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TNO report

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Advisory report inventory uniform measuring method for microplastic fibres from textiles

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Management summary

In 2018, RIVM conducted research into the sources of microplastics (MP) in Dutch waters. From this and other studies, microplastic fibres (MPVs), created during wearing and washing of clothes, emerged as one of the largest sources of microplastics[1]. With support from the Ministry of Infrastructure and Water Management (I&W), the MPV (microplastic fibre) Stakeholder Network was therefore set up at the end of 2019, with the aim of reducing and preventing the emission of microplastic fibres from textiles into the environment. Base of this approach is the precautionary principle. The stakeholder network consists of stakeholders from the textile, washing machine and detergent industries, knowledge institutions, water boards and NGOs.
To reduce MPV pollution, it must be possible to measure the effect of MPV reducing measures. However, no standardised, uniform measuring method is yet available for measuring MPVs in water. Therefore, at the request of the Ministry of Infrastructure and the Environment, this advisory report outlines a possible follow-up programme for the development of a uniform measuring method for quantifying microplastics released from clothing into water, which can be used as effectively as possible throughout the MPV pollution chain from textile production to waste water treatment. This outline is based on a knowledge and stakeholder inventory carried out by TNO and the resulting advice on the best way to achieve a uniform measuring method, which is also described in this report.

The knowledge inventory shows that the following parameters have a major influence on the MPV release of textiles: the twist of the yarn, the fibre type, the fabric structure, the density of the yarn, the presence of detergent and fabric softeners, the temperature during washing, the water volume and the number of times the fabric has already been washed ('pre-wash' is sometimes also applied before sale). The most common MPV type in textiles is polyester, which is also expected to have the greatest impact. The most appropriate units for quantification are number of (plastic) fibres/volume of water and mass of (plastic) fibres/volume of water.
From the background research into different analytical methods, a concept measuring method has been drawn up which is divided into three modules: a washing method, a sampling and pre-treatment method and an analytical method. For the washing method, only relevant for experimental optimisation of textile and washing parameters, it is best to follow the CEN-ISO standard in development. This standard is not yet fixed, but the main lines are clearly described in an article of the University of Leeds that can be used as a guideline. For the sampling of MPVs in water, two different sampling strategies are possible, depending on the expected MPV concentration. Single sampling is used at high concentrations and continuous sampling, using volume-reducing sampling techniques, at low concentrations. For analysis, the sample may require further pre-treatment, whereby other components are removed from the matrix by degradation (organic components) and/or separation based on density (inorganic components). The subsequently available techniques for analysis of the sample can be divided into four groups; mass determination, microscopic techniques, spectroscopic techniques and thermo-analytical techniques. Based on cost and speed, a combination of mass determination and thermo-analytical analysis is recommended, whereby the weight contribution of a type of polymer can be determined quickly. For extra information on size, shape and number of particles, this can occasionally be supplemented with microscopic and spectroscopic measurements.

The partners in the Stakeholder Network MPV are interested in the size and impact of MPV from textiles on the environment and are willing to contribute to a follow-up study in the short term. For measurements in groundwater and surface water, the follow-up research can be linked to the Knowledge Impulse Water Quality (KIWK) programme and the Monitoring Microplastics study within the Monitoring Waterstaatkundige Toestand des Lands (MWTL) programme of the Directorate-General for Public Works and Water Management (RWS).
The main European initiatives and collaborations in this area are the European Microplastics Initiative from the Green Deal, the Microfibre Consortium (tMC) and the Cross Industry Agreement (CIA). In the coming years, the WOMA (Wear Off Microfibres Alliance) consortium, which is working on an MPV label for textiles, could also grow in size. In addition to joining these consortia, it is recommended to join the consortia of the main European projects

[1] See references on page 5.

still in progress (Limnoplast, Euroqcharm, Herewear and MOMENTUM), to share knowledge in the related forums and to remain a member of the CEN/ISO working group CEN/TC 148/WG 47, which is working on measuring standards for MPV from textiles. The approach of these standards is in line with the approach proposed in the knowledge inventory, but publication is only expected in 2 to 3 years' time. In the meantime, the Netherlands can already make great strides and, because of the good match in terms of approach, can also participate in European programmes.

The parties in the MPV textile pollution chain can roughly be divided into three groups: textile industry, washing process and water management. Each of these groups includes several partners from the MPV Stakeholder Network. In order to determine the best follow-up approach to arrive at a uniform measuring method for MPV losses throughout the chain as quickly and efficiently as possible, an inventory was made for each of these three groups of (1) the expected approach to MPV reduction at this point, (2) the common approach to determine MPV losses at this point, (3) the necessary sampling method and (4) the expected best approach with regard to processing and analysis method. Up to and including the washing process, sampling is relatively easy because the expected MPV concentration is high and the water is relatively clean. Towards the end of the chain (sewerage, water purification, surface water) the water becomes dirtier and/or the concentrations lower, which makes sampling more difficult. Pre-treatment and analysis of the samples also becomes more difficult towards the end of the chain. Up to (the point immediately after) the washing process, it is therefore possible to carry out controlled experiments that can be easily analysed, whereas at the end of the chain, due to little influence on the process, contaminated water and low concentrations, this becomes much more difficult. To still get a complete picture of the MPV loss through the chain, it is recommended to complement a simple analysis based on filtration and determination of mass per litre with a thermo-analytical quantification, complemented by microscopic or spectroscopic analysis on a random basis. With thermo-analytical quantification, the mass fraction of a type of polymer in a sample can be determined relatively quickly. The method is also relatively least sensitive to contamination, which makes it applicable throughout the chain.

TNO has been asked by the Ministry of I&W to outline a plan for follow-up research. The purpose of this plan is to further develop and test the proposed uniform measurement method as soon as possible and to gain experience with it in an iterative process of MPV reduction and improvement of the sampling and analysis techniques. In this way, major steps can be taken more quickly, so that the Netherlands is ready in time to assume its responsibility and is prepared to comply with the forthcoming international guidelines. A chain approach is recommended, in which MPV concentrations are mapped at all three main points of the pollution chain (textile, washing process, water management) in parallel, and a start is made in the short term on refining the measuring method by means of pilots. The results of the pilots can be used to make the first improvements in terms of MPV reduction, after which the measurements can be expanded to provide a more complete picture. In addition, a reference study into the effectiveness of the concept measuring method on representative reference samples is recommended, work should be done on European affiliation, the drafting of a detailed measurement protocol, the drafting of a standard for MPV concentrations in water and the drafting of a good approach to monitoring and enforcement.

Contents

1 Introduction

1.1 Microplastics from textiles in the environment

In recent years, the global production of both natural and synthetic fibres has grown significantly. It is expected that in the next 10 years this production will increase by around 30%, from 110 million tonnes in 2019 (TextileExchange, 2020) to 145 million tonnes in 2030. (Wagterveld R. M., 2020) Of these fibres, the vast majority (~ 63%) has a synthetic origin and this fraction will only grow in the coming years. The use of synthetic materials, such as polyester and polyamide, has its advantages: it is cheap, lasts longer and can be blended with natural fibres to give the textile certain properties, such as moisture transport and reinforcement of the fibres. The most well-known combination of polyester blends is polycotton and is often used in sports and outdoor clothing due to the increased water resistance of polyester. (Silver Bobbin, 2021) However, the use of synthetic fibres also has another side: studies have shown that when washing and using synthetic textiles, microplastic fibres (MPVs) are released and end up in the environment (Browne M. A., 2011) (Almroth B. M. C., 2018).

MPVs, defined as polymer-containing fibres with a length between 3 nm and 15 mm and with a minimum length to diameter ratio of 3 (RAC, 2021), fall under the heading of microplastics. Microplastics do not occur naturally in the environment and have therefore attracted intensive attention in recent years because of the potential threat they pose to humans, the environment and animals. Due to the fact that the effects of these particles are not yet unambiguous (Almroth B. M. C., 2018) (Wagterveld R. M., 2020), it is desirable on the basis of the precautionary principle[2] to minimise the emissions of microplastics into the environment wherever possible.

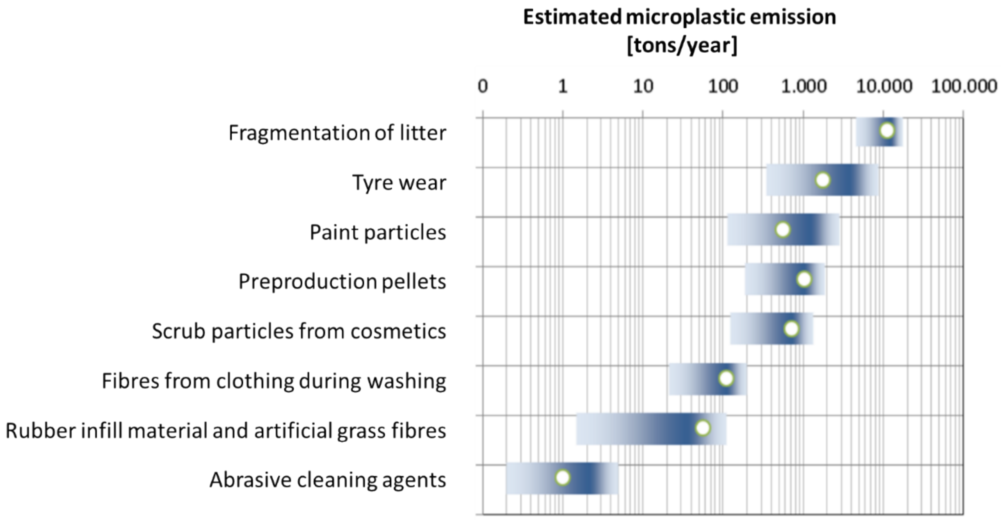

Figure 1 Estimated microplastics emissions in the catchment area of the Netherlands in tonnes per year. The columns show the uncertainty margin, the white dots represent the mean value. Figure taken from source. (Verschoor A., 2018)

In 2018, the RIVM conducted research into the sources of microplastics in Dutch waters. (Verschoor A., 2018) An overview of the estimated microplastic emissions (in tonnes per year) is shown in Figure 1. From this study and many others studies (De Falco F. , 2020) (Jönsson C., 2018) (Cai, et al., 2020) (De Falco F., 2019) (Hernandez E., 2017) (Tiffin & al, 2021), MPVs, generated during the washing of clothing, emerge as one of the largest sources of microplastics. In the Netherlands, this amounts to about 110 tonnes of microplastic fibres to surface water per year (Verschoor A., 2018). With the expected growth of synthetic textiles, these emissions will only increase in the coming years.

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[2] Precautionary principle: https://www.duurzaammbo.nl/ethiek-inleiding/7-juridische-principes

Measures are therefore needed to prevent and reduce MPFs in water. In order to gain insight into effective measures to combat these emissions, it must be possible to measure the impact of the possible measure to be taken. However, there is currently no unambiguous method for measuring MPVs in water, which makes comparison of research results impossible. (Koelmans A. A., 2019)

1.2 Background of this study

With support from the Ministry of Infrastructure and Water Management (IenW), the Stakeholder Network MPV (microplastic fibre) was established at the end of 2019. The aim of this network is to reduce and prevent the emission of microplastic fibres from textiles to the environment. This concerns release to water, air and soil, but initially the network will focus on water. It involves stakeholders from the textile, washing machine and detergent industry, knowledge institutions, water boards and non-governmental organisations (NGOs). An overview of the affiliated partners in the Microplastic Fibres Stakeholder Network is shown in **Table 1.**

Table 1 Overview of the affiliated partners in the MicroPlastic Fibres Stakeholder Network (MPV).

Category	Partner in the MicroPlastic Fibres Stakeholder Network
Textile industry	INretail, Modint
Washing machines	APPLiA, BSH Household appliances, Electrolux, Miele
Laundry detergents	NVZ, Senzora
Laundry services	FTN, TKT
Water Boards and drinking water laboratories	Hoogheemraadschap de Stichtse Rijnlanden, Waterschap Rijnland, Waterschap Rivierenland, Waterschap Vallei-Veluwe, het Waterlaboratorium
Policy	Ministry of I&W, Milieufederatie (EPA)
Research	RIVM, Rijkswaterstaat (RWS), TNO, Leiden University, ZonMW
NGOs	Natuur en Milieu, Plastic Soup Foundation (PSF), Plastic Soup Surfer
Communication	Milieu Centraal, SiJu

In 2020, several discussions have taken place within the MPV Stakeholder Network concerning the reduction of microplastic fibres during washing. During these discussions, a number of actions were formulated that could be taken to reduce microplastic fibre emissions. One of the actions of these discussions was to develop a universal measuring method that can be used as widely as possible by all relevant stakeholders in the MPV textile supply chain to measure the release of fibres into water during washing. To implement this, a working group within the MPV Stakeholder Network has been set up with partners who will eventually apply the measurement method.

Intended applications of the Uniform Measuring Method

- To determine the factors that have the most influence on fibre loss during washing, such as temperature, wash programmes, machine design, type of soap, etc.
- To determine the efficiency of strategies for prevention and mitigation, such as improving textiles to prevent MPV loss, changing the industrial production process or using washing machine filters.
- Quantitatively comparing the impact and feasibility of the different solutions and plotting the impact vs. costs of these measures..
- Categorising/grouping measures on this basis. What is the best order? How will the measures be integrated?
- Determining an acceptable level: working towards a standard for MPVs in water.

Possible related follow-up studies

- Pilot studies in the textile chain to determine relevant local factors and test solutions and mitigation strategies.
- Determining the efficiency of water treatment systems for removing microplastic fibres from sewage.
- Research on microplastic loss during wearing clothes (airborne microplastic fibres).

In this advisory report, TNO has drawn up a plan for the development of a universal measurement method for quantifying microplastic fibre release from clothing into wastewater as a result of washing. The first step in this development was made by making a thorough overview of already existing scientific research, studies and initiatives regarding measurement methods for releasing microplastic fibres from clothing into water, both nationally and internationally, and formulating a follow-up recommendation based on this.

1.3 Structure of this study

The objective of the measuring method under investigation is to determine the concentration (grams per litre and/or particles per litre) of microplastic fibres in water released during textile washing. This method will subsequently be used to determine the concentrations of MPV from textiles in the pollution chain from washing the textiles to the surface water. It is therefore important that the method is applied as uniformly as possible throughout the chain and provides comparable measured values: a uniform measuring method. The measured values can then be used to determine which measures are expected to have the greatest impact in reducing the release of microplastic fibres into water.
The research reported here only covers the first step towards a uniform measuring method: a knowledge inventory, a stakeholder inventory and the subsequent advice on the best way to achieve the desired uniform measuring method. Based on these steps, a recommendation for a follow-up programme is also given.

1.3.1 Knowledge inventory

The knowledge inventory consists of two parts: answering a number of relevant research questions in a literature study and compiling a concept for a uniform measuring method from this.

Part 1: addressing the relevant research questions in a literature study.
What is the available knowledge in this area? The following concrete objectives were pursued:

a) **Identification relevant parameters for fibre release during washing**, such as type of textile, chemical composition, size, quantity and the presence of other substances in the wastewater such as soap and soiling. This is done in line with the current state of knowledge of the MPV Stakeholder Network and important national & international programmes. The underlying question is to what extent a method can be developed that is as independent as possible of the exact washing conditions and the type of textile.

b) **Identifying the most relevant textiles and the type of synthetic fibres.** This also takes account of the current state of knowledge of the MPV stakeholder network about which types of textile are representative in practice. Is only polyester representative enough? Which type of textile is sold the most? Which type of textile is worn the most, washed the most? Which fibre types are most relevant in this case? Which fibres can be considered as 'model fibres' as far as possible (e.g. polyester and recycled polyester)?

c) **Identify the most appropriate unit for quantification of MPV in water**, e.g. the number of synthetic fibres (e.g. polyester and polyamide) per kg of washed textiles or the weight of synthetic fibres per litre of water.

Part 2: Development of a draft uniform measuring method.
The aim is to develop a measuring method that can be used as broadly as possible, so that it can be applied by various stakeholders in the textile production and value chain. For the draft method, information from available sources is combined. However, the concept has not yet been fully defined and tested, this will follow in a later stage. A modular structure has been chosen (washing module; sampling module; analysis module) in order to link up as much as possible with existing microplastics standardisation initiatives.

1.3.2 Stakeholder inventory

Who is doing what at the moment? What are all the relevant initiatives that are currently running around the development of microplastics in water? What is the available knowledge in this area? What are the important initiatives that are ongoing within the EU?

In addition to the relevant stakeholders who are affiliated with the MPV Stakeholder Network, international stakeholders and the relevant initiatives regarding new measuring methods are mapped out. Explicit attention is paid to existing stakeholder initiatives. In order to create support at the European level, an inventory was also made of which existing initiatives could best be cooperated with in order to make a European uniform measuring method possible. To this end, TNO has also participated in the NEN committee 'Textiles & Clothing', which is linked to a CEN initiative to establish a uniform measuring method for microfibres in water.

1.3.3 Follow-up advice

Based on the results of the knowledge inventory and the stakeholder survey, a recommendation will be formulated for the next steps in arriving at a usable uniform measuring method for microplastic fibres from clothing in water.

1.4 Execution of this project

The duration of this study was from 1 March 2021 to 14 September 2021. On 1 March there was a kick-off with the Stakeholder Network MPV, from. From that moment on TNO started with the knowledge inventory and mapping of existing initiatives with regard to a measurement method for microplastic fibres from clothing in water. To this end TNO joined the NEN Textile & Clothing Committee and attended consultations and made contact with key players in the field such as the Swedish research institute RISE[3], the Belgian institute Centexbel[4] and the Microfibre Consortium (see 3.3.1).

On 10 May, an initial outline of the results of these activities was presented to the Uniform Measuring Method working group within the MPV stakeholder network. Based on the results of this presentation and in consultation with the project manager of I&W, it was decided to hold direct interviews with representatives of the various interest groups in the network in the following weeks. These interviews represent an important part of the stakeholder research and have been of great importance in forming a final advice and supplementing the knowledge inventory.

On 16 June, the results of these interviews, together with a first version of the advisory report, were presented to I&W and the MPV stakeholder network. On the basis of follow-up discussions with I&W, the advisory report was further elaborated into an advisory report. The final version of the report was delivered on 14 September 2021, along with a summary in PowerPoint and English translations of both documents.

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[3] RISE: Swedish research creating sustainable growth | RISE

[4] Centexbel: Homepage | Centexbel - VKC

2 Knowledge inventory

The knowledge inventory consists of two parts. The first part consists of an inventory of the most relevant parameters for MPV release from textiles, the most relevant textiles and fibres and the most suitable unit for quantifying MPV release through the MPV contamination chain. In the second part, based on the information available in literature and discussions with the MPV stakeholder network, an advisory concept of the uniform measurement method is elaborated, consisting of 3 modules: washing method (1), sampling and pre-treatment (2) and analysis (3).

2.1 Addressing research questions in literature review

2.1.1 Inventory of relevant parameters for fibre release

In recent years, there has been emerging attention to the presence of microplastic fibres originating from (washing) textiles. This attention has led to a large number of studies investigating fibre release during washing. (Galvão & al, 2020) (Napper I., 2016) (Cai, et al., 2020) (De Falco F. , 2018) (De Falco F., 2019) (De Falco F. , 2020) (Tiffin & al, 2021) (Hernandez E., 2017) (Zambrano M. C., 2019) (Jönsson C., 2018) The diversity of different measurement methodologies in these studies means that the results of the many studies are difficult to compare. (Koelmans A. A., 2019) However, the studies do provide a good overview of the various parameters that influence fibre release during washing. These fibre release parameters can be divided into two categories; material properties and washing conditions. Based on available literature (Galvão & al, 2020) (Napper I., 2016) (Cai, et al., 2020) (De Falco F., 2019) (De Falco F. , 2020) (Tiffin & al, 2021) (Hernandez E., 2017) (Zambrano M. C., 2019) (MERMAIDS, 2019) (Jönsson C., 2018), a recent review article on microfibre release from textiles (Rathinamoorthy R., 2020) and input from the Stakeholder Network MPV, an overview of the relevant parameters per category has been made. Table 2 lists these parameters.

Table 2 Overview of relevant parameters for fibre release.

Category	Parameter
Material properties	Polymer type (polyester, nylon) Polymer origin (virgin, worn, biobased, recyclate) Fibre properties (length, diameter, strength, clarity) Yarn properties (construction, breaking strength, twist, structure, finish) Fabric properties (construction, density, hairiness, compactness of the fibres, thickness, structure, finish)
Washing condition	Duration Temperature Use of detergents and fabric softeners Water volume Type of washing machine (front load, commercial, industrial) Number of wash cycles Washing load

In most studies, some of these parameters are more prominent in their role in the generation of MPVs during washing. For the material properties, this applies to the twist of the yarn, the fibre type, the fabric structure and the density of the yarn. With regard to washing conditions, this applies to the presence of detergents and fabric softeners, washing at high temperatures, the type of washing machine and the water volume of the wash. (Rathinamoorthy R., 2020) These parameters and their expected impact on fibre release are defined in Table 3.

Table 3 Parameters and their influence on fibre release

Parameter	Impact on fibre release
Yarn twist	A higher yarn twist results in lower fibre yield during washing.
Fibre type	A staple fibre has a higher fibre deposit than continuous filaments.
Fabric structure	Fabric with a higher yarn density per unit length is stronger, resulting in less fibre shedding during washing.
Detergents	The presence of detergents in the washing process increases fibre loss compared to washing with water only.
Washing temperature	High temperature washing removes the protective layer around the fibres, damaging the fabric and increasing fibre shedding during washing compared with low temperature washing.
Type of washing machine	A top loading washer has a higher fibre deposit compared to a front loading washer.
Water volume	A higher water volume results in higher fibre deposit during washing.

2.1.2 Identification of most relevant textile types and type of synthetic fibres

The generation of synthetic fibres as a result of washing clothes is estimated to be one of the largest sources of microplastics in Dutch waters. (Verschoor A., 2018) But what type of polymer is this about? What is the most relevant type of textile and what type of synthetic fibres is this about?

Since the 1990s, the share of synthetic fibres in the textile industry has exceeded the share of natural fibres such as wool, silk and cotton. (TextileExchange, 2020) In 2019, the production of synthetic fibres was around 70 million mt (mt = metric tonnes), which amounted to 63 % of the total fibre production (111 million mt, see Figure 2). Of this 63 %, the majority is polyester (~57.7 million mt), with nylon (referred to as polyamide in Figure 2, ~5.6 million mt) following.

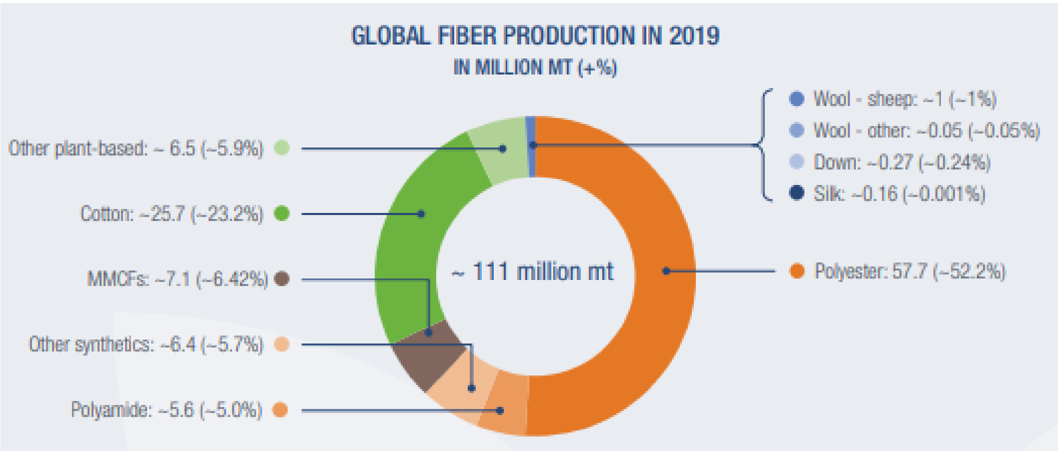

Figure 2 Worldwide fibre production in 2019 in million mt. MMCF = Man Made Cellulosic Fibres. Image taken from source: (TextileExchange, 2020)

Polyester is the most commonly produced synthetic fibre and is also increasingly emerging as the largest contributor to the MPV pollution chain to water. (Rathinamoorthy R., 2020) The vast majority of synthetic fibres detected in water are polyester fibres, but the presence of other synthetic fibres of nylon and acrylic have also been demonstrated in water. (Napper I., 2016)

This is confirmed by the MPV stakeholder network: the composition of textiles is in 95% of cases: cotton, polyester, or a polyester-cotton mix. Cotton consumption has been increasing worldwide for several years, but cotton production is difficult to scale up. To compensate, more and more polyester is added to blends. For an optimal result, polyester is produced in such a way that it mixes well with the cotton: as a staple fibre. The addition of polyester also has its advantages: the fabric becomes firmer, has a longer life and is cheaper.

In summary, both the literature and the MPV stakeholder network point to a clear model fibre: the polyester fibre. A distinction is also made between two types of fibre: continuous filaments and staple fibres. Both fibre types are widely used in the textile industry. (Wang D., 2015)

2.1.3 Identification of quantification unit for method

Prior to establishing a uniform measuring method, it is essential to get an impression from input from the MPV stakeholder network what the desired unit of quantification is. What information do they need to address MPV emissions to the environment? This has a strong influence on the final sampling, method of sample preparation and method of quantification.

An overview of the most commonly used units from the literature is given below:

- Number of (plastic) fibres / volume of water
- Number of (plastic) fibres / mass of textiles washed
- Number of (plastic) fibres / wash cycle
- Mass (plastic) fibres / volume of water
- Mass (plastic) fibres / mass of textiles washed
- Mass (plastic) fibres / wash cycle.

In the MPV stakeholder network, there are several parties that will each measure at a different point in the chain. For instance, measurements will be taken immediately after a washing machine, but also further down the chain at the water treatment plant. A unit that requires information from the washing process, such as the amount of washed textiles, is unsuitable for a number of places in the chain because this information is lost. It is therefore important that the chosen unit is independent of information from the washing process. The MPV Stakeholder Network also revealed a need to look at the quantities of MPVs per volume of water. The units that remain are: number of (plastic) fibres/volume of water and mass of (plastic) fibres/volume of water. Depending on the method of analysis used, the number of fibres or the mass of fibres will therefore need to be determined. Considerations for determining the most appropriate method of analysis are discussed in the next section (see Module 3 Analysis).

2.2 Draft uniform measuring method

The concept measuring method is divided into three modules; washing, sampling and the analysis, some of which are divided into several steps. Module 1 consists of a single step: washing. Module 2 consists of two steps: sampling and sample preparation. Module 3 also consists of two steps: isolation and analysis. An overview of the different modules and their steps is shown in Figure 3.

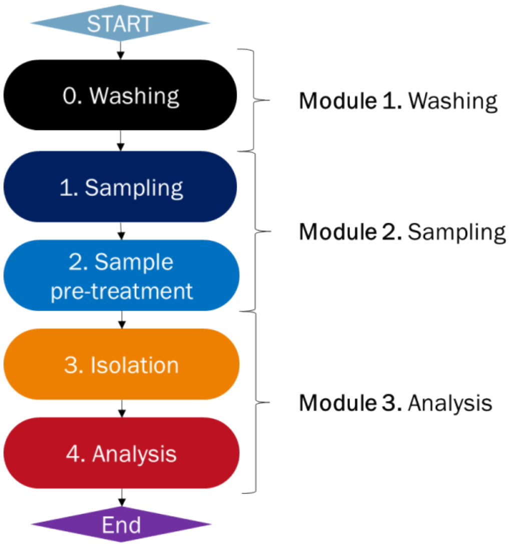

Figure 3 Overview of different steps in the draft measuring method.

2.2.1 Module 1. Washing

In the following module an overview is given of developed washing methods known from relevant research initiatives and advice is given on which washing method can be applied for the uniform measuring method.

In order to minimise experimental variables, several agencies have been (or are currently) working on laundry methods for measuring fibre release during washing. These washing methods specify how the textile has to be prepared prior to washing (textile pre-treatment), what type of washing machine is used, what washing programme and detergents are used and how the machine is rinsed after washing. It is important to note that this concerns the recording of specific experimental washing conditions for, for example, studies on improving textiles in order to prevent MPV loss. At certain points in the MPV textile pollution chain, it is not possible to adjust these washing conditions, e.g. at industrial laundry services or at water treatment plants. In these cases, the measuring method will start with the sampling of the fibres from the water (Module 2).

An inventory was made of washing methods that have already been used and developed: the ISO 105-C06 method (ISO, 2010), the Leeds method (Tiffin & al, 2021), the INDITEX method (INDITEX, 2019), the Eurofins method (Eurofins, 2020) and the CNR[5] method (MERMAIDS, 2019)[6]. An overview of these methods is shown in Table 4.

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[5] CNR: Home | Consiglio Nazionale delle Ricerche (cnr.it)

[6] MERMAIDS: LIFE 3.0 - LIFE Project Public Page (europa.eu)

Table 4 Overview of 5 different experimental washing methods.

Method	ISO 105-C06	Leeds	INDITEX	Eurofins	CNR
Application	Blend of fibres (ISO 1833)	Synthetic fibres and blends	Synthetic fibres and blends	Synthetic fibres and blends	Synthetic fibres and blends
Textiles pre-treatment	Conditioning according to ISO 139: 20 ºC +/-2 ºC; 65% humidity	In the oven (At 50 ºC for 4h)	Conditioning: 20 ºC+/- 2 ºC, 60-68 % humidity	Conditioning: 20ºC+/- 2 ºC, 60-68 % humidity	n/a
Washing machine	Wascator according to ISO 6330	Gyrowash (lab machine) Industrial/ household laundry	GIRBAU Industrial/ Household laundry	7 L cylinder, with perpendicular movements	Conventional BOSCH machine
Wash programme	According to labels and washing instructions	45 min at 40 ºC - 360 mL deionised water+ 50 metal balls	According to households and professional washing programmes: 60 min. at 40 ºC (conventional), 30 min at 20 ºC (delicate), 30 min at 20 ºC (wet cleaning)	Using discs, 30 min, 48 rpm	Synthetic fibres: 1h 47 min. at 40 ºC and 1200 rpm
Detergent	No detergent	n.a.	Commercial detergents (liquid)	n.a.	n.a.
After wash After rinse	2 consecutive washes included in method	Rinsing tubes with distilled water	1 after wash included in method + 1 drain wash	1 after wash included in method + 1 drain wash	2 after washes

The ISO method concerns a washing procedure described in ISO 105-C06 (published in 1994, revision in 2010) and is used as a standard for textile testing for colour fastness. This already developed standard is also used by several parties for research on MPV release during washing, however, this method is not specifically developed for MPV research. The Leeds Washing Method was developed by the University of Leeds (UoL) in collaboration with the Microfibre Consortium (tMC[7]). The method is described in a recently published article by Tiffin (Tiffin & al, 2021). Currently, this method has been proposed to Working Group 34 of ISO Commission 38, which is working on establishing measuring methods for quantifying microfibre release during washing (for more information on this working group and the related CEN working group section, see 3.3.2). The INDITEX and Eurofins methods are internally established procedures that are not affiliated to any consortium or other initiative. The CNR method was developed in the MERMAIDS project, a 3-year EU LIFE+ project investigating mitigation strategies for microplastic fibres caused by textile washing. The MERMAIDS project was completed at the end of 2016. The CNR method is also used for the WOMA label[8].

Advice module 1

Due to the need to link up with other/European initiatives for the further development of a uniform measuring method, it is recommended that Module 1 be linked up as much as possible to the CEN-ISO method that is expected in early 2024. This method will be very similar to the Leeds washing method as described in the article by Tiffin (Tiffin & al, 2021). Interviews with several European stakeholders (RISE, Centexbel) and interviews with participants of the MPV Stakeholder Network showed that this recently published article by Tiffin is widely supported in the textile world. In addition, this method has most recently been compared to other methods (Leeds 2021, CNR 2019 and ISO 2010) and has been established in cooperation with several European parties (CIA[9], tMC). This washing method is therefore already known to important European initiatives and is therefore the most suitable for possible affiliation.

[7] tMC: The Microfibre Consortium

[8] Benchmark for plastic microfiber release - Ocean Clean Wash

[9] CIA: Cross Industry Agreement - EURATEX

2.2.2 Module 2. Sampling

Depending on where you want to determine the MPV content, different sampling and sample preparation steps are required. This is because these steps are highly dependent on the type of water (surface water vs. end-of-pipe sampling closer to the source), the contaminants present in the water and the expected concentration of MPVs (Okoffo E. D., 2019). In the flow diagram below (see Figure 4), module 2 is schematically represented. In this module, a distinction will be made between 2 steps: the sampling (**step 2a**) and the sample pre-processing (**step 2b**). For each step, an overview will be made of the most commonly used methods and the corresponding considerations for the uniform measuring method.

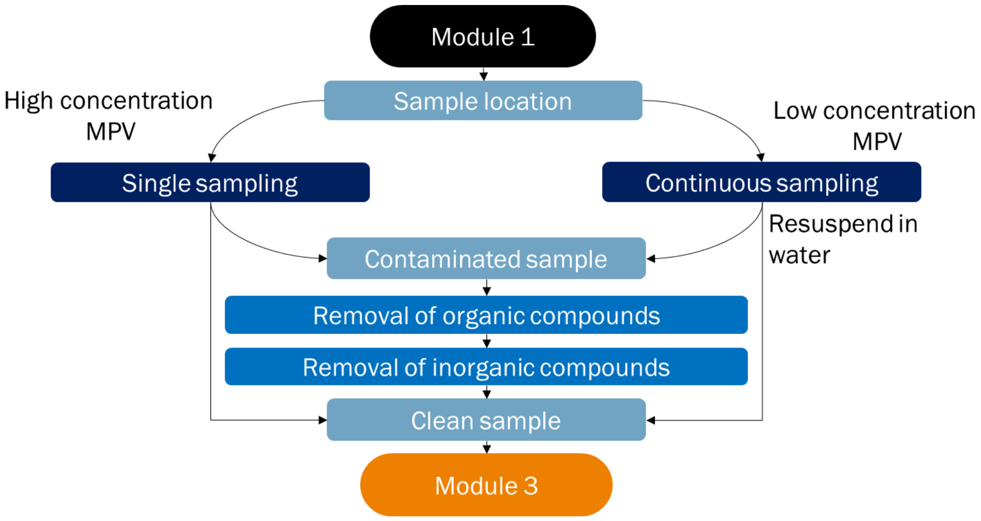

Figure 4 Flow diagram module 2 (sampling).

Sampling

Sampling the right volume of water is an essential first step towards accurate identification and quantification of MPVs in water. Due to the large range of different types of waters in the whole MPV textile pollution chain, it is also necessary to apply different types of sampling strategies for the detection of MPVs through the chain. For sampling MPVs in water, two different sampling strategies are distinguished: *single sampling* and *continuous sampling.*

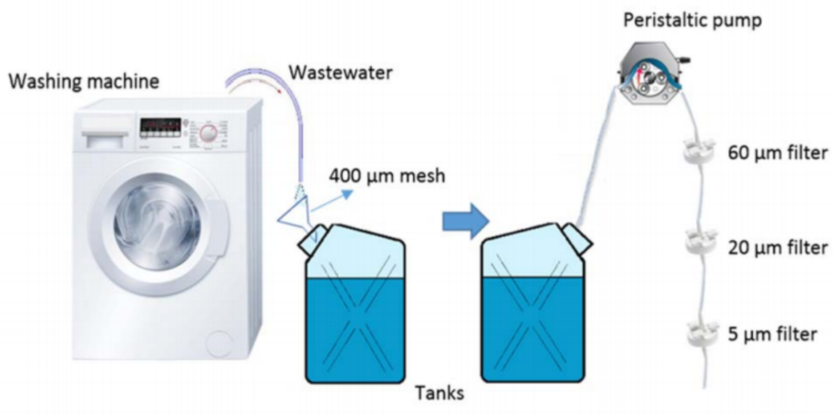

Figure 5 Schematic representation of single sampling of the waste water from a washing machine. Figure taken from source. (De Falco F., 2019)

Single sampling

We speak of single sampling when a certain volume of water is sampled at a specific time. (Okoffo E. D., 2019) A simple example of single sampling is filling a 1 L jerry can or bucket in the surface water of a river. (Razeghi N., 2021) (Pieke, 2021) This type of sampling has the limitation that only small volumes of water can be sampled at a time, so this technique is mostly used in situations where a high concentration of particles to be measured is expected. Furthermore, this technique is only applied when it is possible to collect the entire water volume.

This is, for example, the case after a washing machine; the drain hose can be connected to a sample vessel to collect everything. Between the drain and the waste vessel, a filter can be placed to remove the larger pieces (particles > 5 mm) from the matrix. A schematic arrangement of this type of sampling is shown in Figure 5 (De Falco F., 2019). In this setup, after the single sampling, a cascade filtration (set of sieves/filters on top of each other) driven by a peristaltic pump was also used. The combination of single-sample collection and cascade filtration is a simple method to obtain a pre-selection of the fibre size. The individual filter material can then be analysed by size distribution.

Continuous sampling

As mentioned above, the amount of water to be sampled is strongly dependent on the concentration of particles to be measured in the water. The analysis of water with low concentrations of particles to be measured therefore also requires large volumes of water in order to be able *to measure a minimum number/mass of particles*. Volume-reducing sampling by means of continuous sampling is the preferred sampling strategy for water with low concentrations. We speak of continuous sampling when sampling is carried out over a longer period of time. This can be done by means of active filtration through a pump system and cascade filtration (see right-hand set-up in Figure 5) (WUR/KWR, 2019), the use of in-line centrifuge equipment (Hildebrandt L., 2019) or passive sampling through various types of nets in the water (Razeghi N., 2021). Because particles are collected over a longer period of time, the final sample to be analysed will be relatively concentrated and it is not necessary to transport large volumes of water to a laboratory for analysis (Huppertsberg & al, 2018).

An example where continuous sampling was used as a sampling strategy is in the TRAMP protocol (WUR/KWR, 2019). A representation of the setup used is shown in Figure 6. In this setup, a pump with a flow meter passes the water through a set of sieves after which the remaining water is discharged back into the water through a tube. (WUR/KWR, 2019)

When using nets for continuous sampling, the disadvantage is that only one pore size can be used (Huppertsberg & al, 2018). In addition, the use of nets also has the consequence that less large volumes can be sampled because of blockages that occur in the nets. For these reasons, the use of (trawl) nets for sampling microplastic fibres is not recommended (Razeghi N., 2021).

Many studies on the presence of microplastic fibres in different types of surface waters use various sampling techniques to capture the fibres. Evaluation of these techniques shows that in order to capture most, if not all, fibres, the water must be filtered through pore sizes smaller than the average (micro) fibre diameter (Ryana P. G., 2020). This means that in order to sample as many of the fibres in the water as possible, a minimum pore size of between 15 - 20 µm should be used. However, using these pore sizes results in the filters quickly becoming clogged. To avoid this, the use of a stepwise cascade filtration is recommended: this sampling strategy allows the fractionation of particles of different size classes and minimises the clogging of filters with fine pores (Huppertsberg & al, 2018) (ASTM International, 2020). It is recommended to apply the following range of stainless steel (SS) screens: 5000 µm, 500 µm, 150 µm, 20 µm (ASTM International, 2020). If necessary, a final sieve of 5 µm can be added.

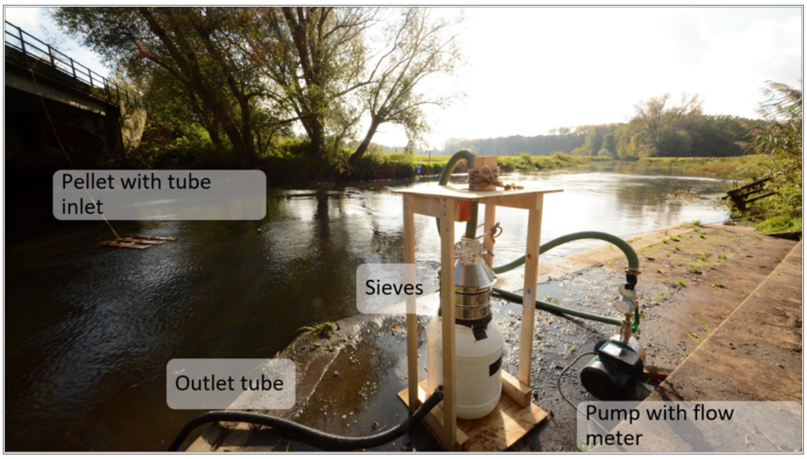

Figure 6 Representation of sampling set-up as described in the TRAMP protocol. (WUR/KWR, 2019)

An alternative volume-reducing sampling technique is by in-line centrifugation. (Hildebrandt L., 2019) A centrifuge system is used which removes the solid particles (including MPVs) from the water. The technique seems promising because disadvantages such as filter clogging and particle size discrimination can be reduced (Hildebrandt L., 2019).

Sample pre-treatment

After the water has been sampled, depending on the contamination in the water, some pre-treatment will be necessary before analysis. For the reprocessing of the sample, both the organic and the inorganic components will have to be removed from the matrix. This is done through degradation (removal of organic components) and separation based on density (removal of inorganic components) (Okoffo E. D., 2019).

Removal of organic components

The most common methods for removing organic components from water samples are degradation in an acidic or alkaline environment, enzymatic degradation and oxidation. (Lusher A. L., 2020) (Sun J., 2019) (Hurley R. R., 2018) However, it has been shown that when removing organic components by adding acids and alkalis to the matrix, common plastics and polymers such as nylon and polyester also degrade in solution. (Enders K., 2017) (Al-Azzawi M. S. M., 2020)

In contrast, the effectiveness of enzymatic degradation for the removal of organic material while retaining polymers and plastics has been demonstrated. However, this method carries the disadvantage of high cost and is time consuming, taking up to 2 weeks per sample. (Lusher A. L., 2020) Due to these factors, enzymatic degradation is not suitable for processing large quantities of water samples.

In the case of degradation in the presence of such hydrogen peroxide (oxidation), the degree of efficiency is strongly dependent on the temperature of the reaction. At higher temperatures, degradation of certain polymers takes place. (Koelmans A. A., 2019) By adding Fenton's reagent (ferrous catalyst), this reaction can be performed at lower temperatures, whereby an effective removal of at least 80% of the organic components is feasible. (Hurley R. R., 2018)

Due to the lower cost and shorter reaction time, degradation by oxidation in the presence of the Fenton's reagent is the recommended method for removing organic components from water samples.

Removal of inorganic components

For the removal of inorganic components from water, density separation using salt solutions is commonly applied. (Lusher A. L., 2020) (Campanale C., 2020) This density separation based on the density of salt solutions causes low-density microplastic particles to float and the higher-density inorganic components to sink to the bottom of the liquid. (BASEMAN, 2018) Commonly used salt solutions are sodium chloride (NaCl (aq), density 1.2 g/cm^3), zinc chloride (ZnCl2 (aq), density 1.5 - 1.7 g/cm^3) and sodium iodide (NaI (aq), 1.6-1.8 g/cm^3).

Density separation with a NaCl solution is cheap and ensures that the low-density fibres float to the surface. However, this technique is not effective for higher density polymers, such as polycarbonate, polyurethane or polyester. (Campanale C., 2020) Effective separation of these polymers requires density separation with ZnCl2 or NaI. Here, ZnCl2 is the most obvious choice because the cost of this method is lower than that for NaI. (Rodrigues M.O., 2020) It has also been shown that the solution can be reused, with an efficiency of over 95% after five reuses. Despite the fact that the use of ZnCl2 is considered the most effective and cheapest, it is a very dangerous and corrosive substance. Therefore, careful handling, disposal and recycling of this salt solution is essential when it is used. (BASEMAN, 2018)

Figure 7 shows example arrangements of the different pre-treatment steps described in module 2.

Figure 7 Example set-ups for degradation (left and centre) and density separation (right) for the removal of organic and inorganic components. Image taken from source (Campanale C., 2020).

2.2.3 Module 3 Analysis

The final module in the measuring method is the analysis of the MPVs. Module 3 consists of two different steps; the isolation (**step 3a**) followed by the analysis (**step 3b**). For the analysis of MPVs in water, several analytical techniques are available which can be divided into 4 different groups; mass determination, microscopic techniques, spectroscopic techniques and thermo-analytical techniques (see Table 5 and (Primpke S., 2020)) A very comprehensive explanation of these analytical techniques can be found in the article by Primpke *et al*. (Primpke S., 2020) The isolation step of the MPVs depends on the analytical technique used.

Table 5 Concise overview of MPV analysis techniques.

Analysis techniques	Examples
Mass determination	Determination of mass by means of an analytical balance
Microscopic techniques	Light microscopy, Electron microscopy (such as SEM)
Spectroscopic techniques	Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy (Raman)
Thermo-analytical techniques	Pyrolysis or Thermal Extraction and Desorption combined with Gas Chromatography - Mass Spectrometry (pyr-GCMS and TED-GCMS)

Mass determination

As can already be deduced from the name of this technique, mass determination is used to determine the mass of particles in water. This is usually done by filtering the entire water sample and then weighing the filter (before and after) (Tiffin & al, 2021). With this technique, it is therefore very important that the mass that is determined actually originates from the solid particles in the water and not from contaminants from the filter itself or other contaminants present. It is therefore essential that the filters are cleaned before and after filtration by, for example, drying them in the oven (example: at 50 ˚C for at least 4 hours) (Tiffin & al, 2021). This method uses glass fibre filters with a pore size of 1.6 µm. A schematic representation of the working method of this analysis technique is shown in Figure 8.

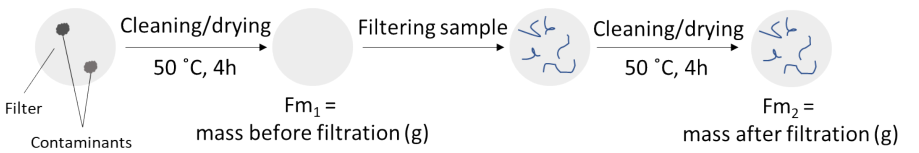

Figure 8 Schematic diagram of the isolation and analysis of MPVs by mass determination.

To finally determine the mass of solid particles in the water (the residue), the following formula can be applied:

$$\mathrm{Mr} = \text{mass of residu (g)} = \mathrm{Fm2} - \mathrm{Fm1}$$

Where:

Fm_1 = dry mass of the filter before filtration (grams)

Fm_2 = dry mass of the filter after filtration (grams)

By applying this analytical technique to determine MPVs in water, insight is gained into the total mass of the solids in the matrix. This technique is fast, simple and therefore very cheap (Tiffin & al, 2021). However, this technique does not provide insight into the polymer composition, the number of fibres and their size. The mass of the residue is determined, which means that this analysis technique often overestimates the proportion of MPVs because it is not possible to distinguish between the fibres and any remaining contamination. This technique is therefore only suitable when the presence of other types of contaminants in the water can be minimised and/or excluded.

Microscopic techniques

When microscopic techniques are applied for the analysis of MPVs in water, the number and size of the particles are determined by means of images. This image is usually obtained by filtering the water and then viewing it under a microscope. Because an image must be made, filtration of the entire water sample is often not possible due to an accumulation of fibres on the filter, which makes discrimination between fibres impossible (Galvão & al, 2020). To avoid this, it is therefore necessary to analyse only part of the sample by means of so-called sub-sampling. This sub-sampling is strongly dependent on the concentration of fibres (and other solid particles) in the water and will therefore have to be optimised per type of water/situation. In addition to filter images, in-line images can also be made using Dynamic Image Analysis (DIA) (Sympatec, 2021) (Hohenstein, 2021). Several techniques based on laser diffraction make it possible to take images of particles in a controlled water flow in order to determine the number of particles and their size.

Thus, on the basis of an image taken, information can be obtained about the size and number of particles in water. A major disadvantage of microscopic techniques is that no distinction can be made between polymer types. This is only possible when a pre-processing step is involved in which other components are removed from the matrix (Hohenstein, 2021). Thus, the more complex the mixture to be measured is, the more complex the pre-processing will be when using this technique. Microscopic techniques are therefore fairly labour intensive, especially when analysing complex water samples.

Spectroscopic techniques

For the analysis of MPVs in water using spectroscopic techniques, information on the chemical composition of the particles in the matrix is obtained on the basis of recorded spectra, for example by means of Fourier-transform infrared spectroscopy (FTIR) or Raman spectroscopy (Raman) (Corami F., 2020). By combining spectroscopic techniques with microscopic techniques, information about the size and numbers of particles in the matrix can be obtained in addition to polymer identification. (Napper I., 2016) First, an image is made of the particles present, after which a spectrum can be recorded per particle (Kaplanscientific, 2021). Because a (static) microscopic image of the particles in the matrix also has to be made here, the same isolation strategy is needed as for microscopic techniques. Depending on the amount of particles in the water, the entire water sample or only a part of it can be filtered. Thus, by combining spectroscopic techniques with microscopic techniques, the number, size, shape and polymer type of the particles in the water can be determined.

Despite the fact that a lot of information can be obtained using this technique, this method of analysis also has disadvantages. For example, the purchase costs of the measuring equipment are often high (Primpke S., 2020), this technique requires the necessary sample pre-processing (labour intensive) (Huppertsberg S., 2018) and the smaller fibres (< 10 μm for FTIR, < 1 μm for Raman) cannot be analysed (Huppertsberg S., 2018).

Thermo-analytical techniques

Analytical methods based on thermo-analytical techniques such as thermogravimetry (TGA), differential scanning calorimetry (DSC) and pyrolysis (Pyr), are also applied for the detection of MP and MPVs in different types of matrices (Huppertsberg S., 2018) (Braun U., 2020). The most commonly applied thermo-analytical techniques are TGA-DSC (based on differences in heat capacity), Pyr gas chromatography coupled to mass spectrometry (Pyr-GC-MS) and thermal extraction and desorption gas chromatography coupled to mass spectrometry (TED-GC-MS, based on pyrolysis products of polymers) (Huppertsberg S., 2018). With these techniques, information about the polymer composition of the sample can be obtained.

TGA-DSC is considered a cheap and easy method that is already widely used in the polymer field. (Majewsky M, 2016) It is a well-known technique, however, it has its limitations when applied to the analysis of complex water samples containing MPVs. Because some polymers have overlapping transition temperatures, it is not possible to apply this technique to all types of polymers. It has also been shown that measurements become more unreliable as more complex mixtures are analysed (due to, for example, additives, impurities and different particle sizes). (Huppertsberg S., 2018) Furthermore, this technique requires extensive pre-processing (filtration, matrix separation and oxidation) compared to other thermo-analytical techniques such as pyr-GC-MS and TED-GC-MS.

With Pyr-GC-MS, the sample is pyrolyzed under inert conditions after which the thermal degradation products are captured. These degradation products are then separated using a column in the GC and identified using mass spectrometry (Dümichen E., Fast identification of microplastics in complex environmental samples by a thermal degradation method, 2017) (Huppertsberg S., 2018) This method works well for the identification of single particles and can analyse between 0.1 - 0.5 mg of sample per measurement. A pre-selection (weighing of a sub-sample) with this technique is therefore a requirement (Dümichen E., Fast identification of microplastics in complex environmental samples by a thermal degradation method, 2017) One of the disadvantages of this technique is that blockages can occur due to pyrolysis products cooling down during the measurement, which often results in high maintenance costs. This is not the case for TED-GC-MS, which uses the principle of thermal extraction and desorption. (Dümichen E., Fast identification of microplastics in complex environmental samples by a thermal degradation method, 2017) The thermal products are, so to speak, trapped in so-called "solid-phase adsorbers", after which analysis with GC-MS allows the identification and quantification of different types of polymers and prevents the formation of blockages. In both techniques, the degradation products are measured, however, TED-GC-MS offers the possibility to measure larger quantities at a time (up to 1 g (Braun U., 2020)), thus requiring less pre-processing and pre-selection. Despite the fact that this technique does not provide information on the numbers and sizes of particles in the matrix, it offers a possibility for fast, complete chemical identification and quantification of different types of polymers (Dümichen E., Fast identification of microplastics in complex environmental samples by a thermal degradation method, 2017), (Dümichen E., 2019)

Comparison of analysis techniques

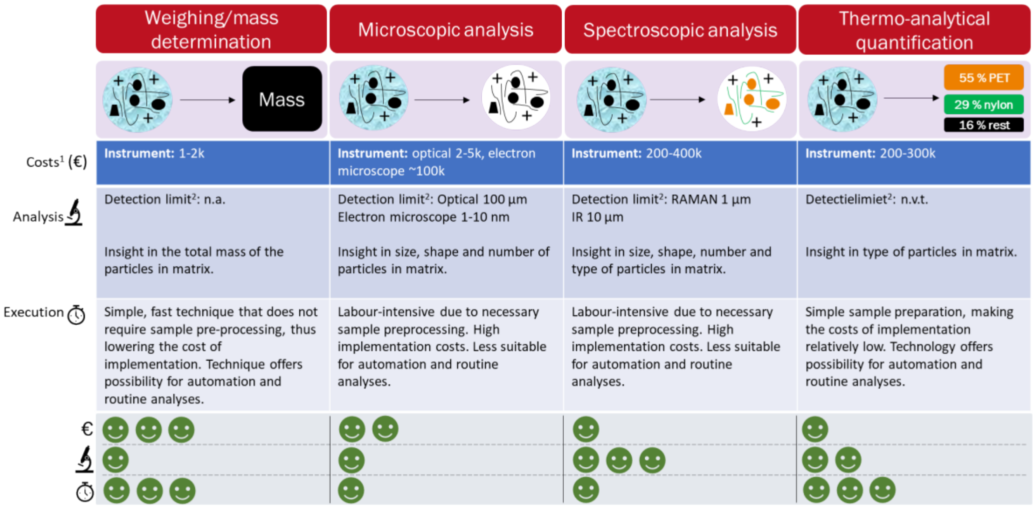

Figure 9 Overview of instrument costs, analysis and implementation of the four different analysis techniques[1]. The instrument costs are a rough estimate based on the article by Primke et al. (Primpke S., 2020) These costs can vary greatly from country to country [2]. The detection limit represents the minimum size at which reliable measurements can still be made.

An overview of the analysis techniques is shown in Figure 9. For each analysis technique, the instrument costs, analysis and implementation have been specified. Mass determination is a fast, cheap and simple technique that gives insight in the mass of the particles in the matrix. However, the technique provides little information on the chemical composition and it is not possible to distinguish between the fibres and any remaining contamination, which often leads to an overestimation of the proportion of MPV.

Microscopic techniques are relatively cheap to buy (depending on the desired resolution) and provide insight into the number and shape of the particles. However, sample preparation and isolation is required, making the technique labour-intensive and involving high analysis costs. In addition, an incomplete picture arises because it is not possible to distinguish between different types of polymers.

This *is* the case when microscopic techniques are combined with spectroscopic techniques. Besides numbers and particles, this combination also offers the possibility of identifying different types of polymers (up to a size of about 10 µm). As with the microscopic techniques, sample pre-treatment and isolation are necessary, making the costs of this technique high (labour intensive + purchase costs). In addition, the required extensive sample pre-processing makes these techniques (both microscopic and spectroscopic) complicated for routine implementation (Dümichen E., 2017).

Thermo-analytical quantification with, for example, TED-GC-MS offers the possibility for fast identification of the polymer types present in a sample. Compared to the spectroscopic and microscopic techniques, the pre-processing is simple, so this technique offers the possibility for automation and routine analyses. A detailed cost estimate of the analysis techniques made by Primpke et al. (Primpke S., 2020) is included in this report (see Appendix A).

2.3 Conclusion of knowledge inventory

Most relevant parameters for fibre release

Several studies have identified a number of parameters that appear to play an important role in the generation of MPVs during washing. These parameters can be divided into two different groups: material properties and washing conditions. According to the literature, the following parameters have a major influence on fibre release: the twist of the yarn, the fibre type, the fabric structure, the density of the yarn, the presence of detergents and fabric softeners, the temperature during washing and the water volume of the wash.

Most relevant textiles and types of synthetic fibres

Based on data from the literature and information from the MPV stakeholder network, a clear, relevant type of textile emerges: polyester. A distinction is also made between two types of fibre: continuous filaments and staple fibres. Both types of fibre are widely used in the textile industry.

Most suitable unit for quantification

The most suitable unit for quantification is a unit that is independent of information from the washing process. This is then either number (plastic) fibres/volume of water or mass (plastic) fibres/volume of water. Based on the evaluation of analytical methods, the latter is the more obvious choice between the two.

Draft uniform measuring method

The draft measuring method is divided into 3 modules: the washing method **(module 1)**, the sampling and pre-treatment **(module 2)** and the analysis (**module 3)**. An overview of the uniform measuring method is shown in the flow chart in Figure 10.

Module 1. Washing method

Due to the need to link up with other European initiatives for the further development of the uniform measuring method, it is recommended that Module 1 be linked up as far as possible with the CEN-ISO method currently under development. This washing method will be very similar to the Leeds washing method as described in the article by Tiffin (Tiffin & al, 2021), which can be taken as a starting point for this. This washing method is also already known to important European initiatives (CIA, tMC) and is therefore the most suitable for possible connection.

Module 2. Sampling and pre-treatment

For sampling MPVs in water, a distinction is made between two different sampling strategies*: single sampling and continuous sampling*. When a high concentration of particles to be measured is expected, *single sampling* is the preferred sampling technique. Furthermore, this technique is applied when it is possible to collect the entire wash volume (directly after a washing machine). In case of a low concentration of particles to be measured, volume-reducing sampling techniques should be applied by means of *continuous sampling*.

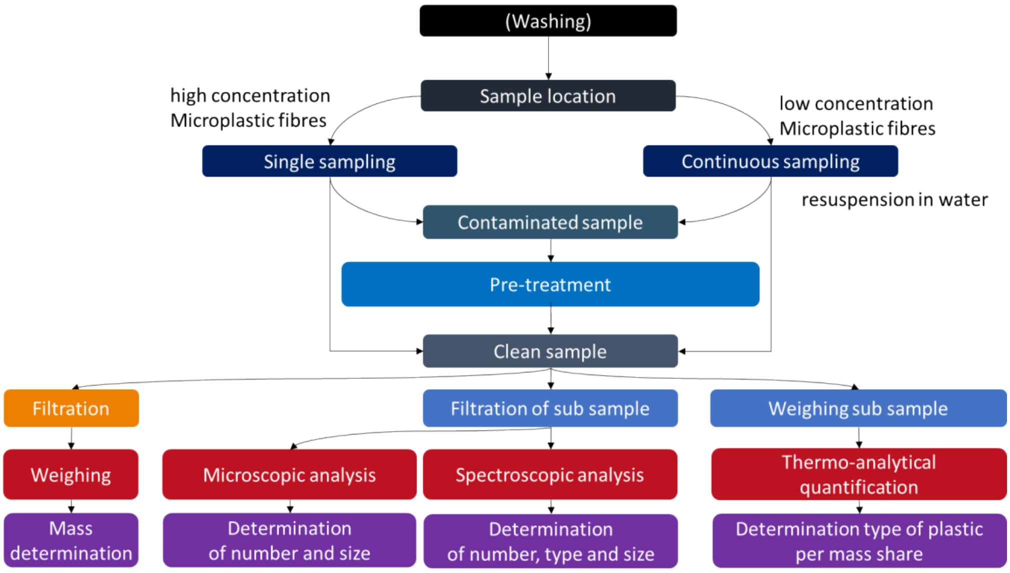

Figure 10 Flowchart draft uniform measuring method for MPVs in water.

For reprocessing of the water samples, organic and inorganic components will have to be removed from the matrix by degradation (removal of organic components) and separation based on density (removal of inorganic components).

Degradation by oxidation in the presence of Fenton's reagent is the recommended method for the removal of organic compounds due to high effectiveness and retention of polymers. For the removal of inorganic components, density separation with a solution of zinc chloride ($ZnCl_2$) is the obvious choice due to the lower costs compared to sodium iodide (NaI) and the higher effectiveness compared to sodium chloride (NaCl).

Module 3. Analysis

For the analysis of MPVs in water, several analytical techniques are available that can be divided into 4 different groups; mass determination, microscopic techniques, spectroscopic techniques and thermo-analytical techniques.

Mass determination is a fast, simple and therefore cheap technique that provides insight in the total mass of the solids in the matrix.

With microscopic techniques, information about the size, shape and number of particles in water is obtained on the basis of an image. The costs of this technique strongly depend on the desired accuracy and vary widely.

The combination of spectroscopic and microscopic techniques offers the possibility to obtain information about the size, shape and number of particles as well as the polymers present. However, the acquisition and labour costs are generally high and the smaller fibres (<10 μm for FTIR, <1 μm for Raman) cannot be analysed.

Thermo-analytical quantification with e.g. TED-GC-MS offers the possibility for fast identification of polymer types. Compared to the spectroscopic and microscopic techniques, the pre-processing is simple, which makes this technique suitable for automation and routine analyses.

Based on these considerations, it is recommended to further develop an analytical module based on mass determination and thermo-analytical quantification for the uniform measurement method. However, it is recommended that during the research and development phase this module be supplemented, if necessary, with the other techniques so that the other characteristics of the released MPV can also be properly verified and so that there is a better connection with the research into the environmental and health risks of this specific MPV.

3 Stakeholder inventory

In addition to the knowledge inventory, for a good follow-up advice it is also important to know what is going on and what initiatives have been taken to prevent MPV release from textiles into water. To gain insight into the interests surrounding MPVs in water, TNO has spoken to relevant stakeholders from the MPV Stakeholder Network.
In addition, both national and international initiatives and stakeholders regarding new measuring methods were mapped. Explicit attention was paid to existing initiatives with which the best cooperation could be sought to facilitate a European uniform measuring method.
TNO also participated in the NEN Textile & Clothing Committee, which is linked to a CEN initiative to establish a uniform measuring method for microfibres in water. A brief description of the status of this initiative is included below.

3.1 Information from the Dutch Stakeholder network MPV

Two meetings were held to share and discuss the results of this study with the MPV stakeholder network: an interim meeting on 10 May and a concluding meeting on 16 June. In addition, interviews were held with the various stakeholders from the network, divided into six groups:

Group 1 Textile industry
Group 2 Washing machine industry
Group 3 Detergents
Group 4 Industrial laundry services
Group 5 Water boards and drinking water industry
Group 6 Policy and NGO.

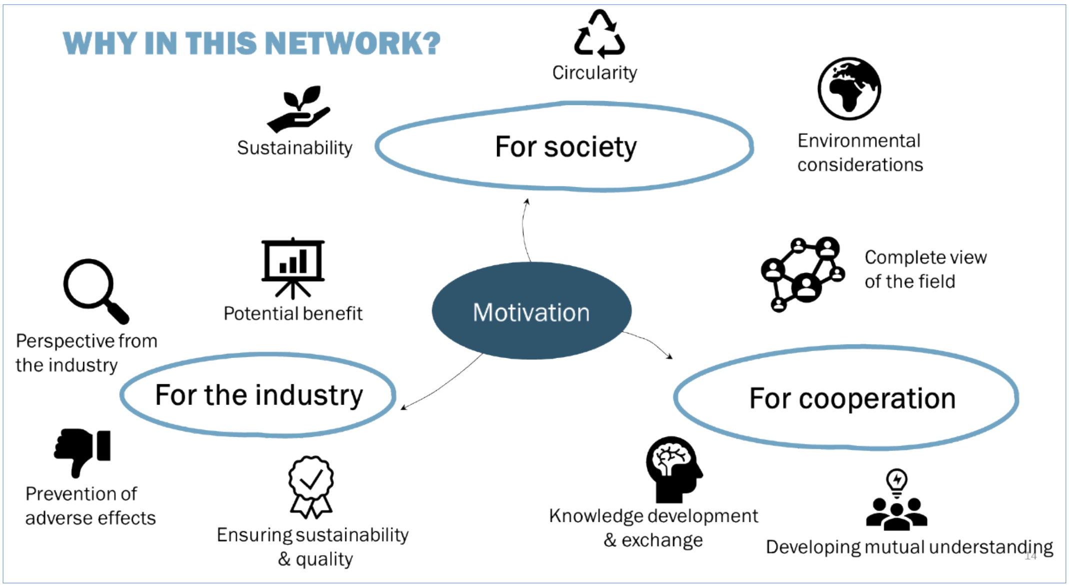

Figure 11 Reasons for Dutch parties to participate in the MPV Stakeholder Network contributing to the development of a uniform measuring method.

During these discussions, TNO talked to various stakeholders about MPV release from textiles to water: what is their position on measures concerning MPVs? What are the interests and considerations in this area within the MPV Stakeholder Network and how well is the Stakeholder Network informed about current initiatives? What solutions do the various stakeholders envisage and what is feasible in the short term? What role does the uniform measuring method play in these foreseen solutions and what has been tried so far to prevent MPV from clothing and by whom?

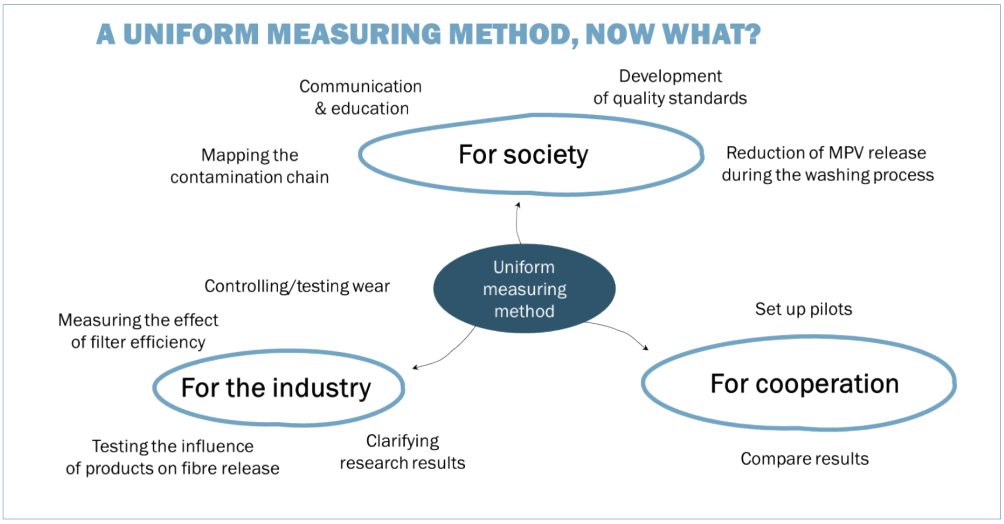

Figure 12 Expected applications of the uniform measuring method from partners in the MPV stakeholder network.

Both the motivation for participating in the MPV Stakeholder Network (Figure 11) and the way the partners expect to use the uniform measuring method (Figure 12) can be summarised in three pillars:

1. Social responsibility
2. Benefit to the industry
3. Benefit of cooperation.

Social responsibility includes, for example, a contribution to communication and education, *benefits for the industry* include the refutation or substantiation of existing claims regarding MPV release of textiles and the *benefit of cooperation* includes setting up pilots.

3.1.1 How to proceed according to the Stakeholder Network MPV

Many parties show willingness to start working with the measuring method in order to achieve a reduction of MPV in water.

The ***textile industry*** is interested in product group studies within the polyester range. What is the fibre loss per group during washing? How does this relate to the MPV problem? More insight is needed into the effect of weave density and weave structure on MPV release. For example, a test with 5-10 product categories for the two main types of yarns: continuous yarn[10] and spun staple fibre yarn[11].

For these studies, initially the measurement approach can be used for which a CEN/ISO standard is being developed. For this reason, Stakeholder Modint also participates in the NEN committee 'Clothing and Textiles'. Modint also sees the possibility of extending the existing tests to more representative situations. For example, with mixed yarns, with the addition of detergents and fabric softeners or with a full machine load.

The ***washing machine industry*** is interested in measuring MPVs in the outlet of washing machines, provided the studies cannot be linked directly to a particular brand (because of competition law). This is to get an idea of the scope of the problem and the need for filters. The washing machine industry is also interested in the effect of using filters directly at the outlet of the machine, for example with the filters of Planet Care[12]. There is concern

[10] Continuous filament: very long threads bundled into a yarn, each fibre being a long continuous filament. In 2017, this accounted for approximately 70% of polyester yarns.

[11] Spun staple fibre yarn: made of shorter pieces of staple fibres (2-3 cm) twisted around each other (spun). About 30% of yarns in 2017.

[12] PlanetCare | The Most Effective Solution To Stop Microfiber Pollution

whether these filters will not lead to higher energy consumption and whether the approach is effective given the long turnaround time of washing machines. It takes 10-20 years before all washing machines are replaced in households.
Development of other washing programmes and washing machine technology to prevent wear and tear on clothes may also be commercially interesting, but such developments are typically in the hands of the manufacturers and intellectual property. However, manufacturers must comply with the Eco-design label and MPV may become part of this in the future. For effective tests/improvements in the field of MPV in relation to washing machines and programmes, it is best to link up with the Eco-design standard development.

Industrial laundry services are also interested in measurements in wastewater, mainly at the end-of-pipe water discharge in industrial washing processes. An advantage of tests at laundry services is that the entire water column can be measured (one-off sampling), that the expected concentrations are high, and that the contamination is relatively well known. It is therefore relatively easy to take a sample in the pipe work or in a wastewater tank.
The branch organisation FTN (Federatie Textielbeheer Nederland) indicates that the washing process for industrial laundry services is virtually fixed. This makes it difficult, although commercially interesting, to conduct tests in which the washing process is optimised to prevent wear and tear/MPV release. However, information about the effect of the washing process could be obtained by performing measurements at different types of laundry services, for which the washing processes vary. In addition, the washing process can be varied somewhat more easily at laundry services, which also fall under the FTN sector organisation. If necessary, research into different types of textile can be carried out at a later stage.
Furthermore, the industrial laundry services are interested in the efficiency of lint filters for the removal of MPV. These lint filters are already used as standard in the laundry services.

The ***detergent industry*** is interested in studies related to the development of clothing protective products and is willing to support them by supplying various products. It is clear that there is an interaction between the use of detergents and the degree of wear. Tests on this have been carried out for decades, which emphasises the need to carry out MPV release tests in situations where detergent is also used. It is important for the detergent industry to be able to respond to general claims, such as that washing powder leads to more MPV loss than liquid detergent, which so far appears to be poorly substantiated.

The ***water boards*** and ***drinking water sector*** want to gain insight into the locations in the Dutch water landscape where the largest quantities of MPVs are found and where they come from. At the moment there is a rough indication, but more insight is needed to find out where intervention should take place. The water boards therefore want to carry out "hot spot" measurements. One suggestion is to carry out continuous measurements at certain hotspots for a rough indication of the composition (monitoring, quick & dirty test), supplemented by more complex measurements to determine more specific properties such as the number and size of the fibres. In addition, the water boards and the drinking water sector would like to investigate whether there is a certain type of fibre that can give a general indication of water quality.

Policy partners and **NGOs** (non-governmental organisations) focus on the prevention of plastic leakage into the environment. However, this must be looked at for each type of plastic; it is impossible to give generic advice for all types of plastic. Each plastic has different applications and moves through all chains. Here too, therefore, more insight is needed into the locations where the largest quantities of MPVs are found and what the main sources of these are for appropriate and effective policy. The expectation is that ultimately the health effect will be the decisive factor in moving society as a whole towards reducing the amount of plastic in the environment.

3.2 Dutch stakeholders and initiatives

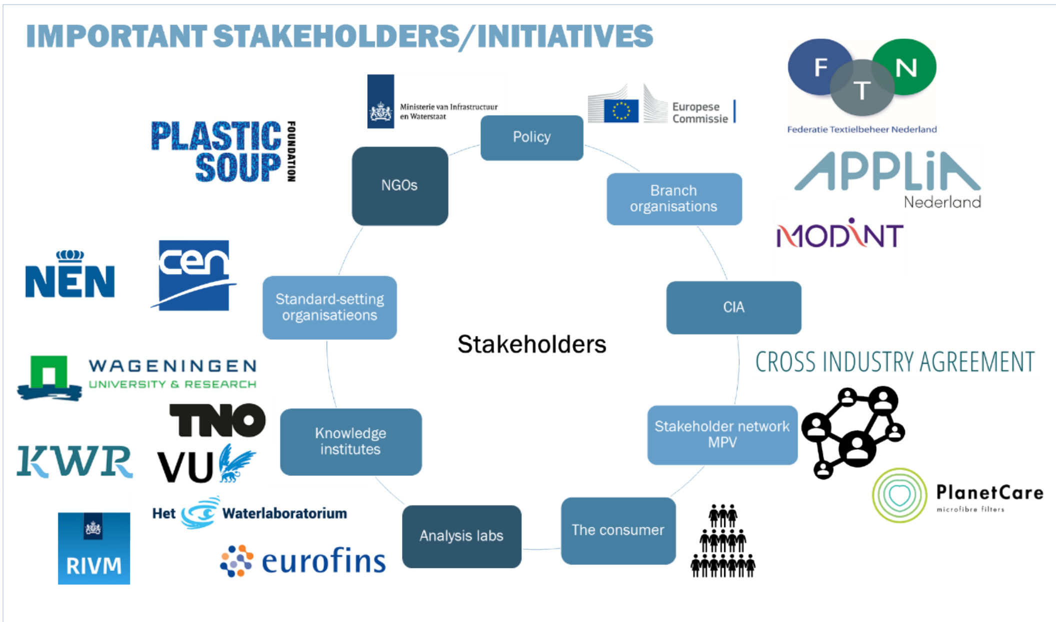

Figure 13 Overview of key stakeholders and initiatives from the perspective of the MPV Stakeholder Network.

In the Netherlands there are several stakeholders and initiatives in the field of mapping microplastics from textiles in water (see Figure 13), also outside the current Stakeholder Network MPV. Table 6 gives a brief overview of the most important initiatives and the role of some of these stakeholders. Microfibres from textiles can be considered as a subclass of microplastic particles, namely microplastics with a fibre-like shape. Therefore, where relevant, initiatives concerning microplastics in water in general have also been included.

It is noteworthy that the Dutch initiatives that also look at measuring methods have so far mainly focused on the measurement of MPV in surface water. Furthermore, academic research is taking place in the Netherlands into the health effects of MPV from clothing.[13]

Table 6 Important Dutch projects related to MPV contamination (from textiles) in water.

Project	Description
TRAMP (Technologies for the Risk Assessment of MicroPlastics) (https://www.kwrwater.nl/en/projecten/tramp/) Duration: 2015-2019 Partners: UU, WUR, KWR	Within STW's[14] Open Technology Programme, the three-year project TRAMP started in 2015. The main goal of the TRAMP project was to map the degree of contamination of Dutch inland waters with micro- and nanoplastics. New methods were also developed in this project to build up knowledge about plastic pollution. The project ended in 2019. At the end of 2021, the official report is expected containing a detailed measuring method (the TRAMP protocol) that focuses on proper sampling in surface waters. This protocol is not specific for textiles.
'Ketenverkenner' within the programme Kennisimpuls Waterkwaliteit (KIWK). (https://www.kennisimpulswaterkwaliteit.nl/) Duration: 2019-2021 Partners: KWR (lead), WUR, RIVM, Deltares	In the Kennisimpuls Waterkwaliteit (KIWK) programme, a large number of parties are working to gain more insight into the quality of groundwater and surface water and the factors that affect this quality. This is necessary to be able to take the right measures to improve water quality and increase biodiversity. The Chain Studies project in this programme investigates how these particles can be reduced earlier in the chain. The project examines the actors involved and the state of affairs within the substance group. The KIWK published the report "Deltafact Microplastics" in early 2021. This document compiles current knowledge on water quality in relation to microplastics and identifies knowledge gaps. In May 2021, the KIWK also published the report "Influencing behaviour in the textile chain", which shows how behavioural intervention aimed at reducing the emission of microplastics in textiles to ground and surface water can be developed in a scientific way.

[13] Inhalable textile microplastic fibers impair airway epithelial growth | bioRxiv

[14] STW: Stichting voor de Technische Wetenschappen (Foundation for the Technological Sciences). The NWO domain for Applied and Technical Sciences was created from STW in January 2017.

Project	Description
'Voorkomen van uitstroom microplastics naar oppervlaktewater' ('Preventing microplastics from leaking into surface water') in the Topsector Water and Maritime. (https://www.kwrwater.nl/projecten/voorkomen-van-uitstroom-microplastics-via-effluent-naar-oppervlaktewater/) Duration: 2019-2021 Partners: The Great Bubble Barrier, Hoogheemraadschap Hollands Noorderkwartier, KWR, PWN Technologies	This project investigated the 'Bubble Barrier' technology. In applying this technique, a tube with holes where air is fed into is placed in a river or canal, creating a bubble barrier. Due to the natural flow of the river and the diagonal orientation of the bubble barrier, the plastic waste is led to the bank, where it can be filtered out of the water. This technology can offer a preventive solution to prevent the flow of microplastics in treated wastewater (effluent) to surface water. It has already been proven that the Bubble Barrier has an effect on microplastics of 1 mm, in this project we will examine whether it also works for smaller particles. For the measurements the TRAMP-protocol is used with an extra reprocessing step because of a fatty substance in the effluent. The samples are analysed in duplicate with LD-IR (laser direct infrared chemical imaging system, by KWR) and broader microscopic research (by Het Waterlaboratorium). Further development of the measuring method is also part of the research.
WEPAL-QUASIMEME research (https://www.wepal.nl/en/wepal/Home/Proficiency-tests.htm) Duration: 2011-ongoing Partners: WEPAL-QUASIMEME and ring research partners	WEPAL-QUASIMEME is an organisation (in cooperation with WUR) that conducts ring tests for various types of particles and compounds in the marine environment (e.g. seawater, marine sediment and shellfish toxins). Results of a first ring test for microplastics were recently published (van Mourik L. M., 2021). The large variation in analysis techniques (n > 7) applied in this study shows that there is not yet a standard measuring method for microplastics. The next step in the research is to use more complex matrices to further develop a standardised measurement method for microplastics.
Microplastics Monitoring in the MWTL programme of Rijkswaterstaat (Public Works Department) (https://zwerfafval.rijkswaterstaat.nl/actueel/nieuws/nieuws/2021/weg-betrouwbare-microplastic-monitoring-grote/) Duration: 2017 – unknown Partners: RWS and several partners	Rijkswaterstaat (RWS) is developing a set-up for monitoring microplastics in the Rhine and Maas in cooperation with various partners. The aim is to find out which plastics are entering and leaving the Netherlands via the rivers and in what quantities. This project is part of the MWTL programme (Monitoring Waterstaatkundige Toestand des Lands) which monitors the water quality in Dutch rivers. In 2021, this project will be extended with several guerrilla studies[15] in cooperation with national partners (regional directorates, water boards, water supply companies, colleges and universities) and international partners (Belgian and German governmental bodies). These studies will pay particular attention to good sampling: depth, sedimentation, resistance of sampling equipment, differences in analysis of the Rhine and Meuse NL compared to Belgium and Germany, sampling of nanoplastics, etc.

In 2022, the above-mentioned 'Monitoring of Microplastics' project (last project in Table 6) will be collecting 'suspended matter' in surface water at 10 different locations in the Netherlands on a monthly basis. Based on these measurement results, an advice will be given with regard to the monitoring of microplastics by RWS. These samples could possibly also be analysed using the analysis methods proposed in this study to obtain a comprehensive picture along the entire chain (see activity 4 in section 5.3).

3.3 European stakeholders and initiatives

3.3.1 European cooperation

There are also several international studies and initiatives that focus on mapping and reducing microplastics (fibres) from textiles in water. In 2019, the European Green Deal made a start with the **Microplastics Initiative (European Commission)**[16] to tackle the unintentional presence of microplastics in the environment. In 2020, measures to reduce microplastics are included in the 'First circular economy action plan'[17]. This plan also states that action must be taken to further develop and harmonise methods for measuring unintentionally released microplastics, particularly from tyres and textiles, and to provide harmonised data on microplastic concentrations in sea water. The focus will be on MPV from textiles, MP from tyre wear and MP from pre-production pellets.

15 Guerrilla research: approach developed by the research approach.
16 Microplastics (europa.eu)
17 First circular economy action plan (europa.eu)

In addition, **The Microfibre Consortium**[18] (tMC) is a non-profit organisation that develops practical solutions for the textile industry in the area of fibre fragmentation and release together with stakeholders from the textile industry. Its membership includes a large number of textile manufacturers and research organisations. In collaboration with the Cross Industry Agreement (CIA) and the University of Leeds (see below), among others, tMC has developed a method for quantifying fibre release during washing. This method has been submitted to CEN in 2020 and is currently under review. In addition, on 21 September 2021, tMC will present the possible next steps in a roadmap, the "**Microfibre 2030 Commitment and Roadmap**":
"The Microfibre 2030 Commitment will form an aligned agenda for the sector against key Roadmap targets with very clear accountable outputs - ensuring a space and place for signatories across the textiles industry to take meaningful, coordinated action."

The Cross Industry Agreement (CIA)[19] is a voluntary cooperation of the five different industry associations AISE, CIRFS, EurOutdoorGroup, Euratex and FESI from the textile value chain. Within the CIA, they are working together to prevent microplastic fibre deposits during the washing of synthetic textiles. In order to find effective solutions to the microplastic fibre problem, CIA contributes to (i) the development of internationally standardised test methods (Leeds method was also co-developed by CIA), (ii) the sharing of information on the progress of research and current knowledge gaps and (iii) supporting industrial research into feasible and effective solutions. The next step for the CIA is to set up a large-scale study to collect data on the origin of microplastic fibres and their presence in the value chain. To illustrate, the following quote from the CIA brochure[20]:
"The Cross Industry Agreement community wishes to pursue a joint research project in an effort to gather mass data which is a necessary step to better understand the phenomenon. This vital comprehensive understanding of fibre fragmentation triggers can then be applied to investigate solutions and ultimately manage fibre fragmentations appropriately during the whole life cycle of products."

With the help of the harmonised test method currently under review by CEN, CIA hopes to initiate and support large-scale research in the coming period in order to ultimately come up with viable solutions to the microfibre problem

3.3.2 Standardisation (ISO/CEN/NEN)
As mentioned several times in this report, a standardised test method for determining the MPV release from textiles into water has been developed within the CIA. In 2020, this method was transferred to CEN Task Committee 248, where it is being further developed into a European CEN standard within Working Group 47 'Microplastics from textile sources'. The Netherlands is involved in the development of this standard via the NEN committee 330061 'Textiles and Clothing'[21], which also includes the Dutch working group 'Circular Textiles'. TNO has become a member of this committee and participates in the development of the related ISO standard (see Table 7).

There are also points of contact with the NEN Committee on Plastics in the Environment[22], which is also affiliated with the ISO working group ISO/TC 38/WG 34. This working group currently overlaps 1:1 with the CEN working group CEN/TC 248/WG 47, because the development of the standard takes place in Europe. This NEN committee has also recently published a White Paper[23] in which the state of affairs regarding a harmonised investigation method for plastics in the environment is charted and in which some suggestions are made for a measuring method for microplastics in water.

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[18] Website: The Microfibre Consortium | TNO has taken part in meeting on 20 May
[19] Website: Cross Industry Agreement - EURATEX. Chair: mauro.scalia@euratex.eu
[20] CIA brochure: CIA brochure (euratex.eu)
[21] Normcommissie Textiel & kleding (nen.nl)
[22] Normcommissie Plastics in het milieu (nen.nl)
[23] White paper - Plastics in het milieu (nen.nl)

Table 7 The three CEN/ISO partial standards under development for measuring MPV losses from textiles in water.

Standard	Description
prEN ISO 4484-1	Part 1: Determination of fibre loss from fabrics during washing
prEN ISO 4484-2	Part 2: Qualitative and quantitative evaluation of microplastics
prEN ISO 4484-3	Part 3: Measurement of collected material mass released from textile end products by domestic washing method

The exact content of the ISO standard under development is only accessible to members of the working group and may not be shared publicly. Currently, the development of the method in part 1 (prEN ISO 4484-1) is the most advanced. This is the method proposed by the CIA and is very similar to the approach published by the University of Leeds (Tiffin & al, 2021), in which a standardised piece of textile is washed in a laboratory environment. Publication of this standard is expected in early 2024.

Part 2 (prEN ISO 4484-2) is still very broad in scope, but corresponds more closely to the uniform measurement approach envisaged in this project. Here as well, for a quick approximation of the quantity of a type of MPV in a matrix, it is recommended to use thermo-analytical techniques. This was also the conclusion of the knowledge inventory in this study, so it is expected that the use of these techniques will fit in well with the standardised methods of the future. Publication of this standard is expected at the end of 2023.

Part 3 (prEN ISO 4484-3) is still under review. This part concerns the use of household washing machines.

3.3.3 Relevant European stakeholders outside the Netherlands

Table 8 Overview and description of relevant European stakeholders outside the Netherlands.

Organisation	Explanation
Organisation for Economic Co-operation and Development (OECD)	Within the OECD, there is an emerging focus on developing mitigation strategies for microplastics from textiles and tyres in water. For example, an inventory is being made of the current policies in the member states and it is being investigated how scientific research and screening methods can contribute to informing and supporting policy on microplastics. OECD organised in February 2020 a workshop on the theme: '*MP from synthetic textiles: knowledge, mitigation and Policy*'[24] During this workshop, mitigation strategies for reducing microplastic fibres in the environment in three different phases were discussed: the design and production phase, the user phase and end-of-pipe. As follow-up actions, the OECD is committed to more research on the emission sources of micro(plastic) fibres, harmonising measuring methods and sharing research results (e.g. in an internationally available database), increasing consumer awareness, creating standard protocols for measuring the efficiency of filter technologies and designing ECO labels for textiles with MPV release indication.
Joint Research Centre (JRC)	JRC is *the* science and knowledge centre of the European Commission.[25] It researches topics relevant to the European Commission in order to provide independent scientific advice and support. In 2020, a major collaborative study took place to identify and compare analytical methods for measuring microplastics in water. This involved 130 laboratories worldwide, including TNO and the Water Laboratory.[26] In this study, the JRC demonstrated its ability to produce a reference sample of PET for use in ring tests. The study shows that in follow-up research, the focus should be on reducing and preventing contamination during sample preparation. Although this does not specifically concern microplastic fibres from textiles, it is an important partner because of its close involvement with the European Commission.
RISE	RISE is the National Research Institute of Sweden[3] that is currently coordinating the MinShed project[27], in which RISE is investigating ways to reduce MPV release from clothing. RISE is also closely involved in tMC and a partner in the European project HEREWEAR, whose role is to develop measuring methods for micro(plastic) fibres. At European level, this research group is therefore an important knowledge partner.

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[24] Website: Workshop on Microplastics from Synthetic Textiles: Knowledge, Mitigation, and Policy (oecd.org)
[25] Website: EU Science Hub | The European Commission's science and knowledge service (europa.eu)
[26] Website: Finding the right methods for measuring microplastics in water | EU Science Hub (europa.eu)
[27] Website: MinShed | RISE

Organisation	Explanation
CNR	CNR is the National Research Institute of Italy.[5] CNR has been coordinator of the EU LIFE+ project MERMAIDS[6] (Table 9). CNR is currently collaborating with the Plastic Soup Foundation[28] within the OCEAN WASH campaign and the WOMA (Wear Off Microfibers Alliance) consortium. Within this consortium, CNR is responsible for measuring fibre release.
UoL/Universiteit of Leeds (School of Design)	At the University of Leeds, the research group of Dr. Mark Sumner and Dr. Mark Taylor collaborates extensively with tMC and the CIA. In early 2021, an article by this group was published in *The Journal of the Textile Institute* with a measuring method for quantifying microplastic fibre release during household washing ((Tiffin & al, 2021). The measuring method described in this article partly corresponds to the method currently being developed within the CEN. At European level, this research group is an important knowledge partner for the measurement of microplastic fibres.
Several NGOs	There are many NGOs taking action on this issue. STOP! Micro Waste[29], for example, placed the Great Bubble Barrier in a canal in Amsterdam in 2019 and contributes to solutions to change consumer behaviour (such as the GUPPYFRIEND laundry bag), the World Wildlife Fund set up a petition in 2019 to push the UN for an international treaty to stop plastic pollution, was a participant of TEXTILE MISSION and sells GUPPYFRIEND laundry bags, the Plastic Soup Foundation is the driving force behind the Ocean Clean Wash campaign and so on. On 23 April 2020, the 'European Strategy for Sustainable Textile, Garments, Leather and Footwear[30] was released, signed by 65 NGOs. This strategy is much broader than just the release of microplastics, but it does indicate how many organisations are currently focusing on human- and environmentally-friendly textiles.

3.3.4 European research projects

Table 9 provides a brief overview of the most relevant ongoing and completed European research projects related to microplastic fibres from textiles. This includes projects that cover a wider spectrum of MP than just MPV fibres from textiles. It is striking that the projects are getting larger over time (more partners) and that more and more industrial partners are participating in the consortia.

Table 9 Overview of the most relevant recent European research projects and initiatives.

Project/ initiative	Duration	Partners[31]	Countries	Description
MERMAIDS (https://life-mermaids.eu/en/)	2014- 2016	CNR (coordinator) Polysistec, Plastic Soup Foundation, LEITAT	Spain, Italy and the Netherlands	EU Life Programme Research into mitigation strategies for microplastic fibre release during textile washing. 500 laboratory tests leading to development of CNR washing method, list of key parameters for fibre release during washing and innovative solutions (e.g. coatings) to prevent this.
Ocean Clean Wash (https://www.oceancleanwash.org/partners/)	2016-Ongoing	PSF (lead), Amberoot, CNR, G-Star Raw, GreenEarth Cleaning, Planetcare, Uni of Plymouth, Rubymoon, Sympatex, Upset Textiles	The Netherlands, UK, Italy, US, Slovenia, Germany	Campaign initiated by the Plastic Soup Foundation to address the complex problem of microfibre release from synthetic clothing. Goal: 80% reduction of MPF from clothing in coming years by closing the textile industry loop. PSF and CNR have, in connection with this campaign, introduced the WOMA (Wear Off Microfibre Alliance) label, which allows textile producers to distinguish themselves based on the level of MPF release. The underlying method is patented by CNR. The aim is to set up a larger WOMA consortium of research parties that are allowed to issue this label.

[28] Website: Plastic Soup Foundation
[29] Website: About Us - STOP! Micro Waste (stopmicrowaste.com)
[30] Civil-Society-European-Strategy-for-Sustainable-Textiles.pdf (fairtrade-advocacy.org)
[31] For an explanation of the abbreviations of the partners mentioned, please refer to the project websites.

Project/ initiative	Duration	Partners[31]	Countries	Description
TEXTILEMISSION (https://textilemission.bsi-sport.de/)	2017-2021	BSI Deutschland (coordinator), Hochschule Niederrhein TU Dresden, Vaude, Adidas, Henkel, Miele, Polartec LLC, WWF	Germany	3-year project with interdisciplinary research to measure MPV release from types of textiles and to map their removal in water treatment. The final report is available
MinShed (https://www.ri.se/en/what-we-do/projects/minshed)	2018-2021	Electrolux Prof., Electrolux, RISE (coordinator), Bergans, Dressman, Fjällräven, Uni Gothenburg, Uni Borås, RNB, ELLOS Group, Boob Design, Filippa K, Ginatricot, Haglöfs, Houdini, STOP! MICRO WASTE, PeakPerformance, TPC Textile, Chalmers UoT, Johanneberg Science Park, Peak Innovation, Nilorn, Guppy Buddy, H&M, IKEA, Scania, Sustema, Varner , Västsvenska Kemi- och Materialklustret, Y. Berger & Co	Sweden	Project to create knowledge and guidelines that will help the textile industry to design and make (partially) synthetic clothes with less MPV emission. The project will also investigate how washing machines are designed and whether they can be equipped with a filter that reduces the emission of microplastics.
Limnoplast (https://www.limnoplast-itn.eu/)	2019-2023	Uni-Bayreuth (coordinator), NTNU, Uni-Bergen, Uni-Goteborg, Uni-Aalborg, HHL Leipzig, Fraunhofer, VU, Uni-Paris, Evonik, Uni-Wien, Kemijski Inst.	Norway, Sweden, Denmark, Netherlands, Germany, France, Austria, Italy	Investigation of the sources, chemical properties, distribution, removal, exposure, prevention and toxicity of MP in freshwater ecosystems and appropriate solutions.
Euroqcharm (https://www.euroqcharm.eu/en/)	2020-2024	NIVA (coordinator), CNR, VU, Ifremer, INCDM, Salt, CSIC, NILU, ILCO, AWI, AARHUS University, CHIRON, Eawag, OGS, Afnor	Norway, Italy, Netherlands, Germany, France, Romania, Spain, Belgium, Switzerland	Research into optimising, validating and harmonising monitoring methods for plastics in the environment (nano, micro- and macro-plastics). Not specifically for textiles.
Herewear (https://herewear.eu/)	2020-2024	CENTEXBEL (coordinator), DITF, TNO, RISE, UAL, EUT, CIRCFASH, MAIBINE, MIRTEC, FINIPUR, MITWILL, VRETENA, SOURCEBK, TCBL, QOR	Belgium, Germany, Netherlands, United Kingdom, Romania, Greece, France, United States Staten and Sweden	Development of bio-based circular textiles. The project includes a work package aimed at developing measuring methods for microfibres (natural and synthetic). RISE is the coordinator of this work package.
Ocean Innovation Challenge (https://oceaninnovationchallenge.org/ocean-innovators#cbp=/ocean-innovations/tackling-microfibres-source-investigating-opportunities-reduce-microfibre)	2021 - 2022	Forum for the Future, APAC	Malaysia, Indonesia, Vietnam and Singapore	Project 'Reducing microfiber pollution from the fashion industry' under UNDP's Ocean Innovation Challenge. Investigating possible solutions for reducing microfibre pollution through textile design and adjustments in the production process.
MOMENTUM (https://www.zonmw.nl/nl/onderzoek-resultaten/life-sciences-health/programmas/project-detail/microplastics-health/microplastics-and-human-health-consortium-momentum/)	2021-2024	UU (coordinator), UMCU, RUG, VU, OU, TU Twente, WU, UM, TNO, ACC, ANTEA, WESSLING, SIMLINEXT, CYTOSMART, NANOCONSULT, AVANTIUM, BRUKER, LYONDELL, PANANALYTICAL, AIMPLAS, EXXON, DA VINCI, VITROCELL, Deltares, RIVM, KWR	Netherlands, Germany, Belgium, United States	Research into the health effects of microplastics and the prevention thereof.

3.4 Conclusion stakeholder inventory

Many international parties are active in researching MPV release from textiles into water. Until now, most of these activities were focused on gathering knowledge and methods to map the magnitude and impact of MPV from textiles in the environment. The stakeholders in the Dutch MPV Stakeholder Network are interested in the size and impact of MPV from textiles and are willing to contribute to the follow-up research for the further development of the measuring method in the short term. With the stakeholders in this network, the largest part of the MPV textile pollution chain in water in the Netherlands can be mapped. The link to international producers runs as much as possible through the Dutch fashion industry.

For an effective follow-up study, it would be wise in the Netherlands to link up with the follow-up activities of the Knowledge Impulse Water Quality (KIWK) programme and the Microplastics Monitoring study within the MWTL programme of RWS. These studies focus on MP research in groundwater and surface water and can be supplemented by studies earlier in the chain at the level of textile producers and laundry services.
There is an international need and willingness to share analysis methods for MPV from textiles. The most important initiatives and collaborations in this area are the European Microplastics Initiative from the Green Deal, the Microplastics Consortium (tMC) and the Cross Industry Agreement (CIA), possibly followed in the future by the WOMA consortium currently consisting of the Plastic Soup Foundation and CNR.

CIA and tMC have also taken a first step towards standardisation of the analysis method. The development of this standard has meanwhile been taken over by CEN/ISO working groups. Publication of the standards developed in these working groups is only expected in 2 to 3 years' time, but through participation in the working groups it is already known that the proposed methods are in line with the results of the knowledge inventory and the follow-up research proposed in chapter 5. In this follow-up research, it is important to link up with the most important European projects that are still ongoing, in particular Limnoplast, Euroqcharm, Herewear and MOMENTUM, and to share knowledge in the corresponding forums. Via the Dutch partners, a rapprochement can be sought with these consortia and, in the case of gaps in the planned research compared to the desired follow-up research, an additional proposal can be submitted within the Green Deal with Dutch partners and the partners from these consortia.

In short, it is recommended to take stock of the possibilities for starting Dutch follow-up research, but also to set up further Dutch and European cooperation for actively reducing MPV from textiles. Participation of research and/or policy partners (I&W, RWS, TNO and/or RIVM) from the MPV Stakeholder Network in the CEN working group, CIA, tMC and the EU initiative is an essential ingredient for this to go well.

4 Follow-up recommendation uniform measuring method

4.1 Improvement process based on precautionary principle

The aim of the uniform measuring method sought by the MPV Stakeholder Network is to contribute to minimising the potential impact of MPV-related environmental pollution. The starting point is the precautionary principle[32]: if an action or measure is likely to cause serious or irreversible harm to people or the environment, and there is no scientific consensus that harm will occur, then the burden of proof is on the person seeking to carry out the action. This principle also means that there is a responsibility to intervene and protect people from exposure to harm where scientific research has found a plausible risk.

The uniform measuring method will contribute to the solution by providing a picture of the critical properties of MPV sources (different types of textile), the extent of the MPV release and the transport of MPV through the water chain. Based on the measured values, it can be determined at which point it is expected to be most effective to implement measures and thus prevent the possible impact of the pollution at the earliest possible stage, in line with the precautionary principle. Subsequently, the method can be used to check the effectiveness of the MPV release reduction measures. In this improvement process, based on the precautionary principle, the aim is to reduce MPV as much as possible, even if a target concentration has not yet been determined. There are different ways to determine a standard value, for instance by research into exposure and effect, on the basis of which risks can be estimated. The determination of a norm can be carried out parallel to the improvement process. Once a norm has been set, it can also be used as the end point of the improvement process. These two parallel processes of improvement and setting of standards are shown schematically in Figure 14.

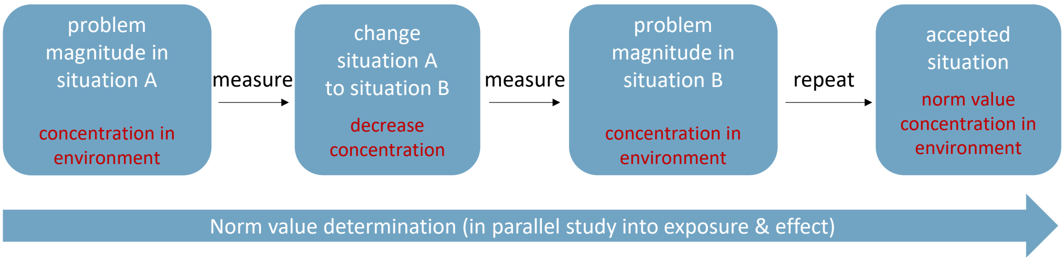

Figure 14 Schematic representation of the approach to a problem based on the precautionary principle. When the problem is detected, the system in which the contamination is taking place is in situation A. Measurements are then taken at various points in the system and, based on these results and the circumstances, the MPV release restriction measure is implemented that is expected to have the highest chance of success, both in terms of feasibility and quantity. After implementing this measure, the system has reached situation B. Again, measurements are performed, and the best improvement measures are determined and implemented. This process is repeated until the contamination is no longer measurable or until in the meantime, in the parallel investigation, a standard value has been determined and achieved.

4.2 The chain approach

The design of the uniform measuring method is based on a lifecycle approach. In order to ensure a good measurement approach at every point in the chain (*see Figure 15)* three different parts of the measuring method need to be tailormade:

1. **The sampling method.** This depends on expected MPV concentration and degree of pollution. The higher the MPV concentration and the lower the contamination, the easier the expected sampling approach.
2. The **possible pre-treatment of the sample**. If the sample is too heavily contaminated, then pre-treatment may be necessary in order to carry out the analysis properly.
3. The **method** of **analysis** for determining MPV. Ideally, the same method throughout the chain so that the results can be compared.

[32] https://www.duurzaammbo.nl/ethiek-inleiding/7-juridische-principes

The expected approach to reduce MPV loss at this point in the chain must often already be taken into account. The three components of the measuring method referred to above must, as far as possible, be compatible with each other throughout the chain, fit in with current initiatives and be implemented in the same way at various points in the chain. In the development phase, this can be ensured by having the development at the various points in the chain carried out in parallel and by the same party. The development phase will ultimately result in a protocol that can be used to roll out the method more widely with the help of commercial parties.

4.3 Follow-up approach per point in the chain

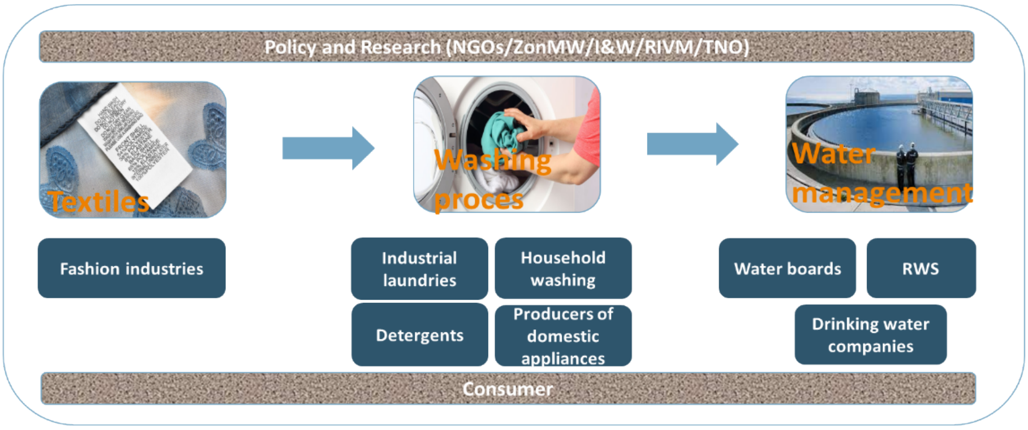

Figure 15 Schematic overview of the chain in which MPV from textiles can occur in water.

The parties in the MPV textile supply chain can roughly be divided into 3 groups: textiles, washing process and water management (see Figure 15). Each of these groups includes several (types of) partners from the MPV Stakeholder Network. To determine the best follow-up approach to arrive at a uniform measuring method for MPV loss throughout the chain as quickly and efficiently as possible, the following 4 points were identified for each of these 3 groups, based on the information from the knowledge and stakeholder inventory:

1 **What is the expected approach for MPV reduction?** Which options will possibly be tested and which parameters should be determined for the tested option, where and how often?

2 **What is the expected/usual measurement approach?** Based on already proposed or used measurements of MPV or other substances/fibres in water. It is important not to reinvent the wheel. Is it possible to supplement/connect with other methods?

3 **Which sampling method is required?** What is the expected concentration? At low concentration probably continuous sampling, at high concentration single sampling. How contaminated is the water?

4 **Advice on measurement approach for sample processing and analysis methods at this point in the chain.** Consideration of research question ←→ cost/quality/time.

4.3.1 Approach to MPV in the textile industry

1	**Expected approach for MPV reduction**
	Optimisation of production method, textile structure (fibre and weave) and choice of material through controlled experiments focused on the textile Polyester is the most common synthetic material for textiles, followed by nylon. It is therefore expected that a start will be made on minimising MPV release from polyester-containing fabrics. It is also expected that tests will be carried out to determine how much a controlled 'pre-wash', before the textile is put on the market, can reduce MPV release during (washing after) use.
2	**Expected or used approach for measurement of MPV**
	CEN method (CIA/tMC) for MPV determination: controlled piece of textile (100% PET) and standardised washing process. Weighing before and after washing (filter + textile scrap). No addition of detergent. Possibly CNR method.
3	**Sampling method**
	Practical sampling: high concentration of MPV per litre expected at this stage. One-time sampling of a limited volume of wash water probably sufficient. This sampling is (reasonably) well developed/existing.
4	**Advice on measurement approach**
	Extension of CEN approach with representative processes, thermo-analytical quantification, additional microscopic research and track & trace. 1. Start with the **CEN approach**[33] or similar in a controlled test environment. This method is good for rapid textile optimisation, but covers a limited range of materials, is not representative of a realistic process and is not compatible with a chain approach. 2. Once enough experience is gained, complement this method in the same test environment with **textile optimisation in representative processes** (also mixed/soiled fabrics, detergent and full load). Weighing the fabric or the filter sample is not sufficient here, but with the addition of a thermo-analytical quantification method, it is quite possible to determine the MPV mass fraction and the polymer type in these situations as well. Because of relatively clean water and **thermo-analytical quantification**, no additional sample processing is likely to be required at this point. 3. In order to get more information on the morphology, composition, type and size of the particles, it is advised to do a lot of **additional microscopic research** at this point in the development phase. At a later stage, this can be done on a random or pilot basis. 4. **Track & trace:** a study into the possible identification of an existing and/or added marker to textiles that makes tracing through the chain possible (e.g. a frequently used type of paint or metal doped plastic[34]). This may help to distinguish between PET from packaging materials and polyester from textiles, for example.

[33] The 'CEN approach' refers to the method developed by Leeds University, which is currently being further developed to become standard, by the working group CEN/TC 248/WG 37 "Microplastics from textile sources". See also Sections 2.2.1 and 3.3.2.

[34] Frehland et al. *"Long-term assessment of nanoplastic particle and microplastic fiber flux through a pilot wastewater treatment plant using metal-doped plastics"*, Water Research 182, 115060, 2020

4.3.2 MPV approach in the washing process

1	**Expected approach for MPV reduction**
	– Installation of a **microplastic fibre filter (e.g. Planet Care)** directly after the washing machine or further down the drain – Possible addition of MPV to **Ecodesign standard regulation**. Minimize MPV loss in Eco wash programme (8 kg wash, 40-50 degrees). Measure this as baseline and determine if improvement is needed. If so, adjust. – **Minimization of wear and tear** by optimized choice of detergent, washing programme and/or washing machine. Controlled experiments focused on the washing process. However, the specific details of the washing process are the intellectual property of the companies, which is why it requires a very large contribution from the industry (competition law). Generally known variations can be tested independently.
2	**Expected or used approach for measuring MPV**
	– **Measuring 'end of pipe' MPV variations** for different types of laundry services (household washing machine discharge, industrial washing machine discharge) with sampling directly after the washing process. Analysis and pre-treatment to be determined. – Measurements **before and after MPV filter.** Sampling is a point of attention here, because the expected concentration before the filter is high, and after the filter low. – **Variation of textile or washing process in adjusted CEN method (CIA/tMC):** controlled pieces of textile in above measurements (100%) with controlled washing process. Sampling after process as mentioned before.
3	**Sampling method**
	– Sampling **after the washing process without filter:** high concentration MPV/litre expected. Single sampling of limited volume of wash water sufficient. – Comparison of **sample before and after filter:** after filter risk of concentration below detection limit. Controlled sampling of large volume required (e.g. with cyclone method).
4	**Measurement approach recommendation**
	First approach 'end of pipe' study. Effect of filters, detergent and washing process possible as refinement. 1. For testing and optimising the measurement approach, a pilot with **'end of pipe' measurements at company clothing laundry services** is a logical starting point because of the relatively simple sampling and expected quality/representativeness of the analysis. The washing conditions do not allow for the CEN measurement approach[35], but the unit of g/l can be used. 2. Subsequently, **identification of representative processes and sample points** for different types of laundry services (consumer and industrial). By comparing laundry services, a first indirect indication can be obtained of the effect of the washing process and detergent. 3. Analysis by **weighing sample with addition of thermo-analytical quantification method** to determine MPV mass fraction and polymer type. Additional pre-treatment in case of ambiguous quantification result: possibly freeze-drying, removal of inorganic material, particle size separation and/or removal of organic material (other than plastic). 4. **Possibly additional microscopic examination** for fibre/particle morphology, composition and size determination for more detailed information on the origin of MPV. 5. **Variations of washing machine/detergent/program** can be carried out separately by manufacturers. Measurements before and after filters in the drain are more complex due to sampling issue. Pre-treatment and analysis methods are expected to be the same.

[35] Information from interview with industrial laundry services.

4.3.3 MPV approach in water management

1	**Expected approach for MPV reduction**
	– **Adaptation of treatment systems at sewage and drinking water treatment plants** to reduce MPV. These are major investments; it is crucial to first have a good picture of the concentrations and size/type of the particles by means of measurements/pilots at earlier points in the chain. Possibly deployment of Bubble Barrier. – Some of the microplastics may sink. Important to **prevent microplastics from entering the environment before arrival at the water treatment plant** via overflows and sedimentation.
2	**Expected or used approach for measuring MP**
	– **Mapping MPV concentrations** before and after purification, in rivers and in drinking water, monitoring over longer periods and possibly repeating after possible adjustments to purification methods. This already happens in the Monitoring Microplastics project within the MWTL programme (Monitoring Waterstaatkundige Toestand des Lands). – Investigate the possibility of a **two-step measurement approach** on this point: more frequent cheap analysis for a quick picture and less frequent more detailed analysis.
3	**Sampling method**
	Sampling is a major challenge: low concentrations, high pollution – Extremely **large water volume (low MPV concentration) and diversity of pollutants** causes major challenge in setting up and harmonising sampling protocol for contaminated (sewage) and clean water (rivers, drinking water, freshly filtered water from WWTPs).
4	**Measurement approach recommendations**
	Limit analysis to polyester and optimise step by step from coarse to fine. 1. Limit the analysis to **polyester (and possibly nylon).** There may still be markers that can be traced back to textiles at this stage. 2. Select **representative sample points** and determine a **good sampling approach**. This will require a lot of trial and error and is estimated to take in the order of years. Linking up with current RWS initiatives is highly desirable. 3. **Optimise pre-treatment.** Additional pre-treatment will be necessary: samples are contaminated, have low concentrations and/or the particles are small (after purification). Analyse with **thermo-analytical quantification method** to determine MPV mass fraction and polymer type, same as at other sample points in the chain. 4. **Assess contribution of textiles by markers or by chain approach:** By taking many sample points at different points between the washing process (private or industrial) and the water treatment plant, and based on this predicting the amount of expected polyester MPV in the effluent by modelling, the contribution of textiles to the total of MPV in surface water can be estimated. 5. **Possible additional microscopic research** for fibre/particle morphology, composition and size determination for more detailed information on the origin of MPV.

4.3.4 Overall picture

Up to and including the washing process, sampling is relatively easy because the expected MPV concentration is high and the water is relatively clean. Towards the end of the contamination chain, the water becomes dirtier and the concentrations lower, which makes sampling more difficult.
Analysis also becomes more difficult towards the end of the chain. Up to and including the washing process, it is possible to carry out controlled experiments that can be easily analysed, whereas at the end of the chain (sewerage, water purification, surface water) it becomes much more difficult due to little influence on the process, contaminated water and low concentrations. To still get a full picture of the MPV loss through the chain, it is recommended to complement a simple analysis based on filtration and determination of mass per litre with a thermo-analytical analysis. This analysis can determine the mass fraction of a type of polymer in a sample relatively quickly and is relatively insensitive to contamination.

For more information on numbers, size and shape of the particles, this can be supplemented with microscopic or spectroscopic analysis. However, to get an initial picture, it is advisable to first take a rough look using the methods mentioned above and to focus (specifically for textiles) on the contamination of polyester microfibres.

4.4 Further considerations for policy and research

In terms of policy, the advice is to map out MPV at all three points of the pollution chain and to start refining the measuring method in the short term by means of pilot projects at these three points. The results of the pilots can then be used to extend the measurements to other points in the chain and for the development of a measurement protocol for longer-term monitoring. The follow-up plan for the implementation of the pilots and the necessary activities around them is elaborated further in the next chapter.

It is important to realise that the zero option, i.e. the complete prevention of MPV release from textiles, does not seem realistic at any point in the chain. Good cooperation and sharing of information and responsibility within the MPV Stakeholder Network is therefore essential for success. The chain approach is essential to form a good picture of the scope of the problem, which is necessary for an effective and cost-efficient approach.
As yet, there are no known European initiatives with a chain approach of this kind. Putting this approach on the agenda of European policymakers and joining European consortia and standards (CEN/ISO) is therefore also an important point for attention.

Parallel issues for policy and research (outside the scope of this advice) are:

- Properly monitor and limit any adverse trade-offs in the approach to reduce MPV, such as additional energy consumption of washing machines when using filters.
- Parallel to the development of the measuring method, research into the risks and exposure on the basis of which a standard for the permissible quantity of MPV in the environment can be determined.
- Related research into the loss of MPV from textiles to air. This is important for a complete picture, but some of the fibres released to air will eventually also end up in water.

5 Outline programme implementation of the measuring method

This research is part of a national policy that is based on the precautionary principle: the presence of microplastic fibres (MPF) in the living environment has potentially harmful effects for people and the environment and it is therefore important to prevent the emission of these particles as much as possible. The aim of the Stakeholder Network MPV is to have the parties involved in the release and capture of MPV from textiles in water take action to limit the release of MPV as much as possible.

As previously reported, an EU policy is being developed under the Green Deal to tackle unconscious MPVs. In September 2021 a study is started into unconsciously created microplastics[36]. The first impact of the policy, in the form of reduction measures, is expected in late 2022. The Green Deal will pay extra attention to microplastics from car tyres, textiles and pre-production pellets.

Unlike car tyres, textiles have a long cycle time. Clothing can remain in circulation and be washed for decades after its production, emitting MPF in the process. Moreover, MPF in textiles are not in all cases easy to replace by other materials. This is the main reason why a chain approach, rather than only a source approach, is expected to be the most effective in reducing MPV from textiles. The uniform measuring method proposed in this report is regarded as a precondition for this chain approach.

The previous chapter outlined the general follow-up advice to achieve a uniform measuring method. In this chapter, this advice is further elaborated into a draft of a concrete follow-up programme for further elaboration and implementation of the uniform measuring method. This outline will provide the Ministry of I&W with quick tools to take the next necessary steps and to link up with the upcoming European policy.

5.1 Objectives

The objective of the uniform measuring method is to, in the Netherlands, be able to take the first steps towards reducing MPV from textiles in water. The objective of the follow-up programme is a successful elaboration and implementation of the uniform measuring method, to reduce the release of MPV from textiles in water. Moreover, it is intended to bring the results of the programme to the attention of European fora and initiatives so that the Netherlands can take the approach to MPV together with the rest of Europe. In particular, it is important to put the chain approach on the agenda.

5.2 Programme design

The intention of the follow-up programme is to elaborate the uniform measuring method as soon as possible, to test it and to gain experience with it in an iterative process of MPV fibre reduction and improvement of the measuring method. In this way, major steps can be taken quickly and the Netherlands will be ready in time to take its responsibility and to comply with international guidelines.

An independent research institute can take on the elaboration and management of this follow-up development, supported by the Ministry of Infrastructure and the Environment (with policy and funding) and the RIVM (for the study on exposure and effect of MPV from textiles), parallel to this programme. A good contribution by the partners in the MPV Stakeholder Network, in terms of relevant contacts, manpower and resources, is essential for the success of the follow-up development. In the short term, the partners in this network will be asked to set up joint pilots for further development and testing of the measuring method. This will make it possible to, within these pilots, already identify leads for reducing MPV in water and to take steps to map out the problem for the chain. In parallel, pilots will be started on the three main components of the chain (textile industry, washing process, water management) to develop and use the method as a first step towards the reduction of MPV.

[36] Microplastics study - Homepage (biois.eu)

Reliable development and testing of the measuring method is expected to be quickest with samples taken directly after the washing process in industrial laundry services. The fastest progress towards MPV reduction is expected through iterative optimisation in the textile industry, where it is expected that the measuring method can be applied in a laboratory environment relatively quickly. Knowledge about and improvement of the influence of the washing process will partly take place in the pilot at the industrial laundry services and partly in the experiments for the textile industry.
In water management (sewage treatment, surface water), the initial situation is the most difficult, but in order to obtain conclusive information throughout the chain, existing initiatives can be sought where samples will be analysed in the same way. The results of the follow-up research will be shared in (inter)national forums and partnerships, whereby connections will also be sought with other (inter)national initiatives. In addition, there are a number of points for attention for the policy approach.

5.3 Activities

To achieve these goals, it is recommended that a programme be set up that includes the following six main activities:

1. **REFERENCE STUDY: Implementation of the thermo-analytical quantification method for analysis of MPV from textiles with artificial reference samples**
   The thermo-analytical quantification method is promising to follow a type of microplastic, e.g. polyester, through the chain and is an important pillar of the recommended measurement approach. To test this method for this specific application, a representative set of mixed artificial reference samples will be selected and analysed for composition (e.g. mixed samples consisting of cotton and polyester fibres in known proportion and mass). The selection of these samples will be done in close consultation with the team of the textile optimisation pilot project.
   These tests will also look at the influence of contamination, e.g. detergent, oil or food residues. The aim of these tests is to be able to assess the systematic and experimental deviation of this method for this application and to learn about possible complications and, as far as possible, to remedy them.

2. **PILOT: Testing and optimisation of the measuring method at the industrial laundry services and first estimation of the extent of MPV release during washing.**
   The testing and optimisation of the uniform measuring method can already yield results in the short term if a pilot project at the industrial laundry services is started soon. This is due to relatively easy sampling (the piping is easily accessible), high MPV concentration, relatively clean water and representative, existing processes. By repeating the test at multiple and different types of laundry services, a first estimate of the magnitude of MPV release at laundry services, depending on textiles and process parameters (as far as known), can be made.
   This pilot project can be led by the research institute, which will further develop the measuring method in cooperation with the FTN, which will provide access to the laundry services and the necessary information, and will take care of any adjustments. Setting up longer term monitoring at the laundry services based on these results is the responsibility of the FTN and its members and falls outside the direct scope of this programme.

3. **PILOT: Controlled, representative experiments aimed at optimisation of textiles and washing process using the uniform measuring method.**
   It is expected that much MPV reduction can be achieved through optimisation of the textile itself. This is also the approach of the current initiative to develop a CEN measuring method: a well-defined piece of MPV fabric is washed without detergent, after which the mass reduction and mass of MPV in a filter after the machine is determined. This process is not representative of a real washing process, which entails some risk, but it can be used for rapid optimisation of textile parameters for reduction of MPV release. It is therefore recommended to start controlled textile optimisation experiments in a laboratory environment (e.g. at

SOHIT), parallel to the other pilot project at the laundries. As a follow-up to the highly controlled CEN-type experiments, more representative tests can then be started in the same lab, step by step, with for instance more variation in fabric characteristics (type of yarn, weave, etc.), washing volume or detergent (see Table 3). Based on these tests, the effect of these variations on MPV release can be mapped out and tools for reducing MPV release from textiles can be identified. More detailed examination of the samples from the above tests may also make it possible to identify a typical tracer for microplastic fibres from textiles, which can be used to estimate the contribution of textiles to the total microplastic pollution in surface water.

This pilot can be coordinated by the research institute that will further develop the measuring method, possibly in close cooperation with another test laboratory that performs the washing experiments. This pilot project also requires input from representatives of the textile industry (Modint, INretail), the detergent industry (NVZ, Senzora) and the washing machine industry (AppliaAPPLiA) for the selection and supply of representative fabrics, detergents and washing processes and the necessary background information.

If the experiments are successful, consideration may be given to setting up a test centre for MPV loss for more detailed research than the initial inventory within this programme. For financing, the possibilities of a Public-Private Partnership (PPP) may be considered, for example through the Knowledge and Innovation Covenant (KIC) for setting up a dedicated laboratory.

4. PILOT: Link up with existing initiatives of the Dutch water management

A good sampling approach for surface water and sewers requires a lot of trial and error and is estimated to take in the order of years. This usually involves heavily polluted water and/or low concentrations, which also complicates the analysis. To get an idea of the contribution of textiles to the amount of MPV in surface water, it is recommended to join existing initiatives for sampling. The Directorate-General for Public Works and Water Management and the Water Boards are working on a programme (RWS-MWTL) to determine the concentrations of microplastics in surface water.

The samples taken within this programme can then be further analysed using the analysis methods proposed in this programme in order to obtain a complete picture from textile production to water purification. As this is only a connection, this pilot is typically a much smaller activity than the other two pilots. The pilot can be led by the research institute that will further develop the measuring method in cooperation with (projects running at) the Water Boards, the Water Laboratory and RWS, which can supply samples for analysis.

5. PARTNERING AND DISSEMINATION: Affiliation with European fora and initiatives

Because of a (for the time being) lack of standards and because it is possible that the issuing of MPV cannot be reduced to a desired level in one part of the chain[37], it is important to create support for the chain approach with a uniform measuring method. Also, the effect of these investments may be much greater if the Dutch government cooperates with other European countries within the EU. The results of this programme and the Dutch approach should therefore be brought to the attention of the EU and other European initiatives. Participation in the CEN/ISO standardisation committee CEN/TC 248/WG 47 can be a good starting point for this, but spreading the knowledge and insights gained at conferences and within other European consortia on this subject, such as stakeholder meetings of The Microfibre Consortium and the European Microfibre Initiative, is also essential.

The research institute can also seek connection with the main current European projects, particularly Limnoplast, Euroqcharm, Herewear and MOMENTUM. Via the Dutch partners, a rapprochement can be sought with these consortiums and, in the event of gaps in the already planned research compared to the desired follow-up research, an additional proposal can be submitted within the Green Deal with the partners from these consortiums.

[37] Estimation based on interviews with the MPV stakeholder network: complete switch to plastic-free textiles is not feasible in view of consumption of alternative raw materials and applications in which plastic is functional, some wear and tear of textiles in washing processes is unavoidable, and with all the losses along the way, water treatment will not be able to remove all MPV.

The Ministry of Infrastructure and the Environment can stimulate this cooperation by financially supporting the Dutch research partners in international projects, as a sparring partner in policy issues and as a participant and representative of the Dutch government in international EU stakeholder meetings.
The research institute that will further develop the measuring method will also draw up a communication plan for the effective dissemination of the results when implementing this programme.

6. POLICY APPROACH: Preconditions for successful implementation to reduce MPV issuance

It is expected that Activity 2 of the chain mapping activities will yield the quickest results, followed by Activity 3 due to its greater complexity, and only much later by Activity 4. Nevertheless, the chain approach is assured and an increasingly reliable picture of the contribution of textiles to microplastics in the environment will gradually emerge.
By working with an iterative process of measure-improve-measure-improve, large steps in MPV reduction can be made at the same time. To ensure that this ultimately leads to the desired reduction of MPV emissions into the environment, a number of issues still need to be worked out: drawing up a detailed measurement protocol, setting a standard and devising a good approach to monitoring and enforcement. For successful implementation, the Ministry of I&W must ensure that these activities are undertaken in cooperation with appropriate research institutes.

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A Cost estimation analysis techniques

Table 10 Cost estimation of analysis techniques. Table taken from source (Primpke S., 2020).

Methods	Unit	Naked eye	Optical microscopy	Nile red staining	Flow cytometry	Flow imaging	FT-IR qualitative	Particle based µFT-IR	µFT-IR imaging	Raman qualitative	Particle based µRaman	py-GC-MS qualitative	Quantitative py-GC-MS	TED-GC-MS	HIS	SEM-EDX
LOD		1 mm	100 µm	3–20 µm	500 nm	2 µm	>300 µm	25 µm	10 µm	>300 µm	1 µm	~1 µg IP	<<1 µg PD	<1 µg PD	NA	nm
Instrument costs[a]	$k	<1	2–3	2–50	>50	>130	25–50	100–125	200–250	50–100	200–400	>150	>215	>250	40-120	>100
Special consumables				Dye and solvent	Cleaning solutions	Cleaning solutions		Liquid nitrogen	Liquid nitrogen			GC-columns and filaments	GC-columns and filaments	GC-columns and filaments		Sample coating
Field applicability		Good	Good	No	No	Possible	Handheld	No	No	Handheld	No	No	No	No	Device dependent	No
Limitations		NoID	NoID, NoM, PA/SA	NoID, NoM, PA/SA	NoID, NoM	NoID, NoM		TA, NoM	TA, NoM		PA/SA, NoM		NoN, NoS	NoN, NoS	LID	LID
Automated data evaluation		No	No	No[d]	No	No	No	Yes	Yes	Yes[e]	Yes	No	No[f]	No[f]	No	No
Measurement time[b]	min	1	60	35	30	30	1	360	240	2	2580–>10 000	35–120	120	120	5	120
Data Analysis time[b]	min	NA			5	5	1	60	360	1	1	5–10	60[g]	60[g]	5	60
Working time[b]	min	1	60	35	48	48	2	120	60	3	60–580	5	30 (qual.) 72 (quant.)[g]	30 (qual.) 72 (quant.)[g]	10	180
Typical fractions per sample		50 P	7 F	7 F	3 REP	3 REP	50 P	1 F	1 F	50 P	1 F	50 P	1–5 CQ	1–5 CQ	1 F	1 F
Instrument availability for analysis[c]	d	261	261	261	237	249	250	250–261	250–261	250–261	250–261	250	250	250	NA	NA
Average working time per sample	min	PND	420	245	144	144	PND	120	60	PND	60	PND	72-216	72-216	10	180
Field of application		MD, MO	MD, MO, R	MD, MO, R	MD, MO, R	MD, MO, R	MD, MO, R, RA, RE	MD, MO, R, RA, RE	MD, MO, R, RA, RE	MD, MO, R, RA, RE	MD, MO, R, RA, RE	MD, MO, RE	MD, MO, R, RE	MD, MO, R, RE	MO, RE	MD, RA, RE

[a] Raw estimates which may strongly vary dependent on the country.
[b] Calculated for one filter/particle per analysis.
[c] Working days (normal work hours/days, maximal 261 if a 2 days weekend applies) exclusive instrument maintenance time.
[d] Image analysis possible.
[e] For Raman microscopes.
[f] Autosamplers are available.
[g] Calculated based on a micro-furnace system with an average sequence size (6 standards, 10 samples).

CQ: pyrolysis cubs or quartz tubes; F: filters; IP: isolated particle; LID: limited chemical identification; MO: monitoring; MD: modeling; NoID: no chemical identification; NoM: no mass determination; NoN: no particle number determination; NA: no information available; NoS: no particle sizes determination; R: routine; RA: risk assessment; RE: research; PA/SA: partial analysis/subsampling analysis on filter; P: particle; PD: polymer dependent; PND: particle number dependent; REP: replicates; TA: total absorption.