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Screening level ecological risk assessment of **microplastics in Dutch surface waters**

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Colophon

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Synopsis

Screening level ecological risk assessment of microplastics in Dutch surface waters

Microplastics are tiny plastic particles. They are found in the soil, surface water and in the air. Particle sizes range from 1 to 5,000 micrometres. Microplastics can be harmful due to either the impact of the plastic particles themselves or chemical additives that leach out of the particles. A key question is the level at which microplastics become harmful to plants, animals and other organisms. In 2025, RIVM concluded that a Wageningen University-developed method is suitable for assessing these particles' harmful impact and that the results can be used to inform policy.

RIVM has now used this method to investigate whether particles have harmful effects on plants and animals in Dutch surface water, with the aim being to inform policymakers about these effects. While the method appears to be suitable in practice, RIVM is currently unable to demonstrate the harmful effects of microplastics. This is mainly due to limited data availability regarding the situation in the Netherlands. The quality of the available data is also not good enough.

As sampling and analysis are labour-intensive processes and measurements are only taken at a small number of locations in the Netherlands, there is still a great deal of uncertainty about the levels of microplastics in water. It is also difficult to compare the data, partly due to the current lack of standard measurement protocols. The smallest particles are particularly difficult to measure (smaller than 20 micrometres).

Such data are also important in determining what is known as the risk threshold. This threshold indicates the level at which the impact of microplastics becomes harmful. The most recent risk threshold used in scientific literature was determined using data that do not meet all quality requirements. This risk threshold shows that there are more microplastics in surface water than is desirable at certain locations and at certain times.

RIVM recommends establishing a risk threshold based on new data that do meet all quality requirements, as this will enable a more reliable assessment of the harmful impact. For insight in microplastics levels more and better data are required, also on the different microplastic particle sizes.

RIVM conducted this study on behalf of the Ministry of Infrastructure and Water Management (IenW).

Keywords: surface water, ecology, microplastics, the Netherlands, ecological risk assessment, plastics, Koelmans method

Publiekssamenvatting

Verkenning ecologische risico's van microplastics in Nederlands oppervlaktewater

Microplastics zijn minuscule deeltjes plastic en komen voor in de bodem, oppervlaktewater en in de lucht. De grootte verschilt van 1 tot 5000 micrometer. Microplastics kunnen schadelijk zijn door effecten van de deeltjes zelf, of via chemische stoffen die uit de plastic deeltjes lekken. De vraag is bij welke hoeveelheden microplastics schadelijk zijn voor planten, dieren en andere organismen. Het RIVM concludeerde in 2025 dat een methode van de Wageningen Universiteit geschikt is om schadelijke effecten te beoordelen en de resultaten voor beleid te gebruiken.

Het RIVM heeft nu met deze methode onderzocht of de deeltjes schadelijke effecten hebben op planten en dieren in Nederlands oppervlaktewater. Het doel is om beleidsmakers hierover te informeren. De methode blijkt in de praktijk geschikt te zijn, maar het RIVM kan nu niet aantonen dat microplastics schadelijke effecten hebben. Dat komt vooral omdat er niet genoeg data over de situatie in Nederland zijn. Ook is de kwaliteit van de beschikbare data niet goed genoeg.

Er blijkt namelijk nog veel onzeker te zijn over de hoeveelheid microplastics in water omdat bemonstering en analyse arbeidsintensief zijn en er daarom nog maar op een klein aantal locaties in Nederland is gemeten. Bovendien zijn de data lastig met elkaar te vergelijken, onder andere omdat er nog geen standaard meetprotocollen zijn. Vooral de kleinste deeltjes zijn moeilijk te meten (kleiner dan 20 micrometer).

De data zijn ook belangrijk om een zogeheten risicogrenswaarde te bepalen. Deze waarde geeft aan in welke mate microplastics schadelijke effecten hebben. De meest recente risicogrenswaarde die in de wetenschappelijke literatuur wordt gebruikt is bepaald met data die niet aan alle kwaliteitseisen voldoen. Volgens deze risicogrenswaarde zitten er op sommige locaties op sommige momenten meer microplastics in oppervlaktewater dan gewenst is.

Om een beter onderbouwde uitspraak over schadelijke effecten te kunnen doen, beveelt het RIVM aan om een risicogrenswaarde te bepalen met nieuwe data die wel aan alle eisen voldoen. Voor inzicht in de hoeveelheid microplastics zijn meer en betere data nodig. Ook over de verschillende grootten van deeltjes microplastics.

Het RIVM deed dit onderzoek in opdracht van het ministerie van Infrastructuur en Waterstaat (IenW).

Kernwoorden: oppervlaktewater, ecologie, microplastics, Nederland, ecologische risicobeoordeling, plastics, Koelmans-methode

Contents

Summary

Introduction

Microplastics are small, synthetic polymer particles released into the environment from various sources such as tyres, clothing, and the breakdown of larger plastics, and have been detected in air, water, and soils worldwide. While their ecological impacts have been studied globally, the specific risks for Dutch surface waters remain unclear. Therefore, this study aims to perform an initial, screening level, assessment of the potential ecological risk posed by microplastics in Dutch surface waters. This is done for particle effects only. Additional effects of additives or other indirect effects are out of scope. In this report, microplastics are defined as synthetic polymer particles largely following the EU REACH definition, but with a narrower size range of 1 and 5000 micrometres. The assessment uses the Koelmans alignment approach (Koelmans et al., 2020) to compare previously measured environmental concentrations with ecological risk limits from literature, while also considering the size and shape of particles.

Methods

Monitoring data on microplastics in Dutch surface waters were collected, their quality assessed and measured number concentrations rescaled to the standard 1 to 5000 micrometre size range. This rescaling used a power law distribution, fitted to particle size data for each water body and detection technique, to correct for size limitations in sampling and detection methods. In addition, mass concentrations were converted to number concentrations as a proof of principle for using mass data in risk assessment. The rescaled exposure particle concentrations were then compared to ecological risk limits (HC5 values) for volume and surface area, as reported by Coffin et al. (2026). These are metrics used to describe adverse effects linked to food dilution and tissue translocation, respectively. Limitations of the applied approach include the limited availability of monitoring data, the use of generic reported risk limits from literature with known limitations in quality of effect data used and not being able to fully measure all polymers which are expected to fall within the microplastics definition.

Results

Monitoring data

The study compiled and evaluated existing measurements of microplastics in Dutch surface waters, distinguishing between data based on particle counts and those based on polymer mass. For risk assessment, only particle number-based data were used. Six studies were identified that reported microplastic particle concentrations in Dutch surface waters between 2017 and 2024, resulting in, in total, 42 samples from the Meuse, Dommel, Rhine, Lek canal, Overijsselse Vecht, and 28 samples from the Werverschoof effluent canal. Most studies used cascade filtration followed by either Laser Direct Infrared imaging (LDIR) or (Micro-) Fourier Transform Infrared (FTIR) spectroscopy to detect and characterize microplastics by size and polymer type. Quality assessments showed that four of the five studies passed all quality criteria, while one included study did not meet all criteria. Overall quality

assessment showed that reporting was insufficient on lab procedures related to control of contamination. Mass based data were obtained from Rijkswaterstaat who applied pyrolysis Gas Chromatography Mass Spectrometry for quantification and detection of polymers.

Exposure assessment
To accurately estimate aquatic exposure to microplastics, measured concentrations from various studies were rescaled to the defined 1 to 5000 micrometre size range, correcting for the size limitations of different detection methods. Overall, the rescaled particle number concentrations range from 3100 #/m^3 to 2.0 x 10^8 #/m^3 covering 5 orders of magnitude. The current dataset is too small to provide a representative view of the microplastics pollution in surface water in the whole of the Netherlands. Two important factors are identified that cause the estimate of exposure concentrations of microplastics in surface waters to be rather uncertain. (i) It is unclear how different studies can be compared as they use different methods, e.g. different measurement techniques and also different sampling approaches. (ii) It remains unclear how large the discrepancy is between the range of polymers measured and what should fall under the definition of microplastics.

Measurement methods should be standardized in order to improve comparability. This includes reporting on which part of the full microplastics spectrum of sizes and polymers is covered. For instance, the FTIR or LDIR based studies cannot adequately detect tyre rubber related polymers. Given tyre wear is a large microplastics source, the measurements thus likely underestimate the exposure concentration. One model study indicates particle number concentrations could be about 10% higher if tyre wear is included, although this remains highly uncertain.

Using the Koelmans approach for rescaling, measurements of microplastic particle count data can be corrected for not covering the full 1 to 5000 micrometre size range. However, focussing on detecting the full size range and specifically microplastics in the <20 micrometre size range could improve our understanding of such corrections.

Mass to particle number conversion
Suspended particulate matter (SPM) microplastic mass concentrations were converted to particle number concentrations as a proof of principle. It remains unclear how well this approach works as there are no measurements that allow for a direct comparison. Further research is needed on the use of mass data for exposure assessment, for instance one could also convert particle number-based risk limits to mass.

Risk limit
Risk limits for microplastics in Dutch surface waters were based on the work by Coffin et al. (2026), who derived hazard concentrations (HC5 values) using ecological relevant metrics (ERM) of volume and surface area to reflect toxic effects of microplastic particles due to food dilution and tissue translocation, respectively. These limits incorporate uncertainty and are highly influenced by the assumed particle size distribution. The study found that HC5 values for volume as ERM have

greater variability than for surface area ERM, highlighting the need for site-specific data in future assessments.

The generic limits used here are 31,000 particles/m³ for food dilution and 2,150,000 particles/m³ for tissue translocation, with broad uncertainty ranges. These were based on a selection of effect studies which passed a subset of quality criteria originally proposed by De Ruijter et al. (2019). This is needed as no study passes all those criteria. The risk limits are, despite the exclusion of several quality criteria, the best risk limits currently available. The exclusion of potentially relevant criteria also means that they are uncertain and further effect studies passing all quality criteria are needed.

Screening level risk assessment
Rescaled microplastic particle concentrations in Dutch surface waters exceed the 95th percentile of the derived risk limits in up to 24 percent and 17 percent of the samples for the volume and surface area ERM, respectively. These exceedances indicate a risk of adverse ecological effects at those moments in time and at those locations, due to exposure to microplastics and under the assumptions of the risk assessment framework. The exact degree of ecological effects to be expected is unclear and dependent on frequency and length of exposure above the risk limit. These results are new for the Netherlands, but consistent with international studies.

Conclusions
This study used the currently best available data and approaches to assess ecological risks of microplastics in surface waters. In some locations and at some points in time, exposure concentrations are estimated to exceed risk limits indicating that adverse ecological effects cannot be ruled out. This conclusion is formulated very cautiously. The exact severity of these effects remains unclear due to the assumptions on particle size distribution, limitation of sampling and detection methods to include all microplastics (i.e. tyre wear), quality and number of effect studies used for deriving risk limits. Addressing these limitations is crucial for improving our understanding of the potential adverse ecological effects of microplastics.

Recommendations
For ecological risk assessment to effectively guide regulatory action, improvements are needed in:

1. Detecting the smallest microplastic particles (< 20 µm).
2. The overall improvement of microplastics measurement techniques to cover the full size range of microplastics.
3. Availability of high-quality effect studies.

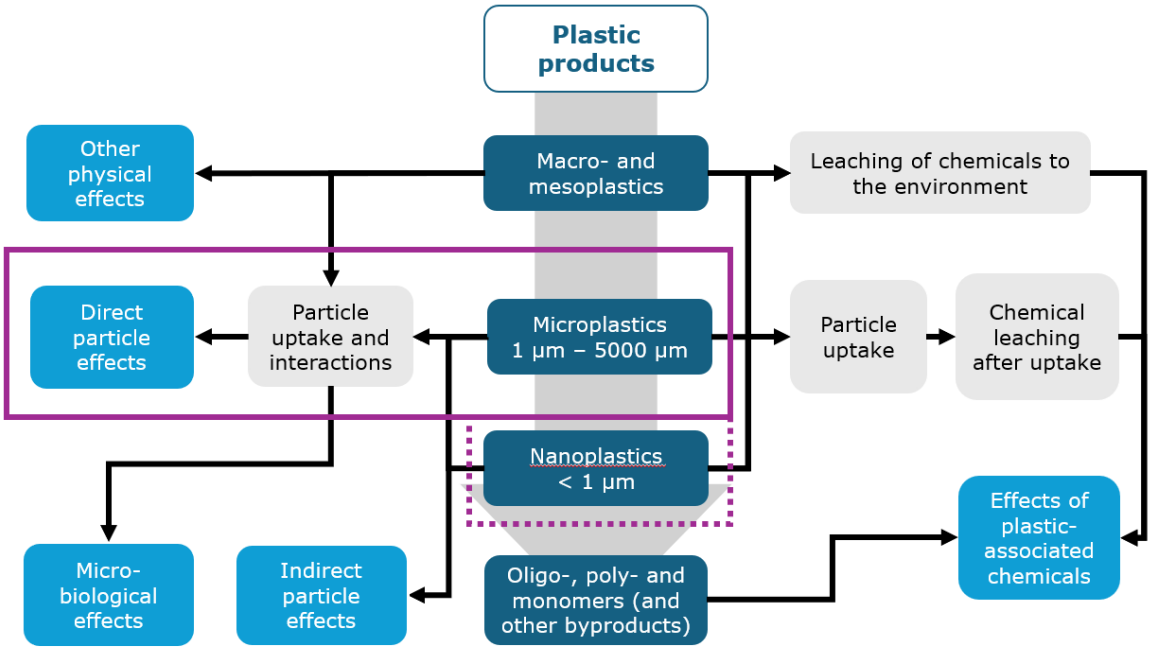
Further research should focus on addressing these three points.

Despite the limitations of the current study, mitigation efforts to reduce microplastic pollution are justified.

1 Introduction

Microplastics are small polymer-based particles emitted to the environment from various sources where polymer materials are used, such as tyres and clothing (Quik et al., 2025, 2024). Microplastics are detected in air (van der Stel and Cassee, 2025), surface water (Leslie et al., 2017; Mintenig et al., 2020) and soils (Lwanga et al., 2023) in the Netherlands. It remains unclear what their ecological impact is. Here we conduct a screening level study of the potential ecological effects of microplastics in Dutch surface waters. This screening level ecological risk assessment is conducted using the best available method (Swart et al., 2025) based on the alignment approach by Koelmans et al. (2020) for comparing measured water concentrations to risk limits.

Figure 1 Simplified conceptual model linking potential ecological effects to the plastic degradation pathway from plastic products via microplastics to polymers and monomers (top to bottom of figure), source: Swart et al. (2025).



Centre grey arrow indicates degradation pathway from plastics products down to micro- and nanoplastics and polymers. Blue boxes indicate potential ecological effects. Grey boxes and black arrows indicate processes. Indirect particle effects include e.g. changes in soil properties, microbiological effects include e.g. changes in microbiome, other physical effects include suffocation or blockages, effects of chemicals are related to the properties of the individual or mixture of chemicals. The purple box indicates the scope of effects considered in this study.

For some regions in the world the ecological impact of microplastics have been assessed. For example, in one study on the Wester Scheldt estuary some measured concentration in industrial locations exceed the risk limit (Liu et al., 2022). Another early study at global scale showed that only a very small fraction of measured concentrations exceeded the risk limit at the time (Adam et al., 2019). A study on the Laurentian

great lakes also applying the Koelmans approach found 10-20% of exposures exceeding risk limits in surface water (Koelmans et al., 2023).
The ecological risks of microplastics in the Netherlands are not yet clear. Several studies report on microplastics in Dutch surface waters (Mintenig et al., 2020; Mughini-Gras et al., 2021; Bäuerlein et al., 2022, 2023; Freriks et al., 2023a; Mintenig et al., 2025). As data are available and from policy and ecological perspective surface waters are an important compartment to focus on we aim to gain more insight into the severity of microplastic pollution in the Netherlands.

In general, assessing the ecological risk of plastics requires a broad, multi-facetted approach because *Direct particle effects, Indirect particle effects, Effects of plastics chemicals, Other physical effects* and *Microbiological effects* all require fit for purpose approaches and related effect data (Figure 1). Here we solely address direct particle effects of micrometre-sized polymer particles (microplastics) following particle uptake and interaction. The microplastics definition considered here is based on the REACH definition (see text box), but with a narrower size range from 1 µm to 5000 µm, as smaller particles cannot be measured in most environmental samples.

Microplastics definition
Microplastics in this study are defined as solid polymers with a length size limit of 1 µm to 5000 µm. Solid polymers included as microplastics are based on the REACH definition which excludes naturally formed polymers, e.g. cellulose, water soluble polymers and polymers that do not contain carbon atoms. This study applies a narrower size distribution than the microplastics definition as applied in the EU REACH restriction on intentionally added microplastics (EC, 2023) which also includes fibres with L:W aspect ratio larger than 3 and length up to 15000 µm and a lower size limit of 0.1 µm.

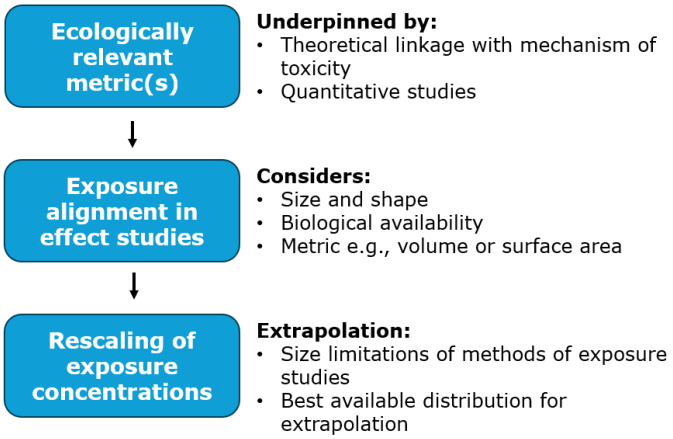
For assessing ecological risk the ecological risk limit needs to be derived using a hazard assessment and the surface water exposure concentration needs to be estimated as part of an exposure assessment. The hazard assessment is based on ecotoxicity studies for different organisms which differ in bioavailability of particles, e.g. larger microplastics can be ingested by fish compared to a water flea (Crustacea). Furthermore ecotoxicity studies (mostly) do not use microplastics representative of the wide variety of sizes and shapes expected in surface waters and different particle properties play a role in observed effects. Microplastics in the environment are expected to vary in colour, shape, polymer composition and size based on how they are formed and further transformed under environmental conditions (see text box: What are microplastics?). This means that interpretation of effect studies for hazard assessment is challenging. Additionally, measuring microplastics in surface water in the full range of sizes from 1 to 5000 µm is extremely difficult and currently not feasible in monitoring studies. To cope with these challenges the risk limits and exposure concentration are aligned following the Koelmans approach (Koelmans et al., 2020). This corrects for differences in bioavailability, in size ranges considered in ecotoxicity studies as well as in monitoring studies.

Colour, polymer type and other differences in composition are not separately considered, as data per polymer type is still scarce and these properties are deemed less relevant for direct particle effects as considered in the present study.

What are Microplastics?
Microplastics can be categorized as either primary or secondary microplastics. Primary microplastics are intentionally produced microplastics used in for example artificial turf infill materials, cosmetics or plant protection products. Microplastics from sources such as tyre wear, paint and fragmentation of macroplastics, are categorized as secondary microplastics as they are formed unintentionally due to wear and tear of polymer based materials (Quik et al., 2024). Eventually microplastics end up in surface waters directly, through discharge of wastewater treatment effluent, deposition from air or via runoff and erosion of microplastics initially contained in and on soils (Rutgers et al., 2022).

The Koelmans approach (Koelmans et al., 2020), as previously described and analysed in Swart et al. (2025), consists of three key steps (Figure 2). First is determining the relevant dose metrics for microplastics, which in contrast to conventional chemicals is characterised by particle specific properties such as shape and size (Koelmans et al., 2017). The currently most used ecologically relevant metrics (ERM) for microplastics ecological risk assessment are surface area and volume (Coffin et al., 2026; Mehinto AC et al., 2022). In the second step, the exposure in each effect study is used to align the reported effect metric (e.g. ECx or NOEC) to the range of microplastics expected to be present in the environment and biologically available. These effect metrics are then used in the conventional way to derive risk limit values using species sensitivity distributions (SSDs). In the last step, measured exposure concentrations are rescaled to the defined range of microplastics expected in the environment in order to compare to the risk limits covering the same range.

Figure 2 Diagram showing key steps in the alignment of exposure and effect data from microplastic studies following the Koelmans approach. Source: Swart et al. (2025).



Although surface area and volume are the metrics used as the ERM, these are all converted to particle number concentrations, which is the unit used as harmonised metric for both the exposure assessment and derivation of risk limits. As a proof of principle mass based microplastics measurements are also converted to particle numbers, but as the size distribution of these mass measurements are unknown and validation of the conversion approach is out of scope of this study, we do not use these data for exposure and risk assessment.

The aim of this study is to conduct an initial screening of the potential ecological risk posed by microplastics in Dutch surface waters considering the microplastics definition (see text box: Microplastics definition). This is done by:

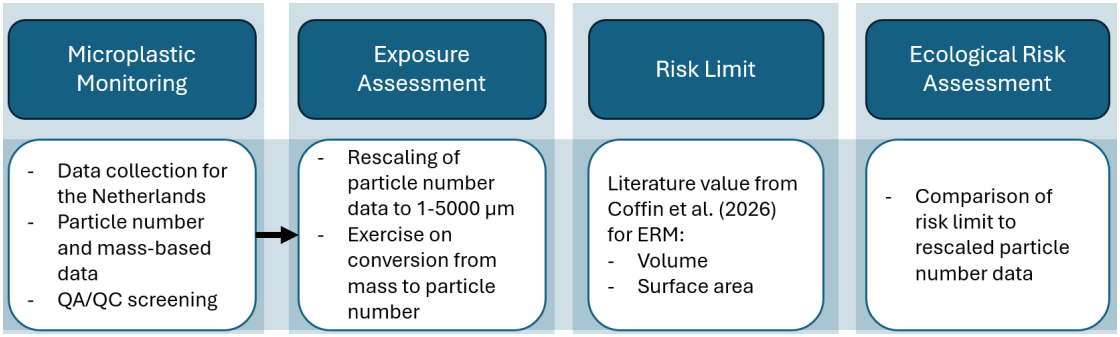
1. Focusing on gathering and interpreting reported surface water measurements of microplastics in the Netherlands.
2. Implementing the Koelmans approach as set forth in Swart et al. (2025).
3. Using the existing hazard assessment by Coffin et al. (2026).

This screening analysis should provide evidence for further research on implementation of ecological risk assessment as part of mitigation measures and (further) development of policies and regulations to tackle plastic pollution.

2 Methods

The key steps of the approach used here are summarised in Figure 3 and described in detail in this chapter and the relevant appendices. The acquisition of monitoring data and approach for quality assessment and control is described in section 2.1 with further details in Appendix 1. As part of exposure assessment, the approach used for rescaling measured particle number concentrations is provided in section 2.2 supported by Appendix 2 and the approach for converting mass-based measurements to particle number concentrations is described in section 2.3. A brief overview of the risk limits from Coffin et al. (2026) is provided in section 2.4, with more detailed summary in Appendix 3.

Figure 3 Overview of methodological approach followed in this study highlighting the approach on acquiring monitoring data, exposure assessment, derivation of risk limits and the main limitations for comparing exposure to the risk limits.



2.1 Data acquisition and quality control

To obtain data on environmental microplastics concentrations relevant for risk assessment purposes a brief literature screening was conducted. The authors of the identified publications that were potentially relevant for the study were contacted and requested to share the raw datasets of measured particle number concentrations of microplastics. The scope of the search was limited to Dutch surface waters. Due to time and budget constraints, we did not perform a full systematic literature search. The respective researchers kindly provided raw particle data. The raw particle data were needed for analysing the particle size distributions and exposure and effect alignment.

All considered studies were subjected to a quality assessment using a scoring scheme based on the criteria by Koelmans et al. (2019) as used by other studies on microplastics in water, e.g. WHO (2019, 2022). These quality criteria are designed to capture basic methodological requirements for microplastic analysis and can be found in Table A.6 in Appendix 1. They relate to sampling methods, sample size, sample processing and storage, lab preparation, clean air, negative controls, positive controls, sample treatment (i.e. extraction of microplastics from natural sample matrix) and polymer identification. When a publication did not describe a given quality aspect with sufficient detail, it was scored as 0, as this hampers repeatability of the study and reduces the robustness of data. Thus, the scoring reflects what is reported even

though it may well have been done in practice. Note that in one case clarifications based on personal communication are shown, see Appendix 1. The quality assessments itself were performed by one author of the current report and reviewed by another to minimize variation in scoring due to differences in interpretation. Furthermore, all authors of corresponding papers were provided with this quality assessment and given the opportunity to provide feedback.

Since the publication of the quality criteria by Koelmans et al. (2019), additional aspects have emerged that are not, or only partially, reflected in the original criteria. Updating these based on the latest insights is deemed out of scope and is part of ongoing efforts by the scientific community to address quality issues related to microplastics measurements see e.g. (Barchiesi et al., 2026). The most important consideration that we believed required alternative interpretation was in applying criterion eight on sample treatment and criterion nine on polymer identification for assessing the quality of the pyrolysis Gas Chromatography Mass Spectrometry (GC-MS) measurements, see Table A13. For instance sample treatment (Criterion 8) for spectroscopic approaches is aimed at cleaning polymer particle surfaces so that the IR spectra can be properly obtained, whereas pyrolysis breaks down the polymers and organic matter.

The results of the quality of the different studies are provided in Chapter 3 together with a description of the sampling and detection methods used.

2.2 Exposure Assessment – rescaling

The detectable size range of microplastics depends on the sampling and analytical methods used in a study, and failing to account for this may introduce bias and errors in the results. In order to compare the results of different studies with each other, and with risk limits, all results were rescaled to the full size range from 1 to 5000 µm.

For this purpose, the best currently available approach to derive a particle size distribution from microplastics particle size measurements are used. Following the work from Koelmans et al. (2020) and Kooi et al. (2021) a power law was used as best educated approach for present risk assessments. This method increases concentrations at both the lower and upper size ranges where detection and sampling limitations are likely to affect particle detection and recovery, while using the rest of the size distribution to derive the power law distribution. This means that, based on the range of particles expected to be present in the environment, the exposure assessment includes the particles that were not measured or are underrepresented in the respective measurement due to analytical limitations. This was done using the Koelmans et al. (2020) approach by following these steps:

1. Power law fitting: Per water body a power law is fit to the measured particle size distribution.
2. Correction factors calculations: Using the particle size distribution correction factors are calculated for scaling the plastic particles to the standardized 1 – 5000 micrometre size range.

1. Power law fitting
A power law was fitted to the (raw) particle size data obtained from the particle number-based measurements. Here, an approach based on Clauset et al. (2009) is used to fit a power law to each dataset of microplastics environmental measurements, aggregated per water body and detection technique. A power law was fitted to the (raw) particle size data obtained from the particle number-based measurements. These raw data should include, for each particle, a record of length, width and polymer type. The latter is required to exclude non-polymer particles. We used the power law exponent fit to the length (the longest particle dimension) and a combination of all polymer particles detected in one water body per measurement technique, see Table 2. We separated LDIR and FTIR based data in performing the power law fit as differences in the techniques, as well as other aspects of the study affect the particle counts. Other aspects are for instance related to differences in spectral libraries or sample filtration.

The fitting of the power law was done by first detecting the part of the particle size distribution that follows a power law and then fitting a power law model to this section. This was followed by estimating the uncertainty of the fit using a bootstrap approach (n=1000) resulting in the reported 2.5% to 97.5% confidence interval. This procedure was kindly provided in personally communication by Yanning Qui and is based on the poweRlaw package in R (Clauset et al., 2009) and first applied in Koelmans et al. (2026). Figures showing the original data and power law fits are provided in Appendix 2.

2. Correction factors calculations
The probability density functions (PDFs) derived from fitting power laws represent the modelled distribution of all particle sizes in a studied sample or set of samples. This distribution is used to calculate the correction factors in order to scale the plastic particles present in a sample (each measurement) to the defined 1 – 5000 µm size range.

Correction factors were calculated for each sample based on equation 1 and represent the factor by which a measured particle number concentration needs to be corrected to match the defined microplastics size range of 1-5000 µm. These correction factors consider uncertainty of the power law fit and the lower and upper particle size limit.

The uncertainty in the power law slope (alpha) was included by taking a triangular distribution using the 2.5th and 97.5th percentiles of the power law slopes found using the bootstrap approach.

Equation 1 Generic formula for the correction factor from Koelmans et al. (2020) where:

$$CF = \frac{X_{UL,D}^{1-\alpha} - X_{LL,D}^{1-\alpha}}{X_{UL,M}^{1-\alpha} - X_{LL,M}^{1-\alpha}}$$

X: The particle number concentration
UL: The upper size limit
LL: The lower size limit
α: The power law slope

M: The range for which data is available (the range to be corrected)
D: The default size range (1 – 5000 µm)

The uncertainty in the reported lower and upper size detection limits is based on assuming a 10% deviation (above and below) of the reported size detection limits. This is done to include variation in the size cutoffs which are often not clear-cut. For instance, Wang et al. (2026) demonstrated that using sieves or filters does not result in a distinct size cut-off, because nominally too large particles could pass through the mesh vertically, while smaller particles may be retained by partially clogged filters. The 10% deviation value is rather arbitrary as no quantification of the deviation was available in the literature. This means that reporting a 10 µm lower size limit is varied via a triangular distribution between 9 and 11 µm with 10 µm being the most likely value. Including this in the correction factor calculations allowed incorporation of some of this variation in a generic way, although it would be better to specify this based on the exact filter/sieving approach used in each study.

2.3 Estimating particle numbers from mass-based measurements

Mass concentrations cannot directly be compared to particle number-based risk limits. To make this possible, microplastic mass concentrations in suspended particulate matter (SPM) were converted to microplastic particle number concentrations in surface water. The SPM mass concentrations were first converted to surface water mass concentrations. This was followed by converting the mass surface water concentrations to particle number concentrations using a power law model and polymer density. These calculations should be considered as a first attempt or proof of principle to better understand relevance and reliability of mass- based measurements for ecological risks assessments. In this report, these conversions were performed for a single polymer only, polypropylene (PP), based on the work from Rijkswaterstaat (Freriks et al., 2023a), using the steps outlined below. We choose PP because PP is also detected by the spectroscopic methods allowing for an initial comparison.

The principle of conversions between microplastics particle number data and microplastics mass is commonly done (Mintenig et al., 2020; Primpke et al., 2020b; Lee et al., 2023). The applied approach here is based on the same principles, but works the other way around, where particle number concentrations are calculated from mass concentrations. This proof of principle exercise aimed to demonstrate that this conversion works in theory.

Specifically, the following steps were conducted to perform the mass-to-particle number conversions:

1. Surface water concentrations
Microplastics SPM mass concentrations were corrected for the recovery efficiency of the sampling procedure in order to compare mass based measurements using a sediment box or centrifuge to measured particle number concentrations. Details on the applied sampling and detection for the mass based data is given in Section 3.3. It is known from

literature that the recovery efficiency of sediment boxes range between 67±5.2% up to 94% recovery for particles larger than 100 µm (Freriks et al., 2023b; Harhash et al., 2023). Much lower recoveries are reported for smaller particles (<100 µm), with values as low as 0.13% recovery reported by Harhas et al., (2023). For this proof of concept study we use a uniform distribution between 10% and 90% for the recovery of sediment boxes based on the assumption that the lower sized particles have a negligible contribution to the overall mass estimates. More exact estimates can be derived if relevant for future studies. The recovery of the centrifuge is reported to be between 86.3±7.1 and 100±16.9% (Harhash et al., 2023), therefore we assumed a uniform distribution between 86.3 and 100% recovery.

SPM water concentrations were used for conversion of microplastics SPM concentrations (g polymer / kg SPM) to microplastics surface water concentrations (g polymer / L water).

SPM concentrations were provided by Rijkswaterstaat for a sampling site near Eijsden in the river Meuse and near Lobith in the river Rhine. The concentrations of SPM in water fluctuate over time. Specifically for the weeks long sampling using the sediment box multiple SPM concentration measurements are available. For these cases, the minimum, maximum, and median values were determined (summary in Table 1) and used to define a triangular distribution, which was then applied to calculate the mass concentration of microplastics in water.

Table 1 Summary of Suspended Particulate Matter (SPM) concentrations in water as provided by Rijkswaterstaat (www.waterinfo.rws.nl). More details in Table A14 on SPM water concentrations per SPM microplastics sample.

Location	**SPM concentration (mg/L) Median (min-max)**
Meuse Eijsden	26 (5.0 – 230)
Rhine Lobith	18 (5.0 – 240)

2. Convert to microplastic volume
The total volume of PP microplastics was calculated using the density of pure PP (Equation 2). This PP density ranges between 898 kg/m^3 and 908 kg/m^3, depending on different polymerizations or crystallinity and excluding other constituents which can be made part of the PP matrix. For the conversion in this study, we used a triangle distribution between 898 kg/m^3 and 908 kg/m^3 with most likely values of 904 kg/m^3.

Equation 2 Total volume of microplastics in sample

$$V_{\text{total}} = \frac{m}{\rho}$$

Where:
m: Mass of microplastics
ρ: Density of microplastics

3. Mean volume of measured particle size distribution
The mean volume of microplastic particles was derived using a power law slope for volume fit to the raw particle number data (Equation 3). This step requires information on the smallest and largest particle volume, which were calculated using the length to width and width to height ratio's reported by Kooi et al. (2021). This includes the variation in cutoff in lower and upper size limits, assuming the same 10% deviation as for the FTIR/LDIR data using a triangular distribution. This deviation is also applied to the height factor (0.67) and width factor (0.67) as the conversion to volume is also uncertain. Moreover, the smallest particle shape was assumed to be of a more flattened ellipsoid, where width and height are described by the minimum length of 1 µm multiplied by their respective factors. For the largest particle, however, height was described by applying both width and height factor to the maximum length of 5000 µm. The power law slope for particle volume is fitted for only PP particles based on the LDIR measurements in the Rhine (alpha = 1.73 (1.58-1.93; 95% CI)) and Meuse (alpha = 1.70 (1.58-1.90; 95% CI)). Although these power law slopes are for PP, they are not based on the same samples as taken using sediment box or centrifuge. Although both approaches have a size dependent recovery efficiency, the mass concentration is assumed to represent the full 1 to 5000 micrometre size range as we correct for the recovery efficiency of the sampling approach in the first step.

Equation 3 Mean volume of microplastics (Kooi et al, 2021)

$$\langle v \rangle = \frac{1-\alpha}{2-\alpha} * \frac{V_{UL}^{2-\alpha} - V_{LL}^{2-\alpha}}{V_{UL}^{1-\alpha} - V_{LL}^{1-\alpha}}$$

where:
$V = volume\ of\ smallest\ (LL)\ and\ largest\ (UL)\ particle$
$\langle v \rangle = mean\ volume$
$\alpha = powerlaw\ slope$

4. Particle number concentration
Finally, the particle number concentration was calculated probabilistically (n = 10,000) by dividing the density of microplastics particles with the mean volume of microplastics particles (Equation 4).

Equation 4. Number of microplastics particles

$$N_{particles} = \frac{V_{\text{total}}}{\langle v \rangle}$$

where:
$V_{total} = total\ volume\ of\ microplastics$
$\langle v \rangle = mean\ volume\ of\ microplastics$
$N_{particles} = Number\ of\ microplastics\ particles$

2.4 Risk limits

As a recent study deriving risk limits was available in the literature it was not deemed effective to perform a full hazard assessment to determine risk limits. Therefore, risk limits were taken from the study by Coffin et al. (2026). The study by Coffin et al. (2026) built on the work

by Mehinto et al. (2022) and Koelmans et al. (2020), and used species sensitivity distributions (SSDs) to provide a hazard assessment of microplastics, using the most recent advances in SSDs, developed specifically for the risk assessment of microplastics. The study by Coffin et al. (2026) uses 14 quality criteria from Mehinto et al., (2022). This is a subset from De Ruijter et al., (2020) fully covering six out of the twenty described in De Ruijter et al. (2020) and some others taken less strict because otherwise no studies would pass the criteria for use in risk limit derivation. Nevertheless, we consider the study by Coffin et al. (2026) the currently best available hazard assessment for MPs in aquatic matrices and the risk limit values were used as reported.

The study of Coffin et al., (2026) derives risk limits based on the ecologically relevant metrics, volume and surface area. These ecologically relevant metrics for microplastic particles are based on known mechanisms of toxicity for the linkage between particles and toxicological effects. Most support exists for the relationship of particle volume and surface area, with food dilution and tissue translocation as mechanism of toxicity, respectively (De Ruijter et al., 2020). Currently there is no evidence that other metrics are more appropriate. We use the reported risk limits (HC5 values) for both metrics expressed in particle number concentrations for the 1 to 5000 µm microplastics size range. The resulting risk limits as derived by Coffin et al. (2026) are compared to the rescaled exposure concentrations derived in the present study. For a summary of the derivation of the risk limits used in the present study, see Appendix 3.

For the purposes of the current report, only the median HC5, or 5% hazard concentration for organismal or population level no observed effect concentrations (NOECs) for chronic exposures were used. This value is a commonly used value for risk assessment in the Netherlands and provides the basis for a proper level of environmental protection, without being overly conservative (EC, 2018).

2.5 Data and code availability

The raw data is (partly)[1] made available together with the code. The code used for data clean-up, fitting the power law and performing the described analysis is made available via https://github.com/rivm-syso/MicroplasticsERA_water.

[1] Can be made available upon request.

3 Results and discussion

The data and results from our analysis are presented in this chapter including discussion of what the results mean, additional supporting data is provided in Appendix 4. In section 3.1 the existing surface water monitoring studies retrieved from literature are described including a brief discussion of the applied measurement methods. In the next section (3.2) the results from rescaling the particle number concentrations are presented and discussed, followed by a description of the conversion exercise of mass to particle number concentrations (Section 3.3). The literature risk limits are provided and discussed in section 3.4. In section 3.5 the screening level risk assessment is shown where the exposure concentrations are compared to risk limits.

3.1 Description of Dutch surface water monitoring studies

Measurements are divided in two types, (i) those reporting particle numbers and which include particle counting data, including size measurements and (ii) those reporting polymer mass.

3.1.1 Particle number based data

3.1.1.1 Study context

Through a literature search, quality assessment (see below) and requests for data from selected research organisations 5 studies provided data on the number concentration of microplastic in Dutch surface waters (Mintenig et al., 2020; Mughini-Gras et al., 2021; Bäuerlein et al., 2022, 2023; Mintenig et al., 2025). This resulted in a dataset of 70 measurements of microplastic concentrations in the Meuse, Dommel, Rhine, Lek canal, Overijsselse Vecht and Werverschoof effluent canal (Figure 4). All samples were taken and analysed between 2017 and 2025 (Table 3). The Werverschoof wastewater treatment plant (WWTP) effluent canal is treated separately (n=28) from the other measurements (n=42) as it is a specific hotspot largely influenced by the waste water effluent which likely contains a lot of microplastics and represents a more artificial surface water body compared to the rest. The canal eventually runs off into the IJsselmeer. These samples are all measured at least 100m from the WWTP effluent discharge point. Samples directly taken in WWTP effluent are discarded. Overall, the measurements cover only a few water bodies in the Netherlands. The data points mainly represent large water ways with only some smaller tributaries included as part of the Dommel.

In all studies, sampling was performed by letting water flow over a cascade of sieves. Sample volumes varied between 500 Liter and ~8000 Liter.

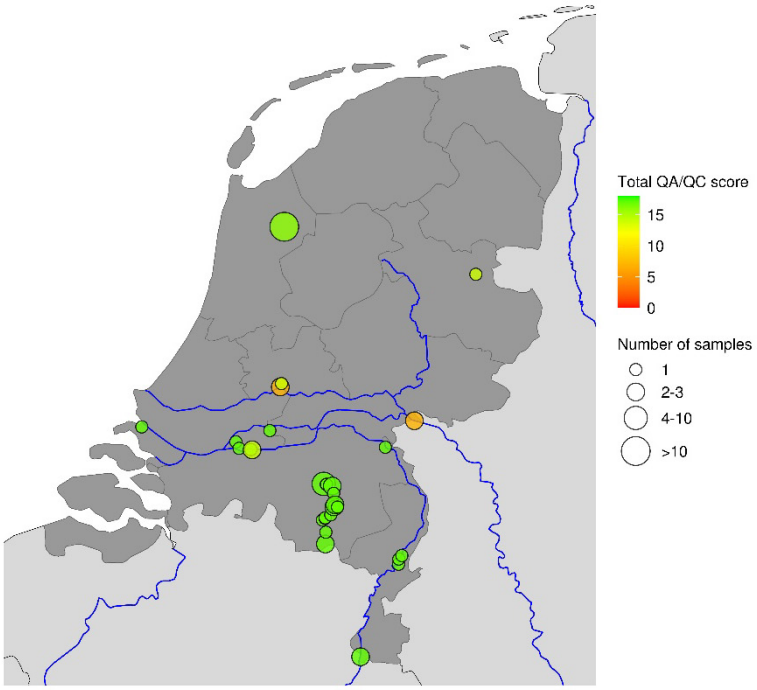
Both LDIR and FTIR measure the length and width of each identified particle. These individual particle measurements were obtained for all studies. This resulted in between 490 and 43834 individual polymer particles being characterized depending on the water body and detection method (Table 2).

Table 2 Overview of particle number data used for exposure assessment providing information on sampling, analysis, quality assessment score and the original data source.

Water body	Sampling period	Number of samples	Sampling method	Sample volume (L)	Analysis method	Total number of particles counted	QA/QC score#	Lower and Upper size limit (µm)	Data source
Dommel	October 2017 – August 2018	18†	Cascade of sieves	1984 – 7736	ATR-FTIR and Micro-FTIR	15375	17 / 0#	20 – 5000	Mintenig et al. (2020)
Dommel	Oct. 2024 – Nov. 2024	4	Cascade of sieves	1438 – 2177	ATR-FTIR and Micro-FTIR	28459	17 / 0#	20* – 5000	Mintenig et al. (2025)
Lek canal	August 2020	1	Cascade of sieves	1000	LDIR	12438	15 / 0#	10 – 500	Bäuerlein et al. (2022)
Lek canal	Juli 2019 - January 2020	2	Cascade of sieves	600	LDIR	3354	7 / 4#	10 – 500	Mughini-Gras et al. (2021)
Meuse	October 2017 – June 2018	11†	Cascade of sieves	4066 – 18230	ATR-FTIR and Micro-FTIR	6837	17 / 0#	20 - 5000	Mintenig et al. (2020)
Meuse	Sept. 2020 – Oct. 2020	3	Cascade of sieves	1000	LDIR	4576	15 / 0#	10 – 500	Bäuerlein et al. (2022)
Overijsselse vecht	July 2019	1	Cascade of sieves	1000	LDIR	490	15 / 0#	10 – 500	Bäuerlein et al. (2022)
Rhine	July 2019 – January 2020	2	Cascade of sieves	600	LDIR	3482	7 / 4#	10 – 500	Mughini-Gras et al. (2021)
Werverschoof WWTP effluent canal	July 2019 – Nov. 2019	28	Cascade of sieves	500	LDIR	19206	16 / 0#	20 - 500	Bäuerlein et al. (2023)

† The samples representing particles > 300 µm are not included, similar to the analysis of Mintenig et al. (2020).
# Number of quality criteria not met, scored 0 points.
* The lower detection limit is based on using a 20 µm filter, although an FTIR pixel resolution of 5.5 µm was used.

Figure 4 Sample locations of the microplastic concentrations from 6 studies, total of 70 samples, considered in this screening level ecological risk assessment. Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).



3.1.1.2 Quality assessment and control

The results of the quality assessment scoring shows that four of the studies score between 14 and 17 out of a total of 18 points (Table 2) with no 'zero' scores for any of the criteria meaning they meet the criteria. In contrast, the relatively older and pioneering study by Leslie et al. (2017) received the lowest score, with only 5 points. The main reasons for the low score are that nothing is reported on lab preparation, positive controls nor sample treatment. Only a partial polymer identification was done for 6% of the particles counted, and only a low sample volume of 2 litres was used. Therefore, the data from this study is not used here due to these limitations.

Mughini-Gras et al. (2021) also does not pass several criteria as it does not report on lab preparation, clean air conditions, or the use of positive or negative controls and some aspects of polymer identification approach remain unclear. This led to the study not meeting 4 out of 9 criteria, resulting in a relatively low score of 7. Nevertheless, the study is included under the assumption[2] that in reality a similar approach was taken (though not reported) as the other two studies by Bäuerlein et al. and this study is deemed screening level. This means that potential issues should be considered for interpretation of the data, for this reason all samples from this study are indicated with an asterisk (*) in further figures.

[2] Based on email contact with author of the study.

The other four studies pass all quality criteria, not scoring any zero's. They did not score the full 18 points, as they did not work in fully clean air conditions. Furthermore, the Bäuerlein 2023 study was scored with 1 point for polymer identification because they used only 2.5% of the sample, making it less representative following the QA/QC criterion 9, see Table A.6. The same for the Bäuerlein 2022 study which also scored a point less as it was relatively unclear on the sampling approach for drinking water and the pumping approach for surface water sampling, other aspects such as sampling date/weather conditions are reported for surface water sampling.

3.1.1.3 Microplastic detection and polymer identification

Detection method

In two studies Laser Direct Infrared imaging (LDIR) was used to detect and measure microplastic particles (Bäuerlein et al., 2022, 2023). Mintenig et al. (2020) and Mintenig et al. (2025) used a combination of Attenuated Total Reflectance Fourier transform Infrared spectroscopy (ATR-FTIR) for microplastics larger than 300 µm, and Micro-FTIR to identify smaller particles, respectively. In Mintenig et al. (2025) Micro-FTIR with a smaller pixel size was used (5.5 µm instead of 20 µm), which likely caused the higher particle numbers being detected (Table 2). Both studies by Bäuerlein et al. focused on the analysis of microplastics smaller 500 µm, and with a lower detection limit of 10 µm.

Overall, LDIR and FTIR are widely used for microplastic identification because they provide polymer-specific spectra, enable automated particle identification, while also providing their size and shape estimates. FTIR is well established, broadly validated, and suitable for environmental samples, while LDIR can be faster and more automated for routine workflows. However, use of these spectroscopic approaches (LDIR or FTIR) has limits. Detection of very small particles (< 20 µm) is constrained compared to Raman, and weathered, biofouled or natural polymer particles can be misidentified when not considered in spectral libraries (Marchand et al., 2025). Further, dark or thick particles may be difficult to analyse. This means that spectral libraries need careful curation, and sample preparation remains critical to obtain reliable results.

Although LDIR and FTIR have common features, the two techniques differ in several other aspects. FTIR imaging measures samples with a wider wavelength range than LDIR and as a pixel grid, whereby the pixel resolution can vary depending on the instrument or the studies interest. Pixels with spectra of the same polymer type are merged into particles, providing polymer identification and size estimates. In contrast, the LDIR first detects individual particles and then measures one point per particle for identification. While FTIR may miss particles located between pixels, the LDIR might oversee particles because it merges any touching particles and assigns only a single spectrum for the identification of such an aggregate.

Both LDIR and FTIR measure the length and width of each identified particle. These individual particle measurements were obtained for all studies. This resulted in between 490 and 43834 individual polymer

particles being characterized depending on the water body and detection method (Table 2).

Polymer identification
Polymer types were identified using spectroscopic libraries as provided by the SiMPle software (Mintenig et al., 2025, 2020) and Agilent software (Bäuerlein et al., 2022, 2023). The latter (LDIR) also builds on the library used in the SiMPle software (Primpke et al., 2020a, 2018), but it remains uncertain what the difference in performance is. The detected polymers differ per study (see Table A.1 to Table A 5), which could reflect true differences in the absence or presence of these polymers but may also partly be explained by the use of different software and libraries. Most relevant however is that some polymer types, such as Styrene Butadiene Rubber (SBR) and Natural Rubber (NR) from tyres remains undetected in these studies due to both techniques struggle to detect dark particles. Tyre and road wear particles contain high amounts of carbon black and form complex and difficult to distinguish aggregates. This is relevant as SBR and NR from tyre wear, are expected to be one of the largest sources of microplastics in the environment (Quik et al., 2024). This means that microplastic concentrations are probably higher than those reported here due to these polymers being missed. However, no corrections are applied based on polymer fractions.

The effect of differences between FTIR and LDIR and other aspects of the studies on detection and recovery of microplastics is not quantified. This could introduce some uncertainty in the exposure assessment, but is not expected to hamper comparing these measurements for exposure assessment.

3.1.2 *Mass based data*

In addition to particle-based methods, microplastics can also be determined using mass-based methods. In the Netherlands, Rijkswaterstaat uses Thermal Extraction-Desorption GC-MS (TED-GC-MS), a pyrolysis-based GC-MS approach, to monitor microplastic concentrations in Dutch rivers. These methods are not limited by the particle sizes or colours, and are able to identify SBR and NR from tyre wear particles. However, these GC-MS approaches usually remain limited to detecting ~8 polymers in total, whereas with FTIR over twenty polymers can be detected (Mintenig et al., 2020). This means that actual microplastic concentrations could be higher than those reported with TED-GC-MS due to polymers being missed. They could also be lower due to matrix effects for specific polymers (Kittner et al., 2022). Further, while FTIR/LDIR based techniques are limited by particle size, the GC-MS based ones are limited by a minimum mass of individual polymers and do not provide any information on the particle sizes, meaning that FTIR/LDIR and GC-MS are ideally complementary techniques.

The next sections describe the study context and the quality assessment of the provided data from Rijkswaterstaat (Freriks et al., 2023b, 2023c, 2023a) following the same criteria as applied for particle number based studies and discusses details of the sampling and detection approaches used.

3.1.2.1 Context

Mass concentrations of microplastics in the rivers Rhine and Meuse in the Netherlands were obtained from Rijkswaterstaat. The data were collected by Rijkswaterstaat through conducting various sampling campaigns and (in part) reported in Freriks et al. (2023b) include samples taken up to July 2024. This dataset comprises measurements of microplastics in suspended particulate matter (SPM) which can be converted to water concentrations using surface water SPM concentrations. SPM concentrations were available for the Rhine at Lobith and the Meuse at Eijsden and corresponded to 38 of the total 107 microplastic SPM measurements provided. These 38 measurements are further considered here and were taken in the river Rhine near Lobith and in the river Meuse near Eijsden (Figure 5) between 2020 and 2024 (Table 3). The remaining measurements were not considered because they could not be converted to concentrations in water.

Figure 5 Sample locations of the microplastic concentrations measured using TED-GC-MS. Data from Rijkswaterstaat (Freriks et al., 2023c, 2023b, 2023a).

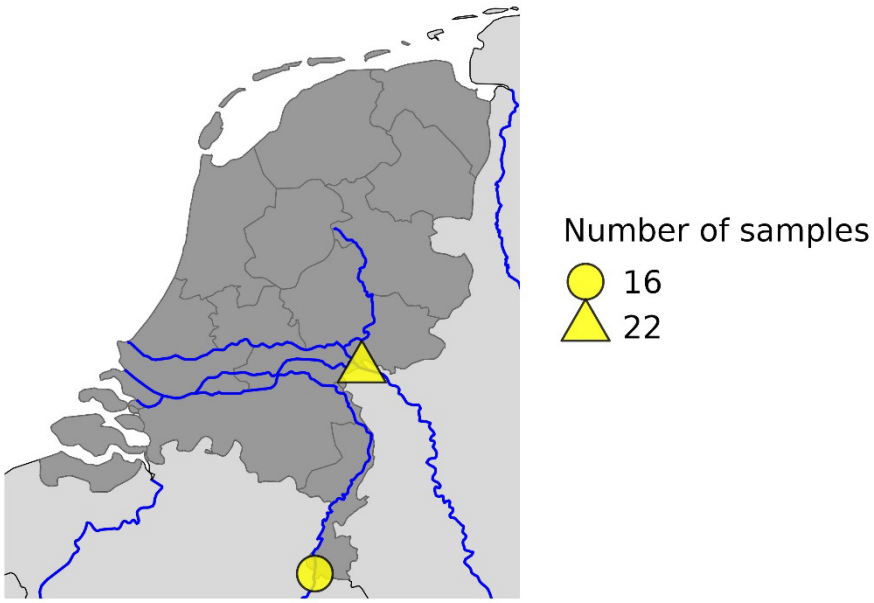


Table 3 Overview of attributes for mass concentrations measured using TED-GC-MS. Data from Rijkswaterstaat (Freriks et al., 2023c, 2023b, 2023a).

Location	River	Sampling methods	Sampling period	Number of samples
Eijsden	Meuse	Centrifuge or sedimentation box	February 2020 to December 2023	16
Lobith	Rhine	Centrifuge or sedimentation box	November 2020 to July 2024	22

Sampling method
The microplastics mass based data, as described by Freriks et al. (2023b), is obtained using two methods for sampling Suspended Particulate Matter (SPM) in surface water: a sedimentation box and a flow through centrifuge.

A sedimentation box is a steel box with multiple partial partitions that force the water to flow along the top and bottom of the box. Water is continuously pumped through the box for a period of 4 weeks resulting in a sampling volume of ~160.000 L. SPM and microplastics are trapped behind the partitions, typically resulting in a sample of 200-300g dried SPM. The retention of microplastics in the sedimentation box (recovery) is estimated to be high for larger particles, up to 94% based on Freriks et al (2023), but a lot lower for smaller particles. Harhash et al. (2023) reported recoveries as low as 0.13% for 11.3 µm polystyrene particles going up to 67% for 228 µm polystyrene particles. It should be noted however, that the mass recovery of the full microplastics size distribution is affected less by smaller particles compared to larger ones. The methodological strength of using a sediment box to sample microplastics lies in its large sample volume potential and ability to provide a time integrated SPM sample.

The centrifuge method is routinely used by Rijkswaterstaat for sampling SPM. Water is pumped with a flow of 1000 L/hr through a centrifuge mounted on a boat or pontoon, and the spinning of the device pushes particles (SPM or microplastics) to the outside of the cylinder, while the water flows through the centrifuge. The sampling period in Lobith and Eijsden lies between several hours and a day, depending on the SPM concentration at the time of sampling. The added centrifugal forces increase recovery of microplastics compared to the sediment box to between 86.3% to 100% based on the same study by Harhash et al. (2023).

As described in the methods section (2.3) the variation in recovery is corrected for in the conversion of microplastics SPM concentrations to microplastics water concentrations depending on sampling technique.

3.1.2.2 Quality assessment and control

Here we provide a compact QA/QC screening of the surface water samples analysed using the TED-GC-MS methodology as described in Freriks et al. (2023b, 2023c, 2023a). The study is scored with the same scheme as used for the particle number-based data. As mentioned, criteria as currently defined in Koelmans et al. (2019) may in a future update be adapted to the latest scientific insights, including specifics for thermal quantification methods.

The quality assessment results in a score of 12 out of 18 points, with two "zero" scores. The laboratory preparation and clean-air conditions criteria were not passed as this information was not reported. The other 7 out of 9 quality criteria were passed. The two criteria that were not reported on were clarified in personal communication stating that laboratory preparation was done in accordance with the criteria and provided argumentation that clean air conditions were considered adequate. The full table of scores and rationales are provided in

Appendix 1. The Freriks et al. (2023b, 2023c, 2023a) studies were deemed of sufficient quality to warrant further analysis of the reported concentrations.

Overall, the study by Freriks and the five spectroscopic studies that passed all criteria show a pattern very similar to what Koelmans et al. (2019) found for many microplastics water studies at that time: strong analytical development and some recovery work, but often incomplete documentation of contamination control and lab environment measures. However, in this case the workflow and performance of pyrolysis-based measurements in combination with centrifuge or sediment box sampling is rather different to the filter-based sampling and spectroscopic detection techniques, which may require refinement of the quality criteria. Some considerations on this are provided in Appendix 1.

3.1.2.3 Microplastic detection and polymer identification

Detection method

Thermal methods like TED-GC-MS or Pyrolysis-GC-MS enable polymer-specific, mass-based quantification of micro/nanoplastics and are largely independent of particle shape and size, as long as the thermal range is adequate to overcome the activation energy of the smallest polymer particles (Paik and Kar, 2009, 2008), which can improve comparability across heterogeneous samples (Becker et al., 2020; Scholz-Böttcher, 2023; Zhang et al., 2024). On the other hand, because particle shape and size are not measured, these need to be derived in order to use the data in risk assessment based on particle numbers. Here we assume the particle size distribution as measured using very different detection and sampling methods. A better option would be to add a size fractionation step using cascade filtration.

It is important to realize that quantification is indirect via marker pyrolysates and therefore sensitive to matrix effects and marker non-specificity. In river suspended particulate matter monitoring, naturally derived compounds (e.g., algae-related fatty acids) can interfere with PE-like signals, illustrating how "polymer" signals can partly originate from the matrix (Kittner et al., 2022).

Polymer identification

During the analysis of samples using TED-GC-MS, the freeze-dried samples are heated from 25°C to 510°C in absence of oxygen. During this pyrolysis, above 290°C each polymer and rubber type breaks down. The pyrolysis product formed by matrix below 290°C are discarded, and the pyrolysis product formed between 290 °C and 510°C are collected and subsequently separated by GC and identified by MS (Freriks et al., 2023c). The polymers analysed in this study were NR, SBR, PA, PE, PMMA, PP, PET and PS. The polymers that were mostly identified are commonly used plastics and rubbers (PE, SBR, PP, PS). The other plastics may also be present, but in concentrations below the detection limit.

Overall, TED-GC-MS measurements are expected to complement FTIR/LDIR based measurements in assessing the actual microplastic concentration in surface waters.

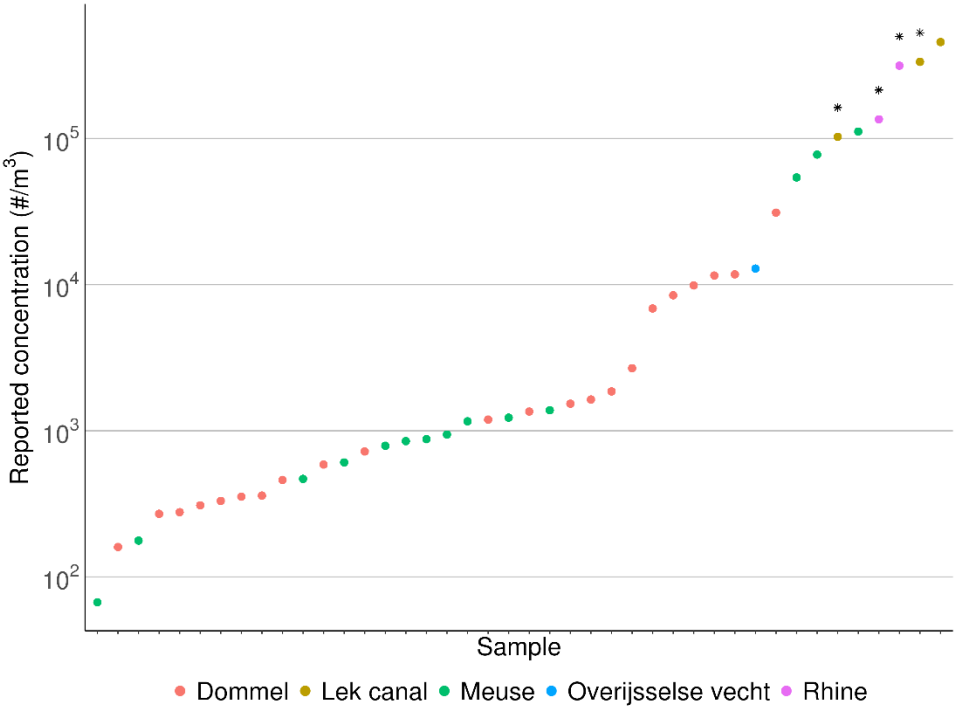
3.2 Particle based exposure assessment – rescaling

As shown in Table 2, all studies included in this report measured only a part of the microplastic particle size range between 1 to 5000 µm. To assess the actual (predicted) exposure concentration of aquatic organisms to microplastics, we rescaled the reported particle concentration in each original study using a power law model following the methods described by Koelmans et al. (2020). Below we first provide the measured number concentrations as reported by each original study (section 3.2.1). Then the calculation of correction factors based on the Koelmans approach in section 3.2.2. Followed by a brief description of the rescaled particle number concentrations 3.2.3 and discussion of the main causes of uncertainty in section 3.2.4.

3.2.1 Reported particle number concentrations

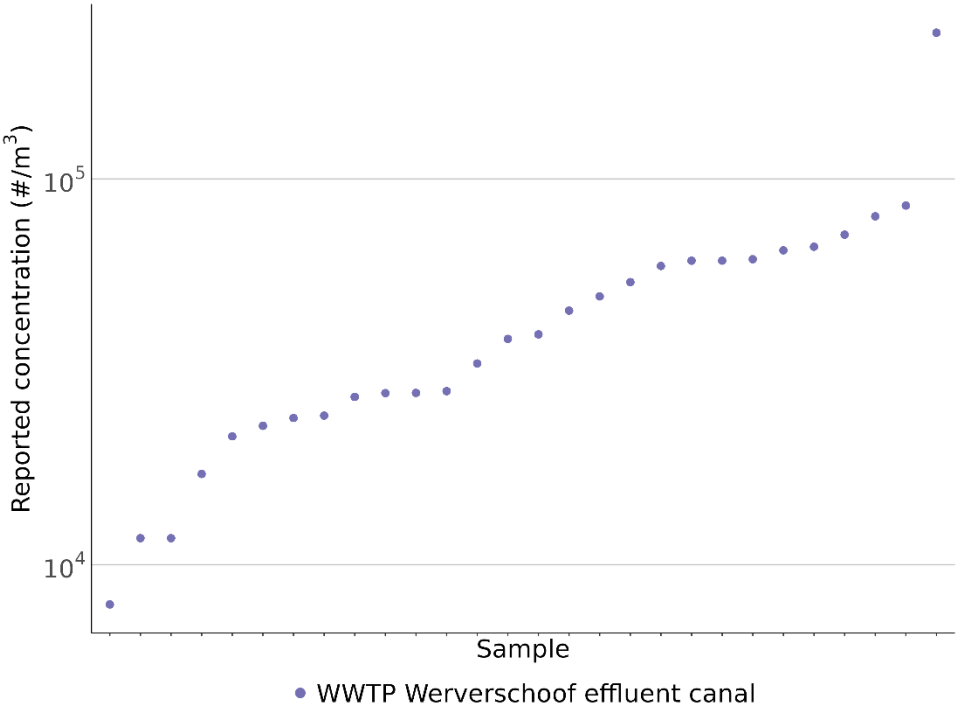
The reported particle number concentrations range between 67 #/m^3 and and 457 000 #/m^3 depending on the location and time of sampling (Figure 6 and Figure 7). The results of samples taken in the Werverschoof effluent canal are reported in a separate figure as this waterbody does not represent a natural habitat and is expected to be highly influenced by the wastewater treatment plant and other urban sources of microplastics.

Figure 6 Reported microplastics number concentrations for the Dommel, Lek canal, Meuse, Overijsselse Vecht and Rhine rivers. Data from Bäuerlein et al. (2022), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).*



*Indicates samples from the study by Mughini-Gras (2021) which did not pass all quality criteria.

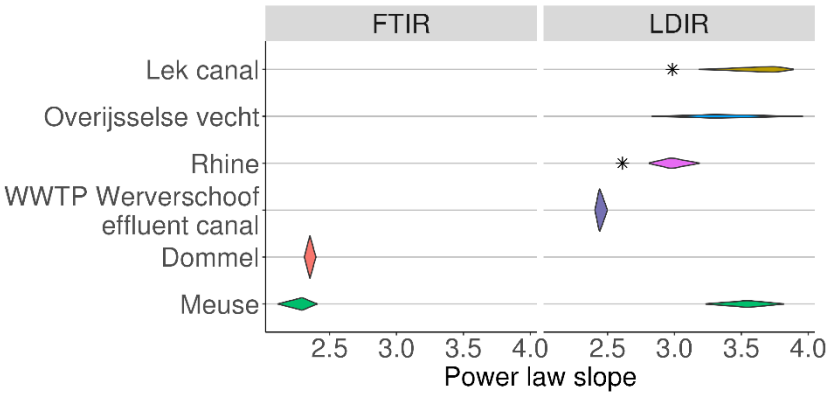
Figure 7 Rescaled reported microplastics number concentrations for the Werverschoof effluent canal. Data from Bäuerlein et al. (2022).



3.2.2 *Calculation of correction factors*

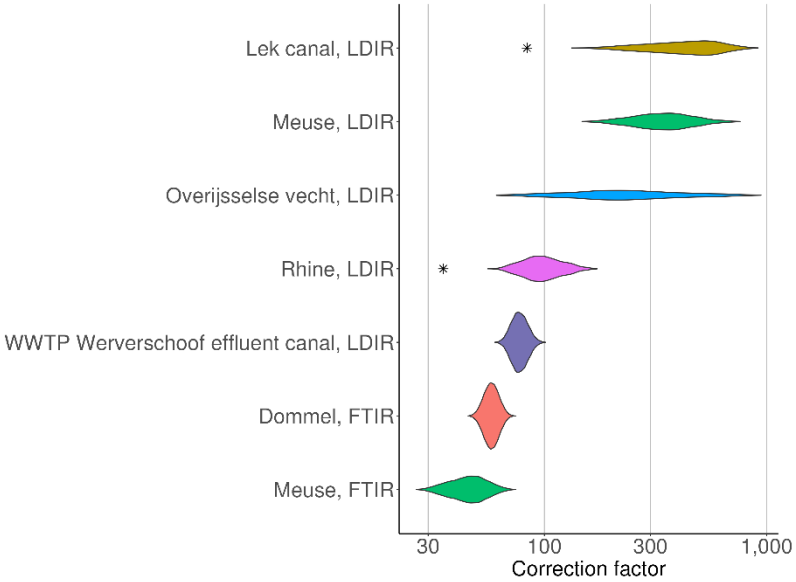
An important step for calculating correction factors is the estimate of the power law slope for each water body and detection method which in itself is uncertain (Figure 8). The power law slope ranges between 2.3 (2.1-2.4, 95% CI) and 3.8 (3.2-3.9, 95% CI) depending on the water body and detection method as used in each study, additionally see figures in Appendix 2. Similarly, the calculated correction factors are also dependent on the water body and study, and range between 46 (31-63, 95%CI). and 440 (190 – 750, 95%CI) (Figure 9).

Figure 8 The power law slopes as derived for different water body's from particle size measurements using FTIR (left panel) and LDIR (right panel) based analysis methods. The points or violins represent the probability (height) and range (width) of values calculated using a bootstrap method (n=1000). Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).*



*These power law slopes are based on data by Mughini-Gras (2021) which did not pass all quality criteria.

Figure 9 Correction factors as calculated using the Koelmans approach for aligning reported concentrations to the full microplastics size range based on the minimum and maximum size detection limits and power law slope. The points or violins represent the probability and range by the height and width of the plotted violin respectively. Logarithmic scale. Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).*



*These correction factors are based on data by Mughini-Gras (2021) which did not pass all quality criteria.

Notably, the smallest correction factors are observed for the samples that cover the largest size distribution (Table 2) and have the lowest power law slope (Figure 8). For example, the corrections factors for the Mintenig et al. (2020, 2025) samples for the Dommel compared to the Mughini-Gras et al. (2021) samples for the Lek canal and Overijsselse Vecht have on average a factor 3 to 8 difference.

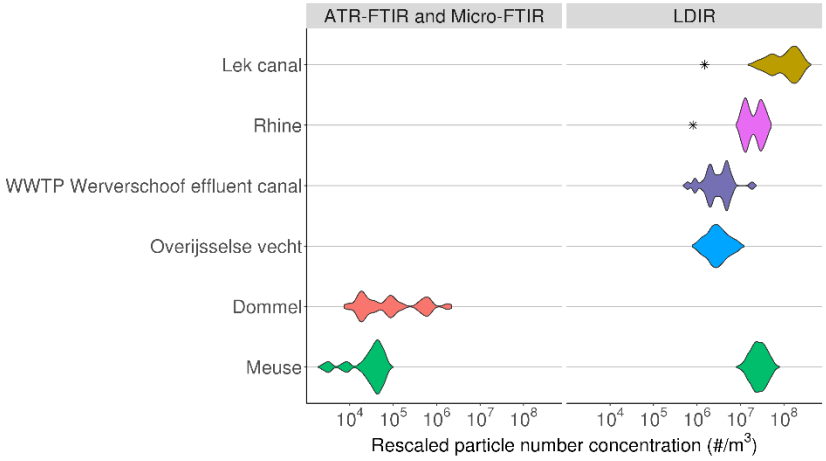
These corrections factors (Figure 9) cause the reported concentrations (Figure 6) to increase between 30 to 750 times depending on the study and water body when rescaled. For samples with a high correction factor the largest part of the rescaled exposure concentration comes from the smallest particles which are not measured.

In part, the uncertainty of the correction factor is a result of the uncertainty in the power law slope, this is largest for the Overijsselse Vecht, Lek Canal and Meuse as measured using LDIR, with correction factors spanning almost 1 order of magnitude (Figure 9). A high uncertainty of the power law slope means that the power law is not able to fully describe the observed particle size data, this could also be compounded by the relatively small size detection window of 10 µm to 500 µm compared to the 20 µm to 5000 µm for the FTIR data. The total number of particles included might also play a role. For example, the Overijsselse Vecht had the lowest particle count (n=490, see Table 2) and a large uncertainty in the correction factor and rescaled concentration.

3.2.3 Rescaled number concentrations

Overall, the average rescaled particle number concentrations range from 3100 #/m^3 to 2.0 x 10^8 #/m^3 covering 5 orders of magnitude (Figure 10). This depends on sample location, water body and date of sampling. The data are rather limited, so analysis of trends in time is not possible. Also, a comparison of the ATR-FTIR combined with Micro-FTIR with LDIR method is not possible as they are not applied here to the same samples.

Figure 10 Rescaled particle number concentrations split per water body and detection method (ATR-FTIR coupled Micro-FTIR and LDIR). Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).



*These correction factors are based on data by Mughini-Gras (2021) which did not pass all quality criteria.

The river Dommel and Meuse are represented by the most data points. The Dommel concentrations range on average between 9.3 x 10^3 #/m^3 to 1.8 x 10^6 #/m^3 and the Meuse concentrations range from 3100 #/m^3 to 4.1 x 10^7 #/m^3. For the Meuse specifically some samples measured using the LDIR are almost 2 orders of magnitude higher compared to the highest concentrations measured using ATR-FTIR coupled Micro-FTIR. Also, the range of concentrations measured using LDIR for the Lek Canal, Rhine and Overijsselse Vecht vary by several orders of magnitude. It remains unclear if the differences in concentration stem from methodological differences as no comparable samples where available, e.g. taken at the same time and location. Even comparing measurements from the Dommel from the 2017-2018 campaign (n=18) to the 2024 campaign (n=4) measured by the same WUR lab is hampered as they used a different instrument with a smaller pixel resolution and it can thus be expected that the 4 samples differ from the 18 from earlier work.

Overall, it remains uncertain how well the Dommel and Meuse samples represent the full temporal and spatial distribution of microplastics in these water bodies. The current data set is deemed to include too few data points to provide a representative view of the microplastics pollution in surface water in the whole of the Netherlands. Further research specifically focussed on getting this country wide overview could inform on the types of surface water or land use that should be included in further microplastics monitoring.

This large variability suggests that there is a need for specific attention to account for this variability in future sampling campaigns. Temporal variability can be averaged out using time aggregated sampling approaches. Spatial variability and choice for sampling locations should

likely be informed based on potential sources and hydrological and ecological characteristics of the location.

3.2.4 Discussion of uncertainties in particle-based exposure assessment

Given the data analysed here two important factors are identified that cause the estimate of exposure concentrations of microplastics in surface waters to be rather uncertain.

1. It is unclear how different studies can be compared as they use different measurement methods, e.g. different techniques and sampling approaches.
2. A discrepancy exists between the microplastics that can be measured and the full range of microplastics that fall within the definition, making it difficult to accurately assess actual particle concentrations of microplastics in waters.

Measurement methods

Comparability of studies is essential for estimating exposure, either by having robust methods or by reporting data that would allow for correcting differences between studies, e.g. recovery or size range covered. Monitoring microplastics in a comparable way means having reproducible methods for sampling, sample preparation, sample analysis and data reporting. Regulatory use of such methods should be based on microplastics specific ISO, CEN or OECD protocols and guidelines.

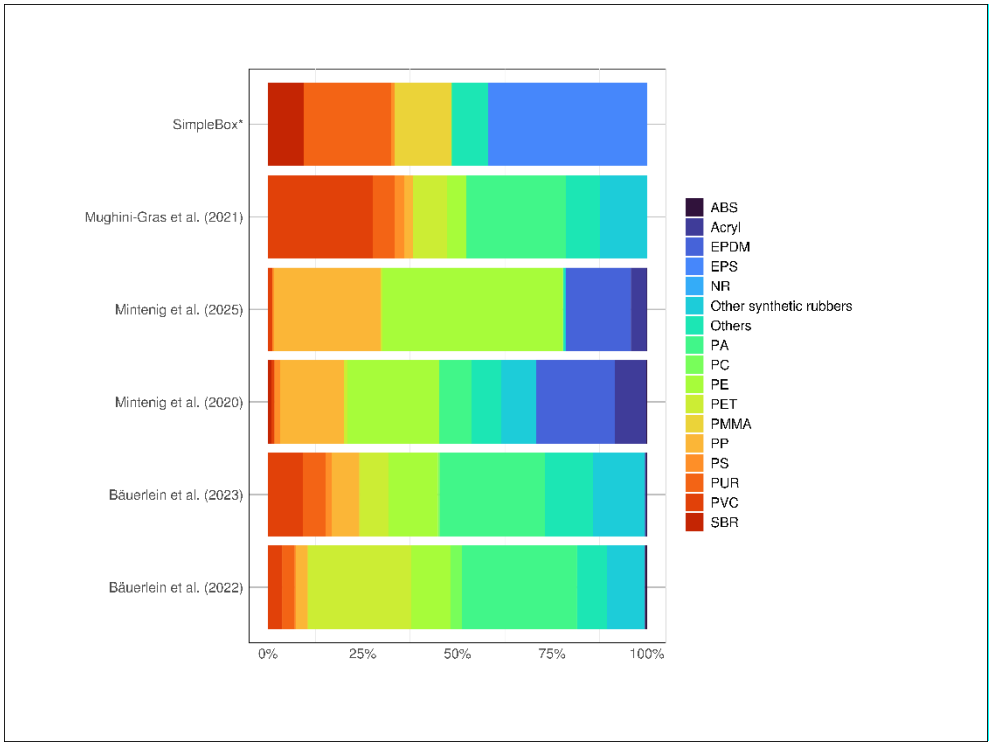
One area of improvement could come from understanding the role the software analysis step plays in interpreting FTIR or LDIR spectra as this could hamper comparison between studies. So far, only two studies compared the results of the same samples using two rapid automated analysis tools for large FTIR microplastic datasets (Moses et al., 2023; Van Loon et al., 2024). Both studies found that results could deviate substantially depending on which software tool was used but showed good agreement for a subset of ten polymers and when excluding the smallest microplastic size classes (< 50µm). Another important cause of uncertainty in the interpretation of FTIR or LDIR spectra is the use of spectral libraries which are mainly optimized for synthetic polymers, but should also account for natural (organic) materials that could be misidentified for plastic (Marchand et al., 2025), such as cellulose fibres or animal furs.

Measuring the smallest particles

Another area of improvement is in sampling and detecting microplastics smaller than ~20 µm. Missing this size range in measurements can cause a correction resulting in 30 to 750 times higher particle counts. There is a lot still unclear for the 1 to 20 micrometre size range, as data on these smaller microplastics remain scarce due to the complexity and cost of such analysis, although possible using Raman or nano-FTIR. Studies by Boersma et al. (2023) and Grigoriadi et al. (2023) show that specific polymer types produce differently sizes particles based on common wear processes. They calculate that these wear processes specifically affect formation of < 20 micrometre particles for which we now have no measurements. Thus, measurements covering the full 1 to 5000 micrometre size range could inform rescaling procedures or reduce the need for correction factors (Figure 9) altogether. A better understanding of the full microplastics particle size distribution and in

particular of those of the smallest particles would contribute to a more robust exposure assessment.

Figure 11 Fraction of polymer types from a SimpleBox modelling study compared to the polymer types detected in surface waters in the Netherlands. Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021) and Brand et al. (2025).



*Model study using SimpleBox, a multimedia fate model, applied to emission estimates for the Netherlands considering 14 different polymer types, details of the study can be found in Brand et al. (2025).

Tyre wear

Microplastics measurement methods have a limited capability to detect particles covering the full 1 to 5000 micrometre size range. This is however, corrected for using the rescaling approach following Koelmans et al. (2020). The microplastics definition also covers a specific set of polymer types (see text box in Chapter 1). From emission estimates it is known that tyre wear particles consisting of Natural Rubber (NR) and Styrene Butadiene Rubber (SBR) are one of the largest sources of microplastics in the environment. These rubbers are not included or consist most 0.75% of particle number concentrations in either of the studies covered in this report (Figure 11), but a modelling study estimated that 9.5% of polymers in surface waters in the Netherlands is expected to be composed of SBR and NR (Brand et al., 2025) based on tyre wear being estimated as one of the largest sources of microplastics to the environment (Quik et al., 2024). The poor detection of tyre wear particles using LDIR or FTIR based methods is explained by: (i) The black colour (Carbon black being present) that absorbs all IR radiation and thus no polymer characteristic peaks are visible. (ii) Tyre wear particles, including road wear, have a combined density that is not retained during the sample extraction step aimed at removing the

mineral fraction. (iii) The heterogeneous character of tyre wear particles, consisting of tyre, road and potentially other materials, potentially makes them even more diverse than other polymers, which makes it more difficult to define the group of reference spectra for these types of particles.

This means that the current exposure estimates are expected to be an underestimation of the microplastics surface water concentration. The degree of underestimation due to misrepresenting tyre rubber remains unclear but based on an indicative modelling estimate the particle number concentrations could be about 10% higher. In future exposure assessments pyrolysis-based measurements could be used to further quantify the expected tyre wear particle concentration.

3.3 Mass to particle number concentrations conversion

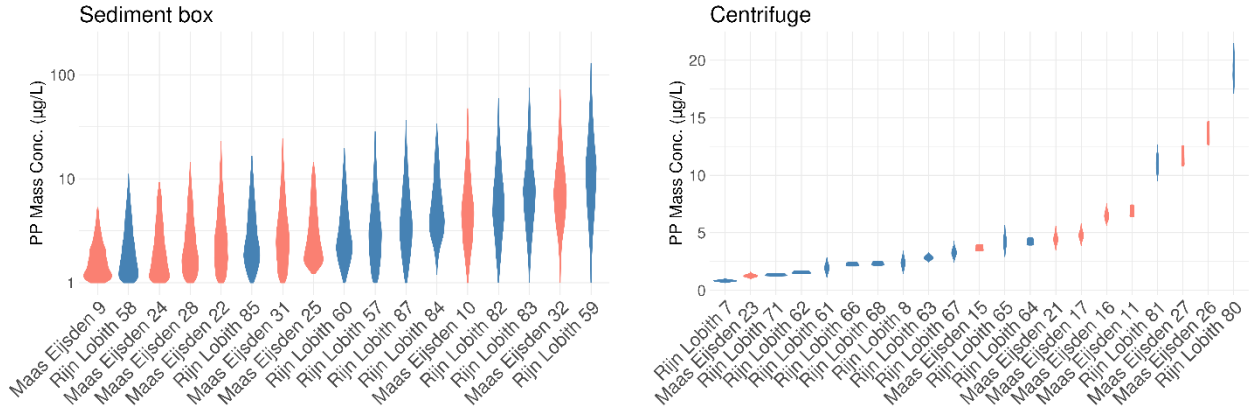
The conversion from microplastics Suspended Particulate Matter (SPM) concentrations to water concentrations for measurements at Lobith (Rhine) and Eijsden (Meuse) results in PP concentrations between 0.2 and 133 µg/L (Figure 12). The sediment box captures a time integrated sample over 27 to 29 days, whereas a centrifuge sample is taken during a much shorter period up to about 1 day. As a result of these differences in the sampling period the calculated water concentrations of PP show a much larger variation in the samples taken using the sediment box compared to the centrifuge, which is the result of differences in the variability of SPM concentrations and in recovery efficiency. The only variation in PP mass concentrations for the centrifuge samples is from the uncertainty in recovery, estimated to range between 86% and 100%.

For assessing exposure of organisms to microplastics a longer time integrated sample is considered more representative compared to one sampled in a short time span. However, it is also relevant to include time resolution in microplastics samples, e.g. having a daily sample in order to better understand the frequency of peaks in time. Furthermore, the sediment box has a much lower recovery compared to the centrifuge which also partly accounts for the observed variation in mass concentrations (left panel Figure 12). Although the sampling approach affects the included variability in time and sampling uncertainty the average Rhine and Meuse concentrations largely overlap (Table 4), which means both approaches are likely to provide useful measurements.

Table 4 Average mass concentration of all SPM samples taken with a Sediment Box over ~4 weeks versus Centrifuge over ~1 day for Rhine (Lobith) and Meuse (Eijsden). Data from Rijkswaterstaat (www.waterinfo.rws.nl).

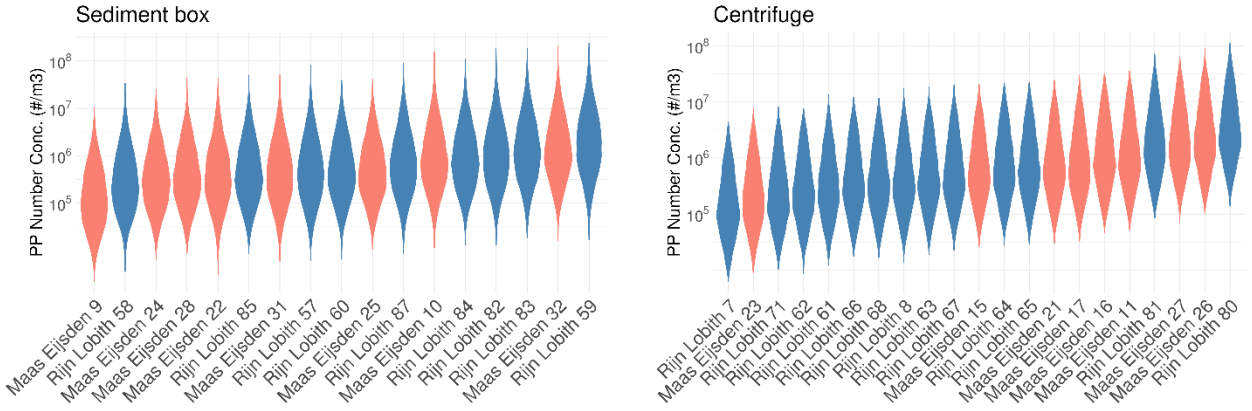
	Sediment Box (µg/L) Average (min-max)	**Centrifuge (µg/L)** Average (min-max)
Rhine	6.30 (1.97 – 15.2)	4.41 (0.817 – 19.2)
Meuse	4.01 (0.927 – 10.2)	6.60 (1.25-13.6)

Figure 12 Water PP mass concentrations measured using TED-GC-MS for samples taken by Sediment box (left) and Centrifuge (right). Including variability of SPM water concentrations and uncertainty of recovery efficiency. Meuse in red and Rhine in blue. Figure on the left with y-axis in log scale. Data from Rijkswaterstaat (Freriks et al., 2023c, 2023b, 2023a).



The points or violins represent the probability and range of values by the height and width of the plotted violin, respectively.

Figure 13 Water PP number concentration for samples taken by Sediment box (left) and water Centrifuge (right) converted from mass concentrations, including uncertainty in particle size distribution. Meuse in red and Rhine in blue with y-axis in log scale. Data from Rijkswaterstaat (Freriks et al., 2023c, 2023b, 2023a).



The points or violins represent the probability and range of values by the height and width of the plotted violin, respectively.

The mass water concentrations of PP were converted to number concentrations using the estimated power law slope as derived for particle volume (Figure 13). The variation in number concentrations increases compared to the variation in mass concentration due to the uncertainty in the particle size distribution. This increase in uncertainty is largely caused by uncertainty in the power law slope (alpha), although for the sediment box the variability in the SPM concentration and uncertainty in the recovery also plays a role as can be seen in the variation shown in the mass PP water concentrations (Figure 12). It seems that uncertainty in recovery could be a lot lower for centrifuge-based samples although inclusion of temporal variability

would be reduced, which would require analysis of more centrifuge samples in time.

Table 5 Average number PP concentrations converted from mass SPM measurements (Table 7) for Sediment Box and Centrifuge samples and measured using FTIR and LDIR for Rhine and Meuse. Data from Rijkswaterstaat, Mintenig et al. (2020) and Mughini-Gras (2021).

	Sediment Box (10^6 #/m^3) Average (min-max)	**Centrifuge (10^6 #/m^3)** Average (min-max)	**Measured (10^6 #/m^3)** Average (min-max)
Rhine	2.5 (0.82 – 6.3)	1.8 (0.33 – 7.8)	81 (42 -120)
Meuse	1.6 (0.37 – 4.1)	2.7 (0.50 - 5.5)	0.091 (0.00044 - 0.82)

Given the sediment box and centrifuge samples do not correspond directly to the particle number based measurements a direct comparison is hampered. Also when comparing the converted mass concentrations to measured particle number concentrations shows either a lower or larger particle number concentration for the Rhine and Meuse respectively (Table 5). This together with the caveat that the particle size distribution of the sediment box and centrifuge samples is unknown limits further analysis or conclusion related to using this approach for exposure assessment.

This proof of principle exercise illustrates that mass to number concentrations are in theory possible. However, to further apply such a mass conversion approach in practice further development is needed including validation using particle-based measurements on the same samples. It is also advised to investigate obtaining particle size data from mass-based measurements, e.g. by cascade filtration. Pyrolysis based methods would further benefit from extending and further developing polymer identification using pyrolysis marker analysis, e.g. coping with matrix effects, and extending the identification of more polymer types. This should increase the overall insight into the full range of polymers making up the microplastics mixture in the environment. And lastly, further analysis of the use of mass data for exposure assessment, converting mass to particle number concentrations or vice versa, e.g. this could also mean converting risk limits to mass. Conversion of particle number data to mass is actually done more often, e.g. (Lee et al., 2023; Mintenig et al., 2020; Primpke et al., 2020b).

3.4 Risk limits

3.4.1 Derivation of risk limits

The risk limits for particle-based microplastics data, based on HC5 values, were derived by Coffin et al. (2026) (Table 6), who incorporated uncertainty across all components of HC5 derivation. This resulted in a much larger variation of HC5 values for the volume ERM compared to the surface area ERM, making those estimates using volume as ERM more variable, spanning four orders of magnitude compared to two orders of magnitude when applying surface area as ERM. The risk limit derivation is dependent on the microplastic particle size distribution, including conversions to particle surface area (m^2) and volume (m^3).

Because of the particle size dependency, Coffin et al (2026) highlight the importance of incorporating site-specific environmental size data, meaning that the size distribution of microplastics in the considered water bodies should also be used for alignment of the hazard studies, which was not possible in the current study. The risk limits, although representative of the full 1-5000 micrometre size range, could change based on the differences in particle size distribution, the power law slope, found per water body in this study. The power law slopes for volume are comparable in range to the ones used by Coffin et al. (2026). However, the power law slope for particle length, used for rescaling, is in several cases lower or higher than the range used by Coffin et al. (2026). The exact implication of such a difference in power law slope needs to be calculated using the SSD++ approach. Omission of this adds to the screening level nature of this study.

Table 6 Risk limits for comparison to exposure concentrations based on HC5 values reported by Coffin et al. (2026) as derived for particle volume and surface area as Environmentally Relevant Metric (ERM).

	HC5 (#/m^3) with **median (p5-p95)**
Volume ERM	31 000 (140-1 500 000)
Surface area ERM	2 150 000 (167 000-38 000 000)

Furthermore, the overall approach to deriving risk limits for microplastics should be done in a way that allows for a common application. Meaning the approach is harmonized at least to the point where derivation of risk limits is similar in their level of protection for adverse ecological effects. Recently, Iwasaki et al. (2026) used another approach to integrate particle characteristics in species sensitivity distributions for specific categories of particles, such as fibers, non-fibers and size categories (length < 83 µm or >83 µm), estimating HC5 values ranging from 0.06 µg/L (fiber, particle length <83 µm) to 111 µg/L (non-fiber, particle length ≥83 µm). It would be good to further investigate how this approach compares to the approach of Coffin et al. (2026), and whether the use of other metrics, such as volume or surface area would reduce the variation in particle characteristic-specific HC5's. Such work on understanding the factors affecting microplastic HC5 values is essential for determining risk limits that can be applied in regulatory context.

3.4.2 Quality assessment and control

The risk limits (Table 6) are based on a dataset where that excluded studies which were considered of inadequate quality. Coffin et al. (2026) and Mehinto et al. (2022) selected studies based on 14 criteria, which are a subset of the quality criteria proposed by De Ruijter et al. (2020) for quality control and screening of effect studies. This was done as no aquatic study in the ToMex 2.0 database currently passes all De Ruijter et al. (2020) criteria. Also the case for the studies used by Coffin et al. (2026), see Figure A.11 and Figure A.12 in Appendix 3. However, good quality effect data should preferably pass all De Ruijter et al. (2020) criteria.

The QA/QC criteria of de Ruijter et al., (2020) that were not considered by Coffin et al., (2026) are related to both the technical criteria and risk assessment criteria.

The technical criteria not considered by Coffin et al. (2026) and Mehinto et al. (2022) are related to exposure verification, they are on aspects such as "chemical purity", "laboratory preparation", "verification of background contamination", "verification of exposure", "homogeneity of exposure". Hardly any of the available studies assessed meet these criteria (Figure A.11). As these verifications often require (additional) MP measurements, these seem to be either not possible, considered too much effort or simply not reported. However, these topics should be reported on as they influence the exposure and thus effect metrics derivation in effect studies. As is also made clear for the monitoring studies, microplastics analysis are hampered by lack of international standardization although quality criteria are available. It is clear that the inclusion of these quality criteria would improve the quality of the hazard assessment. It would also allow the correction of the exposure concentration to account for background contamination, changing the actual effect concentrations. This may be especially important at the lowest test concentrations, to ensure exposure concentrations are not confounded or even surpassed by background contamination. Adherence to these strict quality criteria would also ensure that the observed effects are particle related and not due to chemicals leached from the microplastics or the suspension liquid they are stored in.

The risk assessment related quality criteria not considered by Coffin et al. (2026) relate to environmental realism and estimating effect metrics. Specifically, the latter can have direct consequences on the derivation of the HC5 based on these metrics. The "Concentration Range" criteria is not considered and the "Dose Response" criteria is only partly considered as Mehinto et al., (2022) and Coffin et al., (2026) who use a minimum of three concentrations (excluding control) and one replicate. In contrast, the minimum requirements in the ISO and OECD guidelines, which are developed to ensure the regression-based analysis is robust and as accurate as possible, often require at least five test concentrations (not including the controls) and most often require at least 5 and in some cases 3 replicates (Table A.15).

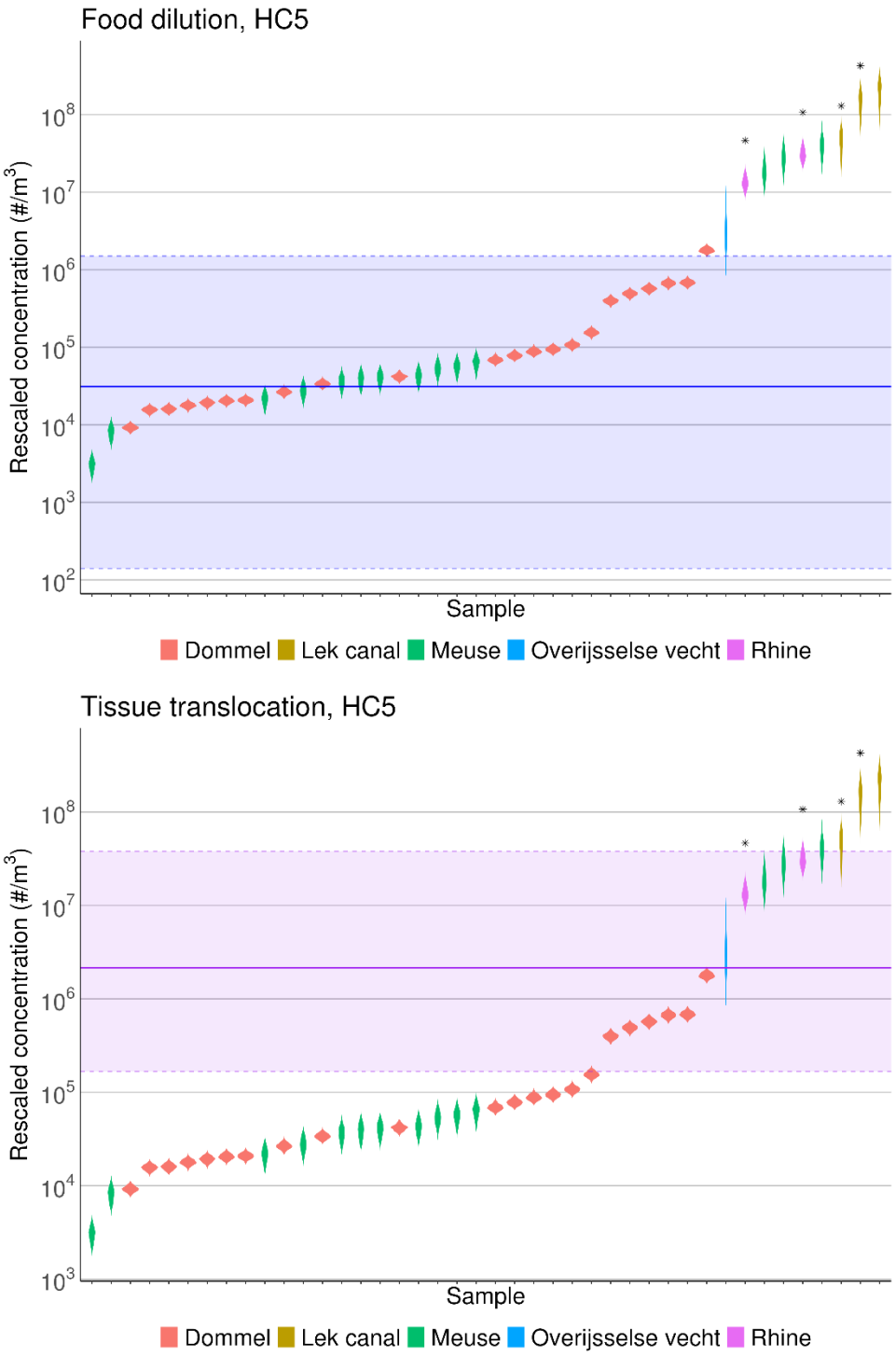
Nonetheless, the risk limits set by Coffin et al. (2026) and used in this study are, despite the exclusion of several quality criteria, the best risk limits currently available. The exclusion of potentially relevant criteria also means, that without further evaluation of the underlying effect studies the risk limits are used at screening level for comparison to the rescale particle number concentrations of microplastics in Dutch surface waters.

3.5 Screening level risk assessment

When using the risk limit based on volume as ERM from Coffin et al. (2026), the 95th percentile risk limit values are exceeded by 8 to 10 out of the total of 42 samples[3] (19%-24%) covering all water bodies, excluding the effluent canal (Figure 14). If you apply the risk limit from Coffin et al. (2026) based on surface area as ERM, exceedance of 95th percentile is observed in 2 to 7 samples (5%-17%), with the range depending on the uncertainty in the rescaled concentrations (min and max)[3] (Figure 14). These exceedances indicate a risk of adverse ecological effects at those moments in time and at those locations due to exposure to microplastics and under the assumptions of the framework. Specifically, such an exceedance is a first indication that for these samples, at least five percent of the species are potentially affected by exposure to microplastics based on the volume or surface area metrics used. Note that in this screening level risk assessment, only direct particle effects were considered. These predicted effects do not result in acute lethality but indicate sub-lethal effects on vulnerable species. Depending on frequency and length of exposure above risk limits population and ecosystem level effects could take place, but this is not clear from the current data.

[3] Note that 4 out of the 10 highest concentration samples (2 from Lek Canal and the 2 from the Rhine) are from the Mughini-Gras et al. (2021) study which did not pass all quality criteria. Indicated in the figures with an asterisk*.

Figure 14 Surface water particle number concentrations for microplastics, rescaled to the 1-5000 µm range and compared to risk limits (line and uncertainty band) as reported by Coffin et al. (2026). Top panel shows the risk limit (median HC5 as blue line) derived using volume as ERM. Bottom panel shows the risk limit (median HC5 as pink line) derived using surface area as ERM. Data from Bäuerlein et al. (2022), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).*



Band depicts the 5th to 95th percentiles for the HC5. Y-axis is log scale. *Indicates samples from the study by Mughini-Gras (2021) whcih did not pass all quality criteria.

Eight other samples overlap with the uncertainty range of both risk limits (5th to 95th percentile range). All samples overlap with the volume ERM. Twenty-six samples are fully below the 5th percentile risk limit for surface area as ERM, meaning adverse effects are not expected to occur based on those samples and under the assumptions of the risk assessment framework. These samples are all related to the Dommel or Meuse catchments.
The particle concentrations of microplastics in samples from the WWTP effluent canal almost all exceeded the 95th percentile risk limit for the volume ERM, while none exceed this limit for the surface area ERM (Figure A.13 and Figure A.14)

There are only a few other ecological risk assessment studies for surface waters available. In one study for Europe by Adam et al. (2019), which did not perform alignment or rescaling of concentrations, no exceedance of risk limits was shown. Studies that did include the alignment and rescaling approach did find exceedances. For North America, a study by Koelmans et al. (2023) on the Laurentian Great Lakes, North America, up to 24% of estimated exposures exceeded risk limits based on particle volume as ERM. In a study in China for the Yangtze River a similar distribution of aligned measured microplastic concentrations is reported (Wang et al., 2024). All but two samples from the Yangtze fall within the range of the 5th to 95th percentile risk limit values, with one sample below and one sample above these uncertainty ranges. These results are similar to those presented here.

Specifically for the volume ERM many samples exceed the median or 5th percentile of the risk limit. Even without rescaling many reported concentrations overlap with the 5th to 95th percentile uncertainty band of the risk limit derived with volume as ERM (Figure A.15 and Figure A.16). This means that without rescaling of the particle concentrations, risks of adverse effects to aquatic species cannot be ruled out at these sites and at those moments in time. On the other hand, the volume-based ERM risk limit is highly uncertain, spanning four orders of magnitude, and the effects data are not all of the highest possible quality. This means that the evidence for the predicted adverse effects is not really sufficient, although the possibility of ecological effects cannot be ruled out either.

In conclusion, this analysis shows that in some Dutch surface waters at some locations and timepoints risk limits, based on best available data, are exceeded. This a first indication that there may be a chance for ecological effects from exposure to microplastics. However, this conclusion is formulated very cautiously. The exact severity of these effects remains uncertain due to the assumptions on particle size distribution, limitation of sampling and detection methods, quality and number of effect studies used for deriving risk limits. Note that uncertainty related to the particle size distribution plays a role in both the alignment of risk limits and in rescaling of exposure concentrations better insight into this interdependency on the size distribution used (e.g. power law slope or other) is needed. Furthermore, as for any risk assessment approach that uses lab-derived limit values, ecological conditions in the field are different than those during laboratory tests, and may exacerbate or attenuate effects of microplastic particles.

4 Conclusions and recommendations

4.1 Conclusions

Rescaling monitoring data following the Koelmans approach allows for correcting for differences in size range covered by different studies. This rescaling partially solves the issue of measurement approaches that do not cover the 1 to 5000 micrometre size range of microplastics. Some gaps remain as no analytical method currently covers all polymer types.

This study used the currently best available data and approaches to assess ecological risks of microplastics in surface waters in the Netherlands. In some locations and at some time points exposure concentrations are estimated to exceed risk limits indicating that adverse ecological effects cannot be ruled out.

However, the potential for adverse effects remains uncertain due to lack of adequate quality of effect data needed for the derivation of risk limits. The exposure data is rather limited as well and does not represent the whole of the Netherlands and comparability of the measurement studies is uncertain. The measurement uncertainty is due to differences in methodology used and in covering the full range of microplastics between 1 and 5000 micrometres which is not corrected for. This stems from the software and libraries being used for polymer identification, sampling approaches and overall recoveries, i.e. misrepresenting tyre wear rubber in current measurements could indicate, based on a rough estimate, that particle number concentrations increase by ~10%. This illustrates the screening level of this study warranting further research into ecological risks.

Further analysis, using effect data that passes all quality criteria would allow for derivation of more robust risk limits. This should also include alignment of effect metrics using water body specific particle size distributions, instead of using generic literature values.

Another aspect that will affect the outcome of assessing the ecological risk of microplastics is based on reducing the need for rescaling or more certainty in calculating correction factors. This means investigating the whole particle size distribution, from 1 to 5000 micrometres, needed for rescaling and aligning the exposure measurements and the effect data.

Furthermore, monitoring microplastics in surface waters with the goal of assessing ecological risk requires studies that take into account all the relevant quality criteria considering the whole workflow including sampling, sample preparation, analysis, and data reporting. Additionally, the study location and time frame should also be considered.

In conclusion the exact degree of the ecological effects remains unclear due to uncertainty in:

- The particle size distribution needed for rescaling and aligning the exposure measurements and the effect data.
- The methods used for measuring microplastic concentrations.

- The effect data for derivation of particle risk limits.

All three topics are crucial to address in further studies in order to improve our understanding of the potential adverse ecological effects of microplastics. Using ecological risk assessment for microplastics as a tool for regulatory action requires consistent measurements of exposure concentrations and robust risk limits covering representative time and spatial scales, ecological endpoints and microplastic particle characteristics. This is only attainable when the above points are sufficiently addressed.

4.2 Recommendations

To reduce uncertainty in ecological risk assessment of microplastics in surface waters we have several recommendations grouped around three topics mentioned above and should be considered in future monitoring campaigns.

Increasing understanding of the full particle size distribution
Increasing our understanding of the distribution of particles across the full microplastics size range, at least covering the 1 to 5000 micrometre range is needed. Improving better measurement of the smallest sizes of microplastics will decrease uncertainty in both alignment of risk limits and rescaling of exposure measurements; better measurements may thus strongly reduce the uncertainty of the assessment and measuring (more of) the full 1 to 5000 micrometre size range will reduce the need for rescaling of environmental measurements.

The proof of principle conversion of mass concentrations to number concentrations showed the need for further research on using mass data for ecological risk assessment. For now, pyrolysis-based GC-MS analyses could be combined with spectroscopic methods using the same samples to obtain particle size data, potentially providing evidence for calibration and correction factors and include more polymers as considered by the microplastics definition, e.g. tyre rubber. Therefore, at least in human health studies, high confidence claims based on microplastics measurements requires the combination of different techniques with adequate selectivity applied to the same target so that one technique's weaknesses are compensated by another (e.g. combining chemical identification with independent confirmation of morphology/particle attributes) (Thomas et al., 2026).

Standardization and harmonization of measurement methods
Reduce uncertainty in measured concentrations by creating clear standardised analytic test guidelines covering all relevant steps from sampling to reporting. Studies comparing different methods using the same sample would greatly improve our understanding of method comparability and performance.

Given that tyre wear particles are not included in the particle number concentrations and as this is a large emission source (Quik et al., 2024), it is recommended to include this in future exposure assessments. A first step might be to include TED-GC-MS measurements of tyre wear particles in follow-up exposure assessments. In absence of

measurements, model predictions based on emission estimates, e.g. as provided in Quik et al. (2025), could also play a role in acquiring a nationwide view of microplastic pollution in surface waters.

Improving quality of effect studies to derive higher quality risk limits
Uncertainty in the derivation of risk limits can be reduced by gathering additional and better quality hazard data and by using location specific data for the alignment of effect metrics and derivation of HC5 values. This should be within reach in follow-up research, where it is important that the generated hazard data meet the latest quality criteria for them to be of additional value. Creating or extending existing ISO, OECD or other types of protocols is needed for performing standardized and harmonized toxicity tests of microplastics. This allows for widespread acceptation of the data derived using these protocols. Specific recommendations from scientific literature on harmonization option are already available, e.g. De Ruijter et al. (2025). Alignment of effect data will likely remain an essential part of microplastics risk assessment, although the use of environmentally relevant microplastic mixtures (De Ruijter et al., 2023) in effect studies could make this superfluous.

Using the water body specific size distributions for derivation of risk limits could be a good next step as we now used the reported (generic) risk limits from Coffin et al. (2026). As more data becomes available distinguishing polymer types in ecological risk assessment could also reduce uncertainty as methods might be better optimized. This would also allow for addressing specific sources of microplastics in order to reduce microplastic environmental impact.

Regulatory implementation
In order to further implement microplastics risk limits within a regulatory context, considering the scope and limitations of the underlying data, it is necessary for regulatory agencies to engage in additional consultation with relevant experts, e.g. using expert knowledge elicitation (EFSA, 2014). This would allow for an evaluation of both the logic of methodology used to derive the risk limits, including the required quality criteria and the soundness of the intended regulatory domain.

In the context of plastics pollution as a whole, the framework for deriving risk limits proposed by Coffin et al. (2026) only covers particle ingestion based mechanisms of microplastics toxicity. This excludes other potential effects of plastics such as those driven by non-ingestion-based mechanisms of toxicity, like entanglement from fibres, the impacts of plastic-associated chemicals, and the role of plastics as vectors for pathogens. These potential sources of adverse effects should also be considered when addressing plastic pollution.

This screening level risk assessment indicates that risks due to microplastics exposure in Dutch surface water cannot be ruled out, although our study has several limitations. Nevertheless, our findings, combined with the fact that microplastic pollution is expected to increase in the coming decades (Sonke et al., 2025), highlight the need for mitigation measures to reduce microplastic pollution and prevent adverse ecological effects to aquatic ecosystems. Additionally, further

research is needed to address the limitations of this study and reduce current uncertainties.

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Abbreviations

Abbreviation	Full term
General:	
ERM	Ecologically Relevant Metric
SPM	Suspended Particulate Matter
(TED)-GC-MS	(Thermal Extraction-Desorption)- Gas Chromatography-Mass Spectrometry
(ATR-)FTIR	Attenuated Total Reflectance – Fourier Transform Infrared (Spectroscopy)
LDIR	Laser Direct Infrared (Imaging)
QA/QC	Quality Assessment/Quality Control
OECD	The Organisation for Economic Co-operation and Development
ISO	International Organization for Standardization
WWTP	Waste Water Treatment Plant
CEN	European Committee for Standardization
PDF	Probability Density Function
EU	European Union
REACH	Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals
CI	Confidence Interval
Effect metrics:	
ECx	x% Effect Concentration
LCx	x% Lethal Concentration
NOEC	No Observed Effect Concentration
LOEC	Lowest Observed Effect Concentration
SSD	Species Sensitivity Distribution
HC5	Hazardous Concentration for 5% of species
Polymer types:	
ABS	Acrylonitrile Butadiene Styrene
PA	Polyamide
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene Terephthalate
PMMA	Polymethylmethacrylate
PP	Polypropylene
PS	Polystyrene
PUR	Polyurethane
PVC	Polyvinylchloride
EPDM	Ethylene Propylene Diene Monomer
NR	Natural Rubber
SBR	Styrene Butadiene Rubber
EPS	Expanded Polystyrene

Appendix 1 Sampling and Detection

Polymer groups

Table A.1 Polymers identified in Bäuerlein et al. (2022) divided over groups as used for combining data from different studies.

Polymer	Group
Acrylates	Acryl
Acrylonitrile Butadiene	ABS
Polyurethane (PU)	PUR
Polymethylmethacrylate (PMMA)	PMMA
Polyacetal	Others
Polyimide	Others
Polysulfone	Others
Polysulfones	Others
GREEN PE	PE
Polyethylene (PE)	PE
Polyethylene Chlorinated	PE
Polyethylene Terephthalate (PET)	PET
Polyethylene Terephthalete (PET)	PET
Ethylene Vinyl Acetate (EVA)	Others
Polypropylene (PP)	PP
Polystyrene (PS)	PS
Isopreen	Other synthetic rubbers
Polybutadiene	Other synthetic rubbers
Rubber	Other synthetic rubbers
Alkyd Varnish	Others
Polyamide (PA)	PA
Polycarbonate (PC)	PC
Polyether	Others
Polylactic acid (PLA)	Others
Polytetrafluoroethylene (PTFE)	Others
Polyvinyl alcohol	Others
Polyvinylchloride (PVC)	PVC
Silicone	Others

Table A.2 Polymers identified in Bäuerlein et al. (2023) divided over groups.

Polymer	Group
Polyurethane (PU)	PUR
Polymethylmethacrylate (PMMA)	PMMA
Acrylonitrile Butadiene	ABS
Acrylates	Acryl

Polymer	Group
Polyacetal	Others
Polyimide	Others
Polysulfone	Others
Polysulfones	Others
Polyethylene (PE)	PE
Polyethylene Terephthalate (PET)	PET
Polyethylene Terephthalete (PET)	PET
Polyethylene Chlorinated	PE
GREEN PE	PE
Ethylene Vinyl Acetate (EVA)	Others
Polypropylene (PP)	PP
Polystyrene (PS)	PS
Isopreen	Other synthetic rubbers
Polybutadiene	Other synthetic rubbers
Rubber	Other synthetic rubbers
Polyisoprene Chlorinated	Other synthetic rubbers
Polyamide (PA)	PA
Polyvinylchloride (PVC)	PVC
Unknown	Others
KWR D9	Others
Agilent A7	Others
KWR B9	Others
Particle Analysis A7	Others
KWR B8	Others
Agilent A9	Others
KWR D4	Others
KWR B7	Others
KWR B10	Others
Agilent A2	Others
Polylactic acid (PLA)	Others
Silicone	Others
Polyvinyl alcohol	Others
Alkyd Varnish	Others
Polycarbonate (PC)	PC
Polytetrafluoroethylene (PTFE)	Others
Unidentified	Others
Polycaprolactone	Others
Polyether	Others

Table A.3 Polymers identified in Mintenig et al. (2020) divided over groups.

Polymer	Group
polychloroprene	Others
polycaprolactone	Others
ethylene-vinyl-acetate	Others
rubber type 3	EPDM
polyethylene	PE
polyethylene. chlorinated	PE
polypropylene	PP
polyamide	PA
nitrile rubber	Other synthetic rubbers
acrylates.polyurethanes.varnish	Acryl
polycarbonate	Others
polystyrene	PS
polyester	PET
acrylonitrile-butadiene	ABS
polyvinylchloride	PVC
polyimide	Others
rubber type 2	NR
polysulfone	Others
polyetyhlene oxidized	PE
rubber type 1	SBR
polyoxymethylene	Others
polyetheretherketone	Others
polyphenylene ether	Others
polytetrafluoroethylene	Others

Table A.4 Polymers identified in Mintenig et al. (2025) divided over groups.

Polymer	Group
polyethylene	PE
polyetyhlene oxidized	PE
polyethylene, chlorinated	PE
polypropylene	PP
polystyrene	PS
polycarbonate	Others
polyamide	PA
polyvinylchloride	PVC
Cellulose artfical modified	Others
nitrile rubber	Other synthetic rubbers
polyester	PET
acrylates,polyurethanes,varnish	Acryl
polychloroprene	Other synthetic rubbers
polycaprolactone	Others
ethylene-vinyl-acetate	Others
acrylonitrile-butadiene	ABS
rubber type 1	SBR
rubber type 3	EPDM

Table A.5 Polymers identified in Mughini-Gras et al. Divided over groups.

Polymer	Group
Polyurethane (PU)	PUR
Polyethylene (PE)	PE
Polyethylene Terephthalate (PET)	PET
Polyethylene Terephthalete (PET)	PET
Polypropylene (PP)	PP
Polystyrene (PS)	PS
Isopreen	Other synthetic rubbers
Polyamide (PA)	PA
Unknown	Others
Polyvinylchloride (PVC)	PVC

Assessment of the quality of microplastic concentration data

Overview of applied QA/QC criteria

The currently existing QA/QC criteria and scores for freshwater microplastics concentrations were used as provided by Koelmans et al. (2019).

Table A.6 Quality criteria and scoring for quality assessment of microplastics monitoring studies as presented in Koelmans et al. (2019).

Scores			**2**	**1**	**0**
Sampling	**1**	**Sampling methods**	**Surface & Ground water:** - Pump - Location - Materials used - Date - Depth of sampling **WWTP/DWTP:** - Location - Treatment - Date - Sampling method - Materials used **No flushing with sample.**	The study reported only a subset of the required characteristics (e.g., date, location, materials used), however is still fairly reproducible.	No/ insufficient reportage of sampling methods.

Scores			2	1	0
	2	**Sample size**	**Surface & ground water:** > 500 L **WWTP:** - Influent: 1L - Effluent: >500 L or until sieve clogging *Sample volume may be smaller if target microplastic sizes are smaller*	**Surface water:** < 500 L "with good cause" (high concentrations e.g.) Trawls without reporting volume is acceptable. **WWTP:** If insufficient volume, sampling till clogging	**Surface water:** < 500 L **WWTP:** Insufficient sampling volume.
	3	**Sample processing and storage**	Sample storing shortly after sampling; any sample handling was avoided before arriving in the laboratory. Sample containers should be rinsed with filtered water. Sample preservation with chemicals should be justified and evaluated for compatibility. *Manta trawl nets are allowed to be rinsed with unfiltered water. Sieving in the field is acceptable if sample volume is large. Precautions should be taken to prevent contamination.*	Standards only partially met or containers are pre-rinsed with samples. Citizen science approach with validation	Samples are handled outside. Storage not mentioned. Citizen science approach without validation

Scores			2	1	0
Contamination mitigation	**4**	**Laboratory preparation**	- Cotton lab coat or non-synthetic clothes - Equipment and lab surfaces wiped and rinsed	- Solely wiping laboratory surfaces and equipment or not wearing a lab coat **IF** negative samples were run in parallel and examined for contamination.	No precautions.
	5	**Clean air conditions**	- Clean room or laminar flow cabinet	Mitigation of airborne contamination by carefully keeping samples closed as much as possible **IF** negative samples were run in parallel and examined for occurring contamination.	No regard of airborne contamination, or solely use of *fume hood.*
	6	**Negative control**	Controls (in triplicate) treated and analysed in parallel to actual samples. Sample concentrations need to be reported accounting for controls.	Insufficient form of a control, e.g. the filtration of air, or the sole examination of petri dishes/ soaked papers placed next to the samples.	No negative controls.
Sample purification/ handling	**7**	**Positive control**	Controls (triplicate) with an added amount of microplastic particles treated the alongside the samples, and for which the particle recovery rates are determined.	Insufficient form of a positive control (e.g. if only a part of the protocol is tested).	No positive controls.

Scores			2	1	0
	8	**Sample treatment (only for surface water and WWTP samples)**	Digestion of complete sample using a protocol with KOH, WPO and/or enzymes. If another chemical was used, effects on different polymers should be tested before application. All sample treatments need to be carried out below 50°C to prevent any damage to microplastics.	If proof is missing that polymers are not affected by protocol (e.g. heated KOH) **OR** in case studies exclusively focus on the bigger microplastics by sieving the samples (mesh size ≥ 300µm). If WPO is carried out without cooling.	No digestion of sample.
Chemical analysis	**9**	**Polymer identification**	Per study; analysis of all particles when numbers of pre-sorted particles are <100. For particle numbers >100, 50% should be identified, with a minimum of 100 particles. Per sample; analysis of all particles up to a maximum of 50 particles per sample. Per filter: ≥25% of the surface area.	Insufficient polymer identification, potentially resulting in an unrepresentative subsample. Identification with SEM/EDX to distinguish polymer vs non-polymeric materials.	No polymer identification.

QA/QC scores of measurement studies

Table A.7 QA/QC score for light microscopy analysis in Amsterdam canals (Leslie et al., 2017).

Score	Criterion	Given Score
1. Sampling methods	Method (bulk sampling with glass jars), location and materials used mentioned. Date not mentioned.	1
2. Sample size	Samples were collected in 2 L glass jars; a 50 or 100 g subsample was analysed.	0
3. Sample processing & storage	Glass jars, pre-rinsed with MQ water	2
4. Laboratory preparation	Not mentioned.	0
5. Clean air conditions	No laminar flow hood, but procedural blanks included.	1
6. Negative controls (blanks)	Procedural blanks, corrected for fibres, number of blanks unknown.	1
7. Positive controls (recovery tests)	No positive controls.	0
8. Sample treatment (digestion / density separation / clean-up)	No sample treatment.	0
9. Polymer identification	No polymer identification performed for the water samples.	0
Total accumulated score:		5
Number of criteria scoring 0		5

Table A.8 QA/QC score for FTIR analysis (Mintenig et al., 2020).

Criterion	Brief rationale	Score (0-2)
1. Sampling methods	Date, and weather condition provided. Pump and applied flow provided, water taken directly at surface layer (upper 5cm), and pumped over 20, 100 and 300 µm.	2
2. Sample size	average 200L on 20 µm sieves, and > 2m3 for the other 2 sieves	2
3. Sample processing & storage	stored in closed (aluminium foil) glass bottles, stored refrigerated	2
4. Laboratory preparation	During sample handling a lab coat and clothes, both made from natural fabric, were worn. Prior to any working step the lab surfaces were wiped off with ethanol (30 %, Carl Roth GmbH & Co. KG, Germany) and paper towels. Prior usage, all chemicals were filtered over 20 µm, all lab materials were rinsed with ethanol and Milli-Q water and covered with aluminium foil. Also the samples were covered immediately with aluminium foil after finishing working with them.	2
5. Clean air conditions	no, but procedural blanks	1
6. Negative controls (blanks)	8 procedural negative controls in parallel to samples. Polymer specific numbers provided per sample. Correction was done with the average of these findings, polymer specific and size specific	2
7. Positive controls (recovery tests)	5 positive controls, 90- 106 µm PE beads, average and SD recovery rate provided	2
8. Sample treatment (digestion / density separation / clean-up)	visual inspection and no sample preparation for MP > 300 µm. MP < 300 µm, several steps, using 20 µm sieve filtration in between, SDS, KOH, H2O2, ZnCl2, all steps set at 35 degrees	2
9. Polymer identification	MP > 300 µm, ATR-FTIR, If the number of sorted particles was <50, all particles were analysed. A subset of 50 randomly chosen particles (32-76%) was identified for eight samples with numbers of sorted particles > 50 (Koelmans et al., 2019). MP < 300 µm, FTIR mapping, around 65% of each sample analysed	2
Total accumulated score (TAS)		17
Number of criteria scoring 0		0

Table A.9 QA/QC score for LDIR analysis (Mughini-Gras et al., 2021).

Criterion	Brief rationale	Score (0-2)
1. Sampling methods	Month and year of 2 sampling moments provided, Water filtered through 2 metal sieves with a mesh size of 500um and 100um with a plankton net at the end. residues transferred in bottles using MQ water. No indication of the pump/ flow used, and no indication of the sampling depth. Water temperature, pH and turbidity were recorded and provided in SI.	1
2. Sample size	Sampling of 450 to 750L of water (no specific amount of water given per sample).	1
3. Sample processing & storage	Each fraction residue was transferred into a glass bottle using Milli-Q ultrapure water (MilliporeSigma, USA) and stored at 4°C	2
4. Laboratory preparation	not conducted, or not reported	0
5. Clean air conditions	not conducted, or not reported. Also no negative controls were run	0
6. Negative controls (blanks)	not conducted, or not reported	0
7. Positive controls (recovery tests)	not conducted, or not reported	0
8. Sample treatment (digestion / density separation / clean-up)	The combined residue suspensions were filtrated over a 10 µm metal mesh and the filter was transferred into a beaker with 10% sodium dodecylsulfonate. After a day, the suspension was filtrated again and the filter was transferred into a beaker with 75 ml 12.5% potassium hydroxide for 5 days at 35 °C. Subsequently, the suspension was re-filtrated, transferred into a beaker with 50 ml 30% hydrogen peroxide for one day at 35 °C and filtrated again. The residues were then transferred into a separation funnel using 100 ml zinc chloride (1.6 g/cm3). The funnels were shaken and left still to enable settling of denser materials. The settled material was discarded by continuously turning the valve of the funnel to prevent clogging, re-suspension and particle loss. About 10 ml of liquid was allowed to remain in the funnel, which was filtrated again over a metal filter. Using 4 ml ethanol, the retained materials were removed from the filter and transferred into a glass vial. A vortex was created in this suspension to distribute the particles evenly. A subsample (20–100 µm) was put on a microscope slide. The sample was analysed	2

Criterion	Brief rationale	Score (0-2)
	using a Laser Direct Infrared (LDIR) chemical imaging system (Agilent, Germany) to detect and characterise 20–500 µm particles (as 20 µm is the technical limit). Concentrations were expressed as particles/m3 water. All analyses were performed in duplicate.	
9. Polymer identification[4]	A subsample (20-100 µm) was put on a microscope slide and analysed with LDIR. However, it is unclear how much ul (from 4 ml Ethanol which contain sample residues after treatment). Additionally, MP concentrations are only presented as averages per duplo samples (variation missing).	1
Total accumulated score		7
Number of criteria scoring 0		4

[4] In the criteria of Koelmans et al.(2019), polymer identification only refers to whether it has been carried out using a valid method. At present, more is known about the uncertainties associated with the various techniques, and this criterion could, for example, include aspects such as those described for GCMS in the section "Microplastic analysis using thermal methods." This could mean that with updated criteria a score lower than 2 might be assigned.

Table A.10 QA/QC score for LDIR analysis (Bäuerlein et al., 2022).

Criterion	Brief rationale	Score (0-2)
1. Sampling methods	Recording of weather conditions (no rain/wind). 2 sampling methods for LDIR: 1. stacked metal sieves (500, 100, 10um - for higher numbers of MP expected), and 2. metal candle filter cascade (500, 100, 10, 5um - for lower numbers). Residues on 500um sieve are not analysed. Indication in SI when method 1 or 2 is used. Unclear how the water was pumped/taken. The sampling depth is thus unknown. Also missing information on DW collection procedure (e.g. running tap before sampling), flow rate.[5]	1
2. Sample size	between 1000 and 10,000L sampled (LDIR) done for 5 DWTPs (1 in parallel to microscopy) circa 1000 L (surface water), > 2000 L (process water and drinking water)	2
3. Sample processing & storage	Residues stored in glass bottles using ultrapure water, stored at 4 degrees Celsius until further treatment. Bottles covered with aluminium foil	2
4. Laboratory preparation	LDIR: Potential contamination occurring during sample handling was minimised by cleaning all working surfaces with ethanol, rinsing equipment and immediate covering with aluminium foil, and wearing a cotton lab coat at all times. Furthermore, solutions of chemicals were filtered (10 µm metal mesh) prior to use. Use of plastic materials during sample handling was minimised (e.g., a metal filter setup with Teflon tubing and glassware for sample storage and separation).	2
5. Clean air conditions	not used, but negative controls (most probably > 3) were run in parallel	1
6. Negative controls (blanks)	NC samples treated in parallel to actual samples, 1 NC in each batch of samples. The total number of blanks is not provided (should be > 3, read between lines).	2
7. Positive controls (recovery tests)	PC samples run with green PE beads, average diameter 100 µm.	2
8. Sample treatment (digestion / density separation / clean-up)	10 µm metal mesh, SDS, KOH, H2O2, ZnCl2. filtered, then transferred in glass vial using 4 ml EtOH, temperature kept at 35 degrees.	2

[5] Sampling date was provided with particle data.

Criterion	Brief rationale	Score (0-2)
9. Polymer identification	LDIR used for plastics between 20- 500 µm. 2 x 50 ul from the total 4 ml (after vortex mixing) analysed >> 2.5% of sample analysed which is not representative enough potentially	1
Total accumulated score		14
Number of criteria scoring 0		0

Table A.11 QA/QC score for LDIR analysis (Bäuerlein et al., 2023).

Criterion	Brief rationale	Score (0-2)
1. Sampling methods	Weather conditions provided (SI), sampling dates provided (8 days). Sketch drawing of sampling device provided (other locations, sampling tube fixated at bank of canal), 4 samples (i.e. locations) taken per day. Sampling depth: 15cm below water surface. Water pumped over sieves/ net of 500, 100 and 10 µm. residues transferred in bottles using MQ water. No indication of the pump/ flow used.	2
2. Sample size	500L	2
3. Sample processing & storage	in glass bottles, kept at 4 degrees	2
4. Laboratory preparation	All laboratory surfaces were cleaned with ethanol, equipment was rinsed and covered immediately with aluminium foil, and a cotton lab coat was worn at all times. Next to this, solutions of chemicals were filtered prior to use. Used materials were not made from plastic wherever possible (e.g., a metal filter setup with a Teflon tube, the separation funnels made of glass).	2
5. Clean air conditions	No, but procedural blanks run	1
6. Negative controls (blanks)	yes, procedural blanks, 1 per batch of 4 samples	2
7. Positive controls (recovery tests)	yes, green PE beads, average diameter of 100um,1 sample per batch of 4 samples	2
8. Sample treatment (digestion / density separation / clean-up)	10 µm metal mesh, SDS, KOH, H2O2, ZnCl2. filtered, then transferred in glass vial using 4 ml EtOH, temperature kept at 35 degrees	2
9. Polymer identification	Microplastics were identified with LDIR, Subsample size was 2 x 50 ul, from the total 4 ml. , meaning that only 2.5% of sample identified	1
Total accumulated score (TAS)		16
Number of criteria scoring 0		0

Table A.12 QA/QC score for FTIR analysis (Mintenig et al., 2025).

Criterion	Brief rationale	Score (0-2)
1. Sampling methods	Link to earlier publication. Date, Pump and sampling depth provided (upper 5cm), and pumped over 20, 100 and 300 µm. Flow rate not provided	2
2. Sample size	100-145L on 20 µm sieves, and > 1.5m3 for the other 2 sieves	2
3. Sample processing & storage	stored in closed (aluminium foil) glass bottles, stored refrigerated	2
4. Laboratory preparation	lab coat and clothes, both made from natural fabric, were worn. Prior to any working step the lab surfaces were wiped off with ethanol (30 %, Carl Roth GmbH & Co. KG, Germany) and paper towels. Prior usage, all chemicals were filtered over 10 µm, all lab materials were rinsed with ethanol and Milli-Q water and covered with aluminium foil. Also the samples were covered immediately with aluminium foil after finishing working with them.	2
5. Clean air conditions	no, but procedural blanks	1
6. Negative controls (blanks)	3 procedural negative controls in parallel to samples. polymer specific LOQ values subtracted from samples. But individual sample findings not provided.	2
7. Positive controls (recovery tests)	3 positive controls, 10- 180 µm PE beads, average and SD recovery rate provided	2
8. Sample treatment (digestion / density separation / clean-up)	visual inspection and no sample preparation for MP > 300 µm. MP < 300 µm, several steps, using 20 µm sieve filtration in between, SDS, KOH, H2O2, ZnCl2, all steps set at 35 degrees	2
9. Polymer identification	all MP < 300 µm analyzed. Problems with post-processing, mentioned potentially wrong identification of PE- containing polymers. So far, the MP > 300 µm only checked for a small subset of 50 MP	2
Total accumulated score (TAS)		17
Number of criteria scoring 0		0

Table A.13 QA/QC score for mass concentration from thermal method (Freriks et al., 2023a, 2023b, 2023c)

Criterion	Brief rationale	Score (0–2)
1. Sampling methods	Sediment boxes and flow-through centrifuge are systematically tested as methods for suspended matter sampling in rivers (1 µm–5 mm). Representativity (depth, flow, retention of small particles, robustness, clogging) is evaluated experimentally and summarized.	2
2. Sample size	Large time-integrated SPM samples are taken via sediment boxes / pump systems over ~4 weeks resulting in about hundred grams of suspended matter sampled. TED-GC-MS subsamples of 20 mg SPM are used, but drawn from a larger 10 gram subsample of the well-characterized SPM samples. See criterion 9; at the end only 0.02% of the total sample (that was 100g of dried suspended matter) was used for GCMS analysis.[6]	2
3. Sample processing & storage	For analysis, SPM / sediment / bank material is dried, ground and homogenized; the method explicitly avoids filtration and chemical treatments "to keep spread in results as small as possible." The reports do *not* describe in detail how samples are stored (time, temperature, containers) between field collection and analysis.[7]	1
4. Laboratory preparation	Reports focus on instrumental setup (TED-GC-MS temperatures, chromatographic separation, standard addition, internal standards) and method performance (RSD, recovery), but do not describe lab prep in the sense of the QA scheme: cleaning of glassware, use of metal vs plastic tools, rinsing protocols, covering of samples, etc.[8]	0
5. Clean air conditions	There is no description of working under laminar flow, clean benches, clean rooms, or specific measures to control airborne fibers (e.g. cotton lab coats, minimizing synthetic textiles, filtered air). The only "clean-up" discussed relates to *thermal* clean-up (TED-window 290–510 °C to remove organic matrix), not air	0

[6] This percentage is very low and may cause representativeness uncertainty. However, such issues with subsampling were not (yet) included in the criteria by Koelmans et al. (2019). For sediment a minimum 10g subsample is used as representative (Redondo-Hasselerharm et al., 2022), this corresponds to the larger subsample, but not to the analysed sample of 20 mg.
[7] Personal communication: Samples are transported to the laboratory in a closed sedimentation box or closed glass jar. Samples are stored in a cooling for a maximum of a few weeks. Then they are freeze-dried for conservation and stored in closed glass containers with aluminium foil to prevent contact of the sample with the plastic lid.
[8] Personal communication: Entire sampling system for Sediment Box is from stainless steel, including tubing. When handling samples in the laboratory, plastic use is prevented where possible, and if not possible, plastics which are not part of the measurement concept are used (e.g. PTFE). If these plastics are used, interference with measurements has been tested and not found. Samples are always covered in closed jars or petri dishes where possible. Glassware is rinsed with tap water, followed by MilliQ water prior to use in the laboratory.

Criterion	Brief rationale	Score (0–2)
	cleanliness. Additionally, no report on procedural blanks to assess potential airborne contamination in the lab.[9]	
6. Negative controls (blanks)	RWS describes extensive instrument / run blanks to control for carry-over in TED-GC-MS: after each high-concentration standard-addition run, they measure a "spoelblanco" (blank without internal standard) followed by a "blanco" with internal standard; sequence design is discussed, and blank signals are used for correction when the sample signal is less than three times the blank. There is no mention of *field blanks* (e.g. empty traps, procedural water blanks) or *full procedural blanks* that go through sampling and sample handling.[10]	1
7. Positive controls (recovery tests)	RWS performs recovery-related work via standard addition to real matrices (SPM, sediment), reports recoveries of 80–120 %, and uses this to justify the quantification approach. They also discuss response factor differences between standards and matrix-spiked samples as motivation for standard addition.	2
8. Sample treatment (digestion / density separation / clean-up)	A key design choice is no traditional pre-treatment (no sieving, no density separation, no oxidative digestion); instead, the whole dried and ground matrix is analysed. Thermal "clean-up" is implemented by only collecting pyrolysis products between 290–510 °C, exploiting that most organic matrix decomposes below this range while the target polymers pyrolyse between ~300–500 °C. They explicitly discuss pros/cons: less pre-treatment bias vs. more demand on chromatographic separation and identification.	2
9. Polymer identification[11]	Per sample, around 20 mg (of 10g homogenized subsample of the ~100g sample) are added to analysis cups (sometimes 2 replicates for a sample).[2] They target eight polymers (PE, PP, PS, PMMA, PA, PET, NR, SBR). Identification is based on GC-MS retention times and mass spectra of pyrolysis products compared to their own standards, using multiple fragment ions and, for reliable identification, ≥ five identification criteria per polymer (combinations of pyrolysis	2

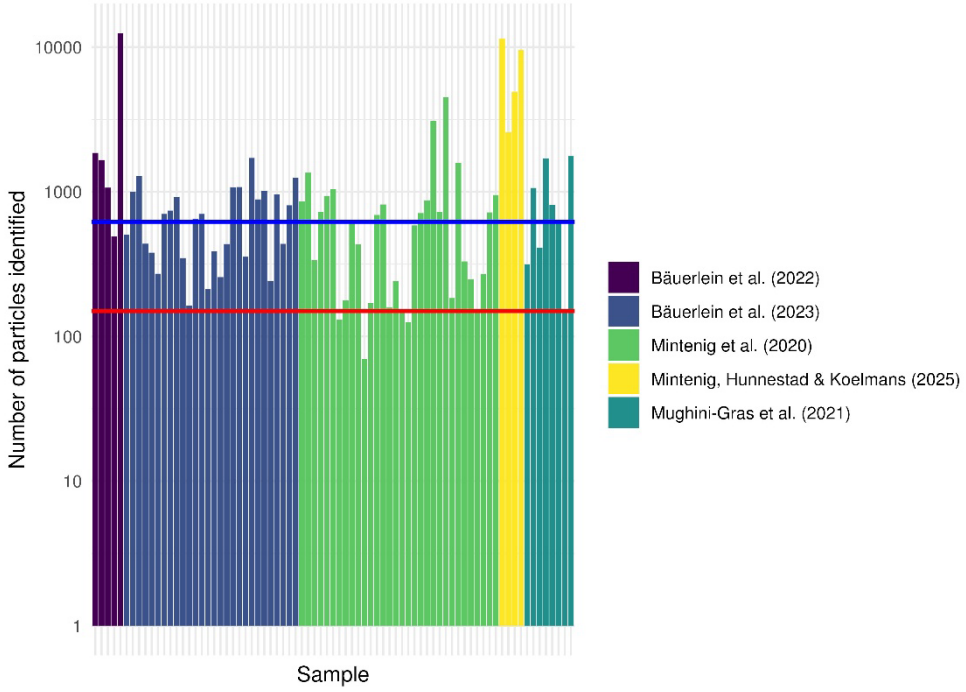
[9] Personal communication: Pyrolysis GC-MS is not sensitive to air borne contamination, this is confirmed by procedural blanks on regular basis. So clean room or laminar flow cabinet is not necessary for this workflow. Samples are much less in contact with air (i.e. Sediment Box is a closed system, samples are always covered, also when freeze drying, no elaborate clean-up methods are used).
[10] Personal communication: Procedural blanks are done on regular basis by filling a SB with milliQ water and clean, baked-out seasand. The seasand and water is kept in a box >4 weeks after which the sample preparation is done via standard procedure (emptying the SB, freeze-drying, milling, analysis) and no blank contamination is found from these steps.
[11] In the criteria of Koelmans et al.(2019), polymer identification only refers to whether it has been carried out using a valid method.

Criterion	Brief rationale	Score (0–2)
	products and fragment-ion patterns). For some polymers (NR, PA, PET, PMMA), fewer criteria are available (low fragment intensity), and these are explicitly flagged as lower-confidence identifications contributing <3 % to summed mass in sediment/shore samples.	
Total accumulated score (TAS)		12
Number of criteria scoring 0		2

Additional considerations when scoring QA/QC criteria in studies that assess microplastic in aqueous environmental samples
The QA/QC criteria (Table A7) and discussion points below relate primarily to spectroscopic, particle counting based methods. Thermal methods, such as pyrolysic GC-MS have different workflows which require different quality criteria or different scoring implementations. This relates for instance to sample size which cannot be assessed based on particle counts (Criterion 2). Or the approach to identifying polymers (Criterion 9) are based on different techniques requiring less attention to the software used but more to other aspects, e.g. related to markers being used.

Sample size and subsampling (Criterion 2 and Criterion 9)
So far, criteria 2 (Sample size) and 9 (Subsampling during Polymer Identification) are treated independently, but should be evaluated jointly, as both determine how well an analyzed subset of microplastics represents their original heterogeneous mixture (Cross et al., 2025). This is in line with further recent studies that move from volume to particle count targets when using spectroscopic techniques (Brandt et al., 2021; Cowger et al., 2020; Cross et al., 2025). Applying statistical error propagation Cowger et al. (2020) showed that at least 96 particles in a sample are required to limit uncertainty to ≤10% when being interested in a single property, i.e. polymer type, size or shape. Instead, approximately 150 particles (10% uncertainty) or 620 particles (5% uncertainty) are needed for multi-property analyses (Cowger et al., 2020). Practically, 150 microplastics per sample should be a feasible target, whereas lower particle numbers could introduce substantial uncertainty, further statistical analysis could provide guidance in selecting a threshold. Of the 77 samples for which raw FTIR or LDIR data were available, there were 3 samples in which less than 150 particles were identified, and 34 samples in which less than 620 particles were identified (Figure A1). The minimum particle number target is not applicable to mass-based measurements for which a different implementation is needed.

Figure A.1 Number of particles identified per sample. Red line at 150 particles. Blue line at 620 particles. ***Logarithmic scale.*** *Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).*



Polymer identification (Criterion 9)
In Koelmans et al. (2019), this criterion is used to assess whether an analytical technique capable of polymer identification and thus discriminate between natural and synthetic materials. This is important for identification of microplastics.
Since the Koelmans et al. (2019) study, various authors have identified additional considerations that should ideally be considered in the QA/QC of microplastic studies. These include but are not limited to reporting instrumental settings, spectral quality thresholds, and post-analysis decisions which allow a better understanding of generated data (Cowger et al., 2020). Adjustment of libraries to also include natural (organic) materials that could be misidentified for plastic (Marchand et al., 2025). Especially software tools for automated spectral interpretation remain under active development and are not directly comparable yet. This means that reporting is needed on exact software versions and settings used together with transparency on the libraries.

Data reporting (Not currently included)
There is currently a lack of standardization in how microplastics monitoring data is reported. This may lead to underrepresentation of actual microplastic concentration, as the utilized method may not be able to detect all polymers or sizes covered by the definition of microplastics. Reporting monitoring data of microplastics should be standardized by adhering to the definition of microplastics and when this is not possible there should be clear communication about which parts are not covered in the reported analysis.
Furthermore, the method of particle size determination should be standardized and reported (e.g. Feret's diameter, Martin's diameter,

etc.), as different methods may result in different reported particle sizes and decrease comparability between studies (Schnepf et al., 2023).

Negative controls (Criterion 6)
Procedural blanks are nowadays widely implemented, but their execution and reporting vary. Ideally, blanks should cover all laboratory steps and, where feasible, also sampling procedures. Although commonly done for the laboratory part, many studies report only averaged blank values, without detailing the variability of findings or the applied correction methods (Dawson et al., 2023). Including sampling procedures is done less often and could be a challenge in field conditions. If in the future a standardised sampling approach, with adequate precautions, can be shown to have negligible effect on detected microplastic concentrations, one could argue to leave this step out.

Positive controls (Criterion 7)
The implementation of positive controls has improved considerably since 2019, but they are often conducted using relatively large or visually distinct particles, while studies may target much smaller size ranges. Positive controls should better reflect the intended particle sizes, shapes, and densities, ideally spanning a broad and overlapping range of properties. Recovery tests should also be conducted under field conditions to evaluate sampling efficiency. This is essential to interpret data and still needs to be performed. This includes assessments of whether surface-floating particles are captured, whether the full targeted size range is retained, or whether retention varies across different particle types.

Suspended particulate matter concentrations
Table A.14 Suspended particulate matter concentrations used for calculating microplastic concentrations in water. Data from Rijkswaterstaat (www.waterinfo.rws.nl).

Location	Start date sampling	End date sampling	Median SPM concentration (mg/L)	Min SPM concentration (mg/L	Max SPM concentration (mg/L)
Meuse Eijsden	13-11-2023	13-11-2023	58	58	58
Meuse Eijsden	27-11-2023	27-11-2023	38	38	38
Meuse Eijsden	31-10-2023	31-10-2023	33.5	31	36
Meuse Eijsden	7-11-2023	7-11-2023	37	32	42
Meuse Eijsden	5-9-2023	3-10-2023	5	5	13
Meuse Eijsden	3-10-2023	31-10-2023	5	5	36
Meuse Eijsden	7-11-2023	5-12-2023	42.5	12	130
Meuse Eijsden	10-3-2021	7-4-2021	5	5	15
Meuse Eijsden	13-1-2021	10-2-2021	39	23	170
Meuse Eijsden	21-3-2023	21-3-2023	18	15	21
Meuse Eijsden	5-12-2023	5-12-2023	14.5	12	17
Meuse Eijsden	14-10-2022	11-11-2022	5	5	7
Meuse Eijsden	14-10-2022	11-11-2022	5	5	7
Meuse Eijsden	3-10-2023	31-10-2023	5	5	36

Location	Start date sampling	End date sampling	Median SPM concentration (mg/L)	Min SPM concentration (mg/L	Max SPM concentration (mg/L)
Meuse Eijsden	4-2-2020	4-2-2020	230	230	230
Meuse Eijsden	13-12-2021	13-12-2021	94	94	94
Rhine Lobith	6-12-2023	6-12-2023	18	11	25
Rhine Lobith	1-11-2023	1-11-2023	8.1	8.1	8.1
Rhine Lobith	17-1-2024	17-1-2024	19.5	18	21
Rhine Lobith	20-11-2023	20-11-2023	28	28	28
Rhine Lobith	20-12-2023	20-12-2023	32.5	24	41
Rhine Lobith	22-1-2024	22-1-2024	21	21	21
Rhine Lobith	3-1-2024	3-1-2024	19	15	23
Rhine Lobith	6-11-2023	6-11-2023	18	18	18
Rhine Lobith	22-5-2024	19-6-2024	19	6.9	96
Rhine Lobith	23-5-2024	20-6-2024	19	6.9	96
Rhine Lobith	19-6-2024	17-7-2024	14	5.9	23
Rhine Lobith	19-6-2024	17-7-2024	14	5.9	23
Rhine Lobith	1-11-2023	29-11-2023	17	7.5	68
Rhine Lobith	26-4-2023	26-4-2023	5	5	5
Rhine Lobith	3-2-2021	3-2-2021	115	110	120
Rhine Lobith	21-7-2021	21-7-2021	48.5	45	52
Rhine Lobith	9-6-2021	9-6-2021	6.9	5.8	8
Rhine Lobith	23-6-2021	23-6-2021	17	11	23
Rhine Lobith	16-12-2020	13-1-2021	12	6	64
Rhine Lobith	18-11-2020	16-12-2020	11	5	20
Rhine Lobith	29-6-2021	28-7-2021	33.5	7	240
Rhine Lobith	2-6-2021	29-6-2021	18.5	5.8	28

Appendix 2 Particle size distribution model fits

All polymers

Figure A.2 Fit of the power law slope (alpha, orange line) to the longest side of the particles for the Rhine (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Mughini-Gras et al. (2021).

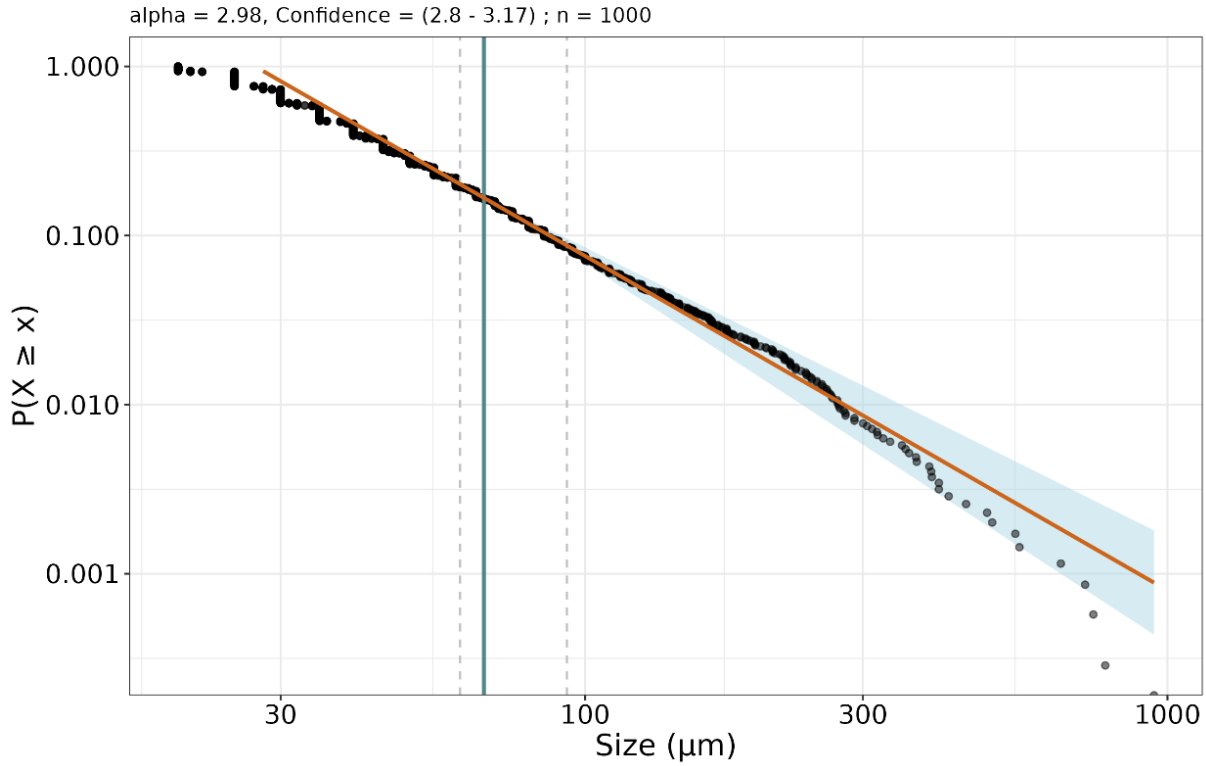


Figure A.3 Fit of the power law slope (alpha) to the longest side of the particles for the WWTP Werverschoof effluent canal (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Bäuerlein et al. (2023).

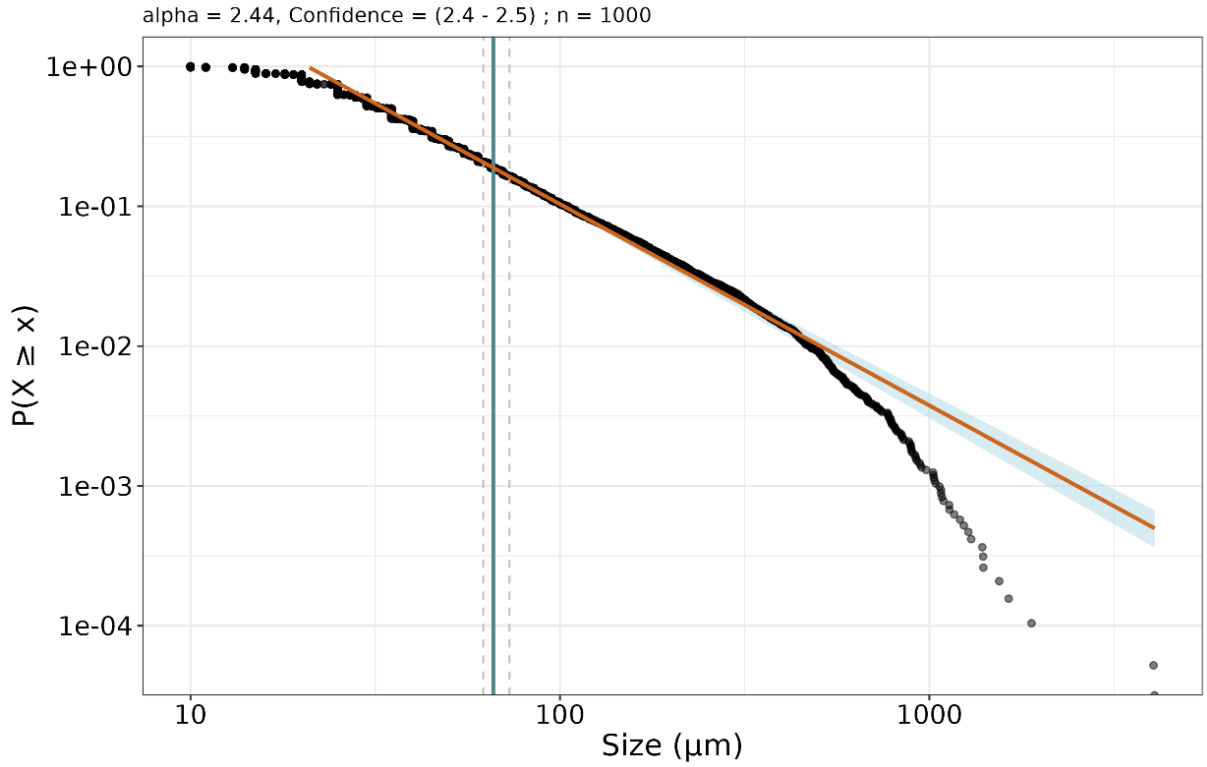


Figure A.4 Fit of the power law slope (alpha, orange line) to the longest side of the particles for Overijsselse Vecht (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Bäuerlein et al. (2022).

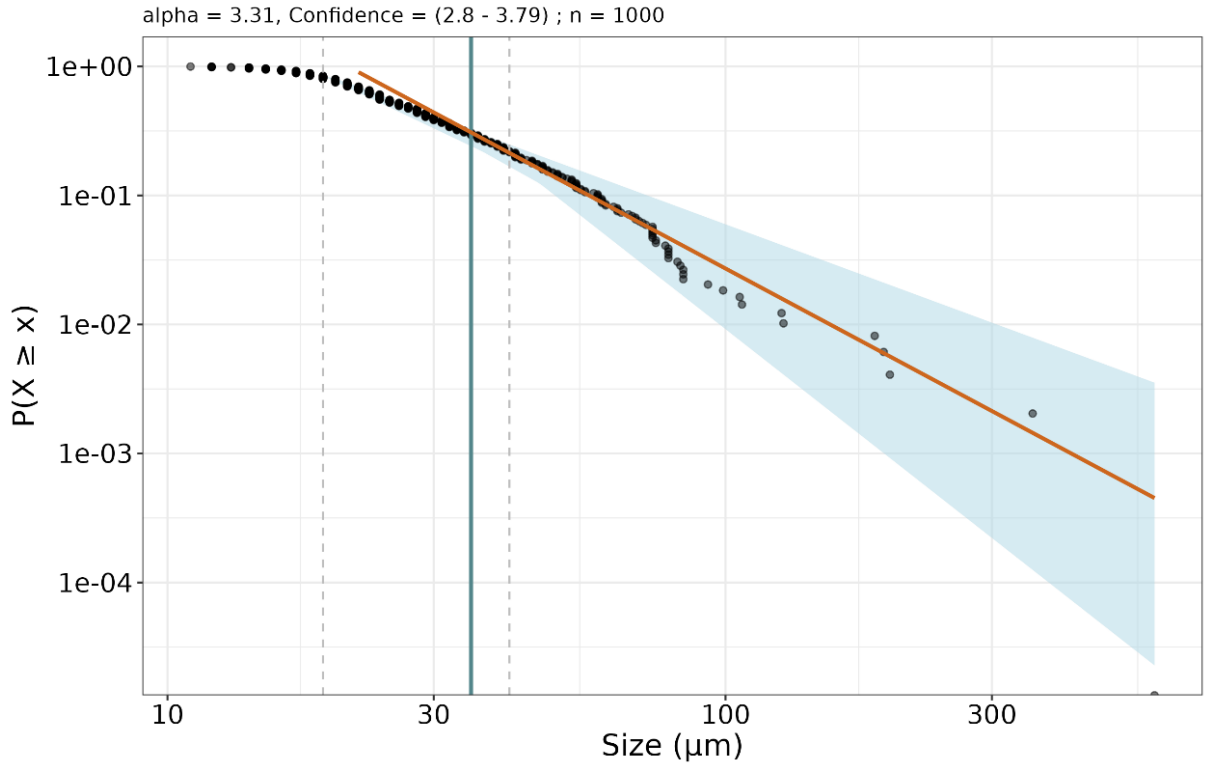


Figure A.5 Fit of the power law slope (alpha, orange line) to the longest side of the particles for the Meuse (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Bäuerlein et al. (2022).

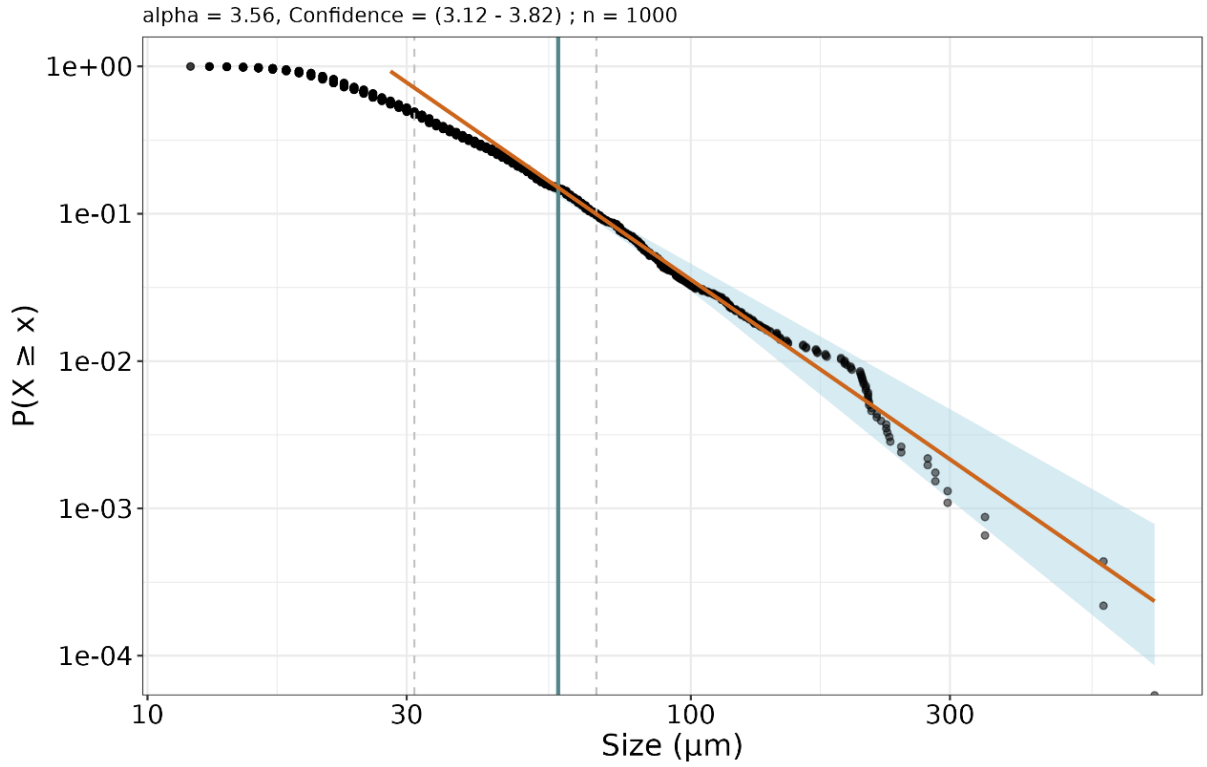


Figure A.6 Fit of the power law slope (alpha, orange line) to the longest side of the particles for the Lek canal (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Bäuerlein et al. (2022) and Mughini-Gras et al. (2021).

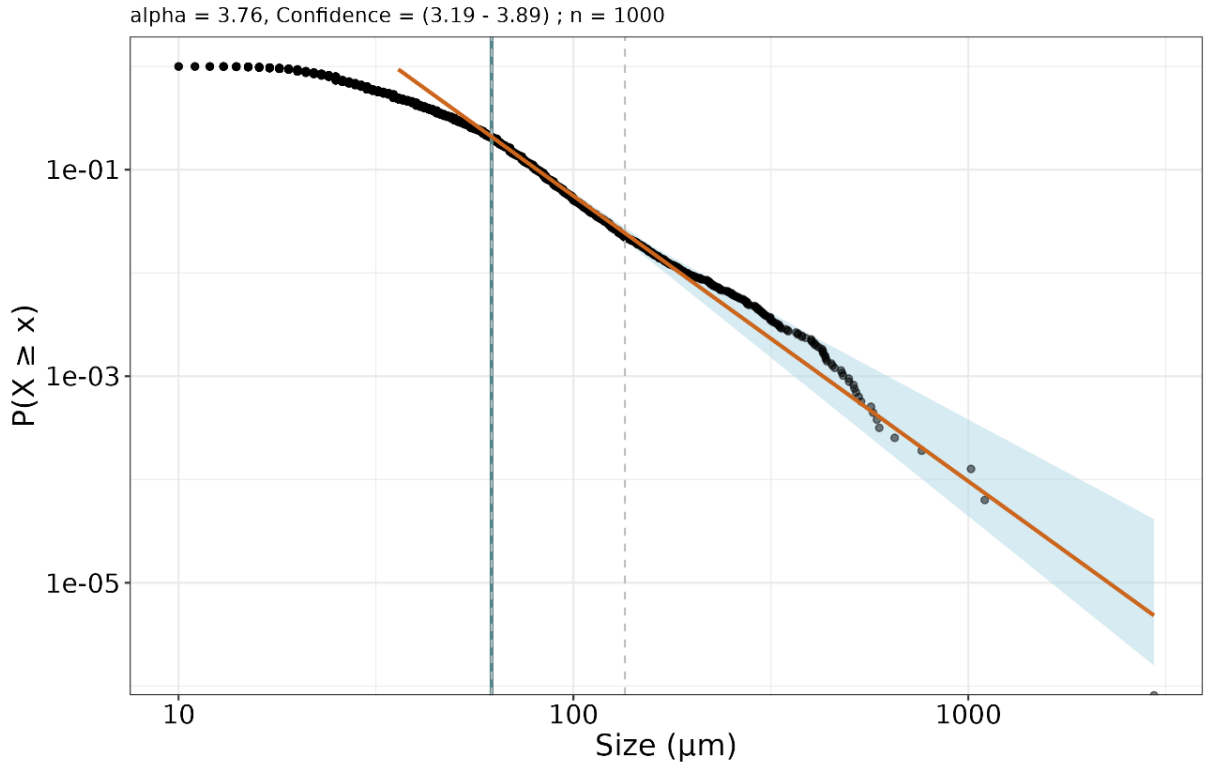


Figure A.7 Fit of the power law slope (alpha, orange line) to the longest side of the particles for the Dommel (FTIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Mintenig et al. (2020, 2025).

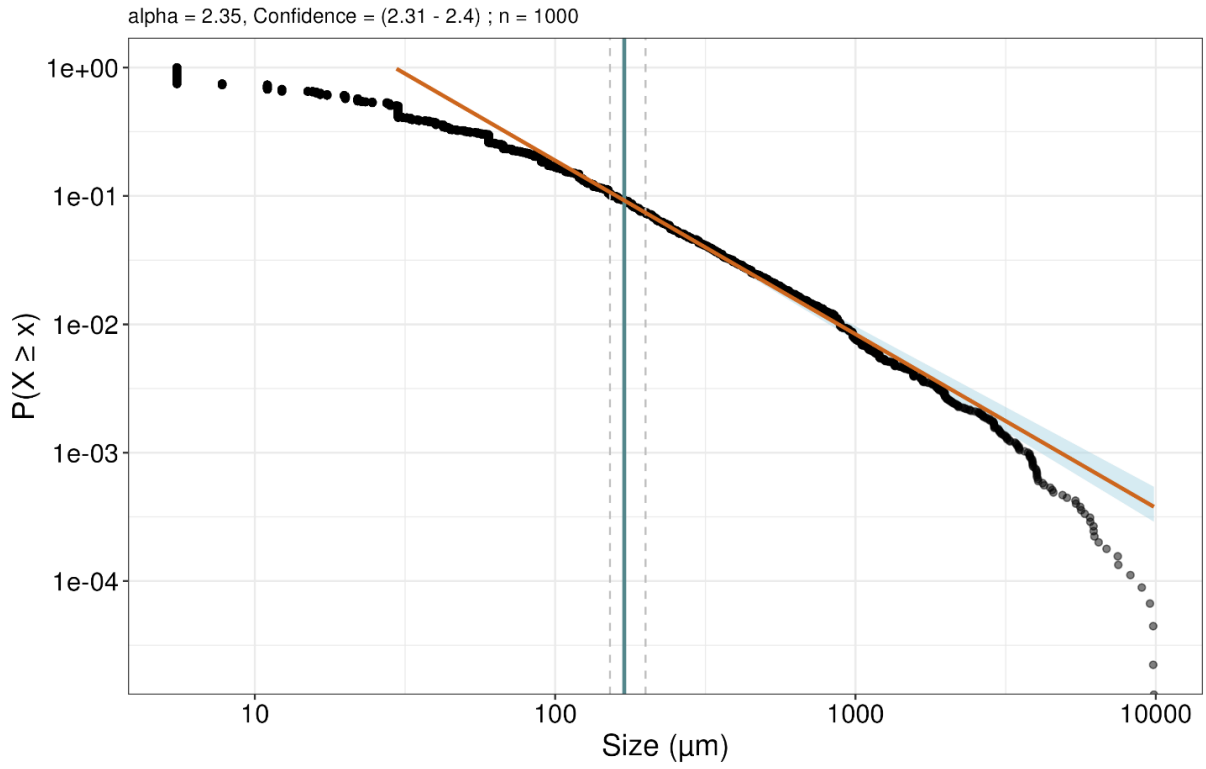
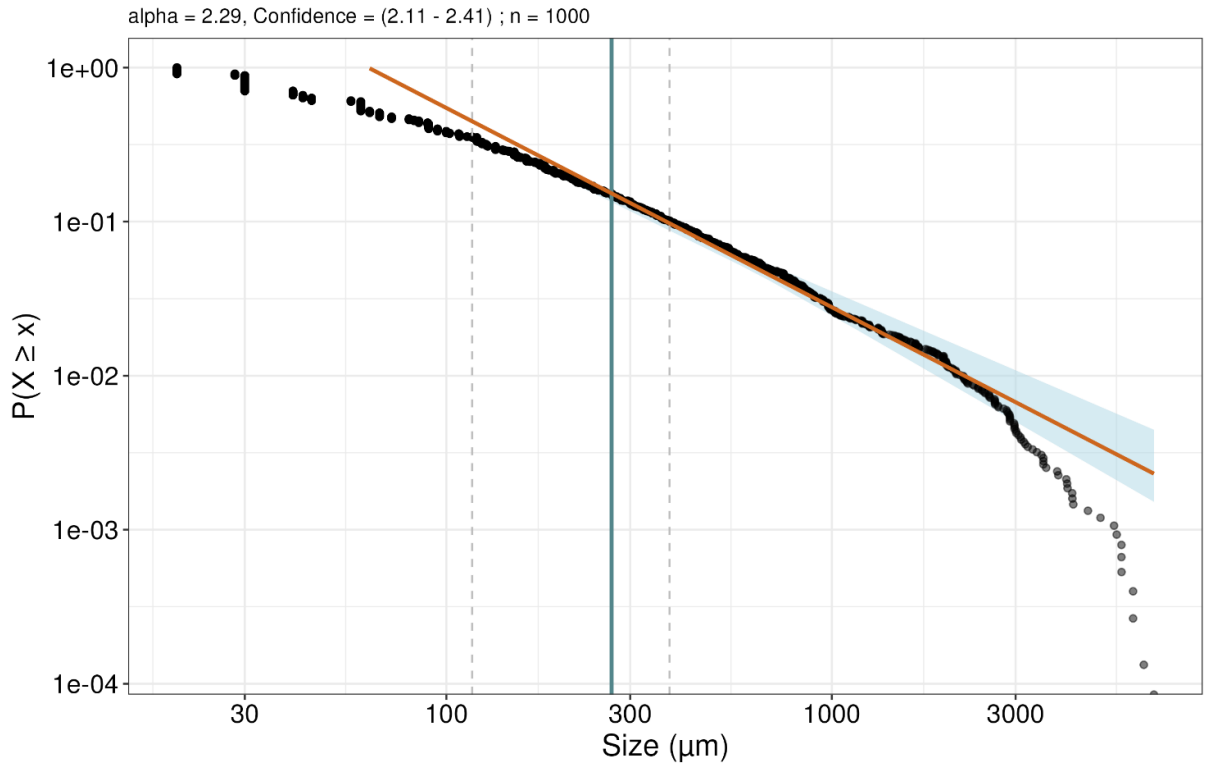


Figure A.8 Fit of the power law slope (alpha, orange line) to the longest side of the particles for the Meuse (FTIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Mintenig et al. (2020).



Polypropylene particles

Figure A.9 Fit of the power law slope (alpha, orange line) to the volume of the Polypropylene particles for the Rhine (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Mughini-Gras et al. (2021).

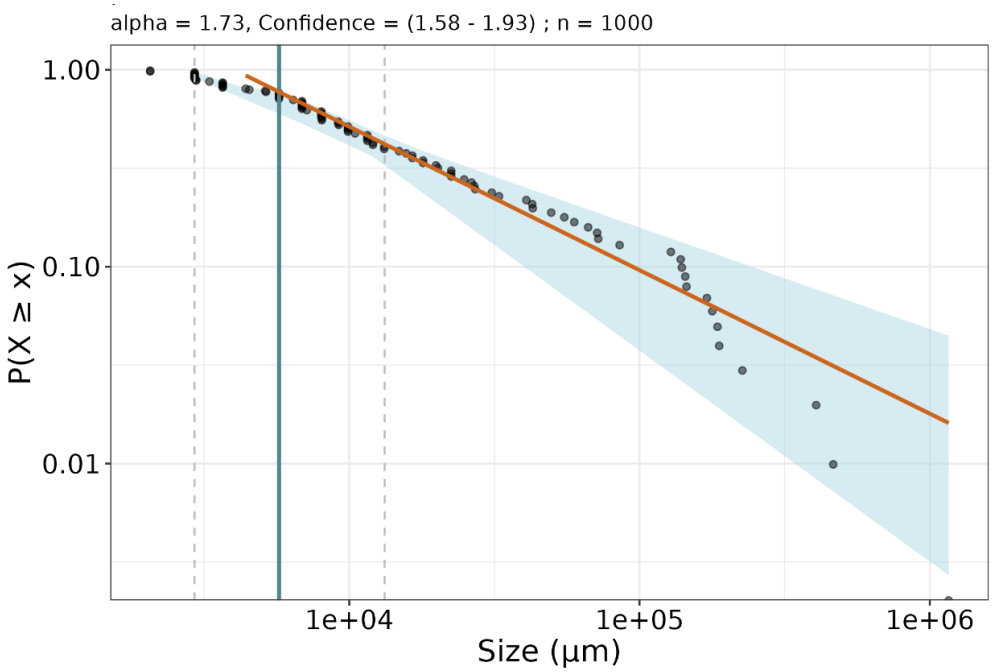
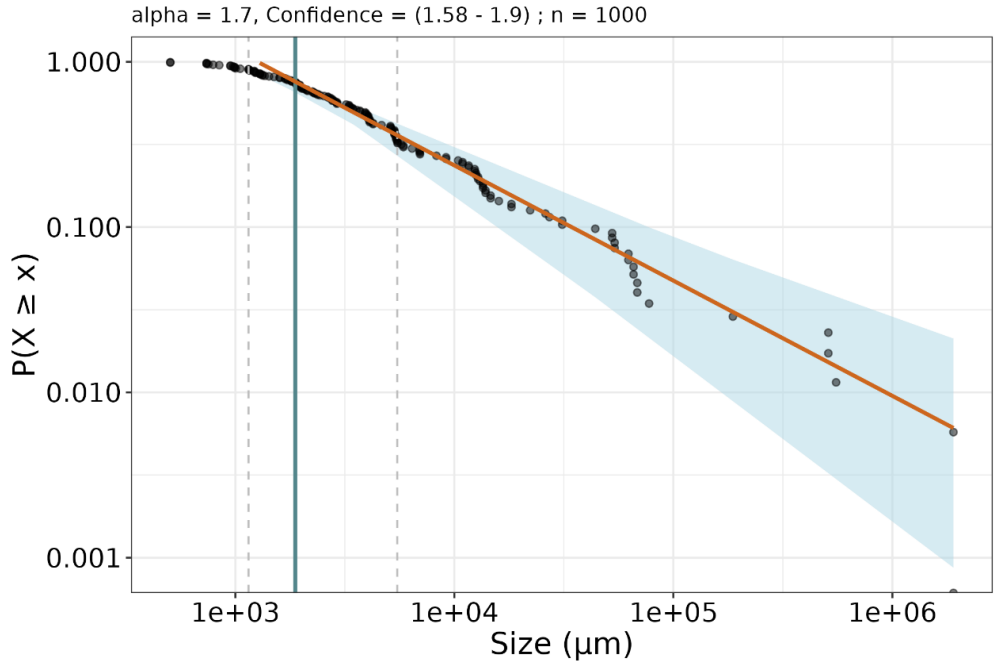


Figure A.10 Fit of the power law slope (alpha, orange line) to the volume of the PP particles for the Meuse (LDIR analysis). The horizontal line depict the minimum particle size (xmin) below which data is excluded for the fit. The 95% confidence interval (n=1000) of the xmin and alpha are given and shown using the vertical dotted line and shaded area, respectively. Data from Bäuerlein et al. (2022).



Appendix 3 Risk Limits background

Summary of the risk limit derivation by Coffin et al (2026)
Coffin et al., (2026) applied the alignment approach from Koelmans et al. (2020) to derive the risk limits for surface area and volume as environmentally relevant metrics. The risk limits are based on the HC5 as derived from SSDs, using data from the ToMEx 2.0 database for research papers studying the ecotoxicological effects of microplastics in water (Hampton et al., 2025). All available studies for freshwater were screened using the quality criteria by Mehinto et al., (2022) which are a subset of the 20 criteria developed by Ruijter et al., (2020). Coffin et al. (2026) then selected studies to ensure the inclusion of ecotoxicological data of adequate quality only (see section 3.4.2, Figure A.11 and Figure A.12). The subset of quality criteria is needed to obtain sufficient data for deriving risk limits. This led to the inclusion of 16 studies of the 144 included in the database, covering 140 datapoints across 10 species.

The studies included by Coffin et al. (2026) provided datapoints reporting either NOECs, LOECs, EC50s or LC50s. These were aligned using the Koelmans approach to the 1-5000 µm size range, for details of the method see (Koelmans et al., 2020; Swart et al., 2025). The alignment was done using environmental distribution parameters, such as the length power law exponent from (Kooi et al., 2021) which partly uses the same data for the Dommel from Mintenig et al. (2020).

In case no chronic exposure data were available in the selected studies, Coffin et al. (2026) calculated these from acute data using assessment factors (AFs). In case no NOECs were available in the included studies, these were derived from lowest observed effect concentrations (LOECs, AF of 2) or 50% effect or lethal concentrations (EC50 and LC50, AF of 10). This conversion was performed for 89 of the 140 datapoints included, as only 51 NOECs were reported (Coffin et al., 2026). This conversion, using assessment factors, is an additional source of uncertainty in the data used for the risk limit derivation. An assessment factor of 10 was applied to derive chronic data from acute studies as also used for chemical assessments. AFs were based on Wigger et al. (2020) and validated for application in MP ecotoxicological studies by Mehinto et al. (2022).

From this aligned hazard data, three types of SSDs were derived by Coffin et al. (2026): traditional SSD, an MC+SSD and a PSSD++. For the ecological risk assessment in the current study, the PSSD++ derived HC5 values are used, as they provide what is currently the hazard assessment method that most accurately describes the uncertainty and variability of the derived HC5 values (Table 6). This is done by approaching the input data and uncertainties probabilistically. This means that input data is mostly a distribution of data rather than a single datapoint, which better describes the variation within this data. Through this approach, the PSSD++ covers uncertainties in toxicity data like inter-laboratory variation, assessment factors for exposure time and dose descriptors as well as uncertainties in the particle alignment. The

resulting HC5 yields more precautionary limits that more accurately represent the underlying data, including its variability and uncertainty.

Both particle volume and surface area are used as ERM resulting in two separate SSDs. These ERM's are theoretically linked to (i) the ecological effect mechanism of food dilution and (ii) particle translocation, which is a prerequisite for effects upon translocation within tissues and cells. As tissue translocation is not considered relevant for all particles sizes, e.g. particles from a certain size cannot cannot be taken up. For this reason an empirical size dependent distribution is applied derived from data reported in 27 particle uptake studies. The relationship is bimodal and issues a lower probability for tissue translocation of larger particles, but not with a strict cutoff as was previously used in Mehinto et al. (2022).

Coffin et al., (2026) used the ToMEx 2.0 database, which contains 144 studies for freshwater species (63 species; 6555 data points). All studies were scored for their quality based on the criteria set by de Ruijter et al. (2020). Studies were selected based on the minimum quality criteria from Mehinto et al., (2022). However, datapoints were also excluded due to an inapplicability of species (e.g., plants and bacteria were not included); the exposure particles being outside of the default (i.e., 1–5000 µm) or bioaccessible (species/ERM-dependent) size range; or the effect metric being an intermediary exposure concentration or a highest observed no effect concentration (HONEC). This resulted in 16 studies (10 species, 140 data points) being selected for use in derivation of the two risk limits (See Figure A.11 and Figure A.12.

In the end Coffin et al. (2026) recommends having more high quality toxicity studies, as this will increase realism and robustness of the derived risk limits. This may be achieved not only by repeating studies, but also by extending studies to other microplastics types underrepresented in the current data, especially fibers, PP, PET and tyre wear particles.

Figure A.11 Technical quality scoring for all criteria for 16 studies included in Coffin et al. (2026). Scores of 0 (Inadequate), 1 (Adequate with Restrictions), and 2 (Adequate) are respresented by red, grey, and blue tiles respectively. Minimum criteria according to Mehinto et al. (2022) are indicated with an asterisk. Source: TOMEX 2.0 (Hampton et al., 2025).

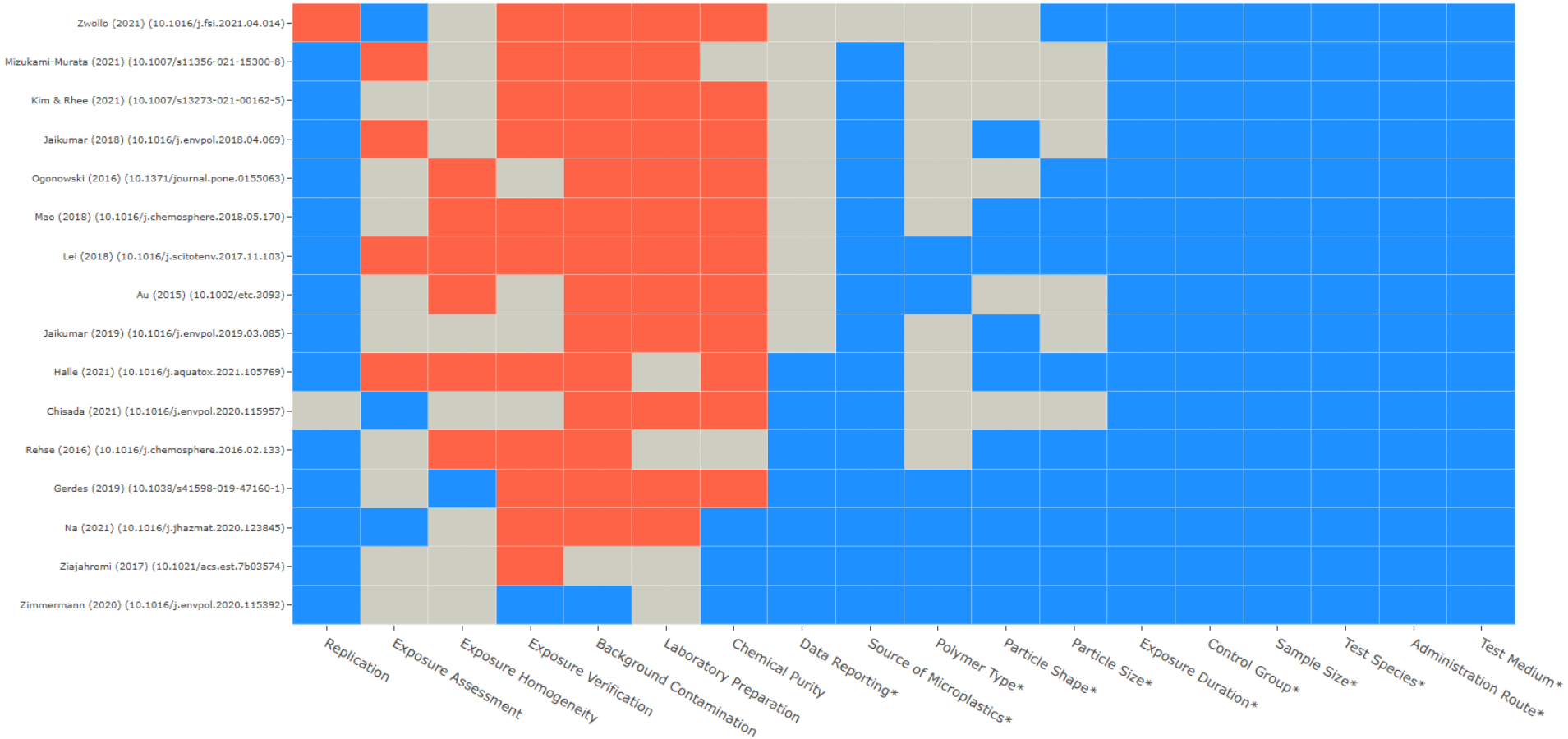


Figure A.12 Risk assessment quality scoring for all criteria for 16 studies included in Coffin et al. (2026). Scores of 0 (Inadequate), 1 (Adequate with Restrictions), and 2 (Adequate) are respresented by red, grey, and blue tiles respectively. Minimum criteria according to Mehinto et al. (2022) are indicated with an asterisk. "Dose response" is inadequate for two studies, as the figure shows the scoring according to the Ruijter et al. (2020), which are stricter for the "dose response" criterium than the study by Mehinto et al. (2022). Source: TOMEX 2.0 (Hampton et al., 2025).

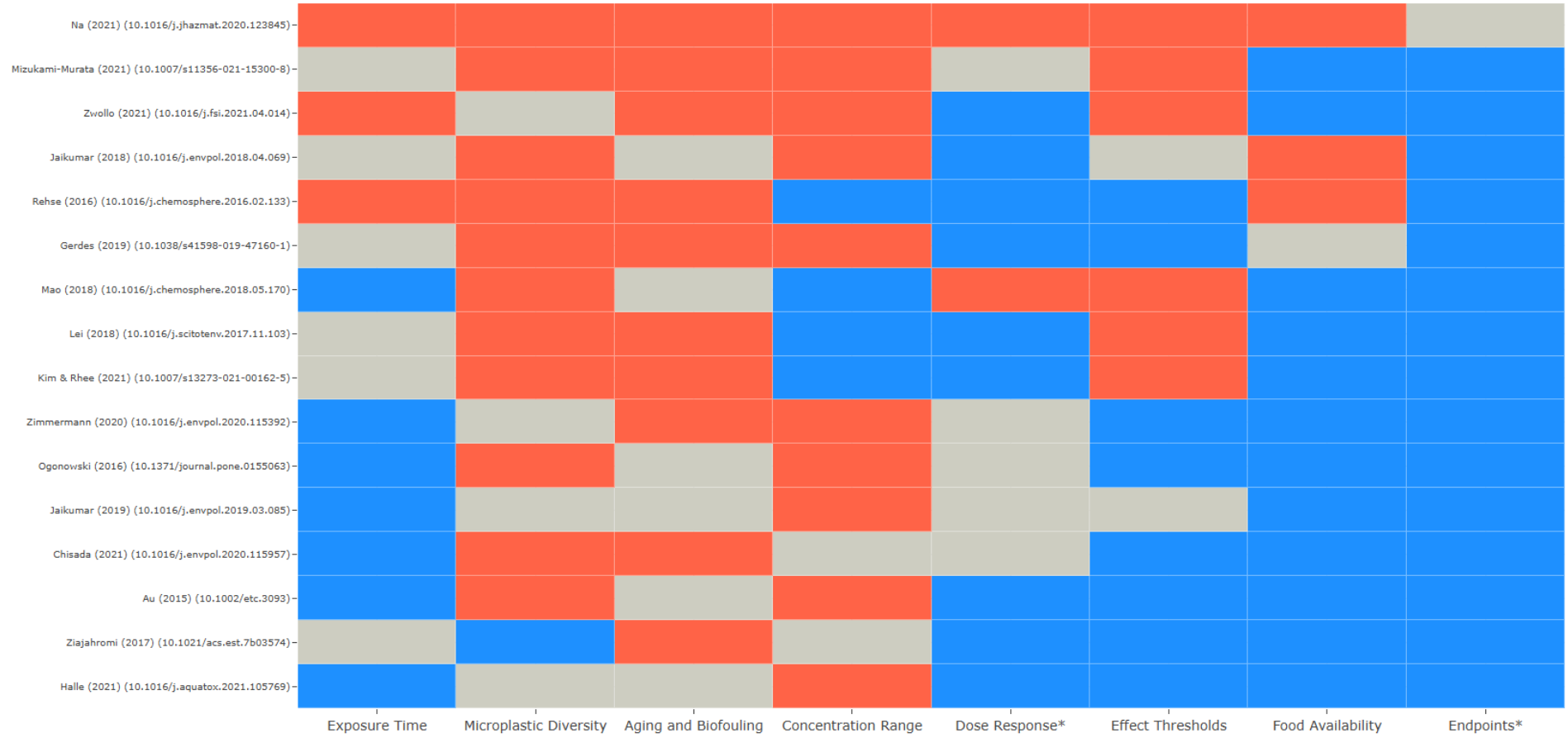


Table A.15 Overview of OECD guidelines of ecotoxicity studies indicating the number of replicates and test concentrations required.

Test	taxonomic group	Biological scale of Test	OECD guideline	Replicates in OECD guideline	No. of test concentrations (excl. control)
Fish, Acute Toxicity Testing	Fish	Organismal to population	203	1, 7 animals per treatment	at least 5
Fish, Early-life Stage Toxicity Test	Fish	Organismal to population	210	4	at least 5
Fish, Juvenile Growth Test	Fish	Organismal to population	215	determined by power analysis	at least 5
Fish, Short-term Toxicity Test on Embryo and Sac-fry Stages	Fish	Organismal to population	212	30 eggs distributed over 3 chambers	at least 5
Fish Short Term Reproduction Assay	Fish	Organismal to population	229	depends on species (eg. 2x(5M+5F) or 4x (3M+3F) or 4x (2M+4F))	3
21-day Fish Assay: A Short-Term Screening for Oestrogenic and Androgenic Activity, and Aromatase Inhibition	Fish	Molecular to population	230	depends on species (eg. 2x(5M+5F) or 4x (2M+4F))	3
Fish Sexual Development Test	Fish	Molecular to population	234	4	3
Fish Embryo Acute Toxicity (FET) Test	Fish	Organismal to population	236	20 wells with 1 embryo	at least 5
Medaka Extended One Generation Reproduction Test (MEOGRT)	Fish	Molecular to population	240	6	5
Fish Cell Line Acute Toxicity - The RTgill-W1 cell line assay	Fish	Molecular to population	249	at least 3T	6
EASZY assay - Detection of Endocrine Active Substances, acting through estrogen receptors, using transgenic tg(cyp19a1b:GFP) Zebrafish embrYos	Fish	Molecular to population	250	3x7	at least 3
Rapid Androgen Disruption Activity Reporter Assay (RADAR)	Fish	Molecular to population	251	3x20	at least 5

Test	taxonomic group	Biological scale of Test	OECD guideline	Replicates in OECD guideline	No. of test concentrations (excl. control)
Rapid Estrogen Activity In Vivo (REACTIV) assay	Fish	Molecular to population	252	3 x8	at least 5
Daphnia sp. Acute Immobilisation Test	Crustacea	Organismal to population	202	4x5 animals	at least 5
Daphnia magna reproduction test	Crustacea	Organismal to population	211	10x1 (static), 4x10 (flow-through)	at least 5
Short-term Juvenile Hormone Activity Screening Assay using Daphnia magna (JHASA)	Crustacea	Molecular to population	253	10x1	at least 3
Sediment-Water Chironomid Toxicity Using Spiked Sediment	Insect	Organismal to population	218	3	at least 5
Sediment-Water Chironomid Toxicity Using Spiked Water	Insect	Organismal to population	219	3	at least 5
Sediment-Water Chironomid Life-Cycle Toxicity Test Using Spiked Water or Spiked Sediment	Insect	Organismal to population	233	8	at least 5
Chironomus sp., Acute Immobilisation Test	Insect	Organismal to population	235	4x5 animals	at least 5
Sediment-Water Lumbriculus Toxicity Test Using Spiked Sediment	Annelida	Organismal to population	225	3 (4 for NOEC/LOEC)	at least 5
Potamopyrgus antipodarum Reproduction Test	Mollusca	Organismal to population	242	6x6	at least 5
Lymnaea stagnalis Reproduction Test	Mollusca	Organismal to population	243	6x5	at least 5

Appendix 4 Additional tables and figures

*Table A.16 Rescaled particle number concentrations including the uncertainty range due to the detection limit and power law slope per sample per polymer. Concentrations in #/m^3, reported as mean (5th – 95th percentile). ND: not detected. *individual particle measurements and identification were not available for the sample. Therefore, it is unknown what the polymer distribution within the sample was. Data from Bäuerlein et al. (2022, 2023), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021).*

Sample ID	ABS	Acryl	Other synthetic rubbers	Others	PA	PC	PE	PET	PMMA	PP	PS	PUR	PVC	EPDM	NR	SBR	Total
Bäuerlein_ 2022_1	1e+05 (7e+04 - 2e+05)	4e+04 (2e+04 - 7e+04)	3e+06 (2e+06 - 5e+06)	3e+06 (1e+06 - 4e+06)	1e+07 (6e+06 - 1e+07)	2e+05 (1e+05 - 3e+05)	9e+06 (5e+06 - 1e+07)	1e+07 (6e+06 - 2e+07)	ND	2e+06 (1e+06 - 4e+06)	4e+04 (2e+04 - 7e+04)	2e+06 (9e+05 - 2e+06)	8e+05 (5e+05 - 1e+06)	ND	ND	ND	4e+07 (2e+07 - 6e+07)
Bäuerlein_ 2022_2	1e+05 (6e+04 - 2e+05)	3e+04 (2e+04 - 5e+04)	7e+06 (4e+06 - 1e+07)	2e+06 (1e+06 - 3e+06)	1e+07 (6e+06 - 2e+07)	2e+05 (1e+05 - 3e+05)	3e+06 (2e+06 - 4e+06)	4e+06 (2e+06 - 6e+06)	3e+04 (2e+04 - 5e+04)	2e+05 (1e+05 - 3e+05)	3e+05 (2e+05 - 4e+05)	7e+05 (4e+05 - 1e+06)	2e+06 (9e+05 - 2e+06)	ND	ND	ND	3e+07 (2e+07 - 4e+07)
Bäuerlein_ 2022_3	4e+04 (2e+04 - 6e+04)	ND	4e+06 (2e+06 - 6e+06)	1e+06 (7e+05 - 2e+06)	6e+06 (4e+06 - 1e+07)	3e+05 (1e+05 - 4e+05)	2e+06 (1e+06 - 4e+06)	3e+06 (2e+06 - 4e+06)	5e+04 (3e+04 - 8e+04)	1e+06 (6e+05 - 2e+06)	1e+05 (6e+04 - 2e+05)	5e+05 (3e+05 - 8e+05)	6e+05 (3e+05 - 9e+05)	ND	ND	ND	2e+07 (1e+07 - 3e+07)
Bäuerlein_ 2022_4	7e+03 (3e+03 - 2e+04)	ND	2e+05 (7e+04 - 4e+05)	5e+05 (2e+05 - 1e+06)	6e+05 (2e+05 - 1e+06)	1e+04 (5e+03 - 3e+04)	8e+05 (3e+05 - 2e+06)	8e+05 (3e+05 - 2e+06)	2e+04 (8e+03 - 5e+04)	2e+05 (6e+04 - 4e+05)	2e+04 (8e+03 - 5e+04)	3e+05 (1e+05 - 7e+05)	8e+04 (3e+04 - 2e+05)	ND	ND	ND	3e+06 (1e+06 - 8e+06)
Bäuerlein_ 2022_5	1e+06 (6e+05 - 2e+06)	1e+05 (7e+04 - 2e+05)	1e+07 (6e+06 - 2e+07)	2e+07 (8e+06 - 3e+07)	6e+07 (3e+07 - 1e+08)	8e+06 (4e+06 - 1e+07)	1e+07 (6e+06 - 2e+07)	6e+07 (3e+07 - 1e+08)	2e+05 (1e+05 - 4e+05)	5e+06 (2e+06 - 8e+06)	3e+05 (1e+05 - 5e+05)	6e+06 (3e+06 - 1e+07)	8e+06 (4e+06 - 1e+07)	ND	ND	ND	2e+08 (9e+07 - 3e+08)
Bäuerlein_ 2023_1	ND	ND	7e+05 (6e+05 - 8e+05)	4e+05 (4e+05 - 5e+05)	2e+06 (1e+06 - 2e+06)	ND	4e+05 (4e+05 - 5e+05)	2e+05 (1e+05 - 2e+05)	ND	4e+05 (4e+05 - 5e+05)	1e+05 (1e+05 - 1e+05)	2e+05 (2e+05 - 2e+05)	7e+05 (6e+05 - 8e+05)	ND	ND	ND	5e+06 (4e+06 - 5e+06)
Bäuerlein_ 2023_11	5e+03 (4e+03 - 6e+03)	1e+04 (9e+03 - 1e+04)	9e+05 (8e+05 - 1e+06)	5e+05 (4e+05 - 5e+05)	1e+06 (1e+06 - 2e+06)	2e+04 (2e+04 - 2e+04)	7e+05 (6e+05 - 7e+05)	6e+05 (5e+05 - 7e+05)	5e+03 (4e+03 - 6e+03)	3e+05 (3e+05 - 4e+05)	3e+04 (2e+04 - 3e+04)	3e+05 (3e+05 - 4e+05)	2e+05 (1e+05 - 2e+05)	ND	ND	ND	5e+06 (4e+06 - 6e+06)
Bäuerlein_ 2023_12	ND	2e+03 (2e+03 - 2e+03)	7e+04 (6e+04 - 8e+04)	3e+05 (3e+05 - 4e+05)	2e+05 (2e+05 - 2e+05)	2e+04 (2e+04 - 3e+04)	8e+04 (7e+04 - 9e+04)	1e+05 (1e+05 - 1e+05)	ND	2e+04 (2e+04 - 2e+04)	1e+04 (1e+04 - 1e+04)	3e+04 (3e+04 - 3e+04)	2e+04 (2e+04 - 3e+04)	ND	ND	ND	9e+05 (8e+05 - 1e+06)
Bäuerlein_ 2023_13	ND	ND	4e+04 (3e+04 - 4e+04)	9e+04 (8e+04 - 1e+05)	9e+04 (8e+04 - 1e+05)	ND	6e+04 (5e+04 - 7e+04)	5e+04 (5e+04 - 6e+04)	ND	3e+04 (3e+04 - 4e+04)	2e+04 (2e+04 - 3e+04)	3e+04 (3e+04 - 4e+04)	2e+05 (2e+05 - 2e+05)	ND	ND	ND	6e+05 (5e+05 - 7e+05)
Bäuerlein_ 2023_15	ND	ND	1e+05 (1e+05 - 2e+05)	4e+05 (3e+05 - 5e+05)	3e+05 (3e+05 - 4e+05)	ND	1e+05 (1e+05 - 2e+05)	6e+04 (5e+04 - 7e+04)	ND	8e+04 (7e+04 - 9e+04)	5e+04 (4e+04 - 6e+04)	1e+05 (1e+05 - 1e+05)	5e+05 (5e+05 - 6e+05)	ND	ND	ND	2e+06 (2e+06 - 2e+06)
Bäuerlein_ 2023_16	ND	ND	6e+04 (6e+04 - 7e+04)	1e+05 (1e+05 - 2e+05)	2e+05 (1e+05 - 2e+05)	ND	8e+04 (7e+04 - 9e+04)	5e+04 (4e+04 - 6e+04)	ND	3e+04 (2e+04 - 3e+04)	2e+04 (1e+04 - 2e+04)	1e+05 (1e+05 - 1e+05)	2e+05 (2e+05 - 3e+05)	ND	ND	ND	9e+05 (8e+05 - 1e+06)
Bäuerlein_ 2023_17	6e+03 (5e+03 - 7e+03)	1e+04 (1e+04 - 1e+04)	4e+05 (3e+05 - 4e+05)	3e+05 (3e+05 - 4e+05)	4e+05 (4e+05 - 5e+05)	6e+03 (5e+03 - 7e+03)	3e+05 (3e+05 - 4e+05)	3e+05 (3e+05 - 4e+05)	9e+03 (8e+03 - 1e+04)	1e+05 (1e+05 - 1e+05)	4e+04 (4e+04 - 5e+04)	6e+04 (5e+04 - 7e+04)	1e+05 (1e+05 - 2e+05)	ND	ND	ND	2e+06 (2e+06 - 3e+06)
Bäuerlein_ 2023_18	ND	1e+04 (1e+04 - 1e+04)	2e+05 (2e+05 - 3e+05)	8e+05 (7e+05 - 9e+05)	4e+05 (3e+05 - 4e+05)	4e+03 (4e+03 - 5e+03)	6e+05 (5e+05 - 6e+05)	4e+05 (4e+05 - 5e+05)	4e+03 (4e+03 - 5e+03)	3e+05 (2e+05 - 3e+05)	2e+04 (2e+04 - 3e+04)	3e+05 (3e+05 - 3e+05)	7e+04 (7e+04 - 9e+04)	ND	ND	ND	3e+06 (3e+06 - 4e+06)

Sample ID	ABS	Acryl	Other synthetic rubbers	Others	PA	PC	PE	PET	PMMA	PP	PS	PUR	PVC	EPDM	NR	SBR	Total
Bäuerlein_ 2023_19	ND	2e+04 (2e+04 - 2e+04)	6e+05 (5e+05 - 7e+05)	5e+05 (4e+05 - 5e+05)	8e+05 (7e+05 - 9e+05)	8e+03 (7e+03 - 9e+03)	5e+05 (4e+05 - 6e+05)	4e+05 (3e+05 - 4e+05)	1e+04 (1e+04 - 1e+04)	3e+05 (3e+05 - 4e+05)	7e+04 (6e+04 - 8e+04)	2e+05 (2e+05 - 2e+05)	2e+05 (2e+05 - 3e+05)	ND	ND	ND	4e+06 (3e+06 - 4e+06)
Bäuerlein_ 2023_2	ND	ND	2e+05 (2e+05 - 3e+05)	5e+05 (4e+05 - 6e+05)	6e+05 (5e+05 - 7e+05)	ND	2e+05 (1e+05 - 2e+05)	7e+04 (6e+04 - 8e+04)	ND	2e+05 (2e+05 - 2e+05)	5e+04 (4e+04 - 6e+04)	8e+04 (7e+04 - 9e+04)	3e+05 (2e+05 - 3e+05)	ND	ND	ND	2e+06 (2e+06 - 2e+06)
Bäuerlein_ 2023_20	ND	ND	1e+05 (1e+05 - 2e+05)	6e+04 (5e+04 - 7e+04)	5e+05 (5e+05 - 6e+05)	ND	2e+05 (2e+05 - 3e+05)	9e+04 (8e+04 - 1e+05)	ND	1e+05 (9e+04 - 1e+05)	4e+04 (4e+04 - 5e+04)	5e+04 (4e+04 - 6e+04)	7e+04 (6e+04 - 8e+04)	ND	ND	ND	1e+06 (1e+06 - 2e+06)
Bäuerlein_ 2023_22	ND	ND	1e+06 (9e+05 - 1e+06)	6e+05 (5e+05 - 7e+05)	2e+06 (2e+06 - 3e+06)	ND	6e+05 (6e+05 - 7e+05)	2e+05 (2e+05 - 2e+05)	ND	4e+05 (3e+05 - 4e+05)	2e+05 (1e+05 - 2e+05)	3e+05 (2e+05 - 3e+05)	6e+05 (5e+05 - 7e+05)	ND	ND	ND	6e+06 (5e+06 - 7e+06)
Bäuerlein_ 2023_23	ND	ND	7e+05 (6e+05 - 7e+05)	7e+05 (6e+05 - 8e+05)	3e+06 (3e+06 - 4e+06)	ND	6e+05 (5e+05 - 7e+05)	9e+04 (8e+04 - 1e+05)	ND	6e+05 (5e+05 - 7e+05)	9e+04 (8e+04 - 1e+05)	1e+05 (1e+05 - 2e+05)	4e+05 (4e+05 - 5e+05)	ND	ND	ND	7e+06 (6e+06 - 8e+06)
Bäuerlein_ 2023_24	ND	ND	2e+05 (1e+05 - 2e+05)	2e+05 (2e+05 - 2e+05)	1e+06 (1e+06 - 1e+06)	ND	3e+05 (2e+05 - 3e+05)	6e+04 (5e+04 - 7e+04)	ND	9e+04 (8e+04 - 1e+05)	2e+04 (2e+04 - 2e+04)	5e+04 (4e+04 - 6e+04)	2e+05 (2e+05 - 2e+05)	ND	ND	ND	2e+06 (2e+06 - 2e+06)
Bäuerlein_ 2023_25	ND	ND	2e+05 (2e+05 - 3e+05)	1e+06 (9e+05 - 1e+06)	2e+06 (2e+06 - 2e+06)	ND	3e+05 (3e+05 - 4e+05)	2e+05 (2e+05 - 3e+05)	ND	9e+04 (8e+04 - 1e+05)	4e+04 (4e+04 - 5e+04)	3e+04 (3e+04 - 4e+04)	3e+05 (3e+05 - 4e+05)	ND	ND	ND	4e+06 (4e+06 - 5e+06)
Bäuerlein_ 2023_26	ND	ND	4e+05 (3e+05 - 4e+05)	2e+05 (2e+05 - 3e+05)	1e+06 (9e+05 - 1e+06)	ND	4e+05 (4e+05 - 5e+05)	1e+05 (9e+04 - 1e+05)	ND	1e+05 (1e+05 - 1e+05)	3e+04 (3e+04 - 3e+04)	9e+04 (8e+04 - 1e+05)	2e+05 (2e+05 - 2e+05)	ND	ND	ND	3e+06 (2e+06 - 3e+06)
Bäuerlein_ 2023_27	ND	ND	6e+05 (6e+05 - 7e+05)	2e+05 (2e+05 - 3e+05)	2e+06 (1e+06 - 2e+06)	ND	7e+05 (6e+05 - 8e+05)	2e+05 (2e+05 - 2e+05)	ND	5e+05 (4e+05 - 5e+05)	3e+04 (3e+04 - 4e+04)	2e+05 (1e+05 - 2e+05)	7e+05 (6e+05 - 8e+05)	ND	ND	ND	5e+06 (4e+06 - 5e+06)
Bäuerlein_ 2023_28	2e+03 (1e+03 - 2e+03)	2e+03 (1e+03 - 2e+03)	3e+05 (3e+05 - 4e+05)	4e+05 (3e+05 - 4e+05)	4e+05 (3e+05 - 4e+05)	2e+03 (1e+03 - 2e+03)	2e+05 (2e+05 - 3e+05)	1e+05 (1e+05 - 2e+05)	ND	7e+04 (6e+04 - 8e+04)	8e+03 (7e+03 - 9e+03)	6e+04 (5e+04 - 7e+04)	7e+04 (6e+04 - 8e+04)	ND	ND	ND	2e+06 (1e+06 - 2e+06)
Bäuerlein_ 2023_29	2e+04 (2e+04 - 2e+04)	1e+04 (9e+03 - 1e+04)	3e+05 (2e+05 - 3e+05)	8e+05 (7e+05 - 9e+05)	4e+05 (3e+05 - 4e+05)	ND	7e+05 (6e+05 - 8e+05)	6e+05 (5e+05 - 7e+05)	4e+04 (3e+04 - 4e+04)	2e+05 (2e+05 - 3e+05)	2e+04 (2e+04 - 2e+04)	6e+05 (6e+05 - 7e+05)	2e+05 (2e+05 - 3e+05)	ND	ND	ND	4e+06 (3e+06 - 4e+06)
Bäuerlein_ 2023_3	ND	ND	3e+06 (2e+06 - 3e+06)	2e+06 (1e+06 - 2e+06)	5e+06 (4e+06 - 5e+06)	ND	3e+06 (2e+06 - 3e+06)	2e+05 (1e+05 - 2e+05)	ND	2e+06 (2e+06 - 2e+06)	3e+05 (3e+05 - 4e+05)	1e+06 (1e+06 - 2e+06)	3e+06 (2e+06 - 3e+06)	ND	ND	ND	2e+07 (2e+07 - 2e+07)
Bäuerlein_ 2023_30	1e+04 (8e+03 - 1e+04)	3e+04 (2e+04 - 3e+04)	3e+05 (3e+05 - 4e+05)	2e+06 (1e+06 - 2e+06)	5e+05 (4e+05 - 6e+05)	1e+04 (1e+04 - 2e+04)	9e+05 (8e+05 - 1e+06)	9e+05 (8e+05 - 1e+06)	1e+04 (1e+04 - 2e+04)	4e+05 (3e+05 - 4e+05)	3e+04 (3e+04 - 4e+04)	8e+05 (7e+05 - 9e+05)	1e+05 (1e+05 - 1e+05)	ND	ND	ND	6e+06 (5e+06 - 6e+06)
Bäuerlein_ 2023_31	2e+03 (2e+03 - 3e+03)	ND	5e+05 (4e+05 - 5e+05)	2e+05 (2e+05 - 2e+05)	5e+05 (5e+05 - 6e+05)	7e+03 (6e+03 - 8e+03)	4e+05 (3e+05 - 5e+05)	2e+05 (2e+05 - 2e+05)	ND	7e+04 (6e+04 - 8e+04)	4e+04 (3e+04 - 4e+04)	7e+04 (6e+04 - 8e+04)	1e+05 (1e+05 - 1e+05)	ND	ND	ND	2e+06 (2e+06 - 2e+06)
Bäuerlein_ 2023_32	ND	1e+04 (1e+04 - 2e+04)	8e+05 (7e+05 - 9e+05)	5e+05 (4e+05 - 6e+05)	9e+05 (8e+05 - 1e+06)	6e+04 (5e+04 - 7e+04)	8e+05 (7e+05 - 9e+05)	6e+05 (5e+05 - 7e+05)	4e+03 (4e+03 - 5e+03)	4e+05 (3e+05 - 4e+05)	1e+05 (9e+04 - 1e+05)	2e+05 (1e+05 - 2e+05)	3e+05 (3e+05 - 4e+05)	ND	ND	ND	5e+06 (4e+06 - 5e+06)

Sample ID	ABS	Acryl	Other synthetic rubbers	Others	PA	PC	PE	PET	PMMA	PP	PS	PUR	PVC	EPDM	NR	SBR	Total
Bäuerlein_ 2023_4	ND	ND	3e+05 (2e+05 - 3e+05)	2e+05 (2e+05 - 2e+05)	5e+05 (4e+05 - 6e+05)	ND	2e+05 (2e+05 - 2e+05)	7e+04 (6e+04 - 8e+04)	ND	1e+05 (8e+04 - 1e+05)	4e+04 (3e+04 - 4e+04)	9e+04 (8e+04 - 1e+05)	3e+05 (3e+05 - 4e+05)	ND	ND	ND	2e+06 (2e+06 - 2e+06)
Bäuerlein_ 2023_5	ND	ND	5e+05 (4e+05 - 5e+05)	9e+04 (8e+04 - 1e+05)	4e+05 (4e+05 - 5e+05)	8e+03 (7e+03 - 9e+03)	2e+05 (2e+05 - 2e+05)	3e+05 (3e+05 - 3e+05)	8e+03 (7e+03 - 9e+03)	1e+05 (1e+05 - 2e+05)	3e+04 (2e+04 - 3e+04)	1e+05 (1e+05 - 1e+05)	1e+05 (9e+04 - 1e+05)	ND	ND	ND	2e+06 (2e+06 - 2e+06)
Bäuerlein_ 2023_7	ND	ND	9e+05 (8e+05 - 1e+06)	3e+05 (3e+05 - 4e+05)	1e+06 (9e+05 - 1e+06)	4e+04 (4e+04 - 5e+04)	6e+05 (5e+05 - 7e+05)	9e+05 (8e+05 - 1e+06)	ND	3e+05 (2e+05 - 3e+05)	4e+04 (4e+04 - 5e+04)	4e+05 (4e+05 - 5e+05)	3e+05 (2e+05 - 3e+05)	ND	ND	ND	5e+06 (4e+06 - 6e+06)
Bäuerlein_ 2023_8	1e+04 (1e+04 - 2e+04)	1e+04 (1e+04 - 2e+04)	6e+05 (5e+05 - 7e+05)	3e+05 (2e+05 - 3e+05)	9e+05 (8e+05 - 1e+06)	ND	4e+05 (4e+05 - 5e+05)	2e+05 (2e+05 - 3e+05)	ND	1e+05 (1e+05 - 2e+05)	4e+04 (3e+04 - 4e+04)	1e+05 (1e+05 - 2e+05)	2e+05 (2e+05 - 2e+05)	ND	ND	ND	3e+06 (3e+06 - 3e+06)
Bäuerlein_ 2023_9	ND	4e+03 (4e+03 - 5e+03)	9e+05 (8e+05 - 1e+06)	9e+05 (8e+05 - 1e+06)	1e+06 (1e+06 - 1e+06)	ND	6e+05 (5e+05 - 7e+05)	9e+05 (7e+05 - 1e+06)	8e+03 (7e+03 - 1e+04)	2e+05 (2e+05 - 2e+05)	2e+04 (2e+04 - 2e+04)	3e+05 (3e+05 - 4e+05)	2e+05 (2e+05 - 2e+05)	ND	ND	ND	5e+06 (5e+06 - 6e+06)
Mintenig _ 2025_1	9e+02 (8e+02 - 1e+03)	8e+04 (7e+04 - 1e+05)	6e+03 (6e+03 - 7e+03)	5e+03 (4e+03 - 5e+03)	0e+00 (0e+00 - 0e+00)	ND	8e+05 (7e+05 - 9e+05)	8e+03 (7e+03 - 9e+03)	ND	5e+05 (5e+05 - 6e+05)	2e+03 (1e+03 - 2e+03)	ND	3e+04 (3e+04 - 4e+04)	4e+05 (3e+05 - 4e+05)	ND	1e+02 (1e+02 - 1e+02)	2e+06 (2e+06 - 2e+06)
Mintenig _ 2025_2	ND	4e+03 (4e+03 - 5e+03)	2e+02 (2e+02 - 2e+02)	3e+02 (3e+02 - 3e+02)	0e+00 (0e+00 - 0e+00)	ND	2e+04 (2e+04 - 2e+04)	6e+01 (5e+01 - 6e+01)	ND	4e+04 (4e+04 - 5e+04)	2e+02 (2e+02 - 3e+02)	ND	5e+02 (4e+02 - 5e+02)	1e+04 (9e+03 - 1e+04)	ND	6e+01 (5e+01 - 6e+01)	8e+04 (7e+04 - 9e+04)
Mintenig _ 2025_3	ND	2e+04 (2e+04 - 2e+04)	1e+02 (1e+02 - 1e+02)	4e+03 (3e+03 - 4e+03)	0e+00 (0e+00 - 0e+00)	ND	4e+05 (3e+05 - 4e+05)	5e+03 (5e+03 - 6e+03)	ND	2e+05 (1e+05 - 2e+05)	6e+02 (6e+02 - 7e+02)	ND	2e+03 (2e+03 - 3e+03)	1e+05 (1e+05 - 1e+05)	ND	4e+02 (4e+02 - 5e+02)	7e+05 (6e+05 - 8e+05)
Mintenig _ 2025_4	2e+02 (2e+02 - 2e+02)	2e+04 (2e+04 - 3e+04)	2e+03 (1e+03 - 2e+03)	6e+03 (5e+03 - 7e+03)	0e+00 (0e+00 - 0e+00)	ND	3e+05 (3e+05 - 4e+05)	5e+02 (4e+02 - 5e+02)	ND	2e+05 (1e+05 - 2e+05)	1e+04 (1e+04 - 2e+04)	ND	9e+02 (8e+02 - 1e+03)	3e+04 (3e+04 - 3e+04)	ND	3e+02 (3e+02 - 4e+02)	6e+05 (5e+05 - 6e+05)
Mintenig_ 2020_1	ND	2e+03 (2e+03 - 3e+03)	4e+03 (3e+03 - 5e+03)	2e+03 (1e+03 - 3e+03)	9e+02 (7e+02 - 1e+03)	ND	1e+04 (9e+03 - 2e+04)	ND	ND	1e+04 (8e+03 - 2e+04)	9e+02 (6e+02 - 1e+03)	ND	ND	6e+03 (4e+03 - 8e+03)	ND	ND	4e+04 (3e+04 - 5e+04)
Mintenig_ 2020_10	ND	3e+03 (2e+03 - 4e+03)	3e+03 (2e+03 - 4e+03)	2e+03 (2e+03 - 3e+03)	2e+04 (1e+04 - 2e+04)	ND	1e+04 (1e+04 - 2e+04)	6e+02 (4e+02 - 8e+02)	ND	3e+03 (2e+03 - 4e+03)	2e+03 (1e+03 - 2e+03)	ND	5e+01 (3e+01 - 6e+01)	1e+04 (8e+03 - 1e+04)	5e+01 (3e+01 - 6e+01)	ND	5e+04 (4e+04 - 7e+04)
Mintenig_ 2020_11	ND	1e+04 (9e+03 - 1e+04)	2e+03 (1e+03 - 2e+03)	3e+04 (3e+04 - 4e+04)	3e+03 (3e+03 - 3e+03)	ND	2e+04 (2e+04 - 2e+04)	6e+02 (5e+02 - 7e+02)	ND	2e+04 (2e+04 - 3e+04)	9e+02 (8e+02 - 1e+03)	ND	3e+02 (3e+02 - 3e+02)	8e+03 (7e+03 - 1e+04)	ND	3e+02 (3e+02 - 3e+02)	1e+05 (9e+04 - 1e+05)
Mintenig_ 2020_12	7e+02 (6e+02 - 8e+02)	1e+05 (9e+04 - 1e+05)	4e+04 (3e+04 - 4e+04)	5e+04 (4e+04 - 5e+04)	1e+04 (1e+04 - 2e+04)	ND	1e+05 (9e+04 - 1e+05)	7e+02 (6e+02 - 8e+02)	ND	1e+05 (1e+05 - 1e+05)	6e+03 (5e+03 - 7e+03)	ND	7e+02 (6e+02 - 8e+02)	5e+04 (4e+04 - 6e+04)	ND	7e+02 (6e+02 - 8e+02)	5e+05 (4e+05 - 6e+05)
Mintenig_ 2020_13	ND	6e+03 (5e+03 - 6e+03)	9e+03 (8e+03 - 1e+04)	4e+03 (3e+03 - 5e+03)	6e+04 (5e+04 - 7e+04)	ND	2e+04 (2e+04 - 2e+04)	5e+02 (5e+02 - 6e+02)	ND	2e+04 (2e+04 - 2e+04)	2e+03 (2e+03 - 2e+03)	ND	3e+03 (2e+03 - 3e+03)	3e+04 (3e+04 - 4e+04)	ND	5e+02 (5e+02 - 6e+02)	2e+05 (1e+05 - 2e+05)
Mintenig_ 2020_14	ND	2e+02 (1e+02 - 2e+02)	5e+02 (4e+02 - 7e+02)	2e+03 (2e+03 - 3e+03)	0e+00 (0e+00 - 0e+00)	ND	7e+03 (5e+03 - 9e+03)	0e+00 (0e+00 - 0e+00)	ND	2e+03 (1e+03 - 2e+03)	6e+02 (5e+02 - 9e+02)	ND	ND	1e+04 (7e+03 - 1e+04)	ND	ND	2e+04 (2e+04 - 3e+04)

Sample ID	ABS	Acryl	Other synthetic rubbers	Others	PA	PC	PE	PET	PMMA	PP	PS	PUR	PVC	EPDM	NR	SBR	Total
Mintenig_ 2020_15	ND	1e+02 (1e+02 - 1e+02)	3e+02 (3e+02 - 4e+02)	1e+03 (1e+03 - 2e+03)	6e+03 (5e+03 - 6e+03)	ND	6e+03 (5e+03 - 6e+03)	ND	ND	8e+02 (7e+02 - 8e+02)	1e+02 (1e+02 - 1e+02)	ND	ND	2e+03 (2e+03 - 2e+03)	ND	ND	2e+04 (1e+04 - 2e+04)
Mintenig_ 2020_16	ND	5e+02 (5e+02 - 6e+02)	8e+02 (7e+02 - 9e+02)	8e+02 (7e+02 - 9e+02)	ND	ND	2e+03 (2e+03 - 3e+03)	1e+02 (1e+02 - 1e+02)	ND	3e+03 (2e+03 - 3e+03)	6e+01 (5e+01 - 7e+01)	ND	6e+01 (5e+01 - 7e+01)	2e+03 (2e+03 - 2e+03)	ND	ND	9e+03 (8e+03 - 1e+04)
Mintenig_ 2020_17	ND	2e+02 (2e+02 - 2e+02)	8e+03 (7e+03 - 9e+03)	4e+02 (4e+02 - 5e+02)	2e+02 (2e+02 - 3e+02)	ND	9e+03 (8e+03 - 1e+04)	ND	ND	1e+04 (1e+04 - 2e+04)	2e+02 (2e+02 - 3e+02)	ND	ND	2e+03 (2e+03 - 2e+03)	ND	ND	3e+04 (3e+04 - 4e+04)
Mintenig_ 2020_18	ND	3e+03 (3e+03 - 4e+03)	4e+03 (4e+03 - 5e+03)	8e+02 (7e+02 - 9e+02)	3e+03 (3e+03 - 4e+03)	ND	8e+03 (7e+03 - 9e+03)	ND	ND	3e+03 (3e+03 - 4e+03)	2e+02 (2e+02 - 3e+02)	ND	ND	4e+03 (4e+03 - 5e+03)	ND	ND	3e+04 (2e+04 - 3e+04)
Mintenig_ 2020_2	ND	5e+02 (5e+02 - 6e+02)	1e+03 (1e+03 - 1e+03)	ND	2e+03 (1e+03 - 2e+03)	ND	1e+04 (9e+03 - 1e+04)	ND	ND	8e+02 (7e+02 - 9e+02)	2e+02 (2e+02 - 3e+02)	ND	ND	3e+03 (3e+03 - 4e+03)	ND	ND	2e+04 (2e+04 - 2e+04)
Mintenig_ 2020_22	ND	4e+02 (3e+02 - 4e+02)	5e+02 (4e+02 - 5e+02)	9e+02 (8e+02 - 1e+03)	2e+02 (2e+02 - 3e+02)	ND	9e+03 (8e+03 - 1e+04)	ND	ND	8e+03 (7e+03 - 9e+03)	ND	ND	ND	1e+03 (1e+03 - 1e+03)	ND	ND	2e+04 (2e+04 - 2e+04)
Mintenig_ 2020_3	ND	7e+02 (5e+02 - 1e+03)	9e+02 (6e+02 - 1e+03)	6e+02 (4e+02 - 7e+02)	6e+02 (4e+02 - 7e+02)	ND	1e+04 (9e+03 - 2e+04)	5e+01 (3e+01 - 6e+01)	ND	6e+02 (4e+02 - 7e+02)	5e+01 (3e+01 - 6e+01)	ND	ND	1e+04 (9e+03 - 2e+04)	ND	ND	3e+04 (2e+04 - 4e+04)
Mintenig_ 2020_30	ND	2e+03 (1e+03 - 2e+03)	2e+03 (2e+03 - 3e+03)	5e+03 (3e+03 - 6e+03)	1e+03 (1e+03 - 2e+03)	ND	2e+04 (1e+04 - 2e+04)	ND	ND	1e+04 (7e+03 - 1e+04)	6e+02 (4e+02 - 7e+02)	ND	ND	6e+03 (4e+03 - 8e+03)	ND	ND	4e+04 (3e+04 - 6e+04)
Mintenig_ 2020_31	ND	2e+03 (2e+03 - 3e+03)	1e+03 (1e+03 - 2e+03)	3e+03 (2e+03 - 3e+03)	9e+03 (7e+03 - 1e+04)	ND	2e+04 (1e+04 - 3e+04)	ND	ND	6e+03 (5e+03 - 8e+03)	8e+02 (6e+02 - 1e+03)	ND	ND	2e+04 (1e+04 - 3e+04)	ND	ND	6e+04 (5e+04 - 8e+04)
Mintenig_ 2020_32	ND	8e+02 (7e+02 - 9e+02)	2e+03 (2e+03 - 2e+03)	8e+02 (7e+02 - 9e+02)	4e+02 (4e+02 - 5e+02)	ND	5e+03 (5e+03 - 6e+03)	ND	ND	1e+03 (9e+02 - 1e+03)	3e+02 (3e+02 - 3e+02)	ND	ND	5e+03 (4e+03 - 5e+03)	ND	ND	2e+04 (1e+04 - 2e+04)
Mintenig_ 2020_33	ND	1e+03 (9e+02 - 1e+03)	1e+03 (1e+03 - 2e+03)	ND	2e+03 (2e+03 - 3e+03)	ND	7e+03 (6e+03 - 8e+03)	ND	ND	4e+03 (4e+03 - 5e+03)	8e+02 (7e+02 - 9e+02)	ND	ND	4e+03 (3e+03 - 4e+03)	ND	ND	2e+04 (2e+04 - 2e+04)
Mintenig_ 2020_34	ND	8e+03 (7e+03 - 9e+03)	6e+03 (6e+03 - 7e+03)	5e+03 (4e+03 - 6e+03)	1e+04 (9e+03 - 1e+04)	ND	2e+04 (1e+04 - 2e+04)	1e+02 (1e+02 - 1e+02)	ND	2e+04 (1e+04 - 2e+04)	8e+02 (7e+02 - 9e+02)	ND	ND	6e+03 (6e+03 - 7e+03)	ND	ND	7e+04 (6e+04 - 8e+04)
Mintenig_ 2020_35	ND	2e+04 (2e+04 - 2e+04)	4e+03 (4e+03 - 5e+03)	9e+03 (8e+03 - 1e+04)	1e+04 (1e+04 - 1e+04)	ND	2e+04 (2e+04 - 2e+04)	1e+02 (1e+02 - 1e+02)	ND	2e+04 (1e+04 - 2e+04)	8e+02 (7e+02 - 9e+02)	ND	ND	1e+04 (1e+04 - 2e+04)	ND	ND	9e+04 (8e+04 - 1e+05)
Mintenig_ 2020_36	ND	9e+03 (8e+03 - 1e+04)	8e+03 (7e+03 - 9e+03)	2e+04 (1e+04 - 2e+04)	3e+03 (2e+03 - 3e+03)	ND	2e+04 (2e+04 - 3e+04)	4e+02 (4e+02 - 5e+02)	ND	2e+04 (2e+04 - 2e+04)	3e+02 (3e+02 - 3e+02)	ND	ND	1e+04 (9e+03 - 1e+04)	ND	ND	9e+04 (8e+04 - 1e+05)
Mintenig_ 2020_37	ND	3e+04 (3e+04 - 4e+04)	5e+04 (5e+04 - 6e+04)	6e+04 (6e+04 - 7e+04)	4e+04 (3e+04 - 4e+04)	ND	8e+04 (7e+04 - 9e+04)	8e+03 (7e+03 - 9e+03)	ND	1e+05 (1e+05 - 1e+05)	2e+04 (1e+04 - 2e+04)	ND	9e+02 (8e+02 - 1e+03)	2e+05 (2e+05 - 3e+05)	ND	2e+03 (1e+03 - 2e+03)	7e+05 (6e+05 - 8e+05)

Sample ID	ABS	Acryl	Other synthetic rubbers	Others	PA	PC	PE	PET	PMMA	PP	PS	PUR	PVC	EPDM	NR	SBR	Total
Mintenig_ 2020_38	ND	1e+04 (1e+04 - 2e+04)	5e+02 (5e+02 - 6e+02)	4e+03 (4e+03 - 5e+03)	1e+04 (9e+03 - 1e+04)	ND	8e+03 (7e+03 - 9e+03)	4e+02 (4e+02 - 5e+02)	ND	8e+03 (7e+03 - 1e+04)	8e+02 (7e+02 - 9e+02)	ND	6e+01 (5e+01 - 7e+01)	8e+03 (7e+03 - 9e+03)	2e+02 (2e+02 - 2e+02)	ND	5e+04 (5e+04 - 6e+04)
Mintenig_ 2020_39	1e+02 (1e+02 - 1e+02)	2e+04 (2e+04 - 2e+04)	6e+04 (5e+04 - 6e+04)	1e+04 (1e+04 - 1e+04)	1e+03 (9e+02 - 1e+03)	ND	2e+05 (2e+05 - 2e+05)	3e+02 (3e+02 - 4e+02)	ND	2e+04 (1e+04 - 2e+04)	6e+02 (6e+02 - 7e+02)	ND	ND	9e+04 (8e+04 - 1e+05)	ND	ND	4e+05 (3e+05 - 5e+05)
Mintenig_ 2020_4	0e+00 (0e+00 - 0e+00)	3e+02 (2e+02 - 4e+02)	2e+02 (1e+02 - 2e+02)	2e+02 (1e+02 - 2e+02)	1e+02 (1e+02 - 2e+02)	ND	9e+02 (6e+02 - 1e+03)	ND	ND	5e+02 (4e+02 - 7e+02)	0e+00 (0e+00 - 0e+00)	ND	ND	1e+03 (7e+02 - 1e+03)	ND	ND	3e+03 (2e+03 - 4e+03)
Mintenig_ 2020_40	ND	1e+04 (9e+03 - 1e+04)	3e+03 (2e+03 - 3e+03)	1e+04 (1e+04 - 1e+04)	4e+04 (3e+04 - 4e+04)	ND	2e+04 (1e+04 - 2e+04)	2e+02 (2e+02 - 3e+02)	ND	1e+04 (9e+03 - 1e+04)	1e+03 (1e+03 - 1e+03)	ND	2e+02 (2e+02 - 3e+02)	2e+04 (2e+04 - 2e+04)	ND	ND	1e+05 (9e+04 - 1e+05)
Mintenig_ 2020_41	ND	3e+03 (3e+03 - 4e+03)	2e+03 (2e+03 - 2e+03)	1e+04 (9e+03 - 1e+04)	2e+02 (2e+02 - 3e+02)	ND	8e+03 (7e+03 - 9e+03)	ND	ND	2e+04 (1e+04 - 2e+04)	ND	ND	ND	1e+03 (1e+03 - 1e+03)	ND	ND	4e+04 (4e+04 - 5e+04)
Mintenig_ 2020_5	ND	5e+01 (3e+01 - 6e+01)	4e+02 (3e+02 - 5e+02)	6e+02 (4e+02 - 8e+02)	5e+01 (3e+01 - 6e+01)	ND	3e+03 (2e+03 - 4e+03)	ND	ND	3e+03 (2e+03 - 4e+03)	3e+02 (2e+02 - 4e+02)	ND	ND	9e+02 (6e+02 - 1e+03)	ND	ND	8e+03 (6e+03 - 1e+04)
Mintenig_ 2020_6	ND	1e+03 (9e+02 - 1e+03)	1e+03 (9e+02 - 1e+03)	3e+03 (3e+03 - 3e+03)	ND	ND	5e+03 (5e+03 - 6e+03)	ND	ND	3e+03 (3e+03 - 3e+03)	3e+02 (3e+02 - 3e+02)	ND	ND	8e+03 (7e+03 - 9e+03)	ND	ND	2e+04 (2e+04 - 2e+04)
Mintenig_ 2020_7	ND	3e+03 (2e+03 - 4e+03)	2e+03 (1e+03 - 3e+03)	2e+03 (2e+03 - 3e+03)	7e+02 (5e+02 - 9e+02)	ND	1e+04 (7e+03 - 1e+04)	4e+02 (3e+02 - 5e+02)	ND	6e+03 (4e+03 - 8e+03)	8e+02 (6e+02 - 1e+03)	ND	ND	1e+04 (8e+03 - 1e+04)	ND	ND	4e+04 (3e+04 - 5e+04)
Mintenig_ 2020_8	9e+01 (7e+01 - 1e+02)	2e+03 (1e+03 - 2e+03)	3e+04 (2e+04 - 5e+04)	5e+02 (3e+02 - 6e+02)	1e+03 (9e+02 - 2e+03)	ND	1e+04 (1e+04 - 2e+04)	ND	ND	2e+03 (2e+03 - 3e+03)	3e+02 (2e+02 - 4e+02)	ND	ND	2e+03 (1e+03 - 3e+03)	ND	ND	6e+04 (4e+04 - 8e+04)
Mintenig_ 2020_9	ND	3e+03 (2e+03 - 3e+03)	6e+03 (4e+03 - 8e+03)	2e+03 (2e+03 - 3e+03)	2e+02 (2e+02 - 3e+02)	ND	1e+04 (7e+03 - 1e+04)	1e+02 (1e+02 - 2e+02)	ND	1e+04 (9e+03 - 2e+04)	2e+02 (1e+02 - 2e+02)	ND	ND	5e+03 (4e+03 - 7e+03)	ND	ND	4e+04 (3e+04 - 5e+04)
Mughini-Gras_ 2021_1	ND	ND	4e+06 (3e+06 - 6e+06)	3e+06 (2e+06 - 4e+06)	4e+06 (3e+06 - 5e+06)	ND	2e+06 (2e+06 - 3e+06)	3e+06 (2e+06 - 4e+06)	ND	1e+06 (8e+05 - 2e+06)	1e+06 (1e+06 - 2e+06)	3e+06 (2e+06 - 4e+06)	1e+07 (7e+06 - 1e+07)	ND	ND	ND	3e+07 (2e+07 - 4e+07)
Mughini-Gras_ 2021_2	ND	ND	2e+06 (2e+06 - 3e+06)	2e+06 (1e+06 - 2e+06)	5e+06 (3e+06 - 7e+06)	ND	1e+06 (8e+05 - 2e+06)	1e+06 (1e+06 - 2e+06)	ND	4e+05 (3e+05 - 5e+05)	1e+05 (7e+04 - 1e+05)	3e+05 (2e+05 - 5e+05)	1e+06 (9e+05 - 2e+06)	ND	ND	ND	1e+07 (1e+07 - 2e+07)
Mughini-Gras_ 2021_5	ND	ND	1e+07 (6e+06 - 2e+07)	7e+06 (3e+06 - 1e+07)	5e+07 (2e+07 - 8e+07)	ND	3e+06 (1e+06 - 5e+06)	1e+07 (6e+06 - 2e+07)	ND	2e+06 (9e+05 - 3e+06)	4e+06 (2e+06 - 6e+06)	5e+06 (3e+06 - 9e+06)	5e+07 (3e+07 - 9e+07)	ND	ND	ND	1e+08 (7e+07 - 2e+08)
Mughini-Gras_ 2021_6	ND	ND	7e+06 (3e+06 - 1e+07)	8e+06 (4e+06 - 1e+07)	2e+07 (8e+06 - 3e+07)	ND	2e+06 (9e+05 - 3e+06)	5e+06 (2e+06 - 7e+06)	ND	7e+05 (3e+05 - 1e+06)	2e+05 (8e+04 - 3e+05)	1e+06 (4e+05 - 1e+06)	5e+06 (2e+06 - 8e+06)	ND	ND	ND	5e+07 (2e+07 - 7e+07)

Table A.17 Sample IDs and the corresponding rivers, data sources and analysis methods. Corresponds to Table A.16.

Sample ID	River	Data_source	Analysis_method
Bäuerlein_2022_1	Meuse	Bäuerlein et al. (2022)	LDIR
Bäuerlein_2022_2	Meuse	Bäuerlein et al. (2022)	LDIR
Bäuerlein_2022_3	Meuse	Bäuerlein et al. (2022)	LDIR
Bäuerlein_2022_4	Overijsselse vecht	Bäuerlein et al. (2022)	LDIR
Bäuerlein_2022_5	Lek canal	Bäuerlein et al. (2022)	LDIR
Bäuerlein_2023_11	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_17	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_28	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_29	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_30	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_31	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_8	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_12	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_18	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_19	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_32	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_9	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_1	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_13	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_15	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_16	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_2	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_20	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_22	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR

Sample ID	River	Data_source	Analysis_method
Bäuerlein_2023_23	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_24	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_25	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_26	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_27	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_3	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_4	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_5	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Bäuerlein_2023_7	WWTP Werverschoof effluent canal	Bäuerlein et al. (2023)	LDIR
Mintenig_2020_12	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_39	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_4	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_8	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_1	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_10	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_11	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_13	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_14	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_15	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_16	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_17	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_18	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_2	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_22	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_3	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR

Sample ID	River	Data_source	Analysis_method
Mintenig_2020_30	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_31	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_32	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_33	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_34	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_35	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_36	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_37	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_38	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_40	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_41	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_5	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_6	Dommel	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_7	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig_2020_9	Meuse	Mintenig et al. (2020)	ATR-FTIR and Micro-FTIR
Mintenig _2025_1	Dommel	Mintenig, Hunnestad & Koelmans (2025)	ATR-FTIR and Micro-FTIR
Mintenig _2025_2	Dommel	Mintenig, Hunnestad & Koelmans (2025)	ATR-FTIR and Micro-FTIR
Mintenig_2025_3	Dommel	Mintenig, Hunnestad & Koelmans (2025)	ATR-FTIR and Micro-FTIR
Mintenig _2025_4	Dommel	Mintenig, Hunnestad & Koelmans (2025)	ATR-FTIR and Micro-FTIR
Mughini-Gras_2021_1	Rhine	Mughini-Gras et al. (2021)	LDIR
Mughini-Gras_2021_2	Rhine	Mughini-Gras et al. (2021)	LDIR
Mughini-Gras_2021_5	Lek canal	Mughini-Gras et al. (2021)	LDIR
Mughini-Gras_2021_6	Lek canal	Mughini-Gras et al. (2021)	LDIR

Figures

Figure A.13 Surface water particle number concentrations for microplastics in the Werverschoof effluent canal, rescaled to the 1-5000 µm range and compared to risk limits (pink line and uncertainty band) as derived by Coffin et al. (2026) for surface area. Data from Bäuerlein et al. (2023).

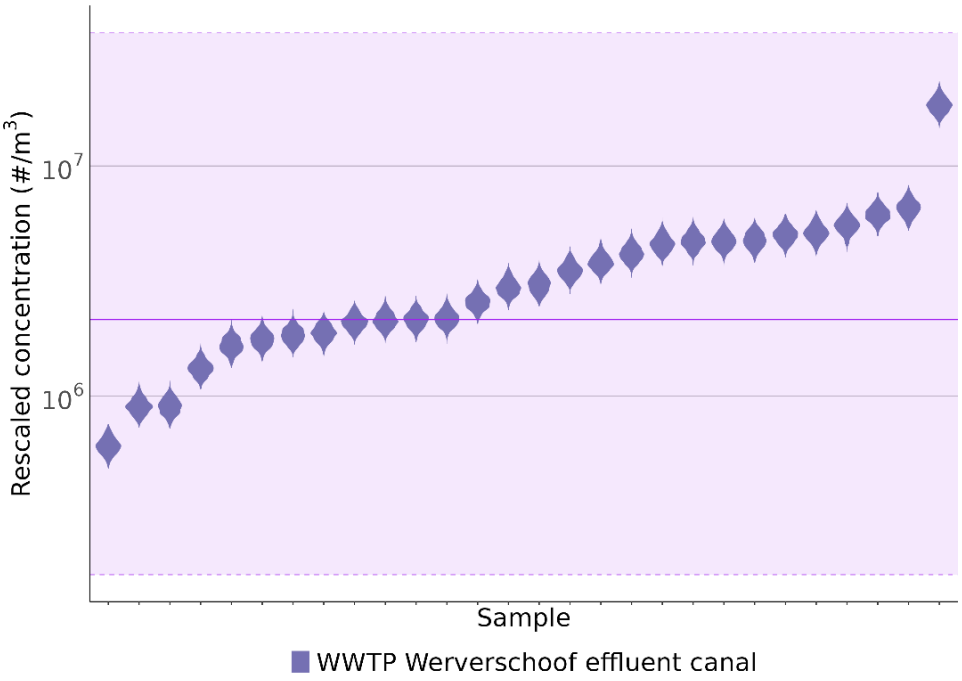


Figure A.14 Surface water particle number concentrations for microplastics in the Werverschoof effluent canal, rescaled to the 1-5000 µm range and compared to risk limits (purple line and uncertainty band) as derived by Coffin et al. (2026) for volume. Data from Bäuerlein et al. (2023).

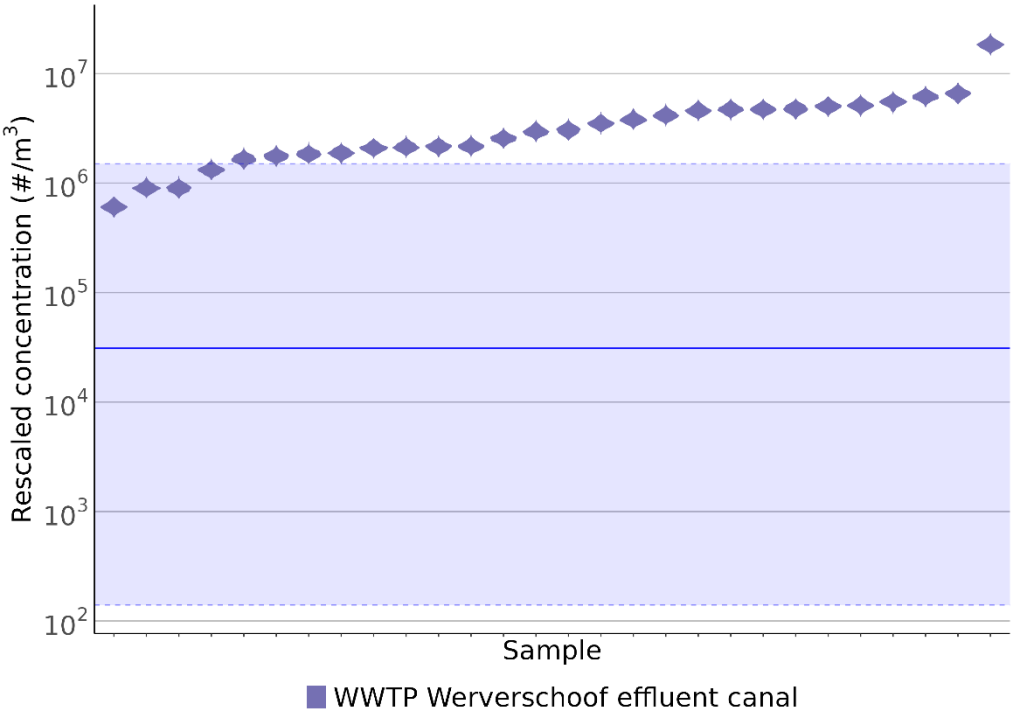


*Figure A.15 Microplastic number concentrations, as reported, for all surface water samples excluding Werverschoof effluent canal. With risk limit for volume (top) and surface area (bottom) as ERM indicated by the line (median) shaded area (p5 – p95). Data from Bäuerlein et al. (2022), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021). *: These datapoints were measured by Mughini-Gras et al. (2021), and have a lower QA/QC score than the other included studies.*

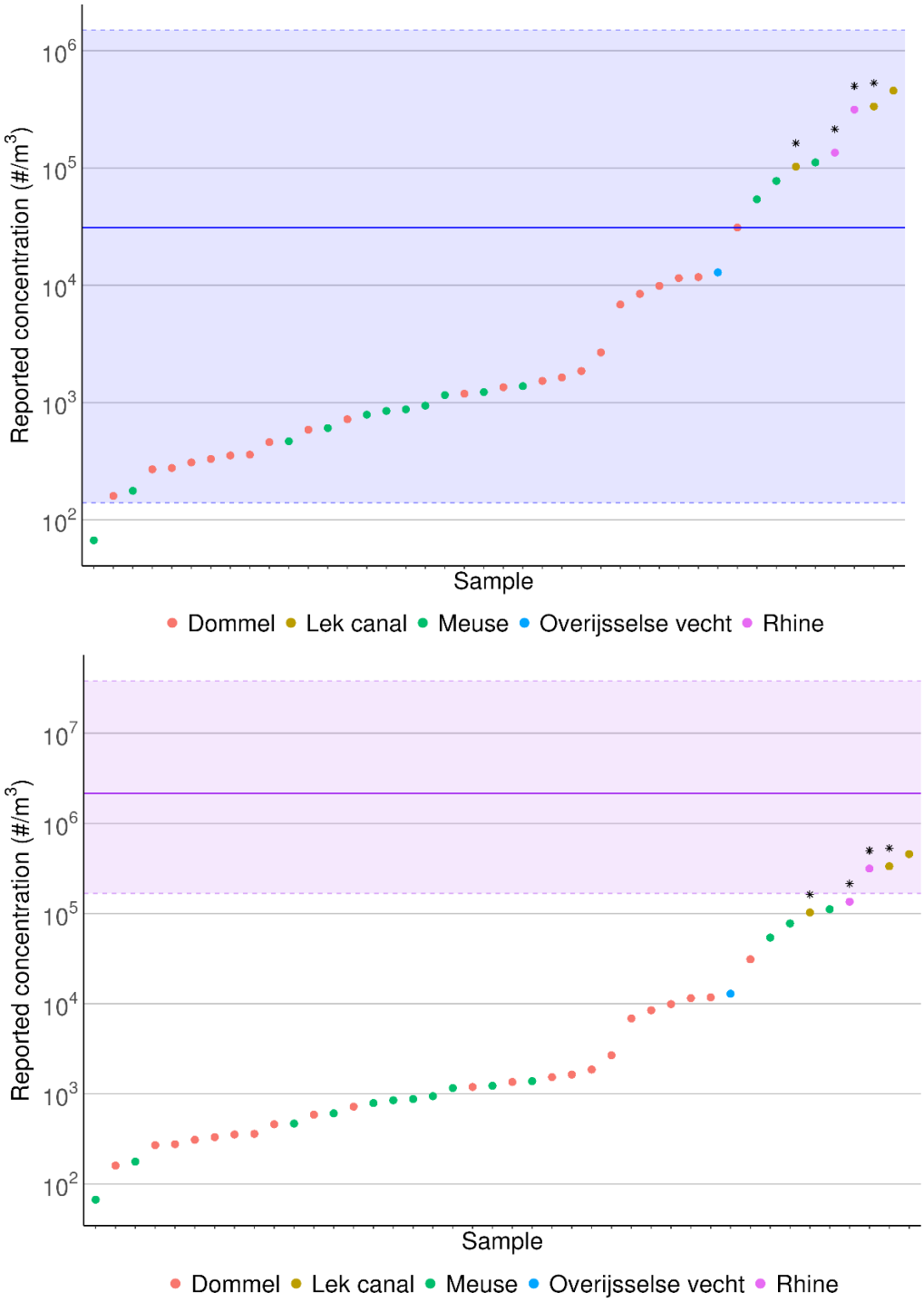


Figure A.16 Microplastic number concentrations, as reported, for the Werverschoof effluent canal. With risk limit for volume (top) and surface area (bottom) as ERM indicated by the line (median) shaded area (p5 – p95). Data from Bäuerlein et al. (2023).

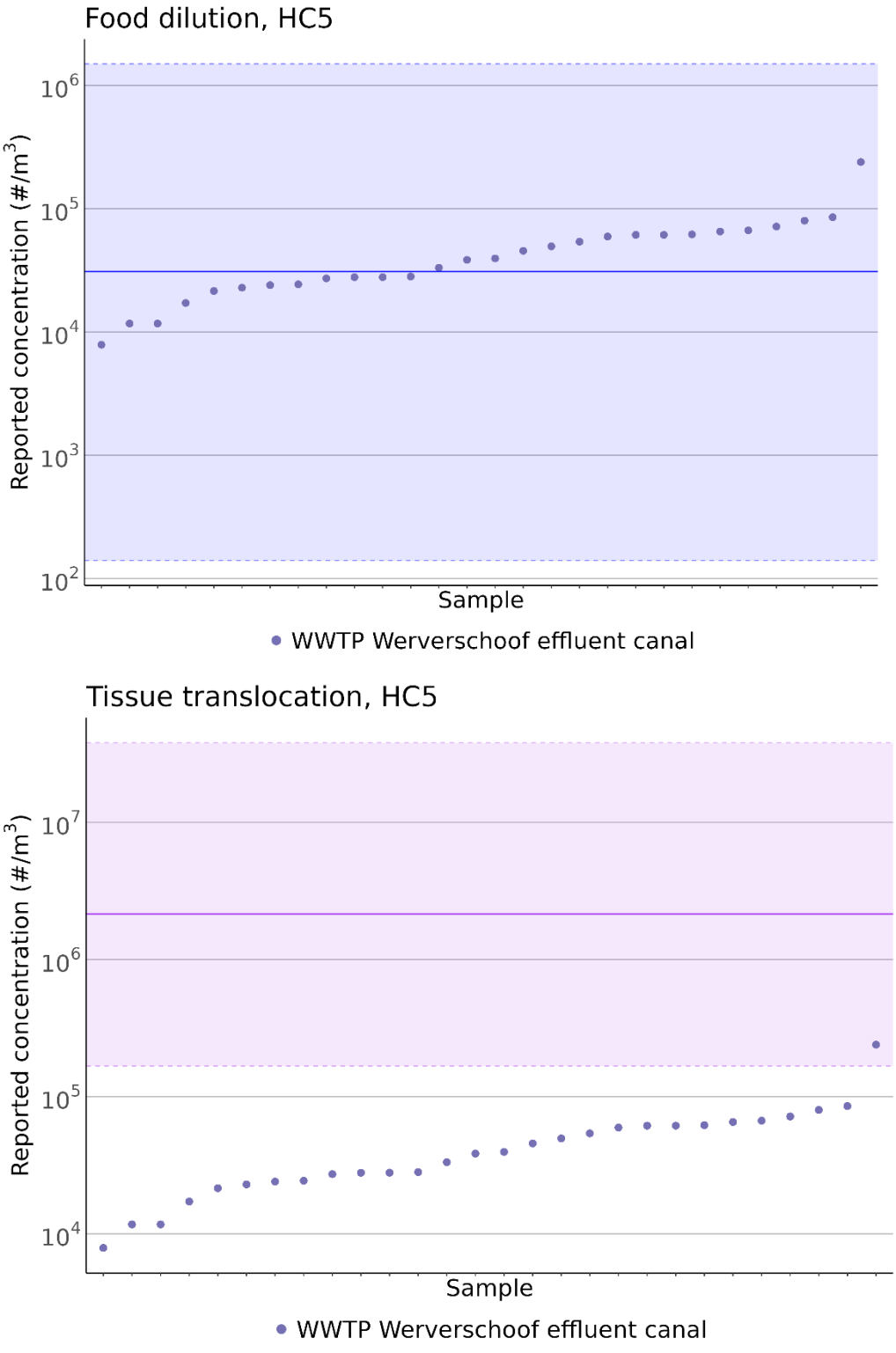
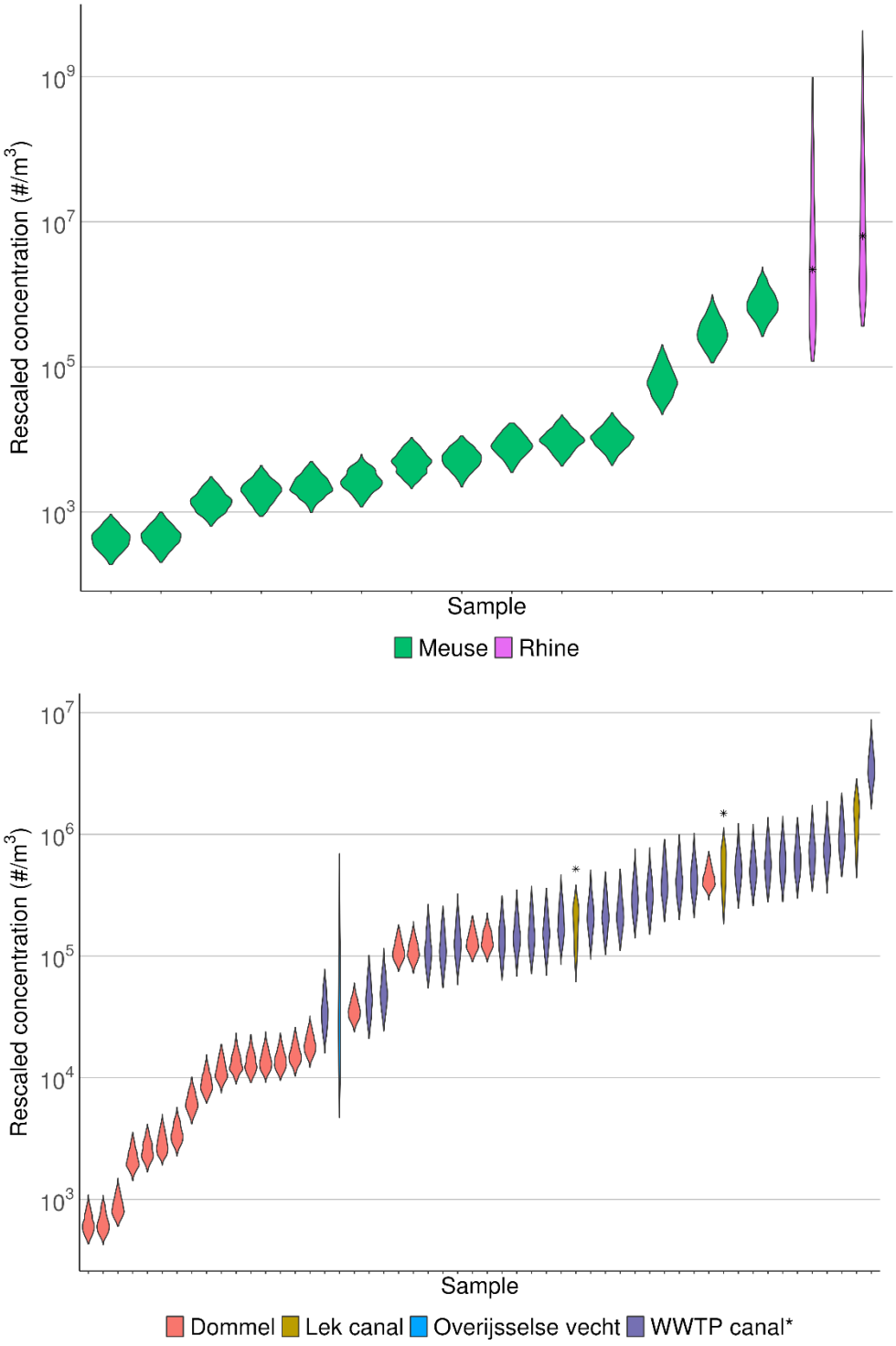


Figure A.17 Water PP number concentration for samples taken in the Rhine and Meuse (top) and other water bodies (bottom). Samples were analyzed with LDIR or FTIR. Includes uncertainty in particle size distribution. Y-axis in log scale. Data from Bäuerlein et al. (2022), Mintenig et al. (2020, 2025), Mughini-Gras et al. (2021). +: These datapoints were measured by Mughini-Gras et al. (2021).



*Werverschoof Wastewater Treatment Plant (WWTP) effluent canal

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