SWEDISH
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Microplastics Research Agenda

Need for knowledge and improvement for the development of instruments and measures

REPORT 7124 | DECEMBER 2023

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ISBN 978-91-620-7124-0
ISSN 0282-7298

Print: Arkitektkopia AB, Bromma 2023
Translation: Accent Språkservice AB
Cover photos: pcess609, iStock and
Henrik Löwenhamn, Swedish Environmental Protection Agency

MILJÖMÄRKT
3041 0843
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Preface

Several problems need to be solved to achieve Sweden's long-term climate goals by 2045, create a circular economy and reduce the amount of plastic in our oceans and in nature. Fossil-based plastics need to be replaced by materials with lower climate impact, and we need to identify the value of plastics to increase recycling and reduce leakage of plastics.

The Swedish Environmental Protection Agency (EPA) is responsible for National Plastic Coordination, which aims to demonstrate the importance of society's efforts and the opportunities to join forces and jointly achieve a societal transition for plastics. National Plastic Coordination gathers and disseminates knowledge to support sustainable plastic use nationally and in the international collaborations in which Sweden participates.

National Plastic Coordination also aims to improve collaboration among stakeholders and to identify and implement activities promoting sustainable plastics use. Collaboration for sustainable utilisation is a joint endeavour and process within and among county administrative boards, regions, municipalities, research, the private sector and public authorities. National Plastic Coordination seeks to be a driving force in this work.

By contributing to increased knowledge and collaboration, National Plastic Coordination will facilitate and strengthen stakeholder efforts to contribute to environmental objectives and the United Nations' global Sustainable Development Goals. This is done by creating measures for the sustainable use of plastics in the right context, in resource- and climate-efficient, non-toxic and circular flows and without any leakage.

This report has been produced as part of the work with National Plastic Coordination.

Stockholm, 4 April 2023

Ingela Hiltula
Department Head
Circular Economy Department

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Summary

Through National Plastic Coordination, the Swedish Environmental Protection Agency (EPA) is responsible for efforts on sustainable plastic use in Sweden. In this work, the Agency is collaborating with a number of other stakeholders. The work includes identifying and filling prioritised knowledge gaps that currently prevent us from attaining that goal. The research agenda aims to provide supporting documentation for a needs-driven prioritisation of research and innovation efforts, facilitating the development of measures, policies and legislation to reduce potential risks with and the release of microplastics.

It begins by describing the knowledge needs at an overarching level, and then specifically for important sources of microplastics already identified. Based on the Swedish EPA's Roadmap for the sustainable use of plastics, the following obstacles significantly impede efforts to reduce the leakage of microplastics into the environment, making them the focus of this agenda:

- Difficulties in assessing health and environmental risks from microplastic releases.
- Difficulties in assessing the cost-efficiency of measures.
- Lack of harmonised and standardised measurement and analysis methods.
- Lack of solutions for reducing leakage of microplastics from certain flows.

Actions highlighted in the agenda have been prioritised according to the following criteria:

- Potential to improve conditions for cost-efficient and effective policies and measures to prevent or reduce the release of microplastics. The size of the microplastic flow being addressed is taken into consideration when assessing this potential.
- Efforts that increase knowledge about preventing and reducing risks to human health and the environment from microplastics.
- How well the response corresponds with the European Commission's Zero Pollution Hierarchy, as stated in the EU's Zero Pollution Action Plan.
- Potential to further contribute to Sweden's environmental objectives and Agenda 2030 by also addressing other environmental challenges, such as sustainable stormwater management and reduced exposure to hazardous substances.

1. Background

1.1 Why do we need a research agenda?

Through National Plastic Coordination, the Swedish EPA is responsible for efforts on sustainable plastic use in Sweden. In this work, the Agency is collaborating with a number of other stakeholders. The work includes identifying and filling prioritised knowledge gaps that currently prevent us from attaining this goal.

Research into microplastics is a relatively new area, which means that a lack of knowledge slows the development of instruments and measures to reduce the release of microplastics into the environment. The Swedish EPA believes that knowledge needs to be developed on the health and environmental risks associated with exposure to microplastics. Developing this knowledge is a fundamental prerequisite for a science-based prioritisation and planning the focus of future efforts.

Despite much research, large gaps in knowledge still exist in several areas of microplastics, such as their environmental impact. Scientific knowledge also needs to be translated into practical knowledge and solutions that can be implemented in different sectors by decision-makers, operators and others. We also need new and improved solutions to reduce microplastic leakage.

The overall goals for sustainable plastic use, along the obstacles to achieving these goals and inspiration for action, are described in the Swedish EPA's roadmap for the sustainable use of plastics (Swedish EPA, 2021a). This research agenda expands the description of how new research can contribute to the roadmap by identifying knowledge and development needs for addressing key barriers to sustainable plastic use, with a focus on microplastics.

The Swedish EPA's report "The Swedish EPA's Roadmap for Sustainable Plastic Use — Inspiring Action".

The Swedish EPA, which has developed this research agenda, recognises that collaboration with other research funding bodies is an important part of future efforts. The research agenda aims to provide supporting documentation for a needs-driven prioritisation of research and innovation efforts, facilitating the development of measures, policies and legislation to reduce potential risks with microplastics and their release.

1.2 Definition and delimitations

No generally accepted definition of microplastics exists. The research agenda defines microplastics as solid particles of plastic and rubber of any shape (such as grains, flakes and fibres) that are between 1 nm and 5 mm in their largest dimension and are insoluble in water. The Swedish EPA basically follows the same definition as the European Chemicals Agency ECHA[1] (ECHA, 2019), but the Agency also includes polymers that occur in nature, such as natural rubber and biodegradable polymers.

[1] ECHA's proposal for future regulations of microplastics are for solid particles of a synthetic polymer, and where $\geq$ 1 weight per cent of the particles has: all sizes 1 nm $\leq x \leq$ 5 mm, for fibre a length of 3 nm $\leq x \leq$ 15 mm and a quota between length and diameter of $>$ 3. Polymers occurring naturally that have not been modified chemically (except through hydrolysis) are excluded, as are biodegradable polymers.

The Swedish EPA emphasises that "biodegradability" depends on environmental conditions that differ, for example, between industrial composting and natural conditions. The assessment of degradability needs to consider this as well as any contribution to the dispersal of microplastics, nanoplastics and additives.

The research agenda is based on identified sources and dispersion pathways of national importance.[2] Since litter is a major source of microplastics, the research agenda includes the breakdown of litter into microplastics, but it does not address how litter enters the environment. Efforts to reduce leakage of microplastics from different sources and dispersion pathways of national importance have not been prioritised.

The research agenda otherwise follows the same delimitations as the Swedish EPA's roadmap for sustainable plastic use.

1.3 Targets for reducing the leakage of microplastics into the environment

1.3.1 Achieve sustainable plastic use through knowledge and development to address important obstacles

According to the Swedish EPA, sustainable plastic use means using plastic in the right place and in resource-efficient, climate-efficient, non-toxic circular flows with negligible leakage. To achieve this, the Agency sees a need for efforts in four impact areas:

- Raw materials and production with minimal environmental impact.
- Resource-smart use.
- Reduced leakage of plastics in nature.
- Greatly expanded and high-quality material recycling.

Efforts in all of these impact areas can help reduce potential risks from microplastics. For example, this can be achieved by avoiding unnecessary plastic use; optimising the lifespan of plastic products, including reducing unwanted wear and tear; choosing raw materials with minimal environmental impact in terms of microplastic leakage and other environmental and social objectives; and substituting hazardous substances.

The efforts highlighted in the research agenda contribute to:

- Greater knowledge of the risks of microplastics and how they can contribute to the difficulties of reaching Sweden's environmental quality targets and Agenda 2030.
- Reducing the release and dispersion of microplastics in a cost-efficient and effective way.

[2] See Chapter 2 on important sources and dispersion pathways for microplastics.

1.3.2 Contributing to the EU's zero pollution vision

In May 2021, the European Commission released its Zero Pollution Action Plan. The action plan runs until 2024 and is part of the European Green Deal, the road-map for a sustainable EU economy. The action plan envisages reducing air, water and soil pollution by 2050 to levels no longer considered harmful to health and natural ecosystems and respecting the boundaries with which our planet can cope.

The action plan also includes six zero pollution targets for 2030[3], including:

- a 50 per cent reduction in litter at sea;
- a 30 per cent reduction in microplastics released into the environment.

These targets point to the need to act and increased ambition to reduce plastic and microplastic leakage. Achieving these targets requires ambitious — and above all effective — measures and instruments. There is uncertainty about the cost-efficiency of different measures to reduce microplastic releases. We need to know more about how much a particular measure reduces microplastic releases and how much damage current releases cause.

The action plan also describes a "Zero Pollution Hierarchy" (see Figure 1), which entails preventing pollution at the source in the first place. If this is not yet fully possible, pollution should at least be minimised. If pollution does occur, it should be rectified, and compensation should be provided for the resulting damage. An important starting point is the precautionary principle: that preventive measures should be taken, that environmental degradation should first be stopped at the source and that the polluter should pay (European Commission, 2021). How well the effort aligns with the intention to prioritise prevention as expressed in the EU Commission's Zero Pollution Hierarchy is one of the criteria used in the agenda to prioritise knowledge and development needs.

[3] This is compared with 2016.

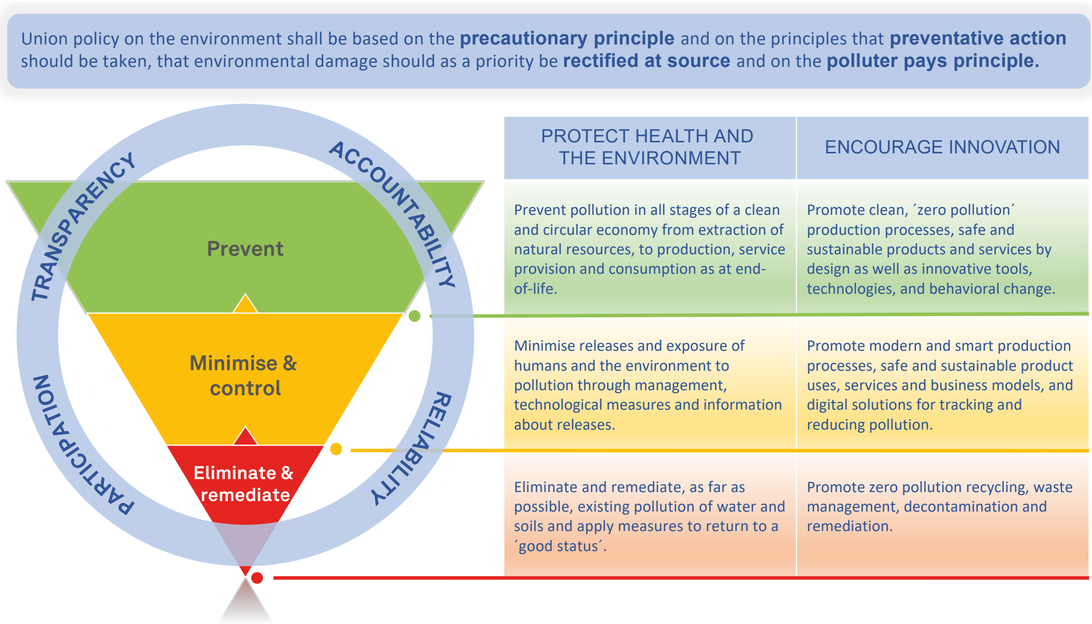

Figure 1. Zero Pollution Hierarchy. Figure from "Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'" (European Commission, 2021a).

1.3.3 Contribute to Sweden's environmental objectives and Agenda 2030 through synergies from efforts to reduce other environment-related risks

The Swedish EPA's work on sustainable plastic use will contribute to several of Sweden's environmental quality objectives and several of the objectives in Agenda 2030, as described in Table 1.

Table 1. Swedish environmental quality objectives and Agenda 2030 goals to which the research agenda contributes.

Swedish environmental quality objectives	Agenda 2030 goals
A Non-Toxic Environment	Life Below Water
A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos	Clean Water and Sanitation
Clean Air	Decent Work and Economic Growth
Flourishing Lakes and Streams	Industry, Innovation and Infrastructure
A Rich Diversity of Plant and Animal Life	Sustainable Cities and Communities
A Good Built Environment	Responsible Consumption and Production
	Good Health and Well-being
	Life On Land

In addition to helping to achieve these goals by reducing leakage of microplastics, the goals can also be supported by utilising synergies from reducing potential risks from microplastics, working on sustainable stormwater management and reducing exposure to hazardous substances. For initiatives to have the greatest possible impact for Sweden's environmental objectives and Agenda 2030, a criterion for prioritising initiatives in the agenda is "the potential to exploit synergies with initiatives addressing other environmental challenges".

2. Starting points for prioritising efforts

In the Swedish EPA's work on microplastics, we focus in particular on the largest quantified sources and most important dispersion pathways of microplastics. We apply the same approach in this research agenda.

Based on the Swedish EPA's roadmap for the sustainable use of plastics (Swedish EPA, 2021a), the following obstacles significantly impede efforts to reduce the leakage of microplastics into the environment, making them the focus of this agenda:

- Difficulties in assessing health and environmental risks from microplastic releases.
- Difficulties in assessing the cost-effectiveness of measures.
- Lack of harmonised and standardised measurement and analysis methods.
- Lack of solutions for reducing leakage of microplastics from certain flows.

The agenda explores the knowledge gaps and development needs for addressing these obstacles.

2.1 Sources

Littering eventually leads to the formation of microplastics due to the breakdown of litter. It is believed that littering contributes to microplastic leakage in Sweden significantly. It could even be the largest source of microplastics nationally. However, this source has not been quantified.

In Sweden, tyre and road wear is the largest quantified source of microplastics. This is followed by synthetic fibres and washing of synthetic textiles as the second largest source of microplastics. Artificial grass also accounts for a significant share of microplastic releases nationally. Leakage of granulate from synthetic sports surfaces accounts for most of these releases, although artificial grass fibres also account for an appreciable portion (Olshammar, Graae, Robijn, & Nilsson, 2021). Table 2 provides a summary of the leakage of microplastics from different sources.

Table 2. Significant, quantified sources of microplastics. All quantities have been rounded to the nearest whole number.

Sources	Quantification
Tyre and roadwear from traffic	About 8 000 tonnes/year
Laundering of synthetic textiles	Up to 1 000 tonnes/year
Synthetic sports surfaces with rubber granulate	475 tonnes/year
Industrial production and handling of plastics	300–500 tonnes/year
Boat hulls	200–700 tonnes/year
Painting of buildings	100–300 tonnes/year
Buoys, etc.	1–200 tonnes/year
Hygiene products	70 tonnes/year
Fishing gear	4–50 tonnes/year
Treatment of organic waste	30 tonnes/year
Indoor dust	1–20 tonnes/year
Rubber surfaces	16 tonnes/year
Synthetic sport surfaces without granulate	2 tonnes/year

Sources: Swedish EPA, 2022; Swedish EPA, 2021b; Krång et al., 2018; Olshammar, Graae, Robijn & Nilsson, 2021.

The Swedish EPA has also identified debris/litter around construction and demolition sites as a potentially significant source (Swedish EPA, 2021b). Within the EU initiative on unintentionally released microplastics (European Commission, 2023), paint and dishwasher and washing machine tablets have also been highlighted as potentially significant sources of microplastics. However, these sources have not been quantified nationally.

2.2 Dispersion pathways

Releases of microplastics with treated wastewater from wastewater treatment plants have been estimated at about 1–19 tonnes of microplastics per year (Magnusson et al., 2017). The removal rate of microplastics is high in many wastewater treatment plants: from 95 per cent and higher for microplastic particles larger than 300 µm (Baresel, Magnér, Magnusson, & Olshammar, 2017). Separation of microplastics in wastewater treatment plants means that the microplastics end up in the sewage sludge and also in other waste fractions. Sewage sludge is the primary mechanism for the release of microplastics into the environment (ETC/CE, 2022). However, Tumlin and Bertholds (2020) have shown that a smaller amount of microplastics than previously thought ends up in sludge. Mesophilic digestion reduces about 40 per cent of microplastics, but it is unclear whether the microplastics are totally degraded or whether they are fragmented to a size that is difficult to detect. The authors also state that the amount of tyre particles found in sludge and effluent is very low. They note, however, that since the method of analysing this is still uncertain, further development is needed to draw more reliable conclusions about the distribution of tyre particles in sludge and effluent. The microplastics believed to accompany litter and grease are incinerated. Since larger wastewater treatment plants separate most microplastics, the share of microplastics coming from overflows is a significant part of the total releases of microplastics from wastewater treatment (Swedish EPA, 2021b). The importance of overflows in supplying microplastics to water recipients has been downplayed in recent studies (Tumlin & Bertholds, 2020), but overflow is still commonly cited as an important factor in the release of microplastics from wastewater treatment plants. In summary, there are strong indications that the removal rate of microplastics at larger wastewater treatment plants (which are the ones most commonly studied) is very high for particles between 50 and 500 µm and above.

Evidence suggests that stormwater is the main dispersion pathway for microplastics to enter the environment. According to Tumlin & Bertholds (2020), based on this assumption, more than 100 times more microplastics could be added to the recipient via stormwater compared to outgoing treated wastewater. According to IVL Swedish Environmental Research Institute's mapping of sources of microplastic releases and dispersion pathways, stormwater accounts for dispersal of most microplastics from tyre and road wear, synthetic sports surfaces, industrial production and handling of primary plastics, surface treatment and painting of buildings, and litter (Magnusson et al., 2017). Surface runoff also serves as an important dispersion pathway for macroplastics — plastic fragments larger than 5 mm (Swedish EPA, 2021b).

Plant bed for managing stormwater, Sweden. Swedish EPA.

Microplastics can also be spread by the air through direct releases and through wind, passing vehicles and street-sweeping. Most atmospheric microplastics come from synthetic textiles, tyre wear particles and road dust. People are mainly exposed to microplastics through inhalation and food. Indoor air plays a particularly important role in human exposure. Studies show that textile workers exposed to synthetic textile fibres have a greater tendency for various respiratory symptoms, including cancer (Zhang et al., 2020). This dispersion pathway is relatively unexplored compared to sources such as stormwater and wastewater treatment plants.

Microplastics can also be spread by snow removal — both by dumping directly into water and through snow depots (Andersson-Sköld et al., 2020). There is currently little knowledge about how much microplastic is present in ploughed snow and how much snow is dumped into water annually (Swedish EPA, 2022). However, a report from the Swedish National Road and Transport Research Institute shows that microplastics can be temporarily stored in snow and ice on and around roads and streets and then released along with other pollutants during thawing to stormwater or surrounding soil. The study also shows the possibility of reducing the dispersion of microplastics by adapting how snow and ice are managed (Blomqvist, Järlskog, Gustafsson, Polukarova, & Andersson-Sköld, 2023).

3. Knowledge and development needed to reduce potential risks of microplastics

Actions highlighted in the agenda have been prioritised according to the following criteria:

- Potential to improve conditions for cost-efficient and effective policies and measures to prevent or reduce the release of microplastics. The size of the microplastic flow being addressed is taken into consideration when assessing this potential.
- Efforts that increase knowledge about preventing and reducing risks to human health and the environment from microplastics.
- How well the efforts align with the European Commission's Zero Pollution Hierarchy, as stated in the EU's Zero Pollution Action Plan (European Commission, 2021).
- Potential to further contribute to Sweden's environmental objectives and Agenda 2030 by also addressing other environmental challenges, such as sustainable stormwater management and reduced exposure to hazardous substances.

All these criteria contribute to achieving Sweden's environmental objectives and Agenda 2030.

A lack of alternatives limits efforts to reduce leakage of microplastics to some extent. One example is tyre wear, which is unavoidable since tyres need to have a certain amount of friction against the road surface for safety reasons. However, the EU's Zero Pollution Hierarchy states that pollution should, if possible, be rectified at source, and the development of pollution prevention sollutions should have priority.

In developing new solutions to reduce microplastic leakage and risks, it is important to consider both synergies and trade-offs when managing other environmental risks. For example, in the production phase, polyester and nylon can be a better option for land and water use than materials like cotton, but worse from a climate perspective (ETC/WMG, 2021).

Furthermore, natural materials also release microfibres that have a relatively unclear impact on the environment (ETC/CE, 2022). Conversely, in addition to reducing the leakage of microplastics, stormwater and wastewater management can also provide synergies by reducing the dispersion of hazardous substances.

The following chapters describe the challenges of reducing risks from microplastics, based on the obstacles identified in the Roadmap for the Sustainable Use of Plastics (Swedish EPA, 2021a) for microplastics (see Chapter 2) and the criteria listed above.

The knowledge and development needs for reducing potential risks from microplastics are described at an overarching level by way of introduction, and then specifically for important sources already identified (in some cases similar sources have been grouped) as described in Chapter 2:

- Tyre and road wear
- Synthetic textile fibres
- Synthetic sports surfaces, rubber surfaces and other outdoor facilities
- Degradation of plastic litter

Several of these areas are interlinked.

Though the industrial production and handling of plastics is an important source of microplastics, the agenda does not describe this in more detail because the research needs for this flow are considered to be comparatively small.

The knowledge and development needs for reducing potential risks from microplastic leakage via different dispersion pathways is described in the overarching section and, where relevant, also for each source. In accordance with the EU's Zero Pollution Hierarchy, the knowledge and development needs for reducing dispersion of microplastics at the source is prioritised.

3.1 Microplastics – overarching

3.1.1 Assessing health and environmental risks from microplastic releases

We need to better understand the exposure of different organisms in different environments, including air, terrestrial and limnic environments. This applies in particular to small fractions of microplastics, because the actual concentrations in the environment appear to have been underestimated (SAPEA, 2019). To reliably assess risks for microplastics, we need a better understanding of which concentration levels can cause adverse health and environmental effects and whether there are threshold levels for these effects. Additional and more accurate modelling of expected dispersion pathways, concentrations and exposure is needed.

We also need to know more about how effects differ among different types (shape, additive, type of polymer including biodegradable polymers) and sizes of microplastics, and how mixtures of different microplastic particles can cause different effects in the environment. Ultimately, knowledge of risks could be translated into threshold values, which could facilitate defining requirements and management. More knowledge is also needed about where concentrations of microplastics exceed these thresholds. Identifying "hotspots" for microplastic leakage can be part of this process (SAPEA, 2019).

Many experiments have used unrealistically high concentrations of microplastics and types of microplastics not present in the environment. As a result, we need more knowledge about physical and chemical effects, including chronic effects, under real environmental conditions (GESAMP, 2016; SAPEA, 2019; ETC/CE, 2022). In particular, we lack knowledge about effects at higher organisational levels, such as population and ecosystem levels, and knowledge about effects in different types of environments, including limnic and terrestrial environments, which have so far been less studied than marine environments.

We still need a better understanding of the links between microplastic dispersion, chemical dispersion and the extent to which microplastics act as vectors for various environmental pollutants (SAPEA, 2019; GESAMP, 2016), although knowledge has increased somewhat in recent years. Other knowledge gaps include how microplastics interact with other stress factors, such as eutrophication, acidification and climate change; the mechanisms of uptake, accumulation and degradation in the body; and non-toxicological effects on carbon and nutrient cycles and on soil and sediment fertility (MacLeod, Arp, Tekman, & Jahnke, 2021).

We also lack knowledge about risks to humans. To better understand risks to humans, we need adequate particle characterisation and selection for toxicity testing; experimental study designs that enable derivation of dose-response curves; and a clearer understanding of microplastic exposure (Thornton Hampton et al., 2022). Regarding human exposure levels, we need better estimates of microplastic concentrations in wastewater, sludge and the air.

Plastic baby bottle, Susanne Kronholm, Johnér.

Although this research agenda mainly discusses microplastics, it is also worth mentioning the gaps in knowledge about nanoplastics. We know considerably less about nanoplastics than microplastics. The size and chemical similarity of nanoplastics to the surrounding environment make them difficult to study. Few studies have succeeded in detecting nanoplastic particles in the environment, indicating a need for advancements in measurement technology and analysis methods. In addition, significant knowledge gaps exist regarding the fragmentation of plastics down to nano size (Materić et al., 2022; Jakubowicz, Enebro, & Yarahmadi, 2021). The same applies when nanoplastics accumulate in the environment. We need to know more about exposure, effects and risks of nanoplastics (Ekvall, Hua, Kelpsiene, Lundqvist, & Cedervall, 2022).

3.1.2 Assessing the cost-efficiency of measures

Assessing the cost-efficiency of measures requires knowledge of the effectiveness of different measures, combined with the estimated costs of their implementation. The assessment should also consider synergies and potential conflicts with efforts to reduce other environmental challenges. Examples of synergies with other environmental challenges include measures to treat microplastics in wastewater treatment plants and leachate, which simultaneously filter out various hazardous substances such as perfluorinated alkyl acid (PFAS) and pharmaceutical residues.

Efforts will prioritise prevention in accordance with the European Commission's Zero Pollution Hierarchy (European Commission, 2021). To reduce the release of microplastics, it would be desirable to develop a concept similar to "essential use" from a microplastic perspective for intentionally added microplastics.

3.1.3 Developing measurement and analysis methods and the need for harmonisation and standardisation

Initiatives to limit and/or ban the release of microplastics in various ways are ongoing in the EU and elsewhere, both for intentionally added microplastics in products (ECHA, 2019) and for microplastics that form in the environment unintentionally (European Commission, 2023). Since analysing the distribution of microplastics is costly, we need to develop cost-efficient sampling and analysis methods that can be used on a large scale. This applies in particular to small microplastic fractions and nanoplastics (SAPEA, 2019; Johannesson & Lithner, 2022). We need to develop sampling and analysis methods, for example, to enable oversight and to monitor microplastics.

Standardisation of measurement and analytical methods is important for facilitating risk assessment, for improving the cost-efficiency of measures and for developing new measures, such as threshold values and labelling. A lack of harmonised and standardised measurement and analysis methods complicates comparing the results of different studies, which makes it harder to draw general conclusions on effects and other aspects.

Degradable plastics are sometimes cited as an answer to the problem of plastic leakage into the environment However, existing standards for degradation do not include microplastics, and degradation depends on the conditions where the degradable plastic is located.

The issue of microplastics has come to the fore relatively recently, so solutions to reduce leakage have not yet been developed in many cases. We do not have the standardised measurement methodology required to develop products in a way that reduces releases of microplastics.

3.2 Tyre and road wear

Efforts to reduce the leakage of tyre and road wear particles should focus on achieving improved tyre quality and durability and on reducing the releases of particles from this source through reduced wear of tyres and road surfaces, including road markings. Work should also focus on the link between particulate matter releases and hazardous substances and on improving the management of microplastic leakage through runoff.

Traffic outside of Gothenburg. Göran Assner, Johnér.

3.2.1 Assessing health and environmental risks from microplastic releases

To encourage efforts to reduce the release of tyre and road wear particles, we need to learn more about their environmental and health effects. To date, only a limited number of studies have been conducted under realistic conditions, and more research is needed to enable risk assessments. Many additives are used to produce tyres, road markings and polymer modified bitumen. We know very little about some of these. For others, we know that they endanger human health and harm the environment. However, we know little about the extent to which these substances are released by tyre and road wear particles (Andersson-Sköld et al., 2020).

3.2.2 Assessing the cost-effectiveness of measures

It is important to learn more about the effectiveness, cost-efficiency and feasibility of different policy instruments and measures to reduce releases of tyre and road wear particles. Such knowledge can provide a support data for decisions by stakeholders on the prioritisation of measures to reduce releases from this source.

The Swedish National Road and Transport Research Institute, VTI, has begun this work within the framework of the government commission on microplastics from road traffic (Johannesson & Lithner, 2022). To facilitate comparisons of the effectiveness of measures, we need to develop standardised protocols and criteria for assessing them.

Improved knowledge has a good potential to facilitate stakeholder decisions on measures in research and development areas, such as:

- How parameters, e.g. air pressure, wheel alignment, wheel balance and vehicle weight, affect tyre wear. This knowledge also has a bearing on other environmental objectives, such as Limited Climate Impact.
- Possible instruments and measures to increase the percentage of tyres with correct pressure and how monitoring of wheel alignment and balance can increase. Knowledge areas also include the connection between releases and driving behaviour, reduced road speeds, tyre types, road surfaces and road surface texture.
- Sustainable stormwater management, the effectiveness of current methods for collecting the smallest microplastic fractions and the development of cost-efficient treatment methods.

Additional evaluations are also needed of such measures as optimised snow management, street sweeping, how dust suppression interacts with street sweeping and whether these methods should be coordinated for increased effectiveness (Blomqvist, Järlskog, Gustafsson, Polukarova, & Andersson-Sköld, 2023; Gustafsson, Polukarova, Blomqvist, Järlskog, & Andersson-Sköld, 2023). This includes increasing knowledge of which hazardous substances could be candidates for restrictions and bans in tyres and road markings.

Rush hour traffic in Stockholm. Peter Lydén, Johnér.

3.2.3 Developing measurement and analysis methods and the need for harmonisation and standardisation

To be able to assess the exposure of different organisms to microplastics, we need to know more about the levels of microplastics from road traffic in different environments (Johannesson & Lithner, 2022). In turn, this can help us identify where the greatest need exists for measures to reduce microplastic releases. To make this possible, we need to develop methods for sampling, preparing and analysing tyre and road wear particles. We also need to develop standards for sampling, preparing and analysing microplastics from road traffic to determine the shape, size, number, chemical content, density and mass of the particles. We also have knowledge gaps on the size distribution of tyre and road wear particles; the distribution of different types of microplastic particles in different environments (marine, terrestrial and limnic); and where they accumulate.

Very few studies have investigated the occurrence and dispersal of tyre and road wear particles in soil and groundwater, which makes it difficult to develop and adapt dispersion models for these particles in soil. In addition, there have been few modelling studies for tyre and road wear particles in the air. In general, these models need improved input data in the form of more and better measurements of tyre and road wear particles; increased knowledge of the properties of microplastics (e.g., size, density, shape and chemical properties); more knowledge about what happens to the particles in nature (aggregation, biofouling, degradation etc.); and how this affects the mobility of the particles (Svensson & Andersson-Sköld, 2021). We need more field measurements to validate modelling studies for microplastics in soil (Svensson & Andersson-Sköld, 2021).

3.2.4 Reduced leakage of microplastics from certain flows

To enable both measures and policy development, we need research and development of low-wear tyres and road surfaces, without compromising road safety and other environmental aspects, such as noise and substances hazardous to the environment and health. We also need research and development aimed at tyres that degrade more readily, without compromising functionality and durability or generating more wear particles (Johannesson & Lithner, 2022).

Road markings on a bicycle path/road in Stockholm. Jens Lindström, Johnér.

Innovations that lead to the development of collection systems for use while driving could also help reduce microplastic leakage.

In developing new solutions to reduce leakage and potential risks from microplastics, it is important to consider both synergies and conflicting goals when addressing other environmental challenges. For example, developing stormwater management can support risk reduction in connection with torrential rains linked to climate change. Methods for road cleaning can have synergies with reducing potential risks from nanoparticles (including nanoplastics) and organic pollutants.

3.3 Synthetic textile fibres

Work to reduce potential risks associated with leakage of microplastics from textiles should be based on a holistic approach to all environmental challenges related to the textile sector, and efforts to reduce leakage of microplastics at the source should be prioritised. The obstacle "health and environmental risk assessment" is covered in Chapter 3.1.1.

Clothing made of synthetic materials. Håkan Hjort, Johnér.

3.3.1 Assessing the cost-effectiveness of measures

Fibre releases can occur throughout the life cycle of the product. We need to know more about which life cycle phases release the most fibre. This includes better understanding of the release of synthetic fibre fragments in the production chain; how different textiles and fibre types, manufacturing processes, weaving techniques and fabric construction parameters, such as brushing and cutting, affect microplastic releases; and how cost-efficient these practices are. We also need to know more about whether recycled fibres and textiles with more bio-based material have an impact on microplastic releases. In addition, we need more knowledge about how releases vary with the age of different garments; which products and materials contribute most to microplastic releases; and how different types of washing machines and dryers affect the amount of microfibres released (OECD, 2021; ETC/CE, 2022). We need also to know more about how different laundries contribute to releases of microplastics (Brodin, Norin, Hanning, & Persson, 2018), as these may constitute hotspots for releases in OECD countries (OECD, 2021). This knowledge can provide a basis for various stakeholders' decisions on requirements and measures, including support for enabling possible limit values for fibre release.

In addition to the knowledge needed to ultimately assess the cost-efficiency of various measures, we need to know what legislation makes it possible to set requirements that minimise releases of microplastics from textiles. We also need to know whether ecodesign criteria are relevant/applicable for products made outside the EU and whether it is possible to use these to establish requirements to reduce releases, or whether these requirements should be established through the initiative on corporate due diligence and how companies report their environmental work.

3.3.2 Reduced leakage of microplastics from certain flows

There is currently a need to develop different solutions that reduce releases of synthetic textile fibres during production, waste management and the use of textiles, such as during washing and care of textiles. These solutions include textiles that release fewer fibres and developing filter solutions to collect fibres before they reach wastewater treatment plants (OECD, 2021). More knowledge is needed on how to stimulate sustainable consumption and the use of textiles (ETC/CE, 2022).

Preventing a release at the source is always the best option. Nevertheless, there is a need for innovative solutions for the post-treatment and management of sludge, where nutrients can be processed and microplastics and other pollutants can be removed (ETC/CE, 2022). In the longer term, innovations that increase resource utilisation of wastewater could lead to wastewater treatment processing and product development that provides new ways to return plant nutrients and soil-forming substances to agricultural land that do not depend on sludge production and spreading.

When developing new solutions, it is always important to take a holistic approach and ensure that the solutions developed do not have a negative effect on other parts of the work on sustainable textiles.

3.3.3 Developing measurement and analysis methods and the need for harmonisation and standardisation

It is difficult to compare the tendency of different materials to release microplastics during different phases of their life cycle due to a lack of standardised measurement and analysis methods. This lack also makes it difficult to compare the impact of different washing methods on microplastic releases (ETC/CE, 2022). This also complicates establishing procurement criteria directed at reducing releases from synthetic textile fibres.

Monitoring various measures over a period of time and assessing their effectiveness would require developing cost-efficient measurement and analysis methods, particularly for monitoring wastewater treatment plants, for both wastewater and sludge. Evidence suggests that the microplastic removal rates of the larger wastewater treatment plants included in many of the studies are very high for particles from 50–500 µm and above. But we still need to know more about the relative contribution of wastewater treatment plants as a dispersion pathway compared to other pathways. It also remains to be seen whether that high treatment efficiency also applies to smaller particle fractions, especially synthetic fibre fragments, and in smaller treatment plants.[4]

[4] Anne-Charlotte Hanning, project manager and researcher at RISE, phone call 3 March 2022.

3.4 Synthetic sports surfaces, rubber surfaces and other outdoor facilities

Efforts to reduce leakage of microplastics from synthetic sports surfaces and other outdoor sports and play facilities should focus on minimising these releases, while ensuring that factors such as play characteristics and safety are not compromised. Efforts to tackle leakage at the source should be prioritised. The obstacle "health and environmental risk assessment" is covered in Chapter 3.1.1.

Fall protection made of rubber, Mälarhöjden School. Johan Willner, Johnér.

3.4.1 Assessing the cost-effectiveness of measures

Evidence suggests that releases from synthetic sports surfaces and other outdoor plastic and rubber surfaces can be reduced by applying relatively simple measures. The European Committee for Standardisation (CEN) has produced a technical report specifying the main measures for synthetic sports surfaces (CEN, 2020). The REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) Regulation also discusses limiting or banning releases. However, the effectiveness of the various protection measures has not been adequately analysed.

3.4.2 Developing measurement and analysis methods and the need for harmonisation and standardisation

Standardised methods to identify synthetic sports surfaces that release large amounts of artificial grass fibres should be developed so that these pitches can then be remedied. More knowledge is needed on why some of these surfaces release more artificial grass fibres than others (Olshammar, Graae, Robijn, & Nilsson, 2021).

No standardised methods for reducing microplastic releases or losses from cast rubber granulate surfaces currently exist. A technical report, like the one developed by CEN for granular infill in synthetic sports surfaces, does not exist for these surfaces either.

Rubber granulate in a football pitch, Stockholm. Henrik Löwenhamn.

3.4.3 Reduced leakage of microplastics from certain flows

There is currently a lack of material concepts that fulfil the criteria fossil-free, free of hazardous substances and no risk of microplastic dispersal (Swedish EPA, 2021b). It would be desirable to develop solutions that fulfil these criteria but also maintain high play quality and price competitiveness.

Microplastic releases can then be minimised by developing alternative materials (Bengtsson & Olshammar, 2021) and by developing systems that completely avoid synthetic materials and that offer synergies of promoting biodiversity and various ecosystem services (Bengtsson et al., 2022).

One form of maintenance that appears to reduce the dispersal of microplastics from rubber surfaces is regular deep cleaning with a cleaning machine. However, there are currently no effective ways to dispose of the water used to wash these surfaces, so a suitable methodology to do this needs to be developed (Olshammar, Graae, Robijn, & Nilsson, 2021).

3.5 Degradation of plastic litter

The research agenda includes the breakdown of litter into microplastics but not the causes of litter entering the environment. As a result, the obstacle "lack of solutions to reduce leakage of microplastics from certain flows" is not addressed for this source of microplastics. The obstacle "assessment of environmental and health risks of microplastic releases" is covered by what is stated in Chapter 3.1.1.

Plastic litter in Årstaviken, Swedish EPA.

3.5.1 Assessing the cost-effectiveness of measures

We need further study to better understand the impacts of littering and to investigate how litter contributes to microplastic releases and its share in relation to other quantified sources. A better understanding of how litter contributes to overall microplastic releases would allow us to better establish measures where they have the greatest impact.

3.5.2 Development of measurement and analysis methods, and the need for standardisation and harmonisation

Lack of knowledge about the processes affecting the degradation of macroplastics to microplastics and then to nanoplastics in different environments makes it difficult to assess the persistence of the particles (SAPEA, 2019). Similarly, there are currently knowledge gaps regarding biodegradable plastics, and existing standards for degradation do not include microplastics.

4. Moving forward with the microplastics research agenda

Through the National Plastics Coordination, this research agenda will be disseminated to multiple stakeholders through regular newsletters and other channels. As noted in the introduction, the work towards sustainable plastic use occurs in collaboration with other stakeholders. This collaboration is fundamental in the continued work to fill knowledge gaps in the field of microplastics. Collaboration with other research funding bodies currently occurs within the framework of the National Plastics Coordination, and a discussion with these stakeholders on how to address the research agenda in calls for proposals represents an important step forward. For example, collaboration could occur with the Swedish Research Council for Sustainable Development; Vinnova, Sweden's innovation agency; the Swedish Water & Wastewater Association; the Swedish Foundation for Strategic Research; the Swedish Energy Agency; and Mistra, the Swedish foundation for strategic environmental research.

The research agenda can also be disseminated internationally through relevant networks. An example of a network that could be relevant is the IG Plastics interest group under the EPA Network[55], which includes several European environmental authorities, some of which fund development projects and research. Another example of international organisations that can benefit from the content of the research agenda is the Nordic Council of Ministers, which funds research projects within the framework of the project "*Norden som en motor i arbeidet mot marin forsøpling og plastforurensning*" [The Nordic Region as an engine for combating marine litter and plastic pollution]. Other interesting organisations with which to collaborate are the regional marine conventions OSPAR and HELCOM. OSPAR is the Convention for the Protection of the Marine Environment of the North-East Atlantic. HELCOM, the Baltic Marine Environment Protection Commission, funds research. Both HELCOM and OSPAR have expert groups within their organisations, where the research agenda can aim to inspire experts and researchers to design projects that will be of concrete use in policy contexts.

Microplastics research has progressed rapidly in recent years, so it is important to continue updating the microplastics research agenda and make it a dynamic document that evolves over time and as new knowledge is contributed. Within the framework of the National Plastics Coordination, the Swedish EPA will follow the development towards reduced risks with knowledge and development, updating the research agenda as necessary.

[5] Network of the Heads of European Environmental Protection Agencies – European Network of the Heads of Environment Protection Agencies (EPAs) (europa.eu)

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REPORT 7124 | DECEMBER 2023 ISBN 978-91-620-7124-0 ISSN 0282-7298

Microplastics Research Agenda

Need for knowledge and improvement for the development of instruments and measures

This research agenda for microplastics has been produced as part of the Swedish Environmental Protection Agency's roadmap for the sustainable use of plastics. It begins by describing the knowledge needs at an overarching level, and then specifically for identified important sources of microplastics. The research agenda aims to provide supporting documentation for a needs-driven prioritisation of research and innovation efforts, facilitating the development of measures, policies and legislation to reduce potential risks with microplastics and their release. It is intended for research funding bodies, experts and researchers and can serve as inspiration for formulating calls for proposals and projects that can be used in policy contexts.

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