benchmarking von Abfallbeseitigungssystemen festgelegt. Dies führte zu einem guten Überblick über die

vorhandenen Techniken. Um in Zukunft einen umfassenderen Vergleich zwischen den einzelnen Abfallbeseitigungssystemen in Flüssen zu ermöglichen, sollte die Anzahl der Kriterien erweitert werden.
Um die Methoden zu harmonisieren und die Ergebnisse noch besser vergleichbar zu machen, müssen die Vereinbarungen zwischen den Partnern hinsichtlich der Auswahlkriterien für die Variablen und Ziele der Abfallbeseitigungssystemen zu Beginn eines Projekts konkretisiert und festgelegt werden.
Insgesamt gab das LIVES-Projekt wertvolle Einblicke in die Aspekte, die für die Schaffung eines leichter anwendbaren Benchmark in der Zukunft erforderlich sind. Der wichtigste Aspekt eines guten Benchmarks ist jedoch die Datenerhebung, die für die Vergleichbarkeit der Abfallbeseitigungssysteme erforderlich ist. Daher sollte der Schwerpunkt jetzt und in Zukunft auf der Sammlung von Daten liegen, damit ein Benchmark erstellt werden kann.

Résumé en Français

Le projet LIVES se concentre sur la réduction des déchets plastiques dans la Meuse et les cours d'eau qui s'y déversent. Un objectif important de l'EUREGIO Meuse-Rhin (EMR) est de développer un environnement sain et attrayant pour vivre, travailler et se ressourcer. Ce rapport est le résultat d'entretiens menés avec cinq partenaires. Ces entretiens portaient sur le deuxième module de travail « Mise en œuvre des mesures » avec un accent particulier sur « l'analyse comparative des techniques de piégeage des déchets flottants » dans la Meuse et les cours d'eau qui s'y déversent.
Globalement, deux conclusions principales peuvent être tirées du projet LIVES. Les deux seront mentionnés et décrits ci-dessous, suivis de leurs principaux arguments.

Conclusion 1 :
De nombreuses informations précieuses ont été générées concernant le choix et l'installation de systèmes dans les eaux. Il est très important d'appliquer ces connaissances acquises dans les futurs projets de suivi et elles devraient être partagées avec d'autres autorités de gestion (de l'eau).

La première conclusion est le résultat de deux idées importantes qui ont émergé des entretiens.
Premièrement, tous les partenaires ont mis en œuvre une multitude de techniques de capture de débris flottants au sein de l'Interreg EUREGIO Maas-Rhin. Ces systèmes allaient des barrières flottantes, des filets de sécurité pour les égouts, des pelles spéciales pour les plongeurs, des personnes dans les bateaux, des nettoyeurs de poubelles dans les moulins à eau et des filets de sécurité sur les bateaux.
La plupart des partenaires ont indiqué que le projet LIVES avait lancé leurs efforts pour installer des systèmes flottants d'élimination des déchets dans le bassin versant de la Meuse. La mise en œuvre a fourni de nombreuses informations précieuses sur les systèmes disponibles sur le marché, dans quelle mesure ils fonctionnent dans différentes conditions et comment ils peuvent être mis en œuvre. Au total, les partenaires entendent intensifier encore leurs efforts pour éliminer le plastique de la Meuse et des ruisseaux qui s'y déversent.

Conclusion 2 :

Une base solide pour une référence pour les systèmes d'élimination des déchets pourrait être établie. Ceci devrait être suivi/continué par un nouveau système d'étalonnage applicable à l'ensemble de la zone Interreg.

La deuxième conclusion a été principalement tirée des enseignements suivants :
Premièrement, les principales étapes de l'analyse comparative des systèmes d'élimination des déchets ont été définies dans le projet LIVES. Cela a permis d'avoir un bon aperçu des techniques existantes. Pour comparer plus largement les techniques de piégeage des déchets de rivière à l'avenir, le nombre de critères devrait être élargi.
Pour harmoniser les méthodologies et rendre les résultats plus comparables, des accords entre les partenaires doivent être conclus quant aux informations importantes pour comparer différentes techniques.

1. Introduction

1.1 Reason for this project and objective

The project LIVES focuses on the reduction of plastic waste in the river basin of the Meuse. One important aim of the EUREGIO Meuse-Rhine (EMR) is to develop a healthy and appealing environment in which to live, work and spend leisure time. Tourism is a significant economic driver for the region. Every year worldwide, our rivers carry an estimated 8 million tonnes of plastic waste into the open sea. This enormous quantity of plastic litter causes serious damage to the environment and poses a danger to public health, the living environment, shipping, and the landscape, resulting in unattractive surroundings. Because rivers are the transport medium for plastic litter, a cross-border approach is essential. There is no relevant EU legislation; all countries and regions have their own strategy. Finding a solution depends on taking a comprehensive, cross-border approach: stop plastic being carried by rivers and clean up what is floating in the sea. LIVES is about developing a cross-border vision, making collective (work) agreements, taking source measures, stopping the transport of litter via waterways and removing litter.

The purpose of LIVES is to organise a coordinated, cross-border approach to reduce plastic litter in the Meuse basin. The project consists of a broad alliance between regional authorities and stakeholders, including universities, NGOs, private and non-profit organisations, and the trade representative association in the plastics industry. Volunteers are also involved and play an important role in tackling the problem as project ambassadors and by participating in litter clean-ups.

The project unfolds in three phases, namely:

1. Survey

Understanding the spread of plastic litter in the EMR by collecting and analysing data from the entire EUREGIO and by means of dedicated cross-border monitoring.

2. Measures

Developing various types of innovative litter capture techniques and testing them at different locations in the EMR. Developing innovative measures for the prevention, transport, and recycling of plastic litter. Organizing litter clean-ups and enforcement actions the EUREGIO Meuse Rhine.

3. Institutional arrangements

Institutionalising the approach as it is developed: cross-border awareness-raising campaigns/communication (businesses, the public, authorities), coordinated efforts to influence policy (national and international); developing an adaption policy and administrative agreements.

This approach will generate long-term engagement, commitment and support and will lead to practical instruments and solutions focused on awareness-raising, management strategies

and influencing policymaking at all levels of government (from local, regional, and national to European) via Political Expert Forums.

On behalf of Waterschap Limburg, Noria Sustainable Innovators has been hired to evaluate and fulfil the activity 'Benchmarking of litter removal systems in a cross-border pilot' (WP T2.3). Based on preparatory research, WP T2 specifically focusses on the implementation of actions and measures for the reduction of plastic in the Meuse and its tributaries in a coordinated manner. The main aim of this work package is to lay the foundation for long-term international cooperation with the implementation of litter removal systems.

Vlaamse Milieumaatschappij is responsible for the coordination of the overall work package. Waterschap Limburg is responsible for delivering a report on the 'Benchmarking of litter removal systems in a cross-border pilot'. Noria Sustainable Innovators has been hired to conduct an assessment on the implemented litter removal systems within the LIVES project, resulting in this evaluation report.

The insights with respect to the 'Benchmarking of litter removal systems in a cross-border pilot' have been gathered from interviews with representatives of the five. This comprises the following partners:

- Waterschap Limburg (WL)
- Rijkswaterstaat – Ministerie van Infrastructuur en Waterstaat (RWS)
- Vlaamse Milieumaatschappij (VMM)
- De Vlaamse Waterweg nv (DVW)
- Wasserverband Eifel-Rur (WVER)

Additional information was gathered from existing documents associated to the LIVES project. It is important to mention, that Roer/Rur are the German and Dutch name for the same river. For this report, the Dutch name 'Roer' will be used.

1.2 Reading guide

The second chapter after this introduction gives an overall overview on the partners and target description per partner. Firstly, the overall structure of the LIVES project is described, which is then followed by a more in-depth description of Work package 2 (WP2) and the focus of this report, namely deliverable WP-T 2.3 'Benchmarking litter removal systems'. The third chapter 'Research and Results' describes the implementation of the litter removal systems per partner and the results of the data collection which were lastly integrated into a practical benchmark. The fourth chapter focusses on the evaluation of litter removal methods from a theoretical point of view, revolving around the use of a benchmark. Based on the findings, the conclusions and recommendations were formulated in chapter 5.

2. Partners and target decription

This chapter describes the overall structure of the LIVES project and the more specific goal of the work package. This report is about WP2.3 'Benchmarking for litter removal systems'. After this chapter the reader should provide a clear overview of the LIVES project itself and the role and objectives of the participating partners.

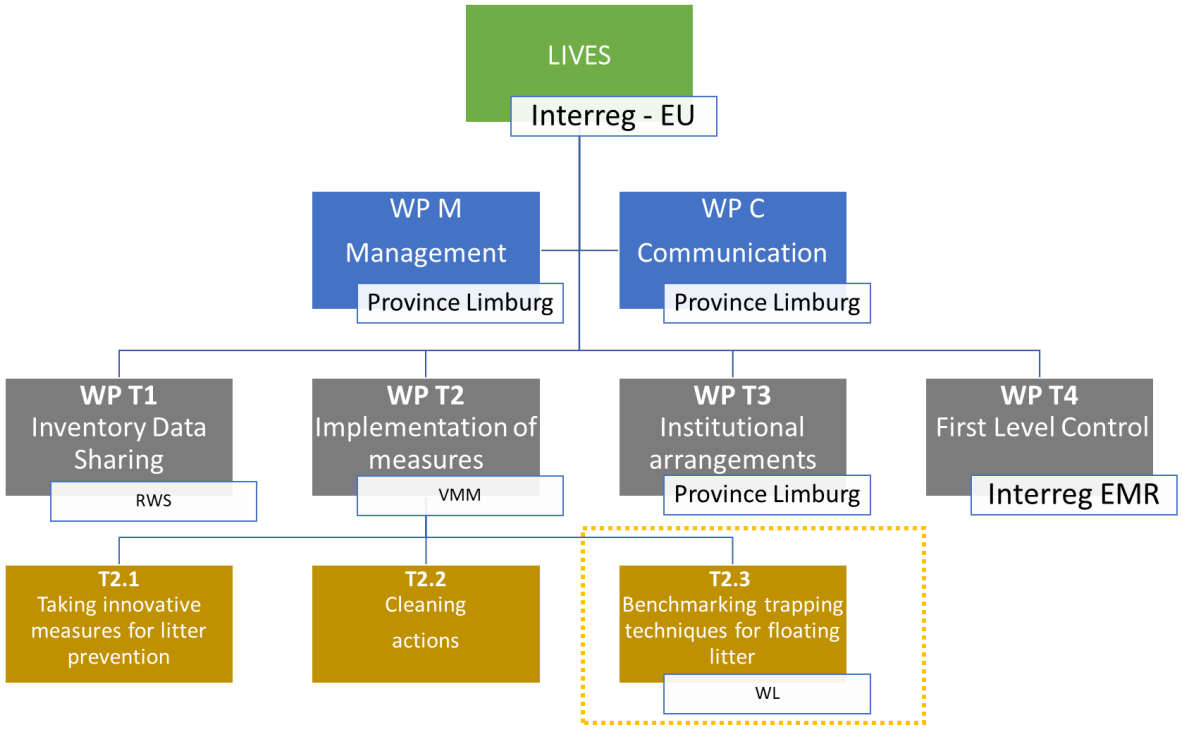

Figure 1 Structure of the LIVES programme with focus on the benchmark of trapping systems for floating litter

The LIVES project follows a layer-based approach (Figure 1). The first two layers comprise the 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). WP2 consists of three activities (T2.1, T2.2 and T2.3). This report focusses on WP 2.3. After establishing the overall structure of the LIVES project, WP2.3 will be described more thoroughly in the following section.

2.1. Benchmarking litter removal systems

This section is dedicated to WP T2.3, since the results of this activity are the focus of this report. For this reason, the deliverables of this activity will be explained. The main aim of this work package is to lay the foundation for long-term international cooperation by the implementation of litter removal systems in Netherlands, Belgium, and Germany. This results in a first benchmark of litter removal systems (T2.3 'Benchmarking trapping techniques for floating litter') that aims for a long-term cooperation in the field of litter removal, sharing knowledge and the maintenance of an international network. The plastic waste problem in the Meuse can only be solved effectively if there is good cross-border cooperation between

the partners in the entire valley of the Meuse. For the benchmarking, a multitude of litter removal systems were tested by the involved partners.
The Vlaamse Milieumaatschappij was responsible for the coordination of WP2, whereas Waterschap Limburg is responsible for bundling the information from all partners and drafting a first benchmark for floating river litter trapping techniques. Overall, five partners have been involved, namely: Vlaamse Milieumaatschappij, De Vlaamse Waterweg nv, Rijkswaterstaat, Wasserverband Eifel-Rur and Waterschap Limburg. All these partners were involved in the process of implementing litter removal systems in their waters in order to reduce the plastic pollution in the Meuse. Through a series of interviews and existing documents all the necessary information was gathered from the partners.

The main objective of all partners within Interreg LIVES project was to create more internal and external focus (e.g., awareness creation citizens) related to the plastic pollution problem. For partners that had previously been addressing the plastic pollution problem, the LIVES project accelerated and stimulated to further tackle this problem. Furthermore, several partners that previously did not pay attention to the plastic pollution problem, realised that there is a large problem concerning plastic pollution, specifically during flooding because it washes up everywhere. Therefore, it was also important to gain insight and familiarity with this problem. Overall, the partners wanted to take more responsibility by jointly tackling this dilemma. Lastly, it was important to work together at an administrative and civil service level on relationship management and goal realisation within the EUREGIO Meuse-Rhine since cooperation is the only way to solve the litter problem.

3.Research and Results

The objective of the entire work package WP T2.3 was to benchmark the litter removal systems implemented by the partners. Noria Sustainable Innovators was hired by Waterschap Limburg to conduct interviews with the partners and gather information regarding the implementation of litter removal systems. This section will describe most valuable information with respect to the litter removal systems within the LIVES project gathered from the interviews with the partners.

The current knowledge and insight of the participating partners and associate partners such as local NGO's who have shown willingness to cooperate was used to determine an ideal site for the placement of litter removing systems and clean up actions. The interviews yielded, that the following litter removal systems were placed by the partners:

Table 1 overview of Litter removal systems that have been tested

Partner	Total	Removal Technique(s)
VMM	9	7x Floating barriers, 2x dirt socks
DVW	2	Implementation of special shovels at culverts and catching-equipment for service boats
WVER	2	1x Tree trunk, 1x Dirt sock
WL	8	1x Trash rack cleaner (Roer), 2x Floating barriers (Roer and Geul), 4x Screens at water mills (Geul) and 1x Screen at a weir (Geul)
RWS	(3)	Several litter removal techniques were tested outside the Euregio Meuse-Rhine. However not within the LIVES project. Extensive monitoring took place both inside and outside the Euregio Meuse-Rhine.

3.1. Litter removal systems per partner

This section aims to provide a general overview of the implementation of litter removal systems per partner. For every partner the following elements will be described.

1. The preliminary choices and characteristics of the waterbody,
2. The implementation of litter removal systems,
3. Other litter removal activities.

3.1.1. Wasserverband Eifel-Rur

The Wasserverband Eifel-Rur is responsible for the supply of raw water for drinking water production, flood protection, watercourse maintenance and wastewater treatment. The water of Wasserverband Eifel-Rur are mainly smaller rivers and streams, with no presence of shipping.

Preliminary choices and waterbody characteristics

The position of this removal system was chosen due to the minimal fluctuations in the water level and discharge in this stream. Furthermore, this location was compared to the other two optional locations, and it was found that it is better approachable with a truck. This makes it both easier to place the tree trunk as well as removing the trapped litter. Additionally, it was also assumed that a large amount of plastic enters the water in the city of Düren and therefore

a location was chosen downstream of the city of Düren and before the plastic enters the Roer. A second potential location was considered in the river Inde, however due to the large width, fluctuating water levels and discharge, this location did not deem to be suitable.
Lastly, Wasserverband Eifel-Rur has investigated the possibility of placing a littertrap in the Worm in Herzogenrath. However, the location where the littertrap would ideally be placed was owned by a company and it was difficult to enter into talks with them in order to realise this. Not being the owner of a site is therefore a key issue in the installation of litter traps.

Implementation of litter removal system

In a first pilot, the Wasserverband Eifel-Rur installed a tree trunk in the 'Dürener Mühlenteich' which is a small stream that flows through the city of Düren. The tree trunk was placed in such a way that it intends to intercept the floating plastic and waste just shortly before it enters the Roer. Flooding deemed to be a problem in the Dürener Mühlenteich in July 2021, since the position of the tree trunk got altered and for this reason the plastic did not get captured as efficiently, according Wasserverband Eifel-Rur.
An example can also be seen above (Figure 2), where for higher water levels the water and consequently the floating plastic is able to bypass the tree trunk.

Figure 2 Tree Trunk in the water of Wasserverband Eifel-Rur

Furthermore, the dirt sock is located in the stream 'Schwarzbach', a tributary of the river Wurm, which is located north of the city of Aachen (Figure 3). The design of the dirt sock was made by an employee of the Wasserverband Eifel-Rur. In the example below the newly installed dirt sock (November 2021) is shown. The dirt sock consists of a metal frame and a net ('sock') at the end of the system that captures the outflowing water from the sewer system. The net can be seen in the pictures of Figure 3.

Figure 3 Dirtsocks that have been installed in Aachen

Other litter removal activities

Wasserverband Eifel-Rur also organized a clean-up action as a part of the LIVES project on the 18th September 2021. The volunteers collected waste especially plastic, from the banks of the Roer. A stretch of 1.5 kilometres was cleaned, starting from the Josef Vosen Park.

3.1.2. Vlaamse Milieumaatschappij

The Flemish Environment Agency or Vlaamse Milieumaatschappij operates as an agency of the Flemish government for a better environment in Flanders. The Vlaamse Milieumaatschappij has a wide range of responsibilities within the domains water, air, and the environment.

Preliminary choices and waterbody characteristics

Since Vlaamse Milieumaatschappij is responsible for the unnavigable channels in Flanders, the floating barriers were placed in this kind of streams or channels. Similar to the placement choices of Wasserverband Eifel-Rur, the location of these systems was predominantly based on minimal fluctuations in the water level and discharge. Furthermore, accessibility was also an important factor. Lastly, the floating barrier and the dirt sock needed to be installed in locations where the system does not function as an obstruction, potentially leading to increased effects of flooding

For the placement of a dirt sock, the location was firstly assessed based on the width of the water body and the space behind an outlet. For this reason, smaller water bodies already did not fulfil this criteria, so therefore larger waterbodies needed to be considered (Dommel, Jeker and Meuse). Also, the accessibility of the location was an important factor, since the system is relatively large and needs to be transported and fixated with larger machines. Ultimately, two locations in the Winterdijk of the Meuse were chosen to install two dirt sock systems. These locations were chosen because the installation of the systems at outlets was simple and straightforward. Hereby it was important that there is no interaction between the dirt sock and the waterbody itself such that no tree branches, fishes, or other waste get caught in the sock. No damage should be caused by the water body on the nets itself and secondly the nets should not function as obstruction in the waterbody such that the probability of flooding is increased.

It can be concluded, that overall, it needs to be assured for the installation of a dirt sock at a location, that the dirt sock does not interfere with the waterbody, that the location is

accessible and that the system easily be suspended and installed in an existing concrete structure towards the watercourse.
Lastly as removal system, Vlaamse Milieumaatschappij also considered the installation of the bubble barrier system. However, one of the criteria for the successful implementation of the bubble barrier, is the need of a larger water body with larger depths. However, since Vlaamse Milieumaatschappij only manages the unnavigable channels, there were no waterbodies that fulfilled these criteria.

Implementation of litter removal systems

Overall, the Vlaamse Milieumaatschappij installed seven floating barriers during the LIVES project and six barriers were placed before the project. A floating barrier is a device that floats on the water surface and is kept in position by a flexible connection with two anchor points at both ends. The purpose of the floating barrier is to collect floating debris in the watercourse at a location where the floating debris can be easily collected. The construction, shape and ballast weight were provided in such a way that the screen lies sufficiently deep in the water to retain most of the floating debris. The anchor points and length of the floating barrier were arranged in such a way that the floating barrier can be set up at an angle of 45° to the axis of the watercourse. All plastic parts of the dirt barrier and all associated components were made of a technical plastic with proven resistance to UV light and water.
Depending on the location and the expected water level differences, pile drivers, sliding couplings or so-called tidal guides are provided at the anchor points so that the barrier can move according to the changing water levels. The anchoring is carried out in such a way that the dirt barrier can be released at one anchor point and not at the other anchor point in case of very high-water levels. In this way the floating barrier can be reinstalled after extremely high-water levels. Overall, the floating barrier is oriented vertically in the water with flow velocities up to 2 meters/second. An example of an installed system by Vlaamse Milieumaatschappij in the municipality of Maaseik can be seen in Figure 4. The emptying of the systems and data collection was done by Francis Telen on a voluntary basis.

Figure 4 Tidal guides that function as a litter trapping system in the Bosbeek

As aforementioned, seven systems were installed during the LIVES projects at the end of 2019 and beginning of 2020. Below, a table is represented with the locations of these systems and other important characteristics (Table 2).

Table 2 Characteristics of the locations where VNN installed litter trapping floating barriers

Location	Stream/River	Width waterbody	Length barrier	Height barrier	Depth	Protruding part above the water
Maaseik Center	Bosbeek	3.0 m	6.0 m	30 cm	20 cm	10 cm
Maaseik (Neeroeteren)	Bosbeek	2.6 m	6.0 m	30 cm	20 cm	10 cm
Maaseik (Opoeteren)	Bosbeek	3.0 m	6.0 m	30 cm	20 cm	10 cm
Pelt (Dommelhof)	Dommel	5.0 m	10.0 m	30 cm	20 cm	10 cm
Tongeren (Kevie)	Jeker	8.6 m	16.0 m	30 cm	20 cm	10 cm
Tongeren (Lauw)	Jeker	8.2 m	16.0 m	30 cm	20 cm	10 cm
Hamont -Achel	Warmbeek	3.0 m	6.0 m	30 cm	20 cm	10 cm

According to Vlaamse Milieumaatschappij, the floating barriers covers an area up to 20 cm below the water surface and 10 cm above. Within this range the floating barriers can also capture floating macroplastics of bigger sizes. If the water becomes more turbulent, the removal efficiency of these systems decreases. Lastly, the floating barrier covers the entire width of the waterbody. One disadvantage however is, that the system becomes less efficient when flooding occurs since then the water level rises, consequently leading to the fact that water and plastic are able to bypass the system. This occurs the flow width of the stream exceeds the fixed width of the floating barrier with increasing water levels.

In principle, there were three locations where the systems were placed, namely: built-up area, nature area and then in the working area of the employed rat-catchers of Vlaamse Milieumaatschappij. Overall, the waterbodies have similar characteristics regarding width, flow velocities, discharge, and water level fluctuations. Since the floating barriers were already used as a removal system prior to the LIVES project, Vlaamse Milieumaatschappij took the opportunity to further improve these systems during the LIVES project. During the project, firstly the system was made more symmetrical to capture more plastic and secondly the system was improved such that it can fluctuate with the water level and if necessary, get detached during extreme flooding.

Next to that, Vlaamse Milieumaatschappij also experimented with so called ‘dirt socks’, that were also used by the Wasserverband Eifel-Rur. These systems were placed at the outlet of sewer systems of unnavigable channels, since Vlaamse Milieumaatschappij is responsible for the unnavigable channels in Flanders. The European engineering consultancy company Sweco assisted with the installation of the dirt sock because they are one of the only companies having expertise with the placement of these systems.

The main interest area of dirt socks are overflow locations of the rainwater system because these are clear point sources for plastic pollution. The placement of systems took place in November and December of 2021 at two locations in the Winterdijk of the Meuse. The

installation deemed to be a difficult process due to the responsibility share between the involved partners (e.g., maintenance of the system). A potential third location was considered; however, this location did not deem to be suitable, due to the complex responsibility share and time constraints. The construction was also not approved by the local authority managing the waterbody, since there is a higher probability of flooding during October and April.

Other litter removal activities

Regarding the cleaning actions, Vlaamse Milieumaatschappij has some agreements with the Regional Landscape Kempen and Maasland which is a partner also involved in the LIVES project, for the Bosbeek. This organization arranges clean-up activities at the Meuse, but this is more related to communication and sensibilisation. There is no effective planning by Vlaamse Milieumaatschappij of these clean-up activities since there is no internal knowledge and expertise with the organization of these activities.

3.1.3. De Vlaamse Waterweg nv

The De Vlaamse Waterweg nv is responsible for all the navigable waters in Flanders, whereby the main responsibility is flood safety.

Preliminary choices and waterbody characteristics

The main determining factor for the use of the special shovels and boats, were the presence of a culvert with apparent plastic pollution and the accessibility of the location. Since the placement of a litter removal system on the Meuse is complex, De Vlaamse Waterweg nv started to look at possibilities in canals.

The H20 barrier from Antea Group was chosen by De Vlaamse Waterweg nv, since it is fish-friendly, has an impact on the entire water column and it does not hinder shipping. The most important factors for the implementation of the H2O barrier were the availability of flow, the flow velocity, and the accessibility of the location to remove the gathered plastic waste. It was for example not possible to install the H2O barrier in the Meuse, since the flow velocities are too high. Compared to other systems, the implementation of the H20 barrier requires a reversed procedure, meaning that after knowing that the H2O barrier is installed, suitable locations need to be found. Normally, removal systems are placed in such a way that firstly the plastic pollution problem is analysed and subsequently a system is placed to tackle the problem at hand. The disadvantages of the H2O barrier are its energy consumption and the large initial costs (exceeding subsidy from the LIVES project).
Three potential locations of the H2O barrier were identified by De Vlaamse Waterweg nv along the Zuid-Willemsvaart from which one ultimately was chosen. However, drawing up the specifications of the H2O barrier was too time-consuming and elaborate and therefore the system has not been installed yet. Nevertheless, there is interest from De Vlaamse Waterweg nv and Antea to implement this solution in the future.

For the WasteShark, the evaluation by De Vlaamse Waterweg nv yielded, that the WasteShark was not suitable for implementation. Following factors were limiting, namely: accessibility due to the presence of nature, fluctuating water levels, flow velocities and discharge. Therefore, it could be concluded, that the implementation along the Meuse was not really feasible.

Implementation of litter removal systems

According to the observations of De Vlaamse Waterweg nv, plastic pollution is specifically a problem close to culverts. Furthermore, the plastic pollution problem is also prominent at the small hydropower plants in Bocholt and Lozen.

According to De Vlaamse Waterweg nv, the plastic pollution problem is the largest at few culverts in their managing area. At these locations De Vlaamse Waterweg nv was the most active to remove the waste. These need to be cleaned in certain intervals. Currently, there is no systematic removal of waste, however a special designed shovel is used such that the plastic waste can be scooped up. This method is being tested to be implemented in a more systematic manner to tackle the plastic pollution close to these culverts. The objective of De Vlaamse Waterweg nv is to use these shovels at every culvert along the Zuid-Willemsvaart for the removal of plastic waste, with the potential of being also implemented in other areas.

A further development within the LIVES project was the experimentation regarding the combination of a boat and a shovel system. The boats cover an area of roughly 4 metres of the waterbody and additionally the location also needs to be accessible for trucks to transport the gathered waste. Presently, two projects are carried out with these systems, for which the results can be shared at a later stage.

A further system that was considered for implementation was the H2O barrier from Antea Group, an international engineering and environmental consulting firm from the Netherlands. The H2O barrier is a system, whereby air is blown into the water from the bottom.

Table 3 Removal locations with system, total items, plastic items and % plastic

Subsequently, a bubble screen is created which transports floating and suspended waste across the entire water column to the water surface. In cooperation, Antea supplied De Vlaamse Waterweg nv with technical and juridical information regarding the H20 barrier. Within the LIVES project this system has not been installed.

Lastly, De Vlaamse Waterweg nv also investigated the potential of a system called 'The WasteShark'. This system is an aquadrone that removes plastics and other floating debris from the water surface. It was designed especially for use in ports and harbours. Shaped like a catamaran, the WasteShark can collect up to 350 kg of trash at a time with a collection depth of 20-40 cm. De Vlaamse Waterweg nv aimed to implement the WasteShark in the 'Maasplassen', a large interconnected network of large and small lakes located in region Belgian/Dutch Limburg. As for the H20 barrier, this system was not installed during the LIVES project.

3.1.4. Waterschap Limburg

Waterschap Limburg is a government organisation and ensures safe dikes, dry feet, clean water and sufficient water in the province of Limburg.

Preliminary choices and waterbody characteristics

Waterschap Limburg has various types of automatic and semi-automatic trash cleaners in use. Early trash cleaners were mainly implemented in front of culverts to collect floating vegetation and wood from trees. Litter can also be found in these places. Where possible collected waste is separated into organic and anorganic material. However, there is no overall picture of the quantities and composition of collected litter. Shipping does not deem to be a problem in these areas since no ships pass by the installed systems.

Implementation of litter removal systems

Waterschap Limburg has several facilities spread over its management area to capture floating/litter waste. The specifications of the removal locations with the respective system, total items, plastic items and percentage of plastic are given in Table 3. These installations catch organic and inorganic (litter) waste, including plastics. Within the LIVES project, a model-based selection process for placing a litter capture system in the Geleenbeek and for capturing and investigating litter in the Geul and Roer was initiated. This was done in order to compare the performance of certain capture systems and to determine the size and composition of the waste. Prior to the LIVES projects following systems had been installed in the management area of Waterschap Limburg: trashrack cleaner over the entire water column (Roer), floating barrier upper layer water column (Geul and Roer over entire width), two grids at watermills for the entire water column (at 'Molentak' over entire width, semi-automated) and two grids at watermills entire water column mill branch wide (at 'Molentak', manual). Grids have been installed in various places for long overpasses (to prevent blockages) and pumping stations (to protect pumps) to capture organic and inorganic (litter) waste. Prior to the LIVES project, Waterschap Limburg also installed and tested a litter removal system in the Gelenbeek and Jeker, whereby students from Zuyd Hogeschool were involved.

ation	Stream/River	System	Total items	Plastic items	Percentage plastic
ECI Waterkrachtcentrale	Roer	Plate at top of water level with crane	2.334	2.032	87,1%
Drijfbalk Roer	Roer	Floating barrier	2.007	1.100	54,8%
Drijfbalk Valkenburg	Geul	Floating barrier	29	48	60,4%
Geulhemermolen	Geul	Grill	67	124	54%
Bovenste molen	Geul	Grill	27	29	93,1%
Volmolen	Geul	Grill	15	16	93,8%
Molen Otten	Geul	Grill	189	275	68,7%
Speltmolen	Geul	Grill	324	538	60,2%
Bours Geul	Geul	Unknown	591	776	76,2%

The current collection and monitoring sites also include the installation of two floating barriers during the LIVES project in the Roer and the Geul respectively.

Figure 5 Geul with seven potential sites of which six were in the end used as removal locations

The blue dots indicate removal and monitoring locations. These locations include one installed floating barrier and five water mills. Grids are installed at active watermills to protect the device that drives the mill. This is a suitable location to catch litter and an opportunity to involve the water users in the research. This furthermore also offers the opportunity to segment and isolate the removal areas along the Geul to establish a relationship between the activities within a segment and the plastic flux.

Figure 6 Roer with two monitoring locations: ECI hydroelectric power station, Floating barrier that can be seen in the top left of Figure 7

In the Roer one removal system ('floating barriers') close to the ECI hydroelectric power station in Roermond was installed. This included the implementation of a floating barrier across the full width of the Roer and further downstream a fully automated fine-mesh trash rack cleaner (protection turbines). An example of the installed floating barrier is given in the image below. It can be seen that the proportion of organic material overweighs the plastic waste, nevertheless the efficiency appears to be satisfactory.

The efficiency of plastic capture can be influenced by extreme conditions such as peak discharge and associated flooding. For the Roer, there are valves and diversions. At peak discharges, part of the water runoff flows through the diversions. In that case, not all the floating litter is captured. The capture systems in the Geul are located in the mill branches. In case of peak discharges, the water is discharged via the main stream and the litter is captured less efficiently.

Figure 7 Left: Floating barriers Roer. Right: Duckweed/litter fences Geul (Grote Molen, & Rothermolen)

Other litter removal activities

Lastly, Waterschap Limburg was involved in clean-up actions. Waterschap Limburg was a participant in the Maas Clean-up in 2020 (Groote Molenbeek, Niers, Deurne Kanaal and Geleenbeek) and 2021 (Deurne Kanaal, Hambeek, Roermond sewage treatment plant and Geleenbeek/Vloedgraaf). Furthermore, in April 2021 Waterschap Limburg commissioned a litter clean-up campaign which was carried out by the contractor Beurs along certain streams in Central and Southern Limburg, including the Geul.

3.1.5. Rijkswaterstaat

Rijkswaterstaat is a national water managing authority with both national and local organizational departments. The local departments are responsible for operational activities like maintenance and cleaning the area. Whilst the national departments are more responsible for policy and research activities.
For this reason, the national department Water Verkeer en Leefomgeving (WVL) [water traffic and living environment] was given the task in 2018[1] to test with three different litter removal systems in three different locations with varying circumstances. This was a national project outside the scope of Interreg LIVES. Since this already took place, the local department of Rijkwsaterstaat decided to fully focus on monitoring and use the results from the national project as input for later decisions.

[1] https://zoek.officielebekendmakingen.nl/kst-30872-222.html

On a national level Rijkswaterstaat is also more focussing on the monitoring part since they believe it's better to remove the litter close to the source, which is before their larger waterbodies.
The three pilots that were performed from 2019 until 2021[2]

1. Catchy (Allseas) in a small harbour (Vijfsluizerhaven) in Rotterdam
2. CirCleaner V1.0 (Noria) in the sluice of Borgharen close to Maastricht
3. Great Bubble Barrier (The Great Bubble Barrier) in the IJssel close to Kampen

A brief description of these systems will be given here below.

Firstly, Catchy is a collection system that captures floating litter brought to the system by the floating arms. The system consists of a floating frame containing a permeable tray with a with a mesh size of 3mm that can be lifted out by crane to remove the waste. The floating frame can move vertically with the tide. Furthermore, the collection system has partitions so that the captured material cannot escape due to unfavourable flow or wind direction. Overall, the two floating arms at Vijfsluizerhaven had a length of 200m and 12m respectively. Under the arms is a screen that extends to 1m below the water surface. The pilot for the Catchy system yielded that the weight of the captured plastics is approximately 75-80 kg/year of dry plastic. For reference, this corresponds to approximately 5 empty PET bottles of 1.5 litres per day.

Secondly, the CirCleaner V1.0 litter removal system is a water wheel with five blades that scoops out the litter. The CirCleaner is driven and rotates against the flow of the water at a speed of approximately 1 rotation per minute. The "scoops" are water-permeable with a mesh size of 3-5mm. Litter collected by the scoop is then transported to the centre of the scoop where it is accumulated. To transport the plastic to the CirCleaner, floating arms are used that covered the full width of the sluice. In this pilot the CirCleaner removed more than 95% of the plastic that was thrown in the water. The remaining plastic was removed by the nets behind the system. After this pilot the system was adjusted into a new version 2.0 which has higher storage capacity and can probably collect even more plastic than version 1.0. This system will be installed in 2022 in the northern part of the Netherlands.

Thirdly, the Great Bubble Barrier is a system whereby air is pumped into a perforated tube that is placed at the bottom of the river. The litter follows the bubble screen and eventually ends up in the collection system. During the preparation of the pilot, it was established that for the realization of the system, including processing and monitoring, significantly more financing is required than is available. The collaborating parties then looked for additional sources of financing and ways to reduce costs. Unfortunately, these efforts have not led to a solution to the shortfall. It has therefore been decided not to continue this pilot.

Due to the short pilots with the CirCleaner and the Great Bubble Barrier, no exact statements can be made about the removal efficiency of these systems.

After these pilots, Rijkswaterstaat has refined its future approach regarding the focus on monitoring and assisting other parties where possible with removing plastic from smaller streams.

[2] https://zwerfafval.rijkswaterstaat.nl/innovatie/vangsystemen-macro-microplastics-rivieren/

3.2. Data collection

Multiple litter removal systems were used to monitor the quantity of the gathered waste and the type of waste. With reference to the type of waste, a distinction can be made between the classification procedure (category 1-9 and OSPAR). For the quantity of gathered litter a difference can be made between the number of items that were found and the mass of these items. Data storage types refers to the manner in which the gathered data was stored, namely either in Excel or the measurement forms were scanned and saved as an Excel. For most part, "-"refers to the fact, that for some parts the monitoring still needs to take place, since some systems were installed towards the end of the LIVES project. An overview can be found in Table 4.

Table 4 4 Overview of different types of data gathered during the LIVES project.

PARTNER	QUALITY		QUANTITY				DATA STORAGE
	Variable	Unit	Variable	Unit	Variable	Unit	Method
VMM	Type of item	Category 1 - 9	Plastic item	Number of item	Mass	kg	Excel, PDF
WL	Type of item	OSPAR	Plastic item	Number of item	-	-	Excel
RWS	-	-	-	-	-	-	-
WVER	-	-	-	-	-	-	-
DVW	-	-	-	-	Mass	kg	-

Looking back on this project, one lesson is that overall, the collected data was not enough and not the correct data to be able to draw conclusions about the reduction of plastic nor about the efficiency of the implemented littertraps. However, with respect to the data analysis from all the gathered data by all partners, important key conclusions could be drawn for future data collection. Although the data did not give insight regarding the benchmarking of litter removal techniques, the project yielded important insights regarding the origin and size of the problem. Furthermore, the main conclusions are listed here below:

3.2.1. Measure variables equally

The delivered datasheets yielded that some variables such as the type of plastic or quantity of plastic were measured in a different way. To be able to compare findings, there is a need for a unified approach, otherwise the comparison between different variables becomes non-viable. This could e.g., refer to the classification of gathered waste, whereby one common approach should be used (in this case every partner uses category 1-9 or the OSPAR analysis). Evidently, this also refers to quantification of captured litter, whereby either the quantity, the number of items or both variables should be measured.

3.2.2. Interpretation and expressiveness of gathered plastic types

In Figure 5 an example is given for one monitoring location at the Bosbeek in Belgium. These measurements were done continuously from March – October 2021. This bar chart clearly exemplifies the strength of continuous monitoring since dominant and less dominant categories can be established. For this specific data, it can be seen that C4 ('Vegetables, fruit and garden waste'), C1 ('Drink/Beverage packaging) and C7 ('Coarse floating litter') were the most found items. One potential reason that C1 is the second highest category could be the

fact that there is no refund of a deposit in Belgium compared to other countries such e.g., Germany or Netherlands. A high number of coarse floating litter could be attributed to the fact that potentially a construction site is in the vicinity.

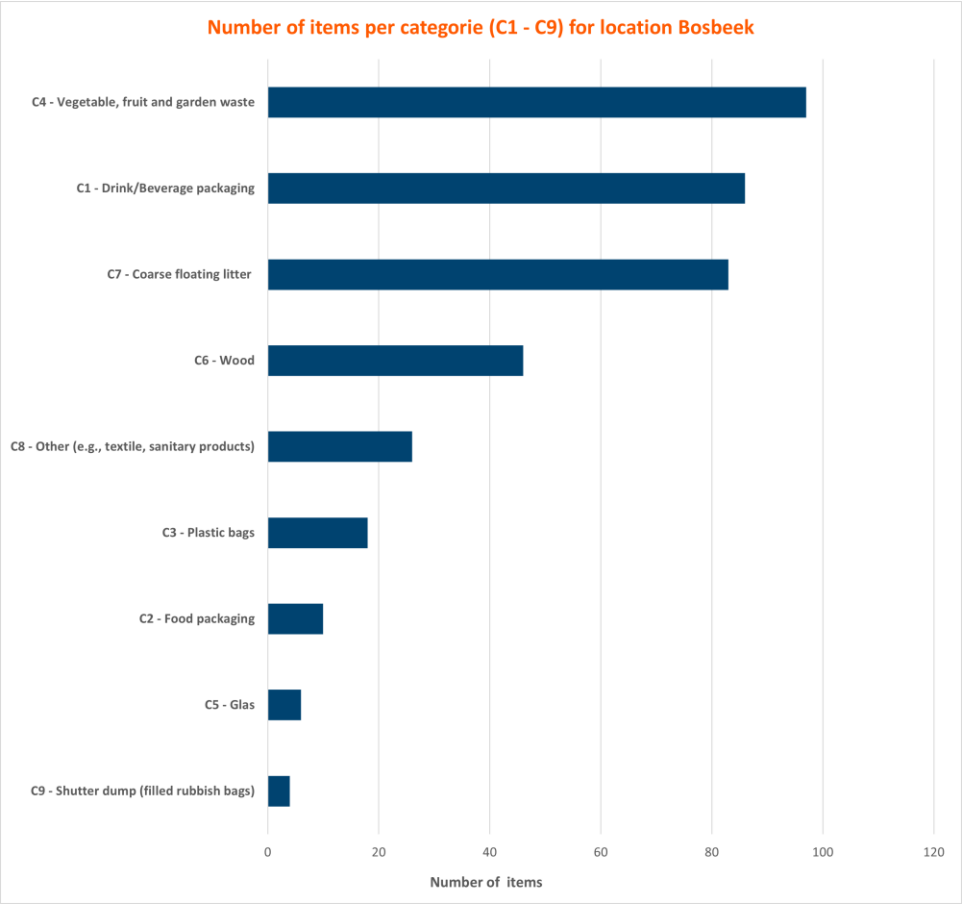

Figure 5 Result from monitoring in the Bosbeek in Belgium.

3.2.3. Outliers in databases can be valuable

Some databases with longer monitoring periods included outliers, which can be considered as one of the most meaningful information from a waste classification analysis. An example

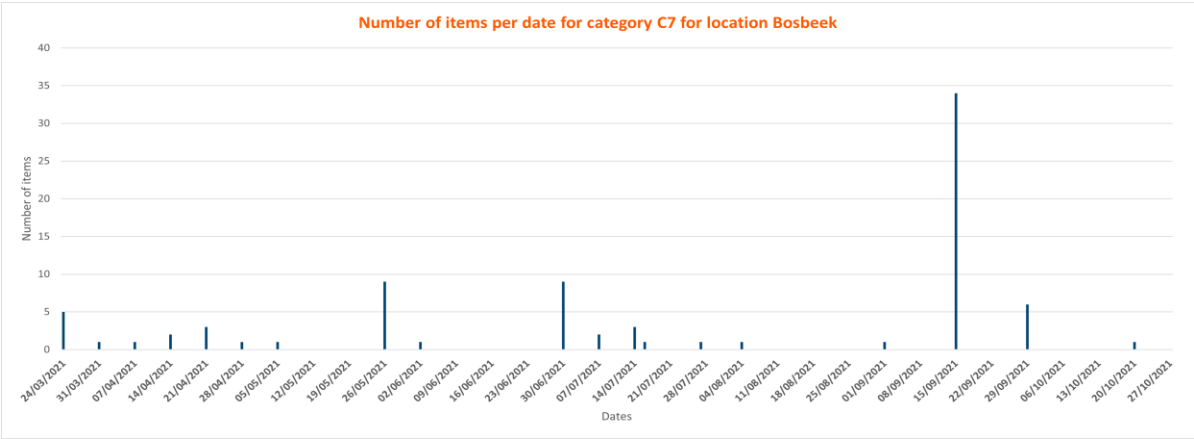

Figure 6 Overview of items per date found at location Bosbeek

from one of the datasets can be seen in Figure 6. Category C7 represents coarse floating litter (e.g., objects such as lost wheel covers, Styrofoam, or isolation material). From the data it can be seen that in a period of eight months (March – October 2021) that an outlier was present on the 15 September 2021. This is more than three times the previous highest amount of found items. Therefore, it becomes interesting to study the cause for this sudden increase in found plastic waste. Was there a flooding event? Did a construction site in the vicinity dump objects in the water? On basis of the data specific measures can be taken in order to prevent these sudden increases in waste fluxes.

3.2.4. Unrealistic data

Few databases also included unrealistic data with respect to the quantity of plastic. A method should be found in order to filter these unrealistic numbers as e.g., double-checking by another partner or person whether the filled in numbers are correct. Higher data quality ensures better and credible results from which conclusions can be drawn.

3.2.5. Generation of data for a benchmark

Before the start of a project, it is crucial to discuss and clarify with all partners what the desired objectives are. If a benchmark for litter removal systems is considered as an example, it would have been important beforehand to make clear what kind of data needs to be generated in order to fill in this benchmark and be able to compare different categories and findings. Based on the objectives a plan can be made, whereby a responsible partner tests periodically that data collection is taking place by the involved organizations. If periodic testing reveals, that if data collection does not take place it should be evaluated what can be done to improve this.

3.2.6. Unified approach for data storage

The predominant strategy for storing the gathered data was either through Excel or scanning the measurement forms. However, every partner has a different approach to storing this data even within an Excel document. Even if the same units were measured, the manner of storing the data can also lead to significant errors. Therefore, it is important to find an unified approach for firstly measuring the data, but also storing the data in e.g., a database for all partners.

Furthermore, it is also important to mention that one partner converted the gathered data into insightful key figures and tables for the Roer (Nov'20 – Sep'21) and the Geul (Okt'20 – Sep'21) (Appendix A). This can be used as guideline to make these kind of studies more comparable. During this time span, 33 measurements were made at six locations at the Geul, yielding 1806 found waste items from which 68.8% were plastic. For two locations in the Roer, 4341 waste items were found from which 72.1% were plastic. Consequently, significantly more waste items were captured in the Roer compared to the Geul. This also stresses the point, that the comparison of data and results becomes more viable, if the assembly of key figures and tables has a harmonized approach. Lastly, it needs to be mentioned that one partner removed the captured litter, however the waste was not analysed in terms of characteristics nor quantified.

3.2.7. DIKAR management model

As a guideline, the DIKAR management model can be used, whereby the letters stand for Data, Information, Knowledge, Action and Result (Figure 7). The entire process encapsulates the transformation of raw data into results, which can be called knowledge management. For

the LIVES project particularly the first management phase, namely the information management has room for improvement. As an example: if there is a harmonized approach for gathering data including e.g. the type of gathered waste and the quantities, the data can yield valuable information with regards to e.g., pollution sources. This information yields knowledge which can then be taken as basis for planning tangible actions e.g., holding partners accountable for discharging plastic. Consequently, this will lead to results, namely the reduction of plastic in the Meuse. Evidently, this principle can also be applied for other similar scenarios.

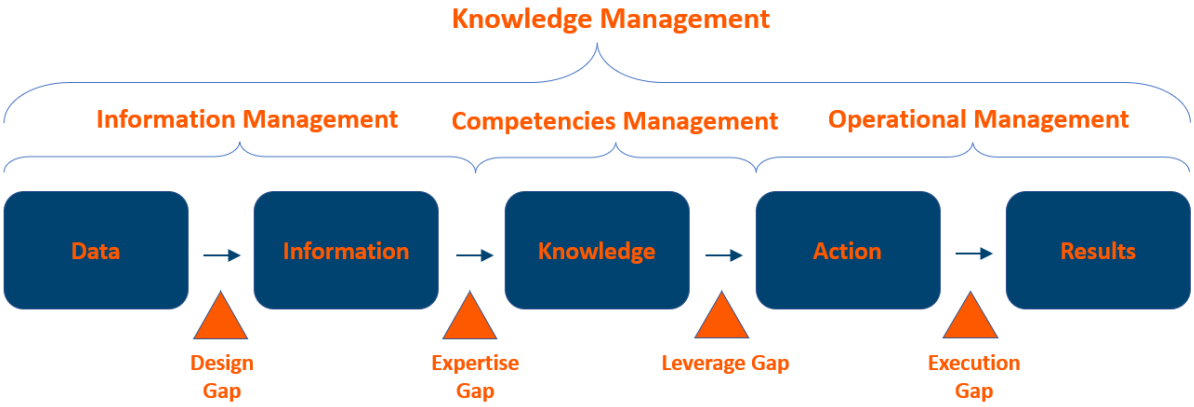

Figure 7 Knowledge management with the DIKAR approach

4. Evaluation of litter removal methods

This chapter describes the evaluation of litter removal methods according to the system overview given by Antea Group. Based on the results recommendations were made for a future practical benchmark for litter removal systems.

The plan of this project was to install and evaluate litter removal systems. This is one of the methods to remove litter from nature. Besides these systems volunteers can be utilized more easily for removing litter from shores before it ends up in the water, whilst litter removing systems can be used to remove plastic litter from the water. The benchmark of WP-T 2.3 was mainly implemented to compare litter removing systems. This comparison can be performed at different phases within the process of removing plastic from the water.

4.1. The right moment to Benchmark

In order to define the best moment to perform a benchmark, first the definition of a benchmark is given. Two separate definitions of a benchmark are: "*a standard for **measuring or judging** other things of the **same type**[3]*" or "*to measure **the quality of something** by **comparing** it with **something else** of an accepted standard*[4]"

Therefore, the goal of a benchmark is to compare systems or measure whether it meets the standard requirements. In the following list we will explain the steps that are important to take if a partner would like to remove litter with a system. Furthermore, it will explain which step(s) in the process are suitable for benchmarking.

1. The process should start with **analysis of the location** where the litter removal system is planned to be implemented. This includes the quantity of litter that passes by as well as the **location characteristics** like the water depth, width, and flow rate of the water.
2. After the location specific characteristics are known, a list with potential solutions can be used to **select potential solutions** that are applicable for that location. The "*Overview Waste in water trapping systems: characteristics and possible use for monitoring"* made by Antea Group in 2018 is one example of such a list (Figure 9)
3. After this selection has been made, the organisation that wants to remove plastic can **decide how to choose a litter removal system**, for example only on price or also on other evaluation criteria like technological maturity, amount of debris captured, etc. A list of these evaluation criteria can be found in the framework of Olivia K. Helsinki et al. (2021)
4. When the evaluation criteria have been selected, the comparison can be performed with usage of a benchmark (a standard for measuring or judging other things of the same type). With this benchmark they can **choose the best scoring solution**.
5. In the fifth step the **solution** should be **implemented**. It is very important not to underestimate this step. During the interviews it became clear that there are many

[3] https://dictionary.cambridge.org/dictionary/english/benchmark noun US
[4] https://dictionary.cambridge.org/dictionary/english/benchmark Verb UK

practical aspects that can result in problems during preparation of the implementation.

6. In the last step, the **implemented solution** should be evaluated to conclude if the solution delivers the expected results.

In this process there are three important steps that have to be explained in more detail since they can be used to select potential solutions, choose solutions to be implemented and evaluate the implemented solutions. The last two are suitable to perform with a benchmark whilst the first can only be realised with a more theoretical list of suitable systems. So, no comparison but only selection.

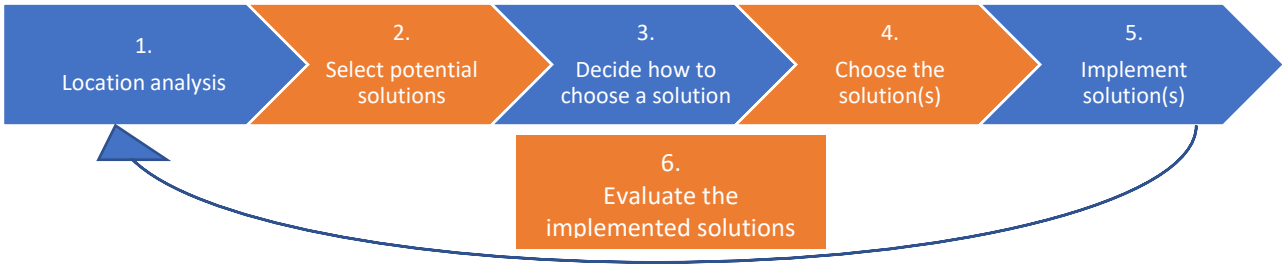

Figure 8 Process from situation analysis toward litter removal system evaluation.

4.2. Process with selection, choice, and evaluation of systems

Within the process of analysing the location and in the end evaluating the solution at that location, three important steps are needed, namely: making the selection of potential solutions (results in small list of applicable techniques), choosing a solution (results in one system), and evaluating the solution at the specific location (results in knowledge regarding the level of improvement compared to the initial situation). These steps will be explained in more detail to understand the locations that are suitable for application of a benchmark.

4.2.1. Select potential solutions (Testing the overview as a benchmark)

The overview with potential solutions was established on the 28th August 2018 by Antea Group. In this overview, various trapping systems for dealing with (plastic) waste in water were analysed on specific criteria. For each system, specific characteristics were used to evaluate or categorise the system from theoretical point of view. This overview of Antea Group was made to perform as a general overview of existing litter trapping systems with specific characteristics. In this report, it will be tested if the scheme would be applicable to perform as a benchmark.

Overzicht Vangsystemen afval in water: kenmerken en mogelijke inzet voor monitoring

anteagroup

Datum:	28-8-2018
Status:	definitief
Projectnummer:	412153
Opgesteld door:	Mark van den Kieboom & Julia Suesan-Regoort (Antea Group) (mark.vandenkieboom@anteagroup.com & Julia.Suesan@anteagroup.com)
Toelichting:	In dit document zijn diverse vang-systemen voor het aanpakken van (plastic) afval in water gebundeld en samengevat in onderstaande lijst. Per systeem zijn kenmerken zoals de plek waar het systeem wordt toegepast, de dekkingsgraad van het water (welk deel wordt meegenomen), het bereik en specifieke locatiefactoren beschreven. Op basis van deze kenmerken is vervolgens een inschatting gemaakt van de geschiktheid voor monitoringsdoeleinden. Hierbij is de op het moment van schrijven beschikbare informatie als uitgangspunt genomen. Deze informatie wordt gebruikt om informatiebehoefte te vertalen naar monitoringsdoelen. Dit document kan daarbij als informatiebron en inspiratiebron worden benut.
	De in dit document opgenomen informatie is tot stand gekomen door literatuuronderzoek en raadpleging van websites. Er is vanwege de beperkt beschikbare tijd geen uitgebreide raadpleging en controle uitgevoerd bij de diverse partijen. Indien er vragen of opmerkingen zijn, kunnen deze worden doorgegeven aan marjan.poortinga@rws.nl of mark.vandenkieboom@anteagroup.com Bronnen:- Overzicht zoals door Rijkswaterstaat verstrekt;- Internetconsultatie in mei, juni en juli 2018;- Arcadis, Plastic verzamelsystemen voor havens en kanalen, 9 november 2017.

In het geval een kenmerk wordt aangeduid met ++/+/+-/-/-- is de waardering als volgt:
'++ = zeker: systeem voldoet voor 90-100% aan genoemd criterium
+ = ja: systeem voldoet voor 75-90% aan genoemd criterium
+/- = niet zeker: systeem voldoet voor 50- 75% aan genoemd criterium
- = niet echt: systeem voldoet voor 30 - 50% aan genoemd criterium
-- = zeker niet: systeem voldoet voor 0 - 30% aan genoemd criterium

NAAM:	Wat is het en waar is meer info te vinden?	Waar kan het worden toegepast?					Locatie specifiek				TRL status	DEKKINGSGRAAD: hier wordt beoordeeld op de effectiviteit van het systeem in relatie tot te locatie waar het wordt ingezet			TECHNISCHE UITVOERING/MOGELIJKHEDEN: hier staan de technische kenmerken en (on)mogelijkheden van het systeem, zoals is het toepasbaar in getijdenwerking, is het op 1 locatie bevestigd, etc?					OPRUIMEN: hier wordt beoordeeld of het systeem geschikt is om als opruimmiddel te worden ingezet			MONITORING: hier wordt beoordeeld of het systeem geschikt is om te bepalen wat er in een watersysteem aan afval langskomt		
		zee	rivier	open water (meer)	stad (gracht, kanaal)	getijdenwerking/ getijde	Vanaf water	(hark/roosters)	Afvoer uit/van maaisel	Anders		effectief voor welk deel waterkolom? D+ drijvend afval WKH = waterkolom hoog (max 50cm) WKM = waterkolom midden (50-100cm) WKL = waterkolom laag (>100cm) WKB = waterkolom bodem	welk deel waterlichaam? G = geheel DM = deels (midden) DK = deels (kanten) LO = alleen langs oevers	extrapolatie van resultaten mogelijk (kunnen de resultaten van 1 locatie worden doorgetrokken voor een groter gebied, langere periode etc)?	kan scheepvaart passeren? (tpv het werkende vangsysteem)	Werking gevoelig voor/door omstandigheden? Get: getijden W: Windrichting en -kracht G: Golfslag S: Stroming	mobiele installatie? (bijvoorbeeld: vaart rond) mobiel-vast? (begeeft zich binnen/op een bepaald traject/gebied) vaste installatie? (deels) verankerd op 1 locatie)	werkt het systeem zo nu en dan (interval) of continu?	systeem aanpasbaar in grootte?	geschikt voor afvangen afval in water?	zo ja, kan er macroplastic [illegible] afgevangen worden?	dezelfde vraag voor microplastic?	eigen effectiviteit (hoeveelheid eigen vangst binnen relevante installatie) bekend t.o.v. totale hoeveelheid passerend afval	geeft het systeem een doorsnede van al het passerend afval dat langs of door installatie stroomt	conclusie: geschikt voor structurele monitoring?
	OPTELLING AANTAL:	5	19	19	21	16	17	1	1	8															
IN UITVOERING																									
Litter Trap (Bandalong)	The Bandalong is een vullvanger die in Australië ontwikkeld is. Vangt vuil, biomassa en ander materiaal in rivieren en beken en open water. De Bandalong is geschikt voor waterwegen van meer dan 2 meter breed (evt. met getijde maar zonder scheepvaart). De Bandalong opereert zelfstandig zonder mankracht.		x	x	(x)	(x)	x				9	D+WKH	G	++	Nee	S	Vast	Continu	Ja	++	ja	nee	>99%	Ja, m.u.v. hetgeen er onderdoor spoelt	++
Plastic Fisher	De plasticvisser heeft twee uitklapbare drijfarmen die met geleideschermen tot een diepte van enkele meters rommel opvangen. De plasticvisser is nog niet geschikt om plastic afval op hotspots in zee weg te vangen. Het opvangsysteem is modulair en biedt afhankelijk van de soorten kunststof, het volume aan afval, alsook de verdere mogelijkheden voor transport en verwerking, verschillende opties voor het opslaan of recyclen van het kunststofafval. Verwerking tot een synthetische diesel is een mogelijkheid. Het systeem is aan te passen op getijdewerking.		x	x	(x)	x	x				9	D+WKH	G	++	Nee	S	Vast	Continu	Ja	++	ja	nee	>99%	Ja, m.u.v. hetgeen er onderdoor spoelt	++
Buddy Witch	De Buddy is een kleine, lichte catamaran. Tussen de twee drijvers bevindt zich een zeef. De voorkant is open, maar de zij-, achter- en onderkant vormen een mand waar het water doorheen kan stromen, terwijl het vuil achterblijft. De grootte van het afval dat in de mand achterblijft is te bepalen door het raster waar het water doorheen spoelt groter of fijnmaziger te maken. De mand is te legen door hem uit de boot te tillen. De Buddy is gemaakt van aluminium – een licht en duurzaam materiaal. De afvalmand van de Buddy is te vervangen door een laadbak waarin tot een ton materiaal kan worden vervoerd.		x	x	x	x	x				9	D+WKH	DM/DK	-	Ja	W/G/S	Mobiel	Interval	Nee	+	ja	nee	90%	Nee. Zeefgrootte bepalend.	-
Water Witch	De Water Witch schept het afval in een aparte bak, wat als voordeel heeft dat de boot niet terug naar de kant hoeft als de bak vol is. Een sleepboot haalt de volle bak weg en plaatst er een lege voor terug zodat de Water Witch door kan werken. De Water Witch kan onder meer olie opruimen, uitgerust worden met een grijper die takken of ander materiaal uit het water vist, of dienen als spuitboot voor de brandweer. http://waterwitch.com/en/products/waterwitch/		x	x	x	x	x				9	D+WKH	DM/DK	-	Ja	W/G/S	Mobiel	Interval	Nee	-	ja	nee	90%	Nee, mazen schepnet bepalend.	-

Figure 9 Overview of litter trapping systems by Antea Group

The characteristics used in this scheme are shortly described below.

Location for system deployment

Evaluation whether the system can be deployed at sea, a river, open water (lake), the city (canals) or in a tidal area.

Location types

Characteristic the table indicates if the system is placed in the water, in front of pumping stations, at locations where grass clippings will be in the water or other.

Technology Readiness Level

This is a method to estimate the maturity of technologies during the development acquisition phase of a program.

Coverage ratio

Here the effectiveness of the system in relation to the location where it is deployed is assessed. It evaluates for which part of the water column the systems are effective, in which part of the water body the system is effective and whether the results from one location could potentially be extrapolated to larger areas and further locations.

Technical implementations and possibilities
This category describes the technical characteristics and possibilities of the systems. Hereby it is assessed whether ships or boats can pass the system, whether the systems are susceptible to certain circumstances (tide, wind direction- and intensity, waves, and flow), needs to be mobile or can be fixed or anchored, is working in intervals or continuously and whether the system is scalable and adjustable.

Suitability as removal system
Hereby the suitability of the system for the use removal system is assessed. The criteria include whether the system is suitable for removing waste from the water and if macro plastics and microplastics can also be removed.

Monitoring
Lastly, the suitability of the system for determining the waste load in a water system is evaluated. This addresses the effectiveness of the system (amount of waste captured within the known range compared to the total quantity of waste passing the system), whether the system provides a cross-section for all the passing waste that flows along or through the plant and lastly whether it is suitable for structural monitoring.

Implementing Results from LIVES in the benchmark

In this project it was examined if the theoretical overview could be filled with the results from the LIVES project (Appendix B) to compare the implemented systems. It was concluded that the overview of Antea provided a solid foundation, however an extension of this overview is needed to create a benchmark. Further research is needed for the compilation of a benchmark. Some criteria of the Antea overview can be used for this purpose, but this list needs to be expanded. From literature several other benchmarking tables were found. For example, the table in which Deltares compared five different litter removal techniques (Buschman & de Fockert, 2021) with usage of a benchmark that was based on an overview from Helsinki et al. (2021). Also, another website[5] by the plastic soup foundation gives an overview of many different systems. However, the information that is presented on this website is minimal and not up to date.

To illustrate this, we will focus on four criteria and explain to what extent these could be suitable for benchmark.

4.2.2. Choose the solutions

After the selection was made based on the characteristics of the location a system can be chosen. In this stadium, the criteria that were agreed upon in the third step (Figure 8) can be used in the benchmark to calculate the score of all potential litter removal systems. The system that scores highest can be selected to be implemented in step 5 (Figure 8).

4.2.3. Evaluate the implemented solutions

After the systems were implemented, measures can be performed to gather data which can be used to evaluate the performance of the system. To evaluate different systems in the same method, which makes it possible to compare the results with each other, it is important to agree upon the criteria that will be used to evaluate the system. In the LIVES project a

[5] Https://www.plasticsoupfoundation.org/oplossingen-voor-plasticsoep/?_categories=uit-zoetwateromgeving-of-stromen&_sort=rating_desc

significant amount of data was gathered and analysed. Nevertheless, the manner of data collection can be improved regarding the coordination and structure. This refers to the fact that it is important to initiate a structured procedure for data collection for the coming period such that later measurements can be compared and gained knowledge can be shared.

To evaluate the effectiveness of the deployed systems, the theoretical benchmark needs to be assessed jointly with results from the practical implementation of these systems. The necessary information and data were gathered from the involved partners through a series of interviews. Lastly, to compare the benchmark from a theoretical and practical point of view, a comparison can be made following the evaluation criteria of the theoretical benchmark.

5. Conclusions and recommendations

This chapter is split up into three different sections. First the conclusions from the research, secondly the recommendations related to removal systems and thirdly the recommendations related to the LIVES project in general.

5.1. Conclusions

The main objective for Work package T.2.3 was 'to benchmark different river litter trapping techniques'. The main conclusion is that this is complex and the results from testing different river litter trapping techniques cannot yet be compared in a benchmark model. However, this project gave extremely valuable insight in how this benchmarking can be performed in the near future.

General conclusions
Overall, the LIVES project facilitated and helped the partners to develop and share knowledge on how to choose a suitable litter removal system at the best location. The project has also strengthened the cross-border cooperation and network within the Meuse basin and increased the awareness in the field of plastic waste in the water column.

More than sixteen ways of removing litter from the water, and even three outside the project scope, have been installed/tested on different locations. Sixteen were fixed on one location and some other manners were with flexible material or people. Many lessons were learned by all individual partners as e.g., which systems are available and to what extent they work at their location with specific characteristics. However, a majority of the litter removal techniques were more or less similar, which makes it less useful to compare individual systems. Therefore, this project is more a comparison between different litter collection locations than a comparison of different litter removal techniques. With this, the LIVES project has resulted in valuable insights to what techniques work in which situations and what are all the aspects that should be considered during installation of those systems.

The LIVES project has led to more attention within governmental bodies and put the problem of polluted water higher on the political agenda. However, sharing information with other partners is still challenging. The way of information registration differs a lot per organisation and there are not yet fixed methods of measuring the results from litter removal methods.

The language barrier seemed to be a challenge. It was mentioned by several partners, that they would prefer to communicate in their respective mother tongue. This refers e.g., to receiving mails in their mother tongue, since it is more comfortable for them to read and reply. During the project gradually more attention was put on addressing the language barrier and implementing solutions to tackle this inconvenience.

Overall, the LIVES project facilitated and helped the partners to (further) install litter removal systems. The project has also strengthened the cross-border cooperation and network within the Meuse basin and increased the awareness regarding plastic waste in the water column. One party for example mentioned that without LIVES the tests with the dirt socks would not have been done at the outlets of the overflow locations from the sewer system. This also left an impact on the managing parties of the sewer system. This showcases that the LIVES project

has a more comprehensive impact on not only the partners from the LIVES project, but also the associated partners, organizations and groups that cooperate with the partners from the LIVES project. This creates a trickle-down effect by generating more awareness towards the plastic pollution problem, it also stimulates more effort to tackle this problem.

From the interviews it became clear that the information exchange between the partners was relatively scarce. Some of the information was gathered on a platform, but nothing was shared actively with the partners (e.g., mail). The platform could use an updated structure, so therefore it was difficult to find relevant documents and get a good insight in the existing situation. Also, not every partner used this platform intensively.

The partners indicated that they are committed to further enhance their knowledge development in the field of plastic litter and removal systems. Overall, the removal of litter needs an integrated approach by involving water users, surrounding water users and volunteers in the prevention and collection of litter. It can safely be concluded that the LIVES project served as catalyst to kickstart cross-border efforts to reduce the plastic flux in the Meuse and to further work on this problem in the future.

The LIVES project initiated and set the first steppingstone for cross border cooperation to reduce the plastic pollution in the Meuse which can be solidified more with future cooperation plans. Since plastic is transported via multiple countries a cross-border approach is the only way to tackle the litter problem in the catchment of the Meuse.

Benchmark related conclusions

Performing a benchmark is a process that needs serious attunement in criteria that should be measured to compare systems with each other. This insight was gained during this project and is important to be aware of in the coming period.

It is important to firstly know the potential locations where plastic can be removed and how suitable these locations are for installing litter removal devices. Factors that have been mentioned during interviews are:

- Accessibility for removing the litter from catching systems.
- Location where plastic already accumulates e.g., at culverts
- Locations before a sea, lake, or Natura 2000 areas.

5.2. Recommendations

General recommendations

It is recommended for future projects to divide the objectives into smaller sub-objectives and work on these with smaller groups. Also, a mid-term meeting in which products must be delivered would be valuable to identify the need for adjusting the initial goals based on the preliminary results in an early phase in the project. Of course, this can be difficult in a project with a timeframe of three years.

For better information exchange it is recommended that more frequent meetings take place between the involved partners and that the progress is shared with each other in easily accessible manners.

Because each country has different ways of managing waste, water quantity, water quality, etc., it would be very valuable to make a video in which it is explained how water management is being organised in the different member states. This video is important since it was mentioned that the explanation was given in the beginning of the project. However, the people who were active in the project altered quite often. Which means that the gained knowledge will also leave the project.

If interregional applicability is the main goal, the attention for differences between project partners must have high priority. Therefore, in the future interregional differences e.g., different language or organisation structure must be consciously included in the project management. This can be emphasized at the start of the project by explaining each other what lessons they have learned in earlier interregional projects. Subsequently, during the project several meetings can be organised in which a facilitator explains something about interregional differences and how this can be overcome in this project. After this general session the individual partners can explain how they experience the differences in their work within the project

Recommendations for benchmarking litter removal systems

From the conclusions in the earlier part of this report the following recommendations are distilled concerning the benchmarking of litter removal systems.

It is recommended that a European way of registering performance of litter removal systems is designed such that they can easily be benchmarked. To harmonize data collection methods, a European dashboard could be made where partners can download templates which they can fill in and upload with their data. This part could potentially be combined with the results from work package T1 'Inventory Data Sharing'.

The overview of Antea Group provided a solid foundation for the extension to a benchmark. For this procedure it is recommended that a consultancy firm with experience in this field is hired to compare the varying systems with each other. It would also be highly advisable if the European Union could finance a Team of Experts that is available for member states to ask complex questions about potential for litter removal systems in their water system. The way of measuring specific criteria requires subject-specific knowledge from both the litter removal systems as well as the benchmarking methods.

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Buschman , F., & de Fockert, A. (2021). *Afvangen plastic zwerfafval, vergelijking resultaten pilots.* Delft: Deltares.

Helsinki et al. (2021) Helinski O.K., Poor C.J. Wolfland J.M., 2021, "*Ridding our rivers of plastic: A framework for plastic pollution capture device selection*", Journal of Marine Pollution Bulletin 165, ref: 112095, https://doi.org/10.1016/j.marpolbul.2021.112095

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Appendix A key figures from litter trap locations of Waterschap Limburg

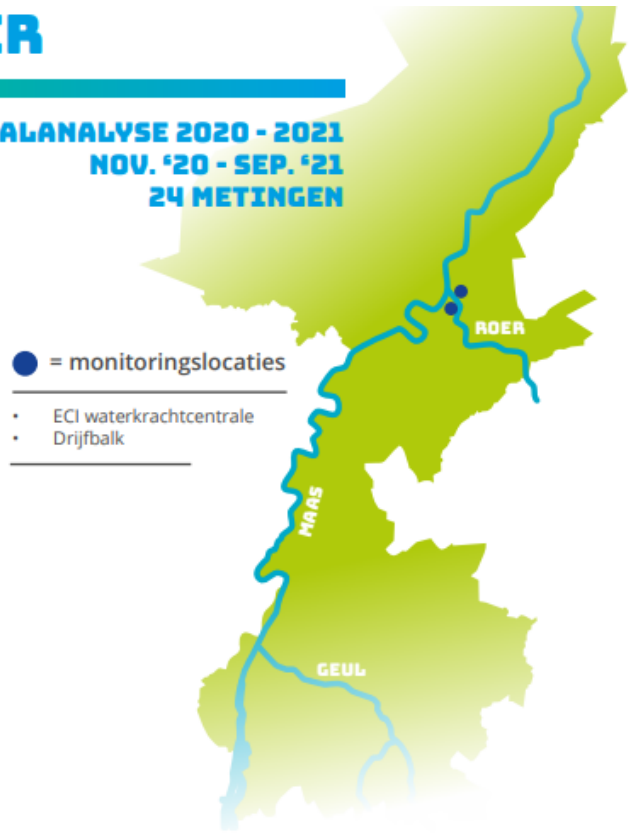
AFVAL AAN DE ROER

HOEVEELHEDEN AFVAL

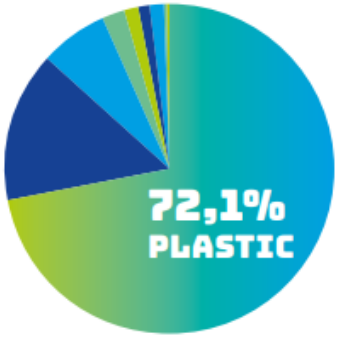
4.341 AFVALITEMS IN TOTAAL, WAARVAN:

3.132	plastic
642	glas
288	metaal
89	rubber
65	sanitair
52	textiel
52	papier
17	medisch
4	hout

TOTAALANALYSE 2020 - 2021
NOV. '20 - SEP. '21
24 METINGEN



SAMENSTELLING AFVAL



72,1%	plastic	1,2%	textiel
14,8%	glas	1,2%	papier
6,6%	metaal	0,4%	medisch
2,1%	rubber	0,1%	hout
1,5%	sanitair		

TOP 10

1. flessen, potten of stukken daarvan
2. plastic folies of stukken daarvan (2,5-50 cm)
3. voedselverpakkingen (plastic)
4. snoep-, snack- en chipsverpakkingen
5. drankflessen (plastic) < 1/2 liter
6. doppen en deksels (plastic)
7. piepschuim > 50 cm
8. drankblikjes
9. stukken hard plastic > 50 cm
10. drankflessen (plastic) > 1/2 liter

AFVAL AAN DE GEUL

HOEVEELHEDEN AFVAL

1.806 AFVALITEMS IN TOTAAL, WAARVAN:

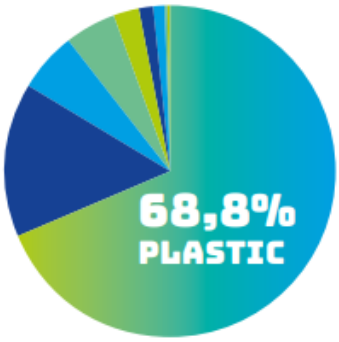
1.242	plastic
273	metaal
106	papier
87	glas
49	textiel
23	rubber
21	sanitair
4	medisch
1	hout

TOTAALANALYSE 2020 - 2021
OKT. '20 - SEP. '21
33 METINGEN

● = monitoringslocaties

- Drijfbalk Valkenburg
- Geulhemermolen
- Bovenste molen
- Volmolen
- Molen Otten
- Speltmolen
- Bours

SAMENSTELLING AFVAL



68,8%	plastic	1,3%	rubber
15,1%	metaal	1,2%	sanitair
5,9%	papier	0,2%	medisch
4,8%	glas	0,1%	hout
2,7%	textiel		

TOP 10

1. drankblikjes
2. plastic folies of stukken daarvan (2,5-50 cm)
3. drankflessen (plastic) < 1/2 liter
4. voedselverpakkingen (plastic)
5. industrieel verpakkingsmateriaal
6. piepschuim > 50 cm
7. drankflessen (plastic) > 1/2 liter
8. flessen, potten of stukken daarvan
9. snoep-, snack- en chipsverpakkingen
10. kartonnen bekers

Appendix B Overview of systems scheme used as benchmark

Overview of systems for catching litter in water:a pratical benchmark

In case a feature is marked with ++/+/-/-/--, the rating is as follows:
'++ = zeker: systeem voldoet voor 90-100% aan genoemd criterium
+ = yes: system satisfies 75-90% of said criterion
+/- = not sure: system meets this criterion for 50-75%.
- = not really: system meets that criterion by 30-50%.
-- = definitely not: system meets the criterion for 0 - 30%.

Name		Implemented or considered (but not implemented)? I = implemented, C = considered but not implemented	Image from implemented solution	What is it and where can you find more information?	Where can it be applied?					Location specific				TRL status
					Ocean	River	Open water	City (canal)	Tidal range	From water	Comb-shaped grid (NL: hark-roosters)	Discharge from/of grass clippings	Anders	
IN IMPLEMENTATION														
Floating beam (tree trunk)	WVER	I		This is a tree trunk placed by WVER and it functions as an interceptor for floating macroplastics.				x mainly small streams and canals						9
Floating barrier	VMM (top), WSL (bottom)	I	 	A floating barrier is a device that floats on the water surface and is kept in position by a flexible connection with two anchor points at both ends. The purpose of the floating barrier is to collect floating debris in the watercourse at a location where the floating debris can be easily collected. The construction, shape, dead weight and ballast weight are provided in such a way that the silt fence lies sufficiently deep in the water to collect most of the floating debris. The construction, shape, dead weight and ballast weight are provided in such a way that the screen lies sufficiently deep in the water to retain most of the floating debris. The anchor points and length of the floating barrier are arranged in such a way that the floating barrier can be set up at an angle of 45° to the axis of the watercourse. All plastic parts of the dirt barrier and all associated components are made of a technical plastic with proven resistance to UV light and water (VMM). For the floating barriers from WSL no technical information is available.		x		(x)				x		6, 7 or 8
Dirt sock/ Pantykous (sewer overflow)	VMM, WSL	I		The waste trap allows waste to be captured at sewer overflows through a large, long pantyhose (giant pantyhose). The method was developed by Sweco (formerly Grontmij Nederland B.V.) for municipalities that want to increase the overflow capacity without waste/environmental problems due to climate change. Further exploration for application at other locations is possible.		x	x	x					x	9
H2O barrier	DWW	C		The H2O barrier is a system that can be placed in a watercourse (small or large) and uses the current and an air bubble screen to create a natural barrier that traps almost all of the dirt. This barrier directs both floating debris and debris found below the water surface to the surface. The correct positioning of the barrier in relation to the current then transports the dirt to a collection point. At this collection point, various options can then be applied to filter the dirt from the water, including a skimmer or a safety net. The great added value of this system is that, in addition to trapping almost all of the dirt, shipping and flora and fauna are not hindered, making it applicable almost everywhere. A mobile or fixed application is also possible. Current status: small-scale test phase, research into test locations and large-scale construction.		x	(x)	x	x	x				5
Wind mills	WSL	I	No image available	Waste often accumulates at water mills. Trapping makes sense in order to reduce the pollution load downstream. There is no policy yet, but a system to capture the waste is being sought. Cost allocation is being sought (government versus polluter).		x	x	x					x	Not known
Wasteshark	DWW	C		The Wasteshark from Ranmarine is a sailing drone that sails independently through the water. The catamaran-like shape ensures that this drone catches the floating plastic. Plastic		x	x	x	x					6

Name	DEPTH OF COVERAGE: assesses the effectiveness of the system in relation to the location where it is deployed.			TECHNICAL FEATURES/POSSIBILITIES: here are the technical features and (im)possibilities of the system, such as can it be used in tidal conditions, is it fixed at one location, etc?					CLEAN UP: the suitability of the system for use as a removal system is assessed here			MONITORING: this is where the suitability of the system for determining what waste is passing through a water system is assessed		
	Effective for which part water column? D = floating waste WKH = water column high (max 50cm) WKM = water column medium (50-	Which part body of water? G = whole DM = partly (middle) DK = partly (sides) LO = only along banks	Extrapolation of results possible (can the results of 1 location be extended to a larger area, longer period etc)?	Can shipping pass through? (in front of the working catching system)	Operation sensitive to/due to circumstances? T: Tides W: Wind direction and force G: Waves C: Current H: High water levels	Mobile installation? (for example: sailing around) mobile-fixed? (moves within within/on a certain route/area) fixed installation ((partly)	Does the system occasionally, intermittently, (interval) or continuously?	System adjustable in size?	Suitable for capture waste in water?	If so, can it be used to caputre macroplastics?	Same question for microplastics?	Own effectiveness (amount of own capture of plastic within the range of the system) compared to total quantity of passing waste	Does the system give a a cross-section of all the passing waste passing by or through plant	Conclusion: suitable for structural monitoring
Floating beam (tree trunk)		G	?	Ships cannot pass	High water levels and flooding	Fixed installation but got moved during flooding	Continuously, but system efficiency was influenced during flooding	? (could be adjustable in size if you saw the wood)	Yes, but influenced by high water levels--> cannot give a rating based on interview (generally giving a rating is not the best choice because it really depends on the local circumstances)	Yes	No	Was not tested	Yes it does, if the plastic does not flow under system or if flooding occurs then plastic can pass the system	Probably during low water levels in a small stream but cannot really be assessed
Floating barrier	D+WKH	G	++	Ships cannot pass	Yes for flooding	Fixed and mobile, however in case of flooding it detaches for floating barrier from VMM. System can move according to water levels	Continuous	Yes (however not sure for systems from VMM? Seems like they are fixed. Again, here it is difficult to generalized for all existing floating barriers)	Yes (rather than giving a rating I would just say yes/no, because the efficiency was not really tested)	Yes	No	Efficient surface removal, unknown what goes underneath (again also for recommendations in the theoretical benchmark it says for floating barrier: Surface >99%, unknown what goes on underneath. Not great to couple a number to it cause this number can really vary with extreme circumstances such as flooding)	Yes it does, if the plastic does not flow under system or if flooding occurs then plastic can pass the system. This is more for the system by VMM compared to WSL (if images are considered) --> debris passes under the floating barrier due to turbulence at very high or low flow speeds	Yes
Dirt sock/ Pantykous (sewer overflow)	Not applicable	G	+/-	Not applicable	-	Vast	Continu	Ja	--	ja	Maybe	100%	Yes, except material smaller than trap openings (pores from sieve)	-
H2O barrier	D+WKH+WKM+ WKL	G	++	Yes	G	Fixed	Continuous	Yes	++	Yes	Maybe	>85%	Still researched	++
Wind mills	(Not known)	(Not known)	(Not known)	No	Not known	Fixed	Continuous	Yes	?	Yes	No	Not known	Not known	Not known
Wasteshark	D	G	--	not known	No, the sieve size is determining	-								