NATUR VÅRDS VERKET

Microplastics in the Environment 2019

Report on a government commission

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PROTECTION AGENCY

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Summary

The occurrence of microplastics in the environment has attracted attention in recent years. This is particularly evident in the huge volumes of initiatives, research, projects and actions that are taking place both internationally and in Sweden. The Swedish Environmental Protection Agency (Swedish EPA) sees the occurrence of microplastics in the environment as an important ongoing issue. While we are dependent on synchronisation of results within the EU and other countries, and sometimes have to wait for others' results, our own work in Sweden needs to continue. The Swedish EPA considers that the conditions for reducing the dispersal of microplastics in the environment has been improved by the measures it proposes here. To continue making progress, we need to increase our knowledge of sources, dispersal and effects.

Proposals for action
The Swedish EPA proposes that the Government:

- Introduces a notification requirement for facilities using artificial grass and moulded granulate surfaces and for equestrian arenas containing rubber or plastics.

The Swedish EPA undertakes to be a national knowledge node for microplastics in the environment. We consider that in the immediate future, the greatest need will lie in the collection and dissemination of knowledge. The measures below could be included as part of this node work and be, to a large extent, financed by the increase requested in the Swedish EPA's budget.

- Measures for supervisory guidance for artificial grass pitches and other outdoor facilities for sports and play.
- Continued financing of pre-procurement purchasing group for artificial grass.
- Work towards a change in criteria in the Ecodesign Directive for washing machines.
- Promote the use of domestic filter solutions for households.
- Measures for laundries.

The Swedish EPA also undertakes to support other authorities as a knowledge node by taking in, collecting and disseminating new knowledge. The agency considers it appropriate for this responsibility be evaluated and reviewed after five years.

Commission
The Swedish EPA has focused on quantified land-based sources. We are reducing the gaps in knowledge and providing the action proposals above. An important starting point for the current commission is the list of the largest

emission sources and important dispersion routes presented by the Swedish EPA in its first commission in May 2017. The largest quantified source, road traffic, is handled by VTI, the Swedish National Road and Transport Research Institute, in a separate commission. The second and fourth largest sources, artificial grass pitches and washing of textiles, are handled in this commission. The work on the third largest source, boat hulls, is coordinated by the Swedish Transport Agency.

Litter is probably a major source of microplastics – perhaps the largest – but very difficult to quantify. In view of the EU's extensive work, for example on its plastic strategy, the recently adopted single-use plastics directive, and ongoing national efforts, such as information dissemination, beach cleaning and the recent concluded inquiry on sustainable plastic use, the Swedish EPA has chosen not to investigate this source in more detail in this commission.

The Swedish EPA reports new sources, such as construction and demolition waste, and other uses of artificial grass.

In its proposed measures, the Swedish EPA has not intended to anticipate the results from the inquiry *Giftfri och cirkulär återföring av fosfor från avloppsslam* [Non-toxic and circular return of phosphorus from sewage sludge], and the commissions of the Swedish National Road and Transport Research Institute (VTI) and the Swedish Food Agency (Livsmedelsverket), respectively.

New knowledge of occurrence and effects

Knowledge of the presence and effects of microplastics in surface waters in lakes and oceans has increased in recent years. However, the presence and effects in soil and air and the health risks to humans are less well-known. There is a consensus among researchers that the negative effects increase the smaller the particles are.

On 30 April 2019, the EU Commission's scientific advisory function, SAM, published a scientific opinion. This outlines increasing concern about the presence of microplastics in air, soil and sediment. It also noted that, although ecological risks are rare at present, there are at least a few local areas, in coastal waters and sediments, in which effects could occur. If future emissions remain at the same level as today or increase, the risks may be extensive within a century. The report has also listed possible measures, such as incorporating microplastics into relevant directives or reducing emissions at source.

New knowledge of artificial grass pitches, outdoor facilities and textiles

Knowledge of emissions from artificial grass pitches, textile production and laundry facilities has increased. We can, with greater certainty, quantify emissions from artificial grass pitches that result in lower, but still large, total emissions than previously estimated. However, knowledge of emissions from other outdoor sports and play facilities is comparatively low. The size of the area involved, the size of the total emissions, life expectancy, etc. are areas

where more knowledge is needed. The emissions from textile production are estimated to be significantly lower than those from laundry facilities, partly because the number of production plants is low in Sweden, compared to the number of laundry facilities. The largest amounts of microplastics from textile washing are still assumed to come from domestic washing. There are already examples of filter solutions that can be installed on washing machines meant to reduce emission of microplastics into the output water, but their efficacy needs to be verified. There is also a need to ensure that the use of filter solutions does not contribute to a conflict of objectives between different environmental impact categories, such as increased energy consumption and climate impact. The Swedish EPA sees a need for further analyses.

No new findings have been made which would reverse or drastically alter either the previous understanding of the major sources or the order of size of emissions. We have, however, expanded our knowledge base in certain areas.

New knowledge of dispersal pathways

Knowledge of what happens to microplastics in wastewater treatment plants has increased. A new study shows that microplastics are present in more purification stages than previously noted and that there are still significant uncertainties in the measurement results. Previous analyses showing a 95–99 % purification rate in outgoing water have been verified. For storm water, a study of storm water wells in Gothenburg shows the presence of microplastics, which are largely assumed to come from tyre wear and road surfacing.

Introduction

Interest around the microplastics issue is still considerable. Microplastics are subject to discussion in the EU and in international forums. The EU's plastic strategy considers the presence of microplastics in the environment to be a problem. The need for research into sources of microplastic and its effects on the environment and health is underlined. Although knowledge of presence and emission has increased in recent years, there are still considerable gaps in knowledge about the effects of microplastics on ecosystems.

In June 2017, the Swedish EPA presented the first report on sources of microplastics and proposals for measures to reduce emissions in Sweden (Swedish Environmental Protection Agency 2017). Of the 24 measures proposed, 20 are in progress or have been implemented.

As with the previous commission, this commission has links to environmental quality objectives, mainly a Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos, Flourishing Lakes and Streams and a Non-toxic Environment.

The government commission

In the Swedish Environmental Protection Agency's appropriation directives for 2018 (Dnr M2017/03180/S and others), the Government has commissioned the Agency with continuing its work of identifying and addressing major sources of emissions of microplastics into the aquatic environment in Sweden, based on previous commissions (Dnr M2015/2928/Ke). See Appendix 4.

According to the Government's remit, the Swedish EPA is to consider various risk management tools, such as support for contracting authorities, changes in regulations and guidances, increased supervision and dialogue with relevant industries.

The Swedish EPA is also to analyse various options for regulating the release of microplastics into the aquatic environment. The analysis should include plans for artificial grass pitches (AGP) and other outdoor sports and play facilities where there is a risk of microplastics being released. Analyses for these pitches and installations are to include the grounds for regulatory proposals for emission control, including requirements for construction and maintenance and whether they could constitute an environmentally hazardous activity with a notification or authorisation obligation.

Socio-economic impact assessments should form the basis for the proposals, as well as for the major measures considered by the agency that they have chosen not to propose. These analyses must be included in the report.

The commission report must be submitted no later than 31 May 2019.

Completion of the commission

Work on the commission by the Swedish EPA took place between January 2018 and May 2019.

A project group was formed for the project, made up of employees from the Swedish Environmental Protection Agency. The project group has consisted of Björn Thews, Åsa Jarsén, Lena Stig, Linda Linderholm, Kristina Svinhufvud, Sebastian Dahlgren Axlsson, Tomas Chicote, Maxi Nachtigall, Julia Taylor (assistant project manager) and Ulrika Hagbarth (project manager). The steering group consisted of the relevant unit directors.

Dialogue and collaboration

The commission has required a great deal of coordination. As both VTI and the Swedish Food Agency were given commissions in parallel with this, a government group met regularly to exchange experiences and information. This group also included representatives from the Swedish Agency for Marine and Water Management, the Swedish Chemicals Agency and the Swedish Transport Administration, which are all working on the microplastics issue.

Two workshops were held. At a workshop on 13 November 2018, reports were presented for discussion in the areas of artificial grass and other outdoor facilities for sports and play and laundry of textiles. Valuable comments were submitted by the participants from municipalities, industry bodies, businesses and associations. On 7 December, preliminary results on concentrations, sources and dispersal pathways from the study of Bohuslän beaches were discussed.

Contacts were made with authorities, industry bodies and several other stakeholders. Contact was also made with the Swedish Association of Local Authorities and Regions (SALAR) and the Swedish Equestrian Federation. The pre-procurement purchasing group for artificial grass has provided opinions from local authorities, industry bodies and others. The project group also participated in several conferences, both nationally and internationally, to gather knowledge and background material for the work.

Supporting documentation

Even though much has happened over the last two years, there are still significant gaps in available knowledge. This report is therefore based on a number of consultancy reports. An initial rough survey of outdoor sports and play facilities was carried out. Knowledge of measures and emissions from artificial grass pitches has also been broadened. In the case of textile laundering, the supporting documentation helped expand knowledge of filter solutions for consumer laundries and contributed more information from laundry facilities. A socio-economic impact assessment was developed for a future revision of the Ecodesign Directive. A study of micro-litter along Bohuslän beaches and in sediment and a review of the state of knowledge on effects on the environment and on humans were conducted.

The starting points for the commission

A significant starting point for the current commission is the list of the largest emission sources and important dispersal pathways presented by the Swedish EPA in its first commission in May 2017. Although the list contains uncertainties about the estimated quantities, it is still relevant, although with some adjustments. The Swedish EPA points out that the following sources of emissions should primarily be addressed in Sweden: tyre wear, road surfaces and paints, artificial grass pitches, industrial production and handling of primary plastics, synthetic fibre washing, marine anti-fouling paint and littering. Another important starting point for the current commission is a survey of relevant work carried out in the rest of the world.

In this commission, the Swedish EPA has included several comments from the consultation round of the previous commission. This includes our recognition of the importance of action at a European level to limit the problem of unnecessary plastic use causing litter. Another area in which several stakeholders commented on is tyre as a source of particle shedding, where more knowledge of how to best address the problem was sought. There were also several comments about the microplastics that end up in sewage sludge.

In this commission, the Swedish EPA closes knowledge gaps and proposes further measures to reduce emissions from some of the most important quantified sources. The agency also reports on progress with proposals from the previous report.

Focus on land-based sources

As in the previous commission, work is restricted to land-based sources of microplastic emissions. This means that microplastics that are already present in the aquatic environment or have been produced by fragmentation of larger pieces of plastic in water are not discussed. Emissions directly into water, such as boat paint, buoys, ropes etc., are only marginally touched on. In Sweden, the Agency for Marine and Water Management leads efforts on offshore sources. The agency has developed both national and international action programmes and is responsible for a number of different initiatives, such as a boat scrapping premium.

Both primary and secondary microplastics are included

Primary microplastics are intentionally-produced microplastic particles, while secondary microplastics are formed when plastic objects fragment into microscopic particles. The European Chemicals Agency (ECHA) has initiated work intended to limit the use of intentionally-added primary microplastics in products. However, this possibility has little impact on most of the major shedding sources in Sweden, such as road and tyre wear, litter and laundry of synthetic fibres. In addition, certain sources of shedding, such as artificial grass pitches, give rise to emissions of both types. For this reason, the Swedish EPA has chosen to include both primary and secondary microplastics in this inquiry.

The precautionary principle should apply

Awareness of the problem of microplastics in the environment is fairly recent. For this reason, there is still a major lack of knowledge about sources, emissions, occurrence and effects in the environment. It is clear, however, that there is a risk of adverse effects on human health and the environment. The Swedish EPA therefore believes that the precautionary principle should be at the forefront of microplastics issues and that release of microplastics should be avoided and addressed to reduce exposure and increased risks in the future.

Delimitations and focus

Several measures to manage emissions from the major identified emission sources were launched after the Swedish EPA presented its previous report. For example, the Swedish National Road and Transport Research Institute (VTI) was given a three-year commission to investigate tyre wear, road surfacing and paint. The Swedish EPA has examined the possibility of supplementing VTI's work by proposing measures that would limit the presence of microplastic particles in the air and, by extension, in storm water, but considers that the knowledge gaps are too large.

Of the major land-based sources that are not managed by any other authority, the Swedish EPA has chosen to focus on increasing the knowledge about the emission of microplastics from artificial grass pitches and other outdoor sports and play facilities and textile laundering, both in households and in large-scale laundries. Proposals for measures to reduce emissions and dispersal from these sources are also analysed and presented. The potential for further reductions in emissions from these sources is considered to be good.

FOCUS ON ARTIFICIAL GRASS PITCHES AND OUTDOOR SPORTS AND PLAY FACILITIES

There is increasing use of artificial grass with and without granules and moulded granulate surfaces. In several studies from Norway and Sweden, granules are found in the environment both as whole granules and crushed granules. Many measures to reduce emissions are currently being implemented, but the Swedish EPA believes that this source is still significant. We have therefore focused on expanding knowledge in the form of background reports and developed proposals for measures.

LAUNDRYING SYNTHETIC TEXTILES IS ANOTHER FOCUS

One of the major sources of microplastic emissions is laundering synthetic textiles, both in households and in large-scale laundries. Wastewater from laundry goes to wastewater treatment plants in the vast majority of cases and forms a major part of the microplastic load. Through upstream work, i.e. reducing emissions directly in washing water from households and large-scale laundries, measures can be implemented at the point where they are most effective. Here, too, several background reports have contributed to a better understanding of the state of knowledge.

NEW SOURCES HAVE BEEN IDENTIFIED

The Swedish EPA has also continued to map potential sources of emissions, work that began in the previous commission. Additional sources of emissions have been reported, such as certain building materials and waste/litter around construction sites, equestrian arenas and other outdoor sports and play facilities with surfaces containing plastics or rubber, and the use of artificial grass in traffic environments and parks.

LITTER IS MARGINALLY AFFECTED

A large land-based source of microplastic – perhaps the largest – is litter. To date, it has not been possible to estimate the quantities. A study by the University of Gothenburg carried out in 2018 shows that the majority of plastic particles on beaches are fragments. The fragments consist of many different colours and shapes, indicating that fragmentation from macroplastic to microplastic is an important source of the microplastic found on beaches. High levels of both macroplastics and microplastics have been measured on beaches along the Bohuslän coast (Karlsson, et al. 2019).

The revised Waste Directive, which is part of the EU Waste Package in the Circular Economy Action Plan, requires Member States to develop measures by 5 July 2020 to identify the products that are the main sources of litter, particularly in nature and the seas; and take appropriate measures to prevent and reduce the waste from such products.

At the same time, measures to reduce litter are an important part of the EU's plastics strategy. The proposal for a new EU directive on the use of disposable plastic items contained in the strategy was adopted by the EU on 27 March 2019.

Litter was examined in the interim report of the inquiry on sustainable plastic materials (Official Reports of the Swedish Government, SOU, 2018:84) and in the commission given to the Swedish EPA, which was then withdrawn in the final phase of the implementation of this commission.

The Swedish EPA has chosen not to investigate this source of emissions in more detail in this commission because of the EU's extensive work in this area, the recently concluded inquiry on sustainable plastic use and other ongoing efforts such as information dissemination and beach cleaning.

National and international developments

There are currently many different initiatives in progress, both to reduce current emission of microplastics and to expand knowledge of potential sources of emissions and to better understand their impact on the environment. The Swedish EPA has carried out a survey of what is happening around the world.

International developments

Microplastics are receiving a great deal of international attention. Within the UN, the EU and several international conventions, projects and research

are ongoing to increase knowledge of the presence and effects of microplastics on the environment. In the previous commission a thorough review of relevant international initiatives was conducted. An updated review is found in Annex 2.

Some of the most important international efforts include:

- The EU's plastic strategy, which covers the entire plastic value chain and the negative environmental impact that arises in the various stages. A key measure of the plastic strategy is the ban on single-use plastic articles (the SUP Directive), which was adopted on 27 March 2019. The single-use plastic directive contains new requirements and bans on the types of products and packaging that are among the ten most prevalent on European beaches. This includes abandoned fishing gear.
- ECHA's work on limiting "intentionally-added" microplastic particles in products or uses that "intentionally release" microplastic particles into the environment. There is now a proposal for a restriction dossier on intentionally-added microplastics in products in line with REACH. If the proposal were to be adopted, it would result in significant reductions in emissions.
- The EU's Marine Strategy Framework Directive requires EU Member States to ensure that the sea litter does not harm coastal and marine environments.
- OSPAR and HELCOM have both developed regional action plans consisting of a number of measures to reduce the amount of litter in the marine environment. Some of these measures focus on microlitter (a significant part of which is microplastic). Indicators for microplastic monitoring are being developed in both conventions.
- The UN has created a global partnership on marine litter.
- The Nordic Council of Ministers has adopted an action programme for the environment and climate, which will strengthen efforts to combat the flow of litter into the sea, not least plastic and microplastics.
- Finland has drawn up a road map for a sustainable plastic economy that includes more than a hundred proposals for improved plastic handling.
- Other Nordic countries have developed strategies and action plans and some very interesting proposals for measures, such as introduction of a municipal subsidy system for measures against microplastic particles and marine litter and the possibility of cleaning microfibre from washing machine drain outlets.

On 30 April 2019, the Commission's scientific advisory function, SAM, published a scientific opinion. It lists potentially relevant areas where consideration could be given to the implementation of measures:

- Review how macrolitter and microlitter are treated under the EU Water Framework Directive.

- An important source of soil microplastics is the use of sewage sludge on arable land, which could be dealt with under the Urban Waste Water Treatment Directive (91/271/EEC) and the Protection of the Environment, in particular of the soil, when sewage sludge is used in agriculture Directive (86/278/EEC).
- The EU directive on air quality does not differentiate between material types and microplastics are therefore included in PM10 and PM2.5, but knowledge about the presence of fibres below 50 µm is lacking and indoor exposure is not managed.
- In addition to legislation, dispersion can be reduced through voluntary commitments, such as education, dissemination of knowledge and behavioural changes, which often are quicker.

The SAM report states that, in the short term, large emission reductions could be achieved through "end-of-pipe" solutions, but that there is too little knowledge to recommend appropriate measures that can be implemented in the short term. Three areas have, however, been identified:

- Release of textile fibres could be reduced by setting performance requirements for washing machines and laundry facilities.
- Microplastic emissions from car tyre wear and from artificial grass pitches could be reduced, for example, by means of specific drainage systems.
- Waste from the production of pellets could be dealt with using the Industrial Emissions Directive.

Developments in Sweden at the national level

Responsibility for the microplastics problem is divided among several authorities and stakeholders who are all active in the matter. In addition, since May 2017, the Government has initiated several processes and commissions to achieve a more sustainable use of plastic and to reduce emissions of microplastics.

Policy agreement on new measures in the January Agreement
Since January 2019, the coalition government has had a policy agreement, known as the January Agreement, with two opposition parties. According to clause 37 of the January Agreement, the emission of microplastics is to be prevented by banning microplastics in more products. In addition, the use of unnecessary plastic articles should be banned and Sweden should push the EU to phase out all single-use plastic.

Tyre wear, road surfacing and paint is investigated by VTI
Wear of vehicle tyres, road surfaces and paints are the largest quantified sources of microplastics in Sweden and is estimated at 8,190 tonnes of microplastic per year. This is about 4 times more than the emission from artificial grass pitches. Of this, more than 90 % is estimated to come from vehicle tyres (Magnusson et al. 2016).

In 2018, the Government's Road and Transport Research Institute (VTI) was commissioned with developing and disseminating knowledge about microplastic emissions from road traffic. VTI will also identify and evaluate potentially effective policy instruments and mitigation measures aimed at limiting emissions. A final report from the commission will be submitted on 1 December 2020. A literature review will be conducted as part of the commission, which will serve as the basis for other activities. Several sub-projects have been initiated, which deal with national emissions of microplastic from tyres, the generation and characterisation of wear from different tyre types in road test machines and field measurements on motorways (Test site E18, outside Västerås) and in urban environments (Stockholm and Gothenburg). In parallel, an inventory of analysis methods and networking around analysis needs and possibilities has also been ongoing.

The Swedish Transport Administration is examining the issue of tyre wear
The Swedish Transport Administration has been working on the issue of the dispersion of rubber particles from tyres for a long time. At present, the agency works mainly with measures aimed at better understanding the situation regarding emissions, dispersion and purification techniques for these particles and their pollutant content. Currently, work is ongoing in areas such as:

- CEDR (Conference of European Directors of Roads), a platform in which European transport agencies collaborate on various issues, including road and tyre microplastics.
- The Swedish Transport Administration, together with the Norwegian Public Roads Administration, runs the project REHIRUP (Reducing Highway Runoff Pollution).

Microplastics in drinking water is being investigated by the Swedish Food Agency
In 2018, the Swedish Food Agency was commissioned with producing a review of the state of knowledge on health risks related to plastic microparticles and nanoparticles in drinking water, because there is very limited knowledge of the field. An important part of the project is a survey/screening of the presence of plastic microparticles in drinking water. The study of nanoparticles has been discontinued as the Swedish Food Agency judges that more development time is needed before reliable analyses of this can be conducted. The commission also includes, if necessary, proposing measures to reduce exposure and is to be reported in December 2019.

The Agency for Marine and Water Management is working on offshore sources
The Swedish Agency for Marine and Water Management (SwAM) is primarily concerned with offshore sources of litter related to marine litter, and principally with macrolitter. The most common plastic products found in marine litter are lost fishing gear, plastic and polystyrene fragments, and ropes and cords (SOU 2018:84).

SwAM focuses on prevention measures and measures to remove macrolitter from the environment before it breaks down into microplastics/micro debris. Here is a short list of ongoing activities:

- The inquiry *Nedskräpning i marina miljöer [Litter in marine environments]* looks at the possibility of introducing incentives for lost fishing gear, plastic and polystirene fragments, and ropes and cords. The inquiry is expected to be completed in 2019.
- Responsibility for Swedish implementation of the EU Maritime Strategy Framework Directive, which has resulted in an action plan for the marine environment for the North Sea and the Baltic Sea (Good Marine Environment 2020).
- Participation in TG litter established at the request of EU Member States in accordance with the joint implementation strategy of the Marine Strategy Framework Directive. This work includes the development of indicators and threshold values for microplastics.
- Co-financing of the Interreg project, Marelitt Baltic, examines such areas as the best possible techniques for the recovery of lost fishing gear. The project will present its final report in March 2019.
- Makes recommendations for the care and maintenance of mechanical boat washes to reduce the emission of microplastic.
- In 2018, the Agency for Marine and Water Management invested SEK 3.2 million in scrapping leisure craft in 2018, most of which are made of plastic materials. The boat scrapping campaign led to the scrapping of 416 leisure craft, and it has been decided that the campaign will continue in 2019.

The Transport Agency coordinates work on emissions from boat hulls
The Transport Agency is responsible for the "Hull Target" initiative[1] – a joint venture for a non-toxic environment. The project is based on two different commissions: the collaborative measure *Anti-fouling paint and environmentally hazardous paint residues* from the Environmental Target Board and *Good Marine Environment 2020*, fact sheet 17, within the Action Programme for the Marine Environment (Agency for Marine and Water Management 2015:30, 2015).

[1] https://www.transportstyrelsen.se/sv/sjofart/Fritidsbatar/Batlivets-miljofragor/Ren-batbotten/skrovmalet/

The Swedish Chemicals Agency sets limits for microplastics in products
The Swedish Chemicals Agency has previously investigated the need to limit microplastics in certain cosmetic products, and there is currently a national ban on microplastics in products that can be washed off or spit out. The agency is now working at EU level with the European Chemicals Agency (ECHA) to extend the restrictions to more product groups, such as paints and varnishes. A decision will be handed down in 2020 at the earliest.

Many different actions and initiatives are also taking place at local and regional levels. It has not been possible and reasonable to try to describe all of these here. However, some examples are shown in the detailed part of the report and in the supporting documentation.

Examples of measures implemented by the Swedish Environmental Protection Agency

The Swedish EPA is actively working on the issue of plastics, including the problem of microplastics. Examples of actions carried out are provided below. Further examples, such as the pre-procurement purchasing group for artificial grass, can be found in other parts of the report.

New guidelines for industrial plastic production and handling
Material losses from industries producing plastic or plastic products have been identified as one of the major sources of microplastics emissions in Sweden. In a previous commission, the Swedish EPA determined that these emissions are best dealt with by including the issue of material losses of microplastics in guidelines to the relevant stakeholder groups. A draft guidance is now available. This guidance will be extended to other industries, such as textile washing and recycling facilities. The guidance is expected to be completed in 2019.

Suggests milestones for storm water
In its 2018 appropriation instructions, the Swedish EPA was tasked with proposing milestones with incentives and storm water measures for reducing the negative effects on water quality. The commission is closely connected to microplastics because storm water is one of the most important dispersal pathways. The commission report was submitted on 31 March 2019.

Investment aid for storm water measures
In its appropriation instructions from 2018, the Swedish EPA was tasked with distributing SEK 25 million for reducing the negative effects of microplastic particles and other storm water pollutants. Under *Regulation (2018:496) on state aid for reducing the release of microplastics into the aquatic environment*, grants were awarded for investments in technology or other measures aimed at removing microplastics and other pollutants from storm water, or otherwise reducing the emission of microplastics and other pollutants through storm water. Applications that received grants during the autumn of 2018 include storm water management, construction of dams and installation of filters in

storm water wells within the detailed development plan, development, and individual properties.

Research call in the field of microplastics
The Swedish EPA, together with the Agency for Marine and Water Management, has issued a research call in the field of microplastics to research their sources, pathways and effects.[2] The initiative is part of the efforts of authorities to reduce the presence of microplastic and toxicants in the environment. Five research projects were awarded funding and share a total of SEK 25 million. The projects will take place between 2019 and 2021.

The research projects focus on:
- Development of measuring methods and techniques for tracing nanoplastics from waste water and natural waterways;
- Increasing knowledge of the risks of microplastics and proposals for environmental and human health thresholds;
- Sources, sinks and flows of microplastics in the urban environment, where a model describing how microplastics are transported, captured and emitted will be created to show where measures should be taken.
- Microplastics in watercourses, where the properties and impact from organisms to freshwater ecosystems will be studied.
- Development of microplastic analysis methods for research and environmental monitoring, where methodical measurements are expected to provide a better understanding of the relative importance of different sources and pathways for microplastics.

Information about sustainable consumption of textiles
In the 2018 appropriations instructions, the Swedish Environmental Protection Agency was tasked with ensuring the implementation of information efforts to increase consumer knowledge about more sustainable consumption of textiles. These efforts are to include consumer knowledge of the environmental and health impacts of textiles at all stages of the value chain. The Swedish EPA will submit its report to the Government Office (Ministry of Environment and Energy) by 28 February 2021. Information efforts will start at the end of May 2019.

Information and knowledge for the public about reduction of litter
During the period 2018–2020, the Swedish EPA is responsible for developing an action plan for public information efforts to reduce litter. The information initiative will help raise public awareness of the impact of plastic on marine environments. The commission will be completed by 31 March 2021.

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[2] Retrieved from http://www.naturvardsverket.se/Stod-i-miljoarbetet/For-forskare-och-granskare/Miljoforskningsanslaget/Stangda-utlysningar/Utlysning-av-forskningsmedel-for-Mikroplaster/ 7 February 2019.

What we can do now, and in the future

The proposed measures and the measures that we have considered, but are not proposing, focus on two of the largest land-based emission sources: artificial grass pitches (outdoor equestrian arenas and sports and play facilities) and laundering textiles. The proposals are presented below, and the measures considered are in Annex 3.

Emissions to seas, lakes and streams from these sources take place in many different ways: via air, via storm water, via water to the municipal sewage system or directly to the water recipient. Since overview of both emissions and dispersion is difficult, the Swedish EPA has chosen to propose measures that reduce emissions at source as far as possible.

Proposal to the Government

Introduce a notification obligation for facilities using artificial grass, moulded granulate surfaces and equestrian arenas containing rubber or plastics

The Swedish EPA's view is that a notification obligation would provide well-balanced reinforcement of measures already in place.

The notification obligation becomes an additional tool that enables municipalities to set the necessary requirements for the construction and maintenance of the facilities concerned. As it is possible to design precautionary measures that are based on operational and site-specific conditions, they can also take into account measures that are already in progress at these facilities.

The Swedish EPA's commitments

The Swedish EPA is to become a knowledge node

Knowledge about microplastics is developing rapidly, both nationally and internationally. This is welcomed since the large gaps in the current level of knowledge limit what actions can be taken to reduce emissions. At the same time, it is difficult to learn about, gain an overview of, and absorb new knowledge. For this reason, the Swedish EPA considers that a knowledge node that develops, coordinates and disseminates new knowledge is urgently required and the agency undertakes to be such a node. The below proposed budget would allow this work to get started in earnest.

A report by the Plastics Inquiry, *Det går om vi vill* [translation: It is possible if we want to], from December 2018 (Official Reports of the Swedish Government, SOU 2018:84), proposes, among other things, that the government should set up a national resource for coordinating the plastic issue. It is also proposed that the Swedish EPA be commissioned with supporting the

appointed plastic resource with a broad, objective and knowledge-based platform. The Swedish EPA is prepared to support a national resource role, such as by committing to be a knowledge node for microplastics. We believe that a knowledge node will be particularly important over the next five years. The initiative should then be evaluated. The node work would be funded through an increased appropriation sought in the Agency's budgetary documents for 2019–2021. In the report, the Swedish EPA has asked that SEK 15 million is reserved from the appropriation directives for reducing plastics in the sea and nature, sustainable textiles and hazardous waste, and that the grant is increased by SEK 75 million for transfers under appropriation item 1:4 during the period. Examples of measures implemented by the Swedish EPA are:

- Initiatives for supervisory guidance for artificial grass pitches and other outdoor facilities.
- Continued financing of the pre-procurement purchasing group artificial grass.
- Working towards changed criteria in the Ecodesign Directive for washing machines.
- Promote the use of filter solutions for households.
- Measures for laundries.

The Swedish EPA also undertakes to support other authorities as a knowledge node by collecting, summarising and disseminating new knowledge. This experience and knowledge could be collated in a synthesis after a few years.

MEASURES FOR SUPERVISORY GUIDANCE FOR ARTIFICIAL GRASS PITCHES AND OTHER OUTDOOR FACILITIES FOR SPORTS AND PLAY

For the introduction of the notification obligation to have the intended effect, the notification obligation needs to be combined with guidelines, including what may generally constitute relevant precautions for various types of pitches and facilities.

Extending existing guidelines to include all outdoor facilities for sports and play with underlays containing rubber or plastic products

If a notification obligation is introduced, Swedish EPA intends to expand existing guidance on prevention and remediation of adverse environmental impacts of AGPs to include outdoor sports and play facilities with underlays containing rubber or plastic products and equestrian arenas.

If no notification obligation is imposed, Swedish EPA may nonetheless regard it as necessary to extend its existing guidance to also cover management, maintenance and other measures for additional sports and play facilities with underlays containing rubber or plastic products.

Supervision campaign to boost operators' and supervisory authorities' knowledge further

Another measure that might help to ensure that a notification obligation has the intended effect is to combine extended guidance with a supervision campaign to increase knowledge, among supervisory authorities and operators alike, of maintenance and management, and to support exercise of effective, uniform supervision.

The overall goal of such a supervision campaign would be to shed light on the problems, provide support in interpreting the law and inform about any protective measures that may be taken during maintenance and management of the facilities. Similar supervision campaigns have been successfully carried out in other areas; there has, for example, been a campaign to promote supervision of the use of plant-protection products in greenhouses and on golf courses. Experience from such campaigns shows that they can be effective tools to enlarge the scope for uniform, effective supervision that takes site-specific factors into account.

CONTINUED FINANCING OF THE PRE-PROCUREMENT PURCHASING GROUP ARTIFICIAL GRASS

The Swedish EPA has funded a pre-procurement purchasing group for artificial grass (BEKOGR) since 2017. The Swedish EPA's assessment of BEKOGR's work so far is that they have achieved a great deal in a short time. The level of knowledge among municipalities and other stakeholders has increased, many municipalities and associations have taken simple but effective measures to reduce emissions, and a number of different development activities have been initiated to solve the environmental problem of artificial grass pitches.

The Swedish EPA considers that continued funding can provide additional momentum in work within the field of artificial grass. Funding of the pre-procurement purchasing group's work in 2019 is done as part of the Swedish EPA's work to reduce plastics in the seas and nature. Continued funding after 2019 requires additional funds.

WORKING TOWARDS A CHANGE IN CRITERIA IN THE ECODESIGN DIRECTIVE FOR WASHING MACHINES

Pushing development of the Ecodesign Directive for washing machines has great international potential. The Swedish EPA, therefore, proposes that introducing criteria for reducing microplastic emissions into the Ecodesign Directive for washing machines continue to be studied. The Swedish EPA will work to develop the supporting documentation needed for regulations, technical solutions and measurement methods.

The Swedish EPA will hold a meeting with stakeholders to promote development of technology for integrated filter solutions into washing machines and to promote development of a standardised measurement method for microplastic from household washing machines, including active representation in the appropriate standardisation working group. Conducting necessary

activities to reduce plastic in the sea and nature requires continued or increased appropriations to the Swedish EPA.

PROMOTE THE USE OF FILTERS IN HOUSEHOLD WASHING MACHINES

Since the effects of a revised Ecodesign Directive will take time, the Swedish EPA wants to encourage the market introduction and use of filters for household washing machines and shared laundry facilities. There are currently different solutions available on the market, but their purification efficacy and ease of use are uncertain. The Swedish EPA wants to contribute to new and improved solutions reaching the Swedish market by promoting an international innovation competition. The competition will also require the development of a measurement method to enable evaluation of entries received. The Swedish EPA will prepare and plan this international innovation competition during the autumn of 2019. It will have an estimated budget of SEK 5 million and is planned for the period 2020–2021.

MEASURES FOR LAUNDRIES

Promoting the introduction of filters and measurement methods for microplastic pollution from laundries

Even though household textiles are a greater source of microplastic pollution than laundry facilities, efforts for the latter should be encouraged, for example in large-scale laundering of hospital textiles. Laundries positively inclined to introducing filters that remove microplastics in outgoing waste water should be encouraged. The effects of different filter solutions need to be verified, which could be done by contracting consultants. This also requires the development of a measurement method, as the method for measuring microplastic emissions from laundry facilities differs from the method required for washing machines.

Develop guidance for the reduction of microplastic emissions from laundry facilities

Laundry facilities will be included in a guidance on measures to reduce the emission of microplastic from industrial production and the handling of plastic. This guidance is being developed by the Swedish EPA. The guidance will be sent out for a consultation round later in autumn 2019.

New identified sources

The Swedish EPA has continued to investigate sources of emissions. Emissions from building work and demolition waste are considered a source of microplastics. The use of artificial grass in, for example, traffic environments and parks may also cause microplastics emissions, albeit to a lesser extent, while Controlled Release Fertilizers (CRF) are not judged to be used to any great extent in Sweden.

Construction and demolition waste

Sweden's construction industry is estimated to consist of around 60,000 companies of very varying sizes. The actions of large contractors have a big impact on the rest of the sector because of the commonly used contractor structure. The construction industry has developed guidelines for resource and waste management in construction and demolition. The Swedish Construction Federation (Sveriges Byggindustrier) has undertaken to keep the guidelines up-to-date, and a revision is currently under way.

Construction and demolition waste were not highlighted in the previous report (Swedish Environmental Protection Agency 2017). The construction sector is estimated to use around 20 % of all plastics consumed in the EU (PlasticsEurope, 2017), and construction waste is recognised as a source of both macro- and microplastics in several reports (Mepex Consult, 2014; GESAMP, 2016; UNEP, 2016; Bråte et al., 2017). In addition, fragments of expanded polystyrene, often used in the construction sector, have been identified as a significant category among the identified microplastic, particularly on urban beaches (Karlsson et al., 2019). While it has not been possible within the scope of the commission to estimate the significance of this source in relation to the major sources already identified, the EU's plastic strategy states that 5 % of plastic waste in the EU came from the construction and demolition sector in 2015. This is in the same order of magnitude as plastic waste from cars and agriculture. By far the largest share (59 %) of plastic waste consists of packaging (European Commission, 2018a).

Ejhed et al. (2018) have identified sources of microplastics in the City of Stockholm. The report highlights litter from packaging materials (such as plastic shrink and stretch wrap) and expanded polystyrene in new construction as sources of microplastic in Stockholm, as well as the lack of waste disposal in demolition and rebuilding. Due to lack of data, however, the authors could not estimate the size of this source. However, they consider that there is a high risk of dispersal of microplastic because of litter from construction sites.

Agreements can be concluded that include requirements for site cleaning, including the local area, to reduce waste volumes. There are examples of such agreements in which the requirement is combined with using apps that facilitate ensuring the cleaning takes place.

Release of microplastic pollution at construction sites can also occur when plastic pipes and rigid insulating foam, which is often made up of polyurethane, are cut or during sandblasting and grinding (GESAMP, 2016).

Awareness of the problem of microplastic emission is probably low in the industry. There are also few recycling systems, no one will accept plastic or plastic-containing materials for recycling, which leads to no source sorting of waste. In a recycling project, manufacturers are trying to recover pipe waste. A similar system already exists for flooring.

In 2015, the European Parliament agreed to revise EU waste legislation, known as the Waste Package. The package was adopted by the Council of the European Union in May 2018. The revisions are intended to promote

a more circular economy and to be incorporated into the legislation of the Member States in July 2020. The package requires the establishment of a sorting system for construction and demolition waste for at least wood, mineral fractions (concrete, bricks, tiles, ceramics and stones), metal, glass, plastic and plaster.

A lack of knowledge and awareness is one reason for the current situation. Information about effects, sources, what can be done, responsibility etc. could improve the situation. Increasing knowledge makes it easier to change behaviour.

All in all, the above shows that the construction sector is a source of microplastic. This is both direct through activities, such as blasting, grinding and cutting, and indirect through littering during new construction and renovations, as well as during demolition. A lack of knowledge has made it impossible to quantify this source, which is why further investigation is needed. Only then can adequate measures be put in place to reduce microplastic emission.

Artificial grass surfaces without granules

Compared to artificial grass pitches with granules and outdoor sports and play facilities, there has been significantly less focus on other non-granule artificial grass areas and the issue of microplastic dispersal. This means there is a lack of basic knowledge of use, wear, life expectancy, etc. for these artificial grass surfaces.

Parks and schoolyards

Artificial grass without granules is mainly used in areas where you want a durable surface and where the utilisation rate is high, such as schoolyards or park areas. Artificial grass is often used as a substitute for asphalt surfaces or natural grass. Granulate-free artificial grass is considered practical, since it also meets the accessibility requirements for disabled people that are applicable in public places. The Swedish EPA has indications that its use is increasing and believes that more knowledge is needed to determine whether measures to reduce the dispersal of microplastics are relevant, considering possible accessibility requirements and so on. More knowledge is needed on the size of areas covered, wear and tear, and emissions generated before measures can be proposed.

Traffic environments

Artificial grass surfaces are also used for aesthetic purposes, for example in roundabouts, on traffic islands and in other traffic environments. Use has increased in recent years. Alternatives to artificial grass areas are ground materials like cork, wood chips or bark (Krång et al., 2019).

The use of artificial grass on potential green surfaces is a major problem from the perspective of society's current aim to protect biodiversity and achieve many other environmental goals, while urban green spaces are decreasing due

to densification and development. Although artificial grass does not stop storm water from being absorbed, it creates an area that is completely lacking in biological qualities.

The Swedish EPA has considered restricting the use of artificial grass in places where solutions are possible that can better promote ecosystem services and urban biodiversity. Swedish EPA wants to see an increased implementation of multifunctional solutions inspired by nature's own ability to treat and purify storm water. These solutions strengthen biodiversity and contribute to more ecosystem services cost-effectively. As application is more linked to biodiversity and ecosystem services rather than to the release of microplastics, the Swedish EPA has chosen not to propose action within the framework of this assignment.

Controlled Release Fertiliser

In a report, the UN's advisory group, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has pointed controlled release fertiliser (CRF) as a global source of microplastics. CRF has benefits, such as reduced nutrient leakage, but can also result in microplastic pollution (GESAMP, 2016). CRF does not appear to be used to any great extent in Sweden, but data on applications and quantities are difficult to access.

CRF is used in garden products, and then with the suffix cote, for example Osmocote, Basacote and Nutricote. Its use is in volumes of a few hundred tonnes a year. It is unclear how much of this volume consists of microplastic. According to Gunilla Frostgard at Yara AB[3], CRF is not found in products used in agriculture or forestry, at least not to any great extent. It also appears that CRF is not used in the nursery growing of forest plants. It is therefore of little interest to study microplastics emissions from CRF.

Future challenges

Reduce uncertainty in emissions

The first survey of microplastic emission sources from 2017 provides a good basis for further work. Much of what emerged then continues to apply. For example, only two new potential sources have been identified in this assignment. The assessments made of emission volumes were largely based on calculations. The volumes were given in intervals and the uncertainties were very high. This assignment has allowed us to make new estimates for artificial grass pitches that point to significantly lower release levels than previous estimates. We also see that we need even more measurements of actual emissions to increase the certainty of the numbers. For that, comparable measurement methods are needed. The Artificial Grass Pre-Procurement Purchasing

[3] Gunilla Frostgard, Yara AB, written communication 16 November 2018.

Group is working on the issue of artificial grass pitches (AGPs). The situation is likely similar for the other sources when it comes to reducing uncertainty of emission level ranges. Measurement methods need to be developed and measurements taken to improve the knowledge base.

Understand more about risks and impact on the environment

Even though knowledge of the distribution and environmental impacts of microplastics is developing quickly, considerable uncertainty remains. An important necessary step is identifying the plastic particles and then connecting them to their source. This improves understanding of the effects at specific levels of microplastics in the environment. A reference level for sediment content has been developed, but further research is needed.

Synchronise with international efforts

Another challenge is synchronising national efforts with international efforts. This avoids duplication of efforts and reduces costs as analyses, which are very expensive. There has been a lot of activity in the EU, such as the ECHA product ban dossier, the Single Use Plastics Directive and a comprehensive report on the state of knowledge from a multidisciplinary research group (SAPEA, 2019). A knowledge node can prove valuable here.

Litter and the Single Use Plastics Directive

The problem of litter is a continuing challenge. Large parts of the litter are made up of plastic products that have been fragmented into microplastics on beaches and in the sea.

Sweden will implement the Single Use Plastics Directive. The directive will reduce the amount of plastic-containing debris, but we also see that such measures as beach cleaning and changes in the behaviour of those who litter are needed.

Road traffic

Tyre wear and road surface wear are today the largest quantifiable source of microplastics. During wear, particles swirl up into the air and are then transported away before they settle. A large proportion of microplastic from road traffic in urban areas can then be assumed to flow into storm water drains along with rain and melt water. One preventive measure intended to reduce the supply of microplastic particles to storm water is to have the best possible waste management and cleaning for urban streets and park environments. Many studies are ongoing both in Sweden and internationally. Not least, the previously noted VTI commission is expected to contribute to increased knowledge and provide potential actions.

To reduce the total amount of microplastic emissions, it is important that the Swedish EPA monitor and promote development in this area both nationally and within the EU.

Measurement and sampling

Measuring microplastics in the environment is challenging and as the field of research is still relatively new, there are still no standardised methods for sampling, sample processing and analysis. This means there is also a lack of reliable quantitative data, and it is difficult to compare the results of the different studies. Research is constantly developing new methods for measuring and categorising microplastics, and work is ongoing to develop common methods for monitoring microplastics within, for example, the OSPAR and HELCOM marine conventions. The development of reliable standardised measurement and analysis methods is important, not least for the work on what mitigation measures to initiate.

The Swedish EPA sees a great need to follow developments in this area, and through our research calls, we also contribute to the development of new knowledge.

Artificial grass pitches and other outdoor facilities for sports and play

Artificial grass pitches have been identified as the second largest quantifiable source of microplastic pollution in Sweden (Magnusson et al., 2016). In the context of this government commission, the Swedish EPA has reviewed the state of knowledge for emission of microplastics from artificial grass pitches and the measures that can be implemented to further limit such pollution.

Regarding the emission of microplastics from artificial grass pitches to the environment and, in particular, the aquatic environment, the focus has previously been exclusively on artificial grass pitches that use loose granules as filling material. However, new information indicates that other artificial grass pitches and other types of outdoor facilities for sports and playing with plastic or rubber substrates may be potential sources of microplastic pollution.

Artificial grass without granules has been given new and more applications and can be found more and more frequently in playgrounds and multi-pitch areas. Examples of other types of outdoor facilities include playgrounds, running tracks or other areas with fall protection or rubber asphalt, on which moulded granulate is used. Equestrian arenas can also be included in facilities which risk emitting microplastics, as surfaces on horse riding pens are increasingly using rubber or plastic products.

With more applications for plastic- or rubber-based substrates, there is a general increased risk of dispersion of microplastics to the immediate surroundings and beyond to the (aquatic) environment. At present, there is above all a better understanding of dispersion from artificial grass pitches with granules, but there is also increasing knowledge about other types of pitches and facilities.

Artificial grass pitches with and without granules

There are around 1,200 artificial grass pitches in Sweden, with many new pitches being laid every year (Swedish Football Association, 2018). This number can be considered low because the Football Association database is not complete, especially for the smaller artificial grass pitches. The total area covered by these pitches is estimated at 6.9 km^2. (Krång et al., 2019). Artificial grass pitches are used on average for 2,000 playing hours per year (Skåne County Administrative Board, 2016).

Figure 1. An artificial grass system consists of fibres (grass threads), backing (substrate to which the fibres are attached), sometimes wrapping wires (wires that attach the fibres to the substrate), often a shock pad and granules. Illustration from Alphaturf.

Granulate artificial grass pitches

Between 60–70 tonnes of granules are used to build a new artificial grass pitch, depending on the material used. If the pitch has a shock pad, fewer granules are required (Krång et al., 2019).

SBR (recycled car and plant machinery tyres) is the most common fill material for artificial grass pitches and is currently used in more than half of all artificial grass pitches in Sweden (Sweco Environment, 2016). Other materials that are used as fill material for artificial grass pitches are EPDM (newly manufactured vulcanised synthetic rubber) and TPE (newly manufactured thermoplastic elastromer). There is a lack of information that shows differences in the emission risks of microplastics in the environment based on the type of granules used.

Organic fill material is also used, such as cork, bark and coconut fibre. These are, however, not used as frequently due to the difficulty in achieving a material that has equally good properties and for other reasons.

A previous report from 2016 estimated that 2–3 tonnes of granules are dispersed annually from an average full-size football pitch (Magnusson et al., 2016). At the time, it was estimated that an equivalent amount could potentially be lost from the pitches. Since 2016, operators responsible for using these pitches have become increasingly aware of and learned more about the microplastic issue and measures have been taken to reduce loss of material.

The 2017 government commission on sources of microplastics and proposals for measures included a flow analysis illustrating the dispersion of microplastics from artificial grass pitches. This has now been updated and supplemented. New estimates show that small amounts of granule (1–2 tonnes) are filled per pitch compared to a previous estimate of 2–3 tonnes (Krång et al., 2019). Not all the filled volume disperses to the surrounding environment. Much remains in the mat, is returned for example by ploughing and raking, or is discarded. It is difficult to estimate the total flow. Emissions from a full-size artificial grass pitch are assumed to be around 550 kg per year based on the new estimates. The total losses from artificial grass pitches in Sweden will then be on the order of 475 tonnes per year. This is significantly less than the previously estimated range of 1,640–2,460 tonnes per year. The smaller quantities

can be partly explained by better care and maintenance of the pitches, but also new knowledge and an improved estimate method. There is still considerable uncertainty in the figures as the base line is based on estimates, not on measured values. Further measurements should be conducted to increase certainty.

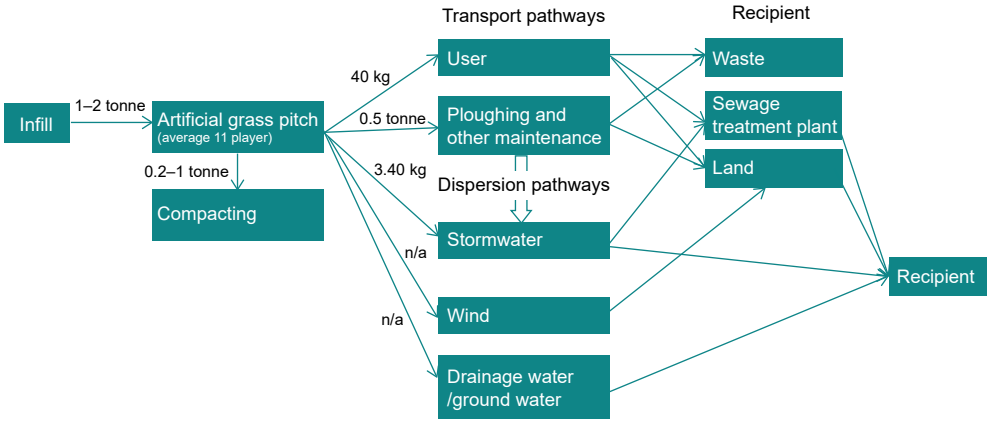

Figure 2. The flow analysis indicates several elements that contribute to dispersion and dispersion pathways from a generic full-size Swedish artificial grass pitch. Model derived by the Swedish EPA from Krång et al., 2019.

Interviews with 20 municipalities show that municipalities differ widely in how much granulate is added to the pitches per year. Some municipalities stated that they add about 500 kg of granulate, while others add 5 tonnes per year and per pitch (Krång et al., 2019).

Granulate is the largest source of microplastics from artificial grass pitches but emissions can also occur from shock pads, backings and artificial grass fibres.

Storm water has been shown to be a dispersion pathway for microplastics to the environment. There is, however, little information about the content and the quantities that are distributed to wastewater treatment plants (Sweco Environment, 2016). Granules can disperse directly to the surrounding environment, for example through wind and precipitation, and can thus reach the final recipient via direct drainage from land (Krång et al., 2019). The results from a Norwegian study analysing bottom sediments from streams near artificial grass pitches show that granules were found in 85 % of the over 100 sediment samples and these granules could be assumed to have come from the pitches (Korbøl, 2018).

A considerable smaller dispersion pathway is via the players who use the artificial grass pitch and carry the granule from the site to changing rooms, surrounding areas or their homes. A major project in Norway measured the amount of granule carried by players on average after training and matches. Players carried 65 tonnes of granule per year from all Norwegian artificial grass pitches (the Norwegian Research Council et al., 2017). A translation into Swedish conditions corresponds to approximately 40 kg per year, per

pitch (Krång et al., 2019). Another study estimates the emission through pitch users at 40–600 kg per year (Regnell, 2017).
During the winter months, snow and subsequent snow clearing can cause a wide dispersion of granules, as the snow cleared from pitches contains large amounts of granules and is often piled at the side of the pitches. When the snow melts, some of the granules remain at the side of the pitch, while a large amount is carried by the melt water and dispersed further through the storm water system.

A survey of both granulate filling and dispersion has been carried out at 30 Norwegian artificial grass pitches. The results show pitches from which snow is cleared for use during the winter are replenished with 3–5 tonnes of granules per year, compared to 0.5–1 tonne for pitches that are not used in winter. (Tandberg & Raabe, 2017). Regnell (2017), who has studied Swedish pitches, estimates that snow clearance of individual pitches can disperse 200–800 kg per year. These figures show that snow clearance is a major factor in the leading to topping up granulate, and this probably also affects the amount of microplastic that is dispersed.

Compacting may also be a significant cause of why the pitches need to be filled with granules, according to most municipalities (Krång et al., 2019). Some municipalities estimate compaction to about 200–400 kg per year.

As can be seen from what has been described above, there is still considerable uncertainty in the total amount of granules that are dispersed into the (aquatic) environment. Since few studies have been carried out and standardised methods of measuring microplastic are not yet available, it has not been possible to quantify total emissions with a high degree of certainty. Although there are uncertainties as to the quantities of granules dispersed annually from Swedish pitches, and the previously estimated quantities have been adjusted downwards, the studies carried out show that there is a significant emission of granules into the environment.

Waste management, or deficiencies in handling, is a significant reason for the emission of macro- and microplastics to the (aquatic) environment (Swedish EPA, 2017). Only limited information about waste management was obtained from the municipalities interviewed. According to this information, mats are often stored in the surrounding area and, in many cases are sent to incineration, landfill or, in a few cases, for recycling. Mats with a large sand content are not suitable for incineration unless the different components (granules, sand, matting) are separated. If this is not done, they end up in landfill (Krång et al., 2019). A lack of waste management can lead to a further dispersion of microplastic, for example, the emissions of microplastic through litter and leachate from storage sites and landfills. However, there is no data on the quantities involved (Magnusson et al., 2016).

In addition to the environmental risk of microplastic, granules may contain substances of very high concern, such as PAHs, metals, phthalates and volatile organic compounds (Swedish Chemicals Agency, 2018). No studies suggest that use of artificial grass pitches or other granular surfaces would

lead to exposure to health hazards. However, precautions should be taken when you are, or have been, on a rubber or plastic-based facility, for example, washing your hands and avoiding getting granules in your mouth (European Chemicals Agency, 2018; Swedish Chemicals Agency, 2018).

Non-infill artificial grass pitches

Non-infill artificial grass is often used in schools, playgrounds, wide football pitches or multi-use sports facilities.

According to suppliers, their service life is about ten years, but may vary with purpose, usage, wear and exposure of the surface. In the interviews conducted by the Swedish Environmental Research Institute (IVL), several municipalities report that mats with granules that no longer meet the standards required for league games are moved to pitches that have lower requirements for playing properties. After removal, the mats are not filled with granules, but are used for up to 15–20 years before they are considered to have reached the end of life (Krång et al., 2019). A longer lifetime may mean that there is a general increased risk of dispersing microplastics to the immediate surroundings and beyond to the (aquatic) environment.

As with a granular artificial grass pitch, there is a risk of dispersal of microplastics from regular use, maintenance, care involving wear of the artificial grass fibres, wrapping wires, backing and shock pads, if present (see the flow model in Figure 2). When a granular artificial grass pitch is considered to be worn out, the material loss has been estimated at about 40 % of the original weight of the mat, and it is likely that non-granular mats have the same material loss from backings and fibres. This could mean a dispersion of about 230 kg microplastics per pitch per year, calculated over a lifetime of 15 years (Krång et al., 2019).

At present, there are few measurements or calculations for microplastic emissions from non-infill artificial grass pitches, which means that it is currently difficult to quantify the importance of non-infill artificial grass pitches as a source of microplastic emissions to the (aquatic) environment.

Examples of ongoing measures

Many municipalities with artificial grass pitches implement measures to reduce the emissions of microplastics from the pitch. Measures have also been implemented at national level. Some of the measures implemented by the Swedish EPA, or in which the authorities are involved, are described below.

Guidance

At the time of publication of the previous government commission (Swedish EPA, 2017), there were no national incentives to reduce the emission of microplastics from artificial grass pitches.

Since then, the Swedish EPA has developed a guide to the construction, maintenance and care of artificial grass pitches (AGPs). The guide was published in March 2018. It focuses on highlighting the responsibilities and obli-

gations of the operator responsible for the AGP, specially aimed at reducing the dispersion of microplastics. The guidance and information have helped many operators to increase awareness of the legislation with which they are obliged to comply.

The effect of the guidance has been deemed to be good, provided that the legal requirements and recommendations described in the guide are complied with. One element of uncertainty is the extent to which the guidance is known and to what extent it is used. If no further measures are introduced, it is likely that the dispersion of microplastics from AGPs will vary widely. Awareness by individual operators and municipalities is crucial. Measures such as notification would provide better tools and a stronger legal basis for minimising the dispersion of microplastics from artificial grass pitches.

The Artificial Grass Pre-procurement Purchasing Group

Most artificial grass pitches (AGPs) are owned, or will be owned, by municipalities or municipally owned companies. This means that the purchase and construction of artificial grass systems and, in some cases, the management of the pitches should occur in accordance with the Swedish Public Procurement Act (2016:1145). Municipalities face similar challenges, and there is a demand for solutions that reduce the environmental impact of the pitches.

To support municipalities and other facility owners in the procurement process and to increase knowledge about the environmental impact of AGPs and how the impact can be minimised, the Swedish EPA initiated a pre-purchase procurement group in 2017. This was one of the proposals of measures presented in report 6772 (Swedish EPA, 2017). The group focuses on the problem of the emission and dispersion of microplastics, but it also examines other related environmental and health aspects.

The Pre-procurement Purchasing Group for Artificial Grass (BEKOGR) is a way of improving the quality of public procurement by jointly building up knowledge and by working together on requirements and methods for procurement and purchasing. By bringing more clients together, the combined purchasing power can help to change supply and practice in the artificial grass market. The demand for alternative materials and artificial grass systems designed to minimise the risk of granule dispersal creates a greater financial incentive for suppliers of AGPs to develop new and improved alternatives (Eunomia Research and Consulting and ICF, 2018).

The pre-purchase procurement group's principal is *Sveriges fritid- och kulturchefsförening* [Swedish Leisure and Culture Managers' Association] (SFK), which is responsible for coordinating and driving the pre-purchase procurement group's work. Members consist of staff from within municipalities' leisure, culture and environmental administrations, property companies, football associations and the Swedish Association of Local Authorities and Regions (SALAR). The members have a common mandate and an opportunity to influence future investments and procurement of artificial grass pitches in their municipalities.

An important part of the pre-purchase procurement group's work is to help coordinate all the initiatives in the field occurring among many different stakeholders. This includes new solutions being tested by municipalities and associations as well as SALAR working in 2019 to produce a framework agreement that will be ready by 2020 (Swedish Association of Local Authorities and Regions, 2019).

Evaluation of the Artificial Grass Pre-procurement Purchasing Group
In 2018, the Swedish EPA evaluated the Artificial Grass Pre-procurement Purchasing Group (BEKOGR). The evaluation shows that the pre-purchase procurement group had a good initial start and that there are clearly documented guidelines and goals for the group's work. Many of the members judge that the pre-purchase procurement group's work will enable a radical reduction in the emission and dispersion of microplastics from AGPs by 2020. (Origo Group, 2019).

The evaluation also shows that there are areas with potential for improvement. These include clarifying the roles and responsibilities of the members, clarifying the process for project funding and intensifying work on procurement criteria, supplier dialogues and procurement documentation.

Based on the results of the IVL report, it is not possible to conclude whether there is any difference in maintenance and measures among the 12 municipalities that form the pre-purchase procurement group and the eight municipalities that are not in the group (Krång et al., 2019). It is clear, however, that the pre-purchase procurement group has brought about a considerable increase in knowledge, with the initiation of several measures as a result. This applies to all the municipalities, i.e., both group members and non-members.

Outdoor sports and play facilities

Facilities with moulded granulate

Substrates with a rubberised surface, such as rubber asphalt or safety rubber, are made of rubber granulate moulded in place. These are often found in playgrounds, running tracks, tennis courts and miniature golf courses, outdoor gyms and other types of sports and play areas, intended to provide shock absorption.

The popularity of the material arises from how it improves availability of playgrounds and increases use throughout the year. There are approximately 430 facilities that use moulded-in-place rubber and more than 100 facilities with safety mats built each year (Krång et al., 2019). While these figures do not show the total amount of these surfaces in Sweden, they still point to a sharp increase in use of this material.

To be approved for fall safety, the rubber surfaces must be 40–100 mm thick. Fall safety rubber is moulded on site into a compact mat, usually con-

sisting of two layers of rubber granules (SBR and/or EPDM). A bottom, yielding layer and a top layer with good UV, heat and weather resistance. The two rubber layers are joined together with a cured binder (Goodpoint, 2016). Running tracks are similarly built, but with less yield. Fall safety mats are pre-moulded and are placed directly on surfaces (Krång et al., 2019).

Figure 3. Fall safety surface where the top layer has been damaged and the base layer is exposed. Photo: Åsa Jarsèn.

The primary reason for replacing a moulded granular surface is because its fall safety properties have diminished or the top layer has deteriorated and the base layer is exposed. In many municipalities, mat wear does not lead to replacing the surface. Instead, the playground in its entirety is only replaced when the play equipment has reached end of life (Krång et al., 2019). This may mean that the moulded rubber is not replaced even if the fall safety layer has become inadequate and there is significant damage. The more wear, the greater the dispersion of microplastics.

Play and sport, ground subsidence and vandalism are among the factors that damage surfaces. Surfaces often show increased wear at the edges, joints and where the surface adjoins sand or gravel surfaces (Krång et al., 2019). This may result in wear, delamination or cracking of the rubber surface, thus increasing the risk of microplastic dispersion. For example, precipitation can transport microplastics to storm water drains.

The granulate that collects in the storm water drains in sand traps or sediment pans can be swirled up and mixed with the storm water during precipitation and high storm water flows. This risks the granulate-laden water being washed away and dispersed via the storm water network to the recipient or wastewater treatment plant. The size of the granulate can be decisive in how much is washed away with the storm water. Smaller sized particles are likely to have a greater tendency to swirl and wash away compared to larger microplastic particles (Krång et al., 2019).

On-site sampling at ten facilities in three Swedish municipalities has shown that loose rubber fragments were found at all facilities, from single pieces up to

5,000 per m^2. Rubber particles were detected in all sediment samples collected from storm water drains directly adjacent to the rubber surfaces, often with the same colour as the encapsulated granulate surface at the site. The result showed a large dispersion of the number of rubber particles, both between different sites and between drains within the same facility. The degree of wear or damage was not clearly linked to the amount of granules found, either on the ground or in the drains (Krång et al., 2019).

A study carried out near a facility with moulded granulate in Lomma found that microplastics had dispersed through the storm water to a nearby river. The storm water drains at the site were equipped with a sand trap, a water trap and a sedimentation pan that the storm water must pass before it reaches the river. Three sediment samples were taken at the outlet of the storm water pipeline and the result showed 130–690 granules per m^2 of the bottom surface. The granules could be traced back to the adjacent facility because the granulate was of a colour and type similar to that used at the facility. Loose granules were observed on all surfaces with moulded granulate. The number varied between 64–36,704 granules/m^2 (Hörman, 2017). In the study, only particles larger than 500 µm have been identified, which may mean underestimation of the microplastic emission.

The amount of granular material dispersed into the environment at national level has not been possible to assess because there are no data on the number and size of the facilities that use moulded granules in Sweden. The granules also consist of different materials and have different sizes, which makes it very difficult to indicate any weight and thus calculate emissions in kilograms. However, IVL has estimated how much granulate may be dispersed from the facilities under investigation. The potential microplastic losses are 135 million granules from the surfaces (285,400 m^2) reported by the interviewed municipalities (Krång et al., 2019).

The results of the sampling from 10 sites included in the survey show a wide dispersal. The volumes of granules measured is often high, but the figures do not show the extent of the losses and even less how much disperses to the (aquatic) environment. Although the sampling is limited, the results of the study are important due to the considerable lack of knowledge in the field. The study is a first step toward recognising a potentially significant source of microplastics, but it is still difficult to assess its importance in relation to other sources.

It is currently uncertain whether outdoor facilities with moulded granules are a significant factor in the delivery of microplastics to the (aquatic) environment. Although it is difficult to estimate the total size of the emissions, the Swedish EPA bases its assessments on data showing that these facilities could be a significant source of microplastic emissions.

Equestrian arenas

Plastic or rubber materials can also be used on equestrian arenas. They are used as surfaces at riding schools, both indoors and outdoors, because they

are considered to improve surface yield and reduce the risk of injury to horses (Krång et al., 2019). Rubber shavings/rubber chips from recycled car tyres or sand mixed with polyester fibre, polypropylene fibre or other synthetic fibres (known as stabilising fibre) are common materials used for equestrian arenas (Swedish Equestrian Association 2014). Their use is increasing and stabilising fibre/rubber chippings are used in most professional facilities, while smaller, often private, equestrian arenas are likely to use them to a lesser extent, possibly due to high purchase costs (Krång et al., 2019).

According to the Swedish Equestrian Association, 52 equestrian arenas have some type of sub-base that consists of plastic or rubber products. This figure is probably on the low side because many equestrian arenas are private and operators have no reporting obligation when changing surfacing materials (Krång et al., 2019).

The problem of microplastics from riding facilities is relatively new, which is why there is not yet enough information about how much is dispersed or the dispersion pathways.

In the interviews conducted by IVL, it is clear that there is little knowledge about the problem of the dispersion of microplastics from equestrian arenas. Many operators probably lack awareness/knowledge of the fact that sub-bases contain plastics or rubber that can disperse to the environment.

Stabilising fibre consists of 10–16 kg synthetic fibre per tonne of sand or 2–3.5 kg per m^2, (higher amounts are used on racecourses to give better traction at higher speeds) (Krång et al., 2019). An average equestrian arena is around 1,200 m^2 in size. This means that 2.4–4.2 tonnes of synthetic fibres are used per arena that can potentially disperse to the environment. One equestrian facility may have multiple riding arenas, which may result in a higher amount of microplastic emission per facility.

It is likely that synthetic fibres are dispersed via raking and mucking out, or directly to the environment from outdoor arenas from wind or precipitation. Equestrian arenas are raked, watered and cleared of horse muck daily or as required. In the case of muck raking, the synthetic sub-base risks ending up on the muck heap. If plastic fibre/rubber shavings are present in manure, which is then distributed for use on arable land, this provides an additional dispersion pathway.

Dispersal from indoor surfaces with a base of plastic or rubber products is likely limited. The problem of dispersal from indoor arenas is that horses transport the sub-base material on hooves and coats, and rider footwear and clothes are also possible dispersion pathways.

When using equestrian arenas, the rubber shavings or stabilising fibre are finely distributed/ground down by sand or horse hooves, enabling them to be dispersed more easily. Municipalities consider stabilising fibre to be worn out based on its age or diminished properties (through wear and tear). The sub-base is either disposed of as waste or transferred to another equestrian arena.

At present, there is limited information about the number of equestrian arenas that use plastic and rubber materials as a sub-base and the amount of

microplastic emitted. This makes it difficult to assess and quantify the source of microplastic emissions from equestrian facilities. Potentially, up to four tonnes of microplastics can be dispersed from an equestrian arena, which can mean that there is a risk of a large amount of microplastic dispersion to (aquatic) environments.

Outdoor sports and play facilities with moulded granules and equestrian arenas

There is currently no guidance on care or maintenance for outdoor facilities using moulded granules and equestrian arenas. The level of knowledge and awareness of the presence and emission of microplastics is considerably more limited in comparison to that for artificial grass pitches. The data that exists, based on the IVL report, indicates relatively large dispersion of microplastics. However, there is considerable uncertainty and further data is needed. Care and maintenance vary greatly between facilities and municipalities. This can vary from a total lack of measures and maintenance to simple measures such as sweeping and washing (but without primary collection of microplastic). If no further measures are introduced, it is estimated that the emission of microplastics from these types of facilities will continue.

Analysis of scope for regulating artificial grass pitches and other outdoor facilities for sports and play

The Swedish Environmental Protection Agency's (EPA's) remit from the Government includes, in particular, analysing various options for regulating the release of microplastics into the aquatic environment. This analysis must cover scope for legislative proposals on regulating their release from artificial grass pitches (AGPs), playing fields and other outdoor sports and play facilities from which there is a risk of microplastic pollution, including installation and maintenance requirements. The analysis must also include whether the above-mentioned pitches, fields and facilities might constitute an environmentally hazardous activity that should be subject to a notification or permit requirement. This section presents the analysis.

Statutory regulation of microplastic emissions

Release of microplastics from AGPs and other outdoor facilities for sports and play can, depending on content, be regulated by laws, ordinances or official regulations.

One prerequisite for regulating emissions of microplastics by statutory means is that there is legal authorisation for doing so. For 'environmentally hazardous activities', such authorisation is available to the Government in the Swedish Environmental Code, in Sections 5 and 6 of Chapter 9.

Can artificial grass pitches and other outdoor sports and play facilities constitute environmentally hazardous activities?

Chapter 9, Section 1 of the Swedish Environmental Code defines what constitutes environmentally hazardous activities. This provision is worded as follows:

'Environmentally hazardous activities' shall mean:

1. the discharge of wastewater, solid matter or gas from land, buildings or structures onto land or into water areas or groundwater;
2. any use of land, buildings or structures that entails a risk of detriment to human health or the environment due to discharges or emissions other than those referred to in point 1 or to pollution of land, air, water areas or groundwater; or
3. any use of land, buildings or structures that may cause a detriment to the surroundings through noise, vibration, light, ionising or non-ionising radiation or similar impact.

As this provision makes clear, the first point covers emissions of, for example, solid matter from land or man-made structures onto land or into in water areas or groundwater, while the second covers use of land or structures in a manner that may cause a detriment to human health or the environment due to discharges or emissions other than those referred to point 1, or to pollution of, for example, land, water areas or groundwater.

Release of microplastics from AGPs and other outdoor facilities for sports and play entails a risk of damage or detriment to human health or the environment for two reasons. First, microplastics do not degrade naturally: they spread and accumulate in the environment. Second, various types of plastic may contain or otherwise spread hazardous substances.

Given these facts, the Swedish EPA has previously taken the position that AGPs, and other outdoor sports and play facilities from which microplastics are released, constitute environmentally hazardous activities under Chapter 9, Section 1 of the Swedish Environmental Code, point one or two. Based on available knowledge and on the investigations undertaken within the framework of this government assignment, nothing has emerged that has given the Swedish EPA reason to change this position. On the contrary, available knowledge indicates that microplastics are released from all categories of AGPs and other outdoor sports and play facilities where rubber or plastic is used as an underlay; see the sections above.

Regulation of environmentally hazardous activities

In general, there are two alternative ways of regulating environmentally hazardous activities: through statutory requirements, which are common to all activities subject to these requirements (general regulations), and through a permit or notification requirement.

General regulations may concern requirements for activities or facilities of a certain type, such as how they must be constructed, maintained and managed.

On the other hand, permit and notification requirements mean, respectively, that a permit must be obtained and notification submitted for installation and operation of the activity in question to be allowed. The permit requirement thus means that, in the absence of a permit, it is prohibited to conduct an activity requiring a permit, while the notification requirement means that conducting the activity before notification has taken place is prohibited.

Conditions may be attached to a permit to conduct an environmentally hazardous activity, as stated in Chapter 16, Section 2 of the Swedish Environmental Code. Such conditions are often individually drawn up for the activity to which the permit relates, by taking into account the specific characteristics of the activity or site, such as the materials used in the activity or the nature of the surroundings.

For the notification requirement, too, in a manner corresponding to that for activities subject to a permit requirement, it is possible to impose individualised requirements based on the nature of the specific activity or site, by ordering precautionary measures.

Regulation of artificial grass pitches and other outdoor sports and play facilities by general regulations and/or a permit or notification requirement

GENERAL REGULATIONS

Chapter 9, Section 5 of the Swedish Environmental Code authorises the Government to issue regulations imposing prohibitions, protective measures, restrictions and other precautions relating to environmentally hazardous activities. Under this authorisation, microplastic emissions can be regulated by general provisions containing requirements for AGPs and other outdoor sports and play facilities.

Such general regulations may, for example, concern requirements for the design of a pitch or facility. They might, for example, stipulate technical solutions to prevent microplastics from spreading in stormwater, such as granule traps or microplastic filters in storm drains next to the pitch or facility, or surface requirements for piles of snow deposited after snow ploughing.

General regulations may also contain maintenance and management requirements, such as an obligation to draw up and follow a maintenance plan. Moreover, general regulations may require self-monitoring and provision of information, such as a requirement to document maintenance measures or report to the supervisory authority on the quantities of infill granules used.

Important questions in this context are whether conditions vary – and the risk of microplastic emissions thereby differs – among categories of pitches and other outdoor sports and play facilities, and if so how.

There is a fundamental difference in technical design among different categories of pitches and facilities, and according to their distinctive areas of use. To some extent, this means that causes of microplastic emissions vary. In addition, within a single category of pitches or facilities, differing techniques are used to install them. Moreover, even for pitches and facilities of identical technical design, conditions can also vary greatly depending on site-specific factors, such as usage patterns or the nature of the surroundings.

Owing to these varying conditions, the Swedish EPA's assessment is that it is difficult to formulate appropriate and effective general requirements covering different categories of pitches and facilities, such as AGPs compared with playgrounds.

Within a single category of pitch or facility, too, defining general requirements that are effective is difficult. This is because it is hard to set requirements that are relevant to different technical designs. This is exemplified by AGPs with and without infill granules. For the former it may, for example, be advisable to impose a surface requirement for snow piles deposited after ploughing, while a granule-free AGP does not necessitate this requirement in the same way. Moreover, for AGPs of a single type, such as those with infill granules, there are often various technical designs depending on the age of the AGP. Accordingly, some requirements are justified on some AGPs, but not on others.

Another important aspect, in terms of the effectiveness of using general regulations, is the rapid technological development of AGPs and other outdoor sports and play facilities. Conceivably, general requirements relevant to existing pitches and facilities may lack relevance to pitches and facilities installed with technology that will become available as early as in the immediate year ahead. Nor, however, is it inconceivable that new requirements for new pitches and facilities of this kind may become necessary. Accordingly, to be kept fit for purpose and effective, general regulations would need to be reviewed regularly. There is therefore a risk of such regulations being one step behind in progress towards effectively regulating microplastic emissions.

One consequence of the foregoing is that, if general regulations are used, provisions would be needed that are specific to different categories of pitches or facilities and, in some cases, also to a variety of technical designs within a single pitch or facility category. Nevertheless, since the parameters of each individual pitch or facility are distinctive, there would remain a risk of such requirements becoming too generally applicable. Accordingly, the requirements would be insufficiently stringent, and consequently ineffective in preventing the risk of microplastic emissions.

All in all, the Swedish EPA's assessment is that there are several different considerations that strongly boost the case against using general regulations to regulate emissions of microplastics from AGPs and other outdoor facilities for sports and play.

PERMIT REQUIREMENT

Pursuant to the authorisation in Chapter 9, Section 6 of the Swedish Environmental Code, the Government issued the Swedish Ordinance on Environmental Licensing (2013:251), which contains provisions on permit and notification requirements for specified environmentally hazardous activities.

If an activity is subject to a permit requirement under the Ordinance on Environmental Licensing, an application for permission to conduct such activity is first examined by the Land and Environment Court ('A' activities) or by the environmental assessment delegation at the County Administrative Board ('B' activities). Under Chapter 22 of the Swedish Environmental Code,

a special procedure applies to such assessment, and it includes environmental assessment under Chapter 6 of the Code. Moreover, under the Swedish EPA's regulations on environmental reports (NFS 2016:8), activities requiring permits are required to issue annual environmental reports. The permit requirement has been deemed justified for activities that typically have the most environmental impact, such as heavy industry.

Based on available knowledge, the Swedish EPA believes that there is no evidence to suggest that the overall environmental impact from AGPs and other outdoor sports and play facilities is, typically, such as to justify imposing a permit requirement.

NOTIFICATION REQUIREMENT

Handling of cases concerning notifiable activities

The procedure for handling cases relating to notifiable activities is set out in Sections 22 and 24–27 of the Swedish Ordinance (1998:899) concerning Environmental Hazardous Activities and Protection of Public Health (the Ordinance). Provisions of this Ordinance include those listed below.

A written notification must be submitted to the supervisory authority in good time before the activity subject to notification begins (see Section 22 of the Ordinance). For AGPs and other outdoor facilities for sports and play, it is the municipality – such as its environmental office or environmental administration – that, pursuant to the Swedish Environmental Code, Chapter 26, Section 3, third paragraph, acts as the supervisory authority.

A notification must contain the data, drawings and technical descriptions that the supervisory authority needs to assess the nature, scope and environmental effects of the environmentally hazardous activity or measure concerned (see Section 25, first paragraph, of the Ordinance).

The government and municipal agencies, and also organisations and individuals who may have a special interest in the matter, must be given the opportunity to comment on a notification (see Section 26 of the Ordinance) in an appropriate manner and to a reasonable extent.

When a notification case has been sufficiently investigated, the agency handling it must order any precautions or prohibitions under the Swedish Environmental Code that are necessary, or require the operator to apply for a permit under Chapter 9, Section 6 of the Code. If such measures are not imposed, the agency must inform the person who submitted the notification that the matter does not give rise to any action on the agency's part (see Section 27 of the Ordinance).

A notifiable activity may be commenced no earlier than six weeks after notification has been made, unless the supervisory authority decides otherwise, as the amended Swedish Environmental Code (SFS 2012:907, available in Swedish only) that came into force on 7 January 2013 makes clear. Accordingly, unless the operator has been informed otherwise within six weeks of the notifying the authority, the activity can start.

Advantages and disadvantages of the notification requirement

One advantage of the notification requirement is that the agency can demand precautions to be taken that are adapted to needs, given prevailing conditions in the specific AGP or facility. Factors specific to the activity and site can then be taken into account. For example, requiring special precautions may be advisable if a facility is located adjacent to a watercourse or protected area.

Consequently, the notification requirement provides scope for adapting the activity by requiring precautions based on factors such as location, technical design, choice of materials, maintenance, information and waste management.

Compared with general regulations, individualised precautions should also be easier to use in relation to technological development. Many different technologies are involved in construction of AGPs and other sports and play facilities. The option of requiring individualised precautions creates scope for the agency to insist on use of the technology that most effectively prevents release of microplastics. There is also scope for linking demands to the technical service life of the AGP or facility. One example is the condition that disposal of end-of-life equipment must conform to waste legislation.

Notification also enables the supervisory authority to prohibit the activity or order the operator to apply for a permit, if there are reasons for doing so.

The notification requirement also means that the Swedish Ordinance on Operator Self-Monitoring (1998:901) becomes effective. This Ordinance entails certain formal requirements concerning the nature and documentation of operators' self-monitoring. The main self-monitoring rule represents extensive, independent responsibility for the operator's part to possess the requisite knowledge and take protective measures, irrespective of supervisory requirements. The requirements in the Ordinance can make it easier for the supervisory authority to assess how the operator's self-monitoring is carried out, thereby making the supervision more effective.

This supervisory area is largely new, and there is therefore a great need for guidance on supervision that promotes its uniformity and effectiveness. Support and advice are required regarding, for example, transmission routes, environmental effects, protective measures, requirement levels and resource management. Experience and results of the supervision are necessary, to develop and streamline it. As long as the state of knowledge is changing relatively fast in the area, there is a need for support and advice to be updated relatively often.

The notification requirement also entails a heavier administrative burden and higher costs for the operator, and more administration for the supervisory authority as well.

An impact assessment of the introduction of the notification requirement and its associated costs may be found in Appendix 1.

Notification requirement in relation to other regulations

Regarding the issue of the additional administrative burden of the notification requirement, it is important to keep in mind which requirements apply and

what inspections of AGPs and other outdoor sports and play facilities – based on other regulations, and especially Sweden's planning and building legislation – are already under way.

Installation of AGPs arranged by municipal clients is usually preceded by planning under the Swedish Planning and Building Act (2010:900). Building permits are required for facilities that constitute sports grounds, but small AGPs and other facilities that are not so categorised are exempt.

Planning under the Swedish Planning and Building Act must take environmental aspects into account and also promote good environmental conditions. In a detailed development plan, the municipality can decide on the location, design and execution of 'construction works', which are defined in the Swedish Planning and Building Act as buildings or other constructions and installations (such as sports grounds). The municipality can also require protective measures to counteract disturbances.

Moreover, under the Swedish Planning and Building Act, general requirements in terms of technical characteristics apply to construction works, for example regarding protection of 'hygiene, health and the environment'. This requirement is specified in the Swedish Planning and Building Ordinance (2011:338), in the rule that construction projects must be planned and executed in such a way as not to entail an unacceptable risk to the hygiene or health of the users or neighbours, particularly as a result of pollution or poisoning of water or soil, and various other environmental hazards.

Under these provisions, the process of planning and obtaining building permits already includes scope for requirements to be imposed, and influence also exerted, on the design of AGPs and other outdoor sports and play facilities, to prevent their adverse environmental impact.

The Swedish EPA believes that there should be synergy effects, based on existing requirements under planning and building legislation, that facilitate management of notification cases owing to the possible introduction of a notification requirement, both for operators and for decision-making agencies.

Moreover, it should be noted that requirements under the Swedish Product Safety Act (2004:451) also already apply to many of the facilities concerned.

Proposed measures

Proposed notification requirement

The Swedish municipalities' awareness of the microplastic problem associated with AGPs has grown. Today, many municipalities are working to a greater extent than in the past in a more structured manner to monitor and prevent emissions from AGPs. The Artificial Grass Pre-procurement Purchasing Group (BEKOGR) and guidance on construction, maintenance and management of AGPs issued by the Swedish EPA are judged to have contributed to this trend.

Nevertheless, many municipalities have indicated that there is opposition to imposing demands on operators without clear, explicit legislative requirements. Within the framework of this government assignment, the Swedish EPA has also received views from supervisory authorities and operators alike that clearer regulation is called for. This is also supported by the Swedish EPA's contacts regarding the work carried out by the Artificial Grass Pre-procurement Purchasing Group and in connection with the Swedish EPA's own provision of guidance for construction, maintenance and management of artificial grass pitches (AGPs).

Of the options analysed above in this document, the Swedish EPA regards imposing a notification requirement as the one with the greatest potential for effectively serving to reduce microplastic emissions. In the Swedish EPA's opinion, the advantages of this option also largely outweigh its disadvantages.

The Swedish EPA's view is therefore that a notification requirement would be a tool that, in a well-balanced way, complements and further reinforces measures already in place. It would represent an additional means for the municipality to set the requirements needed where constructing and maintaining sports and play facilities are concerned. Moreover, it can take into account measures already under way, given the scope for defining precautions based on factors specific to the activity and site.

As reported in the sections above, microplastic emissions from an individual AGP with infill granules can be relatively extensive. Regarding other AGPs, moulded granulate surfaces and equestrian arenas containing rubber or plastic, knowledge is insufficient to obtain reliable estimates of the quantities of microplastics released. Given that the documentation that nonetheless exists indicates that these pitches and facilities may constitute significant sources of microplastic emissions, and that it is also possible for significant amounts to be released from such installations, the precautionary principle should apply. Moreover, although the amounts of microplastics emitted from certain pitches or facilities of this kind may be relatively small, and individually have no major environmental impact, their aggregate volume can be significant. This means that society needs to improve its checking of the above-mentioned facilities as a substantial overall source of microplastic emissions.

In view of the need for more knowledge in this area and the rapid accumulation of knowledge that is constantly taking place, it seems appropriate to analyse the cost-effectiveness of introducing a notification requirement for current pitches and facilities relatively soon after the notification requirement enters into force. In this context, it is also necessary to assess how the notification requirement governs choices of materials for new surface installations.

PITCHES AND FACILITIES THAT SHOULD BE NOTIFIABLE

Based on current knowledge, the Swedish EPA can draw no other conclusion than that all categories of AGPs and other outdoor facilities for sports and play entail a risk of microplastic pollution. One important premise for the notification requirement should therefore be that it must cover all pitches

and outdoor sports and play facilities that have underlays containing rubber or plastic, and not exclude particular categories. This is because the aim is to record all the ways in which plastic or rubber is used in AGPs and facilities, to ensure that none of the latter are left outside the scope of the notification requirement in spite of the risk of spreading microplastics, in the same way as other facilities, associated with them.

Accordingly, the notification requirement should be worded in general terms and cover all categories of AGPs and other outdoor facilities for sports and play where rubber or plastic is used as underlay. Besides every category of outdoor AGPs this includes, for example, outdoor playgrounds, sports grounds and equestrian arenas.

Nevertheless, there should be a lower limit for the scale of activities that are to be subject to the notification requirement. This is essentially connected with the fact that only pitches and facilities on a certain scale should be capable of representing such a major emission risk, as a rule, as to make the activities concerned environmentally hazardous. For practical reasons, too, the starting point should be that an activity must be of a certain size, or on a defined scale, to be covered by the notification requirement. For example, individual fall protection at a playground should not be notifiable unless so much plastic or rubber is used or may be found at other locations within the site, that the notification requirement should apply to the entire playground.

The Swedish EPA considers it important, both for operators and for the supervisory authority, for information on which pitches and facilities are notifiable to be clear. In light of this, the Swedish EPA finds that the criterion for deciding which pitches and facilities are subject to the notification requirement should start with the surface concerned, since the notification requirement is aimed, in particular, at pitches and facilities where the underlay contains plastic or rubber. The surface type is therefore a shared, relevant factor for all pitches or facilities concerned, regardless of what category they are in or their technical configuration. One reason why a different criterion, such as quantities of materials used, is unsuitable is that there is no clear connection, in the same way as for surface type, between the amount of material used and the risk of microplastics spreading. Another reason is that a criterion based on material quantities would entail a lack of clarity regarding which pitches and facilities are covered, partly because of difficulties in calculating and checking the quantities of material used.

From this point of departure, the Swedish EPA has arrived at the position that all pitches or facilities where the total area of underlay containing plastic or rubber exceeds 200 square metres should be notifiable.

At present, facilities that are not for sports or play, such as artificial turf on roundabouts or in parks, should be excluded from the notification requirement. This is connected with, first, the fact that current knowledge of how far microplastics disperse from these areas is limited and, second, that these areas are typically not subject to the same degree of wear as sports or playgrounds; nor, conversely, are they similarly dependent on management and maintenance to remain in use.

Proposed new provision on notification requirement in the Swedish Ordinance on Environmental Licensing

Based on the above considerations, the Swedish EPA has prepared a draft provision on a notification requirement for AGPs and other outdoor facilities for sports and play, according to the summary under the heading Legislative proposal below.

As for other notifiable environmentally hazardous activities, such a provision should be inserted in the Swedish Ordinance on Environmental Licensing. As far as possible, this provision should use the terms and concepts already used in the Ordinance, to link them to existing interpretation and application. Examples are the names of the materials – that is, rubber and plastic – that the provision will cover.

Given that the spread of microplastics is largely a problem concerning pitches and facilities that have already been installed, the Swedish EPA considers that the notification requirement introduced should also cover these existing pitches and facilities. To enable their operators to adapt their activities to the demands imposed by the requirement, it should take effect only after a transitional period. If a notification requirement is introduced, a provision on this transitional period stating when the requirement will become applicable should therefore also be adopted. This provision should come into effect immediately for all new activities – that is, those where installation has not yet taken place and no notification has been submitted. For activities that start before the notification requirement comes into force, and which the introduction of the provision makes notifiable, its effect should be that the activity may continue until a certain specified end date. The activity may then be conducted only following notification and unless the agency handling the notification case decides otherwise. the Swedish EPA considers that a suitable conditional end date for these activities, under the above-mentioned provision, is three years after the notification requirement is introduced.

Legislative proposal

Notification requirement C (and activity code XX) applies to AGPs and other outdoor sports or play facilities or pitches with underlays containing rubber or plastic, if the total area of such underlays within the pitch or facility exceeds 200 square metres.

Efforts for supervisory guidance

For the introduction of the notification requirement to have the intended effect, the notification requirement needs to be combined with guidance on matters including what may generally constitute relevant precautions for various types of pitches and facilities.

EXTENDING EXISTING GUIDELINES TO INCLUDE ALL OUTDOOR FACILITIES FOR SPORTS AND PLAY WITH UNDERLAYS CONTAINING RUBBER OR PLASTIC PRODUCTS

If a notification requirement is introduced, the Swedish EPA intends to expand existing guidance on prevention and remediation of adverse environmental impacts of AGPs to include outdoor sports and play facilities with underlays containing rubber or plastic products.

The proposed notification requirement does not, as such, entail any demands for protective or precautionary measures besides the mandatory self-monitoring requirements that apply to notifiable activities and are elucidated in the Swedish Ordinance on Operator Self-Monitoring. For the notification requirement to result in an expansion of environmental protection, the supervisory authority must take the active step of stipulating precautions that in relation to the individual pitch or facility, unless compliance is deemed unreasonable, are relevant and effective.

If no notification requirement is imposed, the Swedish EPA may nonetheless regard it as necessary to extend its existing guidance to other play or sports facilities with synthetic underlays nonetheless, so that the guidance then also covers management, maintenance and other measures for additional sports and play facilities with underlays containing rubber or plastic products.

SUPERVISION CAMPAIGN TO FURTHER INCREASE KNOWLEDGE AMONG OPERATORS AND SUPERVISORY AUTHORITIES

Another measure that might help to ensure intended effect of a notification requirement is to combine extended guidance with a supervision campaign. This will increase knowledge among supervisory authorities and operators alike during maintenance and care and support effective, consistent supervision.

The overall goal of such a supervision campaign would be to shed light on the problems, provide support in interpreting the legislation and inform people about any protective measures that can be taken during construction, maintenance and care of the facilities. Similar supervision campaigns have been successfully conducted in other areas. For example, there was a campaign to promote supervision of the use of pesticides in greenhouses and on golf courses. Experience from such campaigns shows that they can be effective tools to enlarge the scope for uniform, effective supervision that takes site-specific factors into account.

Continued financing of the pre-purchase procurement group artificial grass

By expanding knowledge levels, the Artificial Grass Pre-procurement Purchasing Group (BEKOGR) has helped many municipalities implement simple but effective measures to reduce emissions and initiate a number of different development activities to solve the environmental problem of artificial grass pitches. An overall assessment of BEKOGR's efforts so far is that it has achieved a great deal in a short time. The Swedish EPA considers that continued funding can provide additional momentum in efforts within the field of artificial grass.

In the case of AGPs and other outdoor sports and play facilities, public stakeholders form the majority of the customer base. So, there is good potential for continued improvements in both the construction and maintenance stages through the work conducted within the framework of the pre-purchase procurement group. An example of a project implemented within the framework of the pre-purchase procurement group is the development of criteria and requirements for public procurement of AGPs. Uniform procurement criteria in municipalities can have a major impact on services and products and promote the development of technology in the field of artificial grass. Continued funding can provide additional impetus for green and innovative procurements, as well as an opportunity to achieve the goal of radically reducing emissions of microplastics from AGPs.

Knowledge about artificial grass with infill granules and its environmental impact is high compared to other sports and play facilities, where plastic or rubber surfaces are used to a significant extent. Since report 6772, the Swedish EPA (2017) has acquired new knowledge that indicates that these sub-bases can also be important sources of microplastic pollution. The Swedish EPA considers that there is now reason to extend the scope of the pre-purchase procurement group's work to outdoor sports and play facilities with other plastic or rubber sub-bases.

In the past, a funding requirement for running a pre-purchase procurement group for AGPs has been estimated at approximately SEK 1.9 million per year over at least a three-year period. During 2017 (6 months) and 2018, the Swedish EPA financed BEKOGR with SEK 1 million and SEK 2.4 million, respectively. Funding of the pre-purchase procurement group's work in 2019 is provided by the Swedish EPA as part of the agency's work to reduce plastics in the seas and nature. Continued funding after 2019 requires additional funds.

In its report 6772 (2017), the Swedish EPA's problem description was that a prerequisite for a pre-purchase procurement group is sufficient interest from the municipalities. The pre-purchase procurement group has now been operating for about 2 years, and there has proven to be great interest. A continuation of the pre-purchase procurement group is regarded as positive by both its members and the Swedish EPA.

Textile laundry

Textile laundry is identified as one of the major sources of microplastic emissions in Sweden. Household laundry produces the most microplastic, followed by emissions from large-scale laundries, while textile production produces the least microplastic.

Reducing emissions of the microplastic generated by washing synthetic textiles is thus a matter of urgency. Some of the actions suggested below take longer to complete, others can be started immediately.

Global production of synthetic textiles has increased from 10 to 65 million tonnes per year since the 1970s (The Fiber Year Consulting, 2018). Less than one per mille of global production is produced in Sweden and totals a few thousand tonnes per year. Consumption of synthetic textiles is more than ten times that of total Swedish production (Swedish EPA, 2017). The consumption of textiles has increased, as has textile laundry. The amount of microplastic generated by washing synthetic fabrics and that accompanies wastewater to the municipal wastewater treatment plant depends on the fibre composition, construction of the textile material and how the material is washed (Salvador Cesa et al., 2017), but also on the way in which the water from the washing machine is purified.

Common synthetic textile fibres include polyester, nylon and acrylic. In Europe, sales of synthetic textiles account for 34–45 %, depending on how viscose is categorised (Eunomia Research and Consulting & ICF, 2018). Textiles are manufactured from various raw materials and using different methods. They can be an environmental burden throughout their life cycle. To avoid emissions of microplastics from textiles, an important preventive measure for avoiding textile microplastic emissions is making changes in production and selection of materials. This will help reduce the ability of the material to shed microplastic into the air and water.

Most textile production takes place outside Sweden and Europe, which limits Sweden's ability to control the choice of materials used. For this reason, demands by individual consumers on the textiles they buy are considered to have the greatest potential for impacting microplastic emissions in Sweden. To make such demands, more knowledge is required. As with estimates from textile laundry, estimates for the emission of microplastic into water from Swedish textile production are very uncertain. Swedish textile production is estimated to generate a maximum of 1 tonne of microplastic emission per year.

Laundry offers another significant opportunity to reduce pollution. When washing textiles, microplastics are shed mainly through wear and tear but also through degradation. In Sweden, microplastic from textile synthetic fibres shed during laundry has been identified as the largest source of pollution upstream of municipal wastewater treatment plants. According to estimates, household laundry contributes 8–950 tonnes per year (Magnusson 2016), which is a higher emission of microplastic than the contribution from laundry facilities of 2.2–115 tonnes per year (Brodin, 2018b).

The large range in the emission estimates reflects the lack of measurement data and knowledge. Measurement methods are needed to be able to compare different textiles, identify improved textile processes and develop better purification methods.

Tumble drying causes 3.5 times more textile fibres to shed than machine-washing (Pirc, 2016). This means that the lack of filters in combined dryer and washing machines poses a bigger problem than the lack of filters in ordinary washing machines. This is because the dry microfibres also go directly into the drains from the combined washing machine/tumble dryers.

The Swedish EPA has produced several reports. The results were presented at a workshop on 13 November 2018 in Stockholm to communicate and acquire knowledge. Participants included representatives from government agencies, companies, laundry facilities and municipalities. The meeting revealed that it is important to look at the textile and microplastic issue from an overall perspective, to strive for circular flows and to take into account other factors that influence the environmental impact. It is also important to work to reduce the tendency of textile materials to shed microplastics. Both general and specific views and suggestions from the participants have been taken into account in the preparation of the proposed measures.

Consumer laundry

Consumer advice

Consumer advice and information about handling and washing synthetic textiles can be one way of reducing microplastic emissions. The Swedish EPA has therefore tried to verify various washing instructions, including those produced by the Mermaids Life project Ocean Clean Wash (2018). Goodpoint was appointed to verify these instructions. Verification was done through independent studies and to include discussion of other environmental factors associated with laundry. The instructions were also studied based on other environmental and health aspects than microplastic pollution.

The potential of the washing instructions for reducing emissions was difficult to estimate. One problem in verifying the instructions is that the conducted studies were not carried out under the same conditions and are therefore not comparable. Another problem is that different types of washing machines differ in terms of microplastic emissions. Top-loading models produce more emissions due to centrifugation at higher speeds and with more water consumption than for front-loading models (Hartline, 2016). A third problem is that the usefulness of some washing instructions could only be verified by a single study.

Consumer instructions could be reformulated to account for more environmental aspects than just reducing microplastic emissions, but some advice is difficult for consumers to apply, for example because washing programmes are often fixed.

The results of the verification will be used in the Swedish EPA's appropriations directives on Information about sustainable consumption of textiles. Information initiatives began in May 2019.

Filter solutions for washing machines

Washing machines may need different filter solutions. Filters can be designed as a laundry bag that is placed in the wash drum itself, as surface-mounted filters, or integrated in the washing machine. EnviroPlanning, with RISE IVF (formerly Swerea IVF) as a subcontractor, has compiled data and initiatives relating to filter solutions for washing machines on behalf of the Swedish EPA. They have also evaluated the function and user-friendliness of three non-integrated filter solutions (Brodin, 2018a).

The summary shows that there are already several filter solutions on the market aimed at consumers. It identifies filters for top- and front-loaded washing machines and filters for individual drains and inadequate drainage systems.

They selected three commercially available filters that were tested for ease of use and the ability to filter out microplastic. The three filters tested are different: One filter is a wash bag, while the other two are fitted on the washing machines at the water outlet.

Figure 4. Tested filter solutions.

All three filter solutions were found to work and capture 30-60 % of the microplastic fibres generated by washing. Ease of use is difficult to assess but does not need be an obstacle. However, the fact that some filters are expensive, both to purchase and to test, is a major obstacle. This shows that filters for water output are available on the market, but verification of how well they work and how best to use them is needed.

Municipalities may benefit from testing filter solutions for household wastewater. This can be done in the form of test and/or pilot installations. There should be information initiatives to raise awareness of the problem and to promote available technical solutions, but only after the filter solutions have been verified.

Integrated filter solutions in washing machines should also be developed. The Ecodesign Directive has an important role to play here.

Influencing through the Ecodesign Directive

Anthesis AB (formerly Anthesis Enveco AB) was assigned by the Swedish EPA to conduct a socio-economic impact assessment based on the filter solutions report (Brodin, 2018a). The aim was to provide further understanding of the Ecodesign Directive as a driving force for reducing microplastic emissions, to provide a basis for future in-depth impact studies, to identify critical knowledge gaps and to place the Ecodesign Directive into the microplastic policy context.

The background report states that a filter criterion may have the potential of achieving the goal of reducing microplastic emissions from new washing machines, but the effect depends on how the requirements are formulated, how effective the filters are and how users use the filters (Swedish EPA, 2019a). According to available sales statistics, a significant proportion of Swedish households with a washing machine should own a new washing machine with a filter more than 10 years after implementation (15 years for the EU as a whole). This means that the impact of the possible inclusion of criteria in the Ecodesign Directive will take almost 5 to 10 years from the introduction of criteria. As we have previously stated, washer dryers currently on the market are expected to release more microplastic into water than conventional washing machines.

There are two ways to formulate the requirements, either as a criterion for filter technology more specifically or as an emission limit. An emission limit has the advantage of being flexible, as a target is set for the amount of microplastic that can be generated during washing, but machine manufacturers are then free to decide how to achieve the target themselves. However, it is uncertain what potential there is for the incentive to contribute to achieving targets for reduced microplastic emissions, and this depends on the level of emissions allowed and on the ability to measure and check the effects regularly. With greater flexibility in how emission requirements should be achieved, an emissions limit would be a more cost-effective solution than deciding that filters should be used.

Whether a filter criterion or emission limit is applied, Anthesis notes that extended reporting and control systems and procedures will be required and these are associated with different types of transaction costs. For example, a standardised method for measuring microplastic emissions will be needed to determine the emission limit. Product development and testing of washing machine-integrated filter solutions should therefore be promoted. If market-based filtration solutions are available, testing of these solutions should be facilitated. The closer to market introduction the integrated filter solutions are, the better potential for introducing criteria for reducing microplastic emissions in the Ecodesign Directive. More knowledge is needed about:

- How to guarantee the performance of the filters outside a controlled test environment.
- How risks associated with user behaviour can be minimised.
- How conflicts with energy efficiency and climate goals can be avoided.
- The extent and distribution of transaction costs linked to reporting and control.

Laundries

The Swedish EPA awarded EnviroPlanning AB, with RISE IVF (formerly Swerea IVF) as a subcontractor, the commission to conduct measurements on wastewater from at least five different laundries that used water-based textile washing. The measurements were meant to improve understanding of the extent to which laundry facilities contribute to the dispersion of microplastic, whether the amount of microplastic generated varies between different types of laundry and how emissions can be limited. The measurements were to provide answers to both the size and type of microplastic generated. In addition to gaining more knowledge of emissions, development of the measurement method was of great interest. The textiles that were washed were healthcare clothing, workwear, hotel textiles and mats (Brodin, 2018b).

In total, six laundry facilities participated in the study. Two of the laundries studied use their own chemical treatment, one uses biological treatment, while the wastewater from the remaining three laundries goes to municipal wastewater treatment plants.

The analyses of the wastewater from the six laundry facilities showed that particles of size 5–15 µm predominate, regardless of the textile type and purification, and that the majority of these are not microplastic. In total, laundries release between 5,000–5,375,000 microplastic particles per kilo of washed textile.

Table 1. Release of microplastic particles from the 6 laundries – worst case scenario.

Textile type	Textile material	Amount of laundered textile tonnes/day	Purification	Number of microplastic particles per kg wash
Work clothes	Polyester, cotton, polycotton, nylon blend	4.3	Biological	N/A
Work clothes	Polyester, cotton, polycotton*	5.1	Chemical	5,375,000
Healthcare clothing	Polycotton*	39.4	No	1,620,000
Healthcare clothing	Polycotton*	41.3	No	249,000
Mats	Cotton, nylon, rubber	5.8	Chemical	534,500
Hotel textiles	Cotton, polycotton*	22.7	No	15,000

* Polycotton is a textile mixture of 50 % polyester and 50 % cotton.

The measurements show that the laundries with cleaning systems had reduced emissions of fibre-shaped particles. Purification reduced emissions of synthetic micro-fibres by 65 % for mat washing and 96 % and 97 % respectively from laundry facilities where work clothes were washed.

Both of the two facilities that washed healthcare clothing do not have cleaning of their water discharge. The result differs significantly between the two laundry facilities. The reason for this is discussed in the report (Brodin, 2018b). The measurement method requires refinement.

A better understanding is needed about how to prioritise filters from sources where emissions are highest. Another possibility for reducing microplastic emissions is introducing closed water systems for laundries.

Removal of microplastic in laundry facilities

In Sweden there is currently no direct control connected to water laundries with regard to the microplastic issue, but wastewater from major water-based laundries are normally sampled and analysed for BOD, COD, oil, phosphorus, nitrogen and metals (Svensk Vatten, 2012).

Chapter 31, Section 1 of the Swedish Ordinance on Environmental Licensing (2013:251) places notification requirements on laundry facilities that do not use solvents, if the facility handles more than 2 tonnes of laundry per day and is not connected to an external wastewater treatment plant.

According to information from two of the largest providers in the laundry industry, outgoing water from most laundries goes to municipal wastewater treatment plants and is thus not covered by notification requirements.

Laundries that currently lack purification and are connected to municipal wastewater treatment plants, for example in industrial scale washing of hospital textiles, are in favour of introducing filter purification. They would also like to continue to participate in the process of verifying filter solutions to promote development of measurement methods. The potential for removal of microplastics from laundry facilities is therefore considered to be very good.

Measurements from industrial-scale laundries show that laundries employing purification have reduced their emission of microplastic. There are thus great opportunities from removing microplastics directly at the laundry. An advantage of early purification is that it minimises the risk of the microplastic degrading or breaking down into smaller sizes. The introduction of filter solutions in laundries compared to purification further downstream can also create added value in the form of reduced emission of other undesirable substances.

The Swedish EPA has considered whether control/requirements for removing microplastic can be made through the Public Water Services Act but has chosen to proceed with other measures for laundries, such as in the form of guidance.

There are examples of municipalities that have produced guidelines for new establishments and changes to laundries, such as the City of Stockholm.

The Swedish EPA is developing guidance on measures to reduce microplastics from industrial production and handling of plastics, and laundries will be included into this guidance.

Methodology development and standardisation

There is a great need for validated and standardised methods to compare the tendency of textiles to shed microplastics, to measure emissions in textile production or laundries, and to set emission limits.

The measurement methodologies differ because the purpose, potential and conditions vary, depending on whether the emissions are from textile production, household laundry or commercial laundries are to be measured.

A measurement method for the analysis of microplastic in water from laundry facilities needs to be developed. Factors that influence the method are how the samples are taken, what is being laundered, what laundry methods are used and how pure the samples are. We have no knowledge of international groups focusing on developing a method of measuring microplastic emissions to water from industrial-scale laundry facilities. The method used for measuring microplastic in textile production cannot be used, for example, in water samples from laundry facilities.

As regards standardisation of the measurement method for household laundering, work has progressed further than for commercial laundries. The same applies to measuring methods for the development of textiles that shed less microplastic, such as the one published by Swerea IVF (Jönsson, 2018).

The European Commission's plan (European Commission, 2018c) for standardisation in 2019 refers to the work of the Cross Industry Agreement (Euratex, 2018). No sub-committee to the European Committee for Standardisation has yet been set up. It is thought that it may take at least three years for a method to be established.

On the other hand, the development of a voluntary industry standard for measuring textile microplastic is under way, based on a method developed at the University of Leeds. Dr Mark Taylor from Leeds University predicts that there will be a standard within one year, provided that ongoing tests do not fail.

Textile production

Most production of synthetic textiles in Sweden takes place in only a few plants. The plants' total production amounts to 1,400–4,128 tonnes.[4] The plants are subject to permits and wastewater output goes to municipal wastewater treatment plants.

[4] These figures are based on the environmental licences of the plants for 2018.

The previous report (Swedish EPA, 2017) concluded that there was a lack of knowledge about microplastic problems among textile manufacturers. In the work with *Dialogue for a sustainable textile value chain*, the Swedish EPA, together with the Swedish Chemicals Agency, conducted a microplastics workshop.[5]

Swerea IVF was assigned by the Swedish EPA to analyse microplastic emissions from a few Swedish textile production plants (Swerea IVF, 2018). The measurements identified microplastic fibres of mainly polyester and polyamide. The number of microplastic fibres greater than 100 µm was estimated at between 1.7 million and 1,175 million per production week.

A rough estimate gives an annual emission to water of 167–705 kg of microplastic from the production units studied.[6] Microplastic fibres less than 100 µm are not included, but total emissions are estimated to be under 1 tonne per year. Compared with the estimate of microplastic emissions from Swedish laundry facilities of 2.2–115 tonnes per year (Brodin, 2018b), microplastic emissions from textile production in Sweden is estimated to be significantly lower.

The study was followed up by a compilation of existing knowledge on analysis of microplastic emissions from textile production plants globally (Goodpoint, 2018). There were no or few new results concerning measurements of microplastic emissions from textile plants, but several initiatives related to methodology development and global microplastic-related textile production were identified.

One of the initiatives under way is a FORMAS funded project called MinShed that is coordinated by Swerea IVF (Rise, 2018). One ongoing project investigating the load of microplastics in the Baltic Sea is Bonus Micropoll (Bonus Micropoll, 2017).

There are several ways to reduce upstream microplastic emissions from textile production. The initiatives that industry is looking at are textile production, changes in washing techniques and improved purification. A report commissioned by the European Commission (Eunomia Research and Consulting & ICF, 2018) presents the state of knowledge in Europe and a series of proposals for measures to reduce microplastic emissions.

One initiative aimed at defining common measurement methods, sharing knowledge and stimulating industrial research is the Cross Industry Agreement (Euratex, 2018).

The *Don't feed the fish* project was presented at ISPO on 29 January 2018 (Mather, 2018). Another ongoing study is by the German BSI, which, through its Textile Mission and its efforts to develop textiles that shed fewer micro-

[5] http://www.naturvardsverket.se/Kalendarium/Dokumentation-fran-seminarier/Dokumentation-fran-Dialog-for-en-hallbar-textil-vardekedja-med-fokus-pa-miljo-och-kemikalier---andra-motet/

[6] Mean diameter 10–20 µm, length 1,000 µm, density polyester 1.37 g/cm-3 = weight per fibre 0.441 ug – 1.7262 ug).

plastics, is studying other washing techniques, such as industrial prewash, and improved removal of microplastics.
In early 2018, Sweden submitted an Initial Position for the EU's work with the Textile BREF. It has helped to clarify the lack of data as well as the need for a harmonised measurement and analysis method at EU level.

The healthcare sector and the National Agency for Public Procurement have asked for more knowledge in order to be able to set criteria to limit upstream microplastic pollution. That is to say, to be able to demand and set requirements for textiles to be purchased.

Proposed measures

Textile laundry is identified as one of the major sources of microplastic emissions in Sweden. Household laundry produces the most microplastic, followed by emissions from commercial laundries, while textile production produces the least microplastic.

Reducing microplastic emissions generated by household washing machines by introducing microplastic criteria in the Ecodesign Directive could have a significant effect. Before any criteria can be introduced, however, more knowledge and research are needed. If a standardised measurement method is available at the next revision of the Ecodesign Directive and integrated filter solutions have been developed and tested, this would increase the potential for incorporating criteria for reducing microplastic emissions into the Ecodesign Directive.

Since the effects from introducing criteria in the Ecodesign Directive will take time, it is also important to have measures to accelerate the introduction of other filter solutions, such as those that can be used with outgoing water from washing machines. This is also justified by the risk of an increase in microplastic emissions should combined household washer dryers without filtration become more common.

Introduction to criteria in the Ecodesign Directive

The socio-economic impact assessment on the introduction of criteria in the Ecodesign Directive for washing machines shows that there may be potential to reduce microplastic emissions. There is a greater potential for combined washer/dryers. In principle, the criteria can be formulated in two ways, either by setting emission limits or by imposing filter solution requirements. Emission requirements require a standardised measurement method for microplastic pollution, while filter solution requirements require the availability of functional filters.

In January 2019, a revised Ecodesign Directive was adopted for washing machines and combined washer/dryers with requirements that will apply from 2021. The revised directive does not place requirements concerning microplastics, but it is stated in Article 8 of the directive that, at the next revision, the

European Commission will assess the feasibility and appropriateness of new requirements for reducing microplastics in water outlets, such as filter requirements. The next revision will occur no later than six years after the recently adopted directive takes effect.

The Swedish Energy Agency will receive the produced documentation on technological solutions and measurement methods and will communicate these to the European Commission. The Agency will also monitor the revision process that will introduce requirements for reducing microplastic emissions from household washing machines.

PROMOTING THE DEVELOPMENT OF THE ECODESIGN DIRECTIVE FOR WASHING MACHINES

The Swedish EPA therefore proposes that additional studies be conducted on introducing criteria for reducing microplastic emissions into the Ecodesign Directive for washing machines. This work will include assembling supporting material needed for developing regulations, technical solutions and measurement methods.

There is great international potential in driving development of the Ecodesign Directive for washing machines forward. This would have an impact throughout the EU, and there is a good chance for it to disseminated to other countries outside the EU.

The Swedish EPA sees several different initiatives that could both pave the way for a revision of the Ecodesign Directive in the slightly longer term while also reducing emissions from textile laundry in Sweden within a few years. Two of these initiatives are described below.

Consultation meeting with stakeholders to promote technological development

The closer to market introduction the integrated filter solutions are, the greater potential there is for incorporating criteria for reducing microplastic emissions into the Ecodesign Directive.

A consultation meeting can be useful for gaining an overview of which stakeholders we need to interact with and to clearly signal to the companies that develop filter solutions that we are pushing for including microplastic emission requirements/limits in the Ecodesign Directive.

The Swedish EPA intends to collaborate with funding organisations to hold an information and consultation meeting to stimulate and facilitate the development of filter solutions. Washing machine manufacturers, filter manufacturers, academia and other stakeholders will be invited. A consultation meeting can also be the start of an innovation contest.

Standardised measuring method for microplastic pollution from household washing machines

A standardised measuring method needs to be developed before the next revision of the Ecodesign Directive and to be able to move forward in the development of filter solutions for household washing machines. Without such a method, it is difficult to compare how effective different filter solutions

are and what purification effect can be achieved. One way of supporting the development of a standardised measurement method for washing machines at the EU level is to actively participate in the appropriate standardisation working groups.

Continued or increased funding of the Swedish EPA's allocations for reducing plastics in the seas and nature are necessary for conducting necessary activities.

PROMOTE THE USE OF FILTER SOLUTIONS FOR HOUSEHOLDS

As the effects of a revised Ecodesign Directive will take time, the Swedish EPA wants to encourage the market introduction and use of filters in households and shared laundry facilities. This is also justified by the risk of increased microplastic emissions from household washer/dryers without filtration. There are currently a number of different solutions available on the market, but their purification efficacy and ease of use are uncertain.

The Swedish EPA wants to contribute to new and improved solutions reaching the Swedish market by promoting an international innovation competition. The competition framework will also require the development of a method of measurement, which will allow a practical evaluation of the entries received. An innovation contest can also serve as an information initiative that communicates the microplastic problem.

The Swedish EPA intends to produce ground rules for an international innovation contest in the autumn of 2019. The competition will have an estimated budget of SEK 5 million, and it is planned to be held during the period 2020–2021, as long as the funding is secured.

MEASURES FOR LAUNDRIES

Several laundries are in favour of voluntarily introducing microplastic purification. Several such initiatives are also in the start-up phase. Upstream work resulting in reduced emissions to wastewater treatment plants from laundry facilities is positive and should be encouraged.

Promoting the introduction of filters and measurement methods for microplastic emissions from laundries

As household textiles laundering constitutes a greater source of microplastic emissions than industrial laundries, these should be given priority, but industrial laundries interested in introducing filtration and, thus, verifying filter solutions and promoting development of measurement methods should also be encouraged. One example of this is large-scale washing of hospital textiles.

Verification of different filter solutions could, for example, be accomplished using consultants. A measurement method is needed to permit these examinations. The method for measuring microplastic emissions from laundries will differ from the method required for household washing machines since the conditions for sampling and measurement differ.

To do this, continued or increased funding of the Swedish EPA's allocations for reduction of plastics in the sea and nature will be required.

Guidance for laundries

The Swedish EPA is developing guidance *on measures to reduce microplastic emissions from industrial production and handling of plastics*, and laundries will be incorporated into this guidance. The proposed guidance will be sent out for comments later in autumn 2019.

In the context of this work, the Swedish EPA will investigate how many of the laundry facilities have their own wastewater treatment and whether they discharge water to the recipient, storm water system or directly to the wastewater network. Other information that will be collected is how many of the laundries have reporting obligations, how they are classified, and what they are washing. According to information from Berendsen[7] and Textilia[8] (oral communication), the majority of wastewater from laundries is sent to wastewater treatment plants. They are therefore not subject to notification requirements.

[7] Rickard Sjögren, Senior Advisor, phone conversation, 22 February 2019.

[8] Jonas Olaison, Director of Environment and Quality, phone conversation 5 February 2019.

The state of knowledge and dispersion pathways

A great deal of research on microplastics is being conducted, but even though there is a growing base of knowledge, there are still considerable uncertainties. The Swedish EPA has, therefore, conducted several projects aimed at gaining a better understanding of sources, dispersion pathways, presence, measurement methods and effects of microplastics (Magnusson & Norén, 2014; Magnusson et al., 2016; Kärrman, Schönlau & Engwall, 2016; Rotander & Kärrman, 2019a; Karlsson, 2019; Ašmonaitė & Carney Almroth, 2019; Karlsson et al., 2018). It is also important to continue to work actively in relevant international forums, such as OSPAR, HELCOM, AMAP and the EU, to promote the development of new methods and to gain knowledge, experience and good practices. In this chapter, we focus on new knowledge about occurrence, effects, sources, dispersion pathways and measurement methods.

Definition

As yet, there is no generally accepted definition of "microplastic" in the research literature, but it generally refers to small pieces of different types of plastic (GESAMP, 2016). In this government commission, as in the past commission, we have chosen to use a broad definition of "plastic". The term includes man-made polymers made from either oil or by-products from oil, or from biomaterials, bio-based plastics. Non-synthetic polymers, like natural rubber and polymer-modified bitumen, are also included, since they share similar environmental characteristics with plastic microparticles.

Plastic particles between 1 nm and 5 mm are regarded in this commission as being microplastic. When we refer to "microplastic particles" or "microparticles of plastic" in this commission, "particle" refers to solid particles, regardless of their form, such as grains, flakes and fibres.

Microplastics are often divided into two groups, primary and secondary microplastic. Primary microplastic is intentionally produced plastic pellets, such as the plastic pellets produced as raw material in the plastic industry. Primary microplastic is also used as scrubber material in various products, and as an ingredient in cosmetics. Secondary microplastic is formed when plastic objects fragment into microscopic particles, for example from plastic litter and during the use of different plastic and plastic-like products. Plastic debris breaks down and fragments in the environment from exposure to sunlight and other external forces. Secondary microplastic is also released from road wear, car tyres and artificial grass pitches (AGPs). AGPs also cause primary microplastic pollution, as the rubber granules that are sometimes used as infill material consist of newly manufactured granules.

The distribution of microplastics in the environment

Although there are high levels of uncertainty, we know with certainty that microplastics are broadly dispersed in the environment and that researchers around the world have found microplastics in seas, lakes and waterways, in sediments, on land, in the air and in animals (Ašmonaitė & Carney Almroth, 2019). High levels of microplastics have been measured on beaches on the Swedish west coast, and results show that the plastic particles on beaches mainly consist of fragments, which indicates that fragmentation of macroplastics is an important source (Karlsson et al., 2019). Measures that reduce the dispersion of macrolitter to the seas and to beaches are therefore also effective in reducing microlitter. In this chapter, we focus on new knowledge about presence of microplastics in Sweden.

Distribution and levels of microplastics in seas, lakes and sediments and on beaches

Distribution and characterisation of microplastics on beaches

Researchers from the University of Gothenburg, on behalf of the Swedish EPA, studied the distribution and composition of microplastics on beaches and in sediments on the west coast of Sweden in 2018 (Karlsson, et al., 2019). The aim was to investigate sources and dispersion pathways, as microplastic can be both carried in by sea currents from far away while also potentially coming from nearby local sources. Presence of microplastic on beaches is rarely investigated, but several beach cleaning initiatives have been conducted along the Bohus coast, which makes it possible to compare the presence of microplastic with the presence of macroplastics. Macroplastic is believed to be an important source of microplastic in seas, but it has been difficult to calculate its significance (Magnusson et al., 2016). The study's results show that the majority of plastic particles on surveyed beaches are fragments of many different colours and shapes, which shows that fragmentation from macroplastics is an important source of microplastics present on beaches (see Figure 5).

Expanded polystyrene (styrofoam) is a common material in beach microplastics, especially on beaches close to urban areas. Fibre from ropes and lines is also common. In addition to fragments, there are also plastic pellets and so-called "fluff", a pre-production plastic that is used in the manufacture of such things as plastic pellets. This demonstrates the importance of good industrial handling of plastic pellets and fluff to reduce waste and dispersion to the environment.

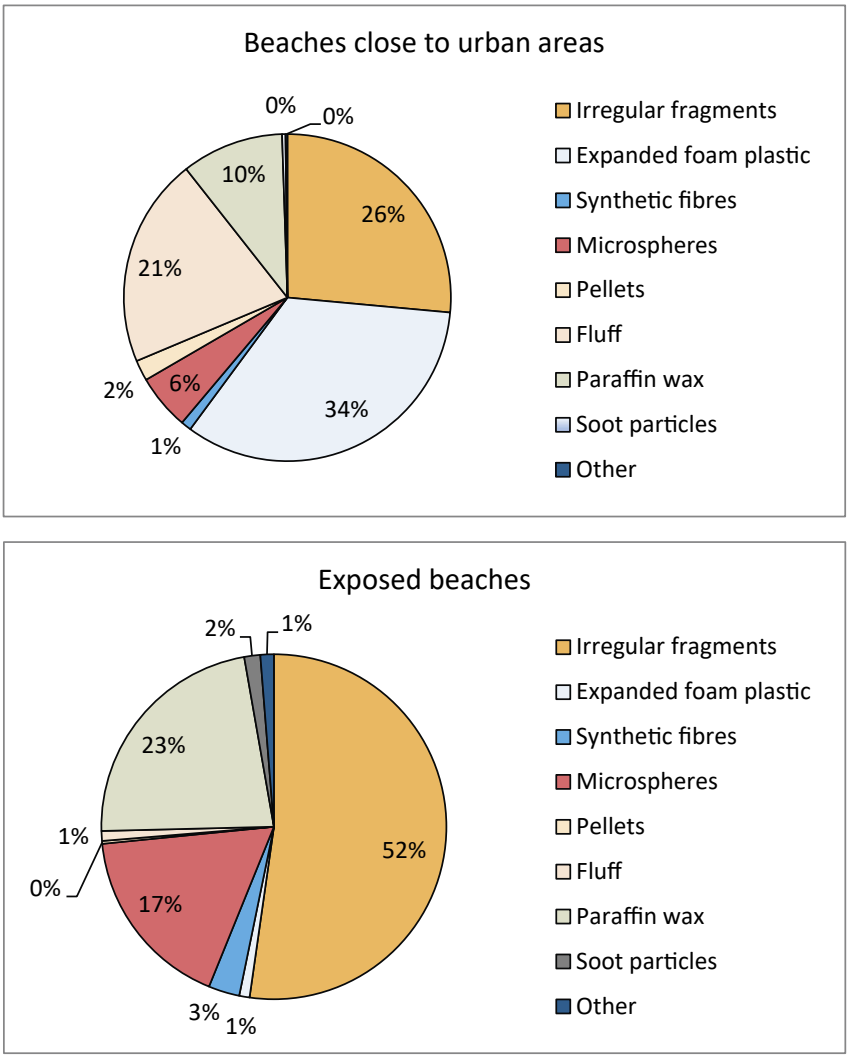

Figure 5. Composition of microparticles on urban and exposed beaches on the Swedish west coast (Karlsson, 2019).

Relatively large amounts of transparent microspheres containing an air bubble (see Figure 6) were also found, something that has not been previously identified. The microspheres in this study consisted of PMMA (polymethylmethacrylate) and are used as filler material in the construction and automotive industries and in asphalt. According to Anna Kärrman[9] at Örebro University, these have not been found by microplastic projects in fresh water conducted in Sweden by Örebro University, but in water samples from the west coast. Additional uses should be investigated to understand how these microplastics are dispersing to the seas and beaches.

[9] Anna Kärrman, Örebro University, Written communication, dated 21 December 2018.

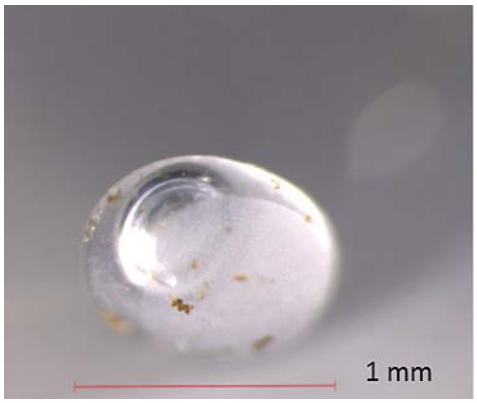

Figure 6. Transparent microspheres, identified as PMMA, have been found on beaches and in the sea on the Swedish west coast. Photo from the University of Gothenburg (Karlsson, 2019).

The study from the west coast found between 3,700 and 97,500 particles per kg, dry weight, on the beaches, several times higher even than the highest reported values from previous studies. For example, concentrations were between 72 and 1,512 microplastics per kg in a survey along 23 European beaches (Lots et al., 2017). However, a direct comparison is difficult since different methods of sampling, sample preparation and analysis were used. However, measurements of macro litter along European beaches show that Sweden's west coast is particularly vulnerable, due to surface currents that transport large amounts of floating debris to Skagerrak from both the North Sea and the Baltic Sea.

A recently published studied (Everaert et al., 2018) estimates that the concentration of microplastic that would have no effect at 540 particles per kg of sediment. The concentration of microplastic measured on the west coast is thus 200 to 4,000 times higher, which shows that the beaches along the Bohus coast are particularly vulnerable areas.

Microplastic in sediment

A significant part of the microplastic entering lakes and seas probably sinks to the bottom eventually. Figure 7 illustrates the type of micro litter identified in sediment outside Stenungssund and the types of polymer of the commonly occurring semi-transparent fragments. The black elastomeric fragments found in the sediment were most likely to be identified as tyre particles. As particle size decreased, the number increased sharply and it was observed that they were encased in sediment close to their sources. The semi-transparent fragments consisted mainly of polypropylene (PP) and polyethylene (PE) and, to a lesser extent, polyvinyl chloride (PVC).

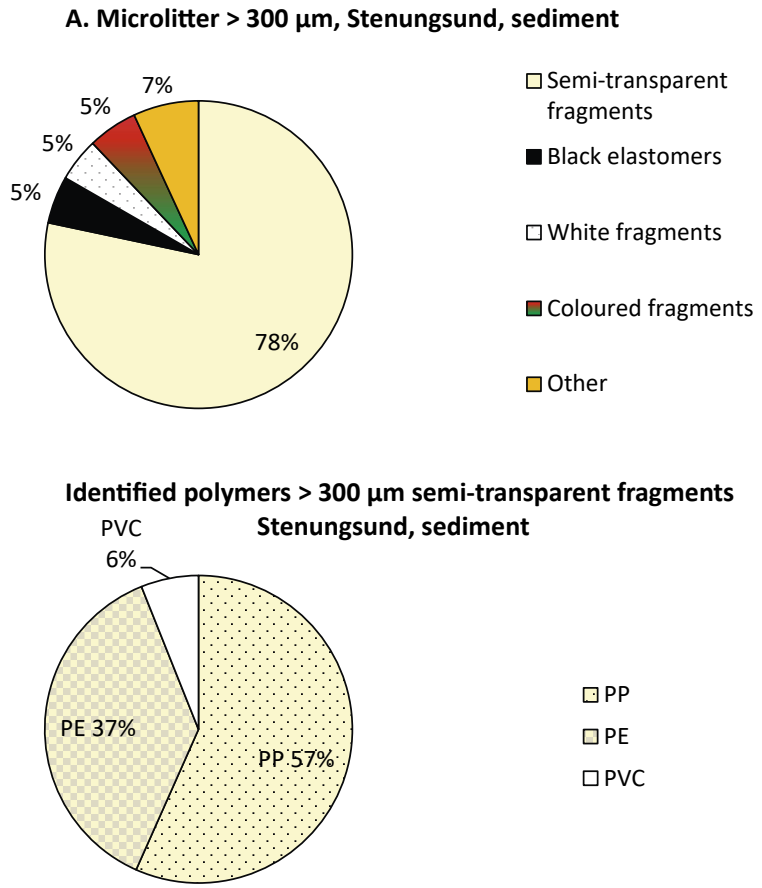

Figure 7. Type of micro debris in sediment from the Stenungsund area and identified polymer types in the commonly present semi-transparent fragments (Karlsson et al., 2019).

Microplastic in lakes

Relatively few studies have been carried out in freshwater environments. In 2017, researchers at Örebro University conducted the first scientific survey of microplastics in the Swedish lakes Vänern, Vättern, Mälaren and Hjälmaren (Rotander and Kärrman, 2019b). The aim was to be able to estimate the presence of microplastics in surface water, both within a lake and also between lakes, and to show possible differences, both in the amount and types of microplastics, between different supply flows to the same lake. The results show that the highest measured levels of microplastics were found in the near-urban inflows to Hjälmaren and Vättern. The measurements also show that the part of the Mälaren lake in central Stockholm had higher levels of microplastics than areas more distant from the city. As cities are a significant source of microplastics, it is to be expected that the highest concentrations will be found in their vicinity and that the concentrations fall with distance and dilution.

The study also reveals the difficulty of measuring microplastics in water, as the amount of microplastics at a measuring point is dependent on many factors, such as season, weather, summer tourism and the ecosystems of the lakes. These factors may vary even on the same day, which affects the results

of the sampling. The presence of microplastic particles of a varied nature could be demonstrated in the four lakes, both in the surface waters and at depth. A statistically significant comparison of the lakes would require a longer longitudinal series of measurements and sampling of larger volumes of water, since the levels of microplastics were low, especially in outer areas of the lake.

Presence of microplastics on land

There is very little knowledge about the presence of microplastics in terrestrial environments, i.e. on land in Sweden, or in other countries. This is partly because it is difficult to measure microplastics in soil (Hurley & Nizzetto, 2018). However, there are some studies conducted on agricultural land where sludge from wastewater treatment plants was used as fertiliser. A Swedish study from 2018 (Ljung et al., 2018) measured microplastic content in sludge-fertilised land as lower than theoretical predictions, based on the content of microplastics in sludge.

Soil fertilised with 1 tonne of DM[10] per hectare per year showed no difference between land that was never fertilised by sludge, while soil fertilised with 3 tonnes of DM per hectare per year had ten times the levels of soil that was not fertilised by sludge. The reason for this is unclear, but the results show the difficulties in measuring microplastic in soil and understanding and interpreting the data available on the basis of limited knowledge about the presence and dispersion of microplastic in soil.

The European Chemicals Agency (ECHA) proposes a ban on the deliberate addition of microplastics to chemical products (European Chemicals Agency, 2019). They have determined that a ban at the EU level is justified to protect health and the environment from the emission of microplastic since microplastics are extremely slow to degrade and virtually impossible to remove once they have been released into the environment. According to ECHA's assessment, microplastics are probably mainly collected in the soil, while a much smaller proportion is directly deposited in the aquatic environment. ECHA also notes that the long-term effects of microplastic emissions (European Chemicals Agency, 2019) cannot be assessed at present.

All in all, there is a continuing need for more knowledge on fragmentation and degradation potential, as well as on microplastic concentrations in arable land and the impact of microplastic effects on organisms living in the soil.

[10] Dry matter.

Effects

In recent years, we have built up a more detailed and nuanced picture of the risks associated with microplastics. The report, "A Scientific Perspective on Microplastics in Nature and Society" (SAPEA, 2019) states that microplastics present no major risk to the environment and health in present concentrations, although there may be locations where there may be a risk of effects. One such site could be beaches along the Bohus coast where concentrations of microplastics are measured 200–4000 times higher than concentration levels in sediment considered safe. If the supply of microplastics to the environment continues in the same way as today, the ecological risks of microplastics could be widespread within a century.

What we know about the effects of microplastics

The Swedish EPA has tasked researchers from the University of Gothenburg to compile the state of knowledge on the effects of microplastics (Ašmonaitė & Carney Almroth, 2019). That report has been used as a basis for this government commission.

The main research in microplastics has been conducted in marine environments. At present, microplastics in fresh water and on land are much less explored. The ecological risks of microplastics are not well known (Gewert, 2018). There are still considerable knowledge gaps about their effects at the organism, population and ecosystem levels, even though extensive studies of the effects of microplastics have been carried out in recent years. The health risks to humans are also very uncertain. At present science has not been able to reach agreement on the health risks of humans. There are also relatively few studies carried out under conditions that would make it possible to extrapolate to conditions that occur in the real environment (Ašmonaitė & Carney Almroth, 2019).

The main difference in the state of knowledge compared with 2016 is that the research world now has a clearer understanding of the complexity of the problem and the mechanisms behind the effects of microplastics (Ašmonaitė & Carney Almroth, 2019). There is also greater consensus on the view that the risks associated with microplastics are lower than we have previously feared, given the current levels of microplastics in the environment. However, the risks can increase as plastic production and consumption increase and as emissions of microplastics and the levels of microplastics continue to increase in the environment. Scientific Advice for Policy by European Academies also comes to a similar conclusion (SAPEA, 2019).

The vast majority of studies are conducted on marine organisms. Effects of microplastics have been studied at several levels of biological organisation, ranging from lower levels, such as molecular interactions like protein changes, to higher levels, such as effects in individual organisms and effects on the ecosystem level (Ašmonaitė & Carney Almroth, 2019).

The state of knowledge is still deficient regarding exposure of microplastics in terrestrial systems, and although there is increasing research on micro-

plastics in this environment, we still know much less about exposure and the processes behind distribution, chemical changes and degradation of microplastics in terrestrial systems than we do in marine systems.
More and stronger negative biological effects are visible at lower organisational levels, such as at the cell level, compared to higher levels, like the organism level. Impact studies show that microplastics can cause oxidative stress, which can lead to damage to DNA. Microplastics can also affect the immune system. Chronic exposure of microplastics through food can lead to damage to the intestines, cell necrosis, changes in metabolism, and changes in fat and energy reserves (Ašmonaitė & Carney Almroth, 2019).

At the individual level, several different types of effects have been observed, including endocrine disrupting effects and effects on animal behaviour, such as foraging and/or mating. The production of gametes can also be affected (Ašmonaitė & Carney Almroth, 2019). However, these studies are often based on extrapolations and theories rather than proven effects, and we therefore note that there is a lack of knowledge about the effects of microplastics at the ecosystem level.

Limitations to the relevance of research studies on the effects of microplastics in the environment

Particle size has been shown to have an impact on the toxicity of plastic particles, in that toxicity generally increases with reduced size. Smaller micro- and nanoparticles have been shown to have greater effects, compared to large micro- and mesoparticles. The shape can also be an important parameter when discussing effects, in that irregular shapes have been shown to cause more and greater effects than smooth, round particles. However, very little is known about the effects of fibres (Ašmonaitė & Carney Almroth, 2019).

Risk assessments of microplastics have often been difficult to make, as in the impact studies of microplastics concentrations or exposure levels have been higher than those found in the natural environment (two to seven times higher). However, there may be some areas of the environment (e.g. microplastic accumulative hotspots or point sources of emissions) with greater risks than elsewhere, where concentrations in these areas can reach levels comparable to concentrations used in laboratory experiments (Ašmonaitė & Carney Almroth, 2019).

The majority of completed effect studies have examined spherical, commercially available microplastics, which rarely have environmental relevance, as microplastics in natural environments both vary in size and shape and consist of different materials with different chemical contents. They have also been affected by degradation from UV radiation and other forces. Many ecotoxicological studies have also focused on concentrations that are significantly higher than those normally found in the environment, which has called their relevance into question. In recent years, an increasing number of studies have also shown a lack of adverse effects from microplastics (Ašmonaitė et al., 2018a; Ašmonaitė et al., 2018b; Rochman et al., 2017). The importance of microplastics has also been compared to other naturally occurring particles,

such as sand and clay (Backhaus & Wagner, 2018). It is still difficult to draw general conclusions about the negative effects of microplastics, but there is more or less consensus in research that the degree of negative effects increases with reduced particle size.

Low potential for bioaccumulation

Microplastics can be taken up in the food web and have been found in organisms far down the food chain, such as plankton, invertebrates and even small fish, as well as in top predators, like marine mammals and seabirds. Transfer of microplastics between different trophic levels, biomagnification, has also been demonstrated in various laboratory experiments (Ašmonaitė & Carney Almroth, 2019).

In marine systems, exposure to microplastics is probably mainly due to intake through food, but exposure can probably also occur through respiratory intake. Microplastics can be taken up directly or through food, i.e. via prey containing microplastics (Ašmonaitė & Carney Almroth, 2019). Growth of microorganisms and the incorporation of chemicals in plastics contribute to the active intake of plastic by making the plastic smell or taste like food. The colour of the plastic also seems to be important.

The role of microplastics as vectors for hazardous substances

Plastic often contains additives that can potentially leach into the surrounding environment. One example of this is additives like softeners, stabilisers and flame retardants (Groh et al., 2019). Some additives used in plastics have known carcinogenic properties, are mutagenic and disturb reproduction (Lithner et al., 2011) and have been shown to be broadly dispersed in the aquatic environment (Ašmonaitė & Carney Almroth, 2019).

Microplastics have also been reported to be able to bind to hydrophobic organic contaminants like nonylphenol, PCB and DDE in seawater, thus enabling them to act as vectors for various environmental pollutants with known hazardous properties (Mato et al., 2001). However, a review of the latest research led to the conclusion that microplastics are probably of negligible importance as vectors for environmental pollution. Plastic nanoparticles, however, that have a larger surface area compared to volume may have a greater importance in this context (Ašmonaitė & Carney Almroth, 2019).

Risks to humans

Several studies show that humans can ingest micro- and nanoplastics, e.g. through water (Pivokonsky et al., 2018; Strand et al., 2018) and food, such as fish or shellfish (Barboza et al., 2018). Other studies have not shown any statistically significant levels of microplastics in drinking water (Uhl et al., 2018). Exposure to microplastics through the consumption of mussels has been shown to be minimal, especially compared to airborne microplastics in dust (Catariono et al., 2018). There are still considerable knowledge gaps in human exposure pathways, and no conclusions can be drawn at present on the risks to humans (Ašmonaitė & Carney Almroth, 2019).

Sources

Even though more and more studies in recent years have established that significant amounts of microplastics are continuously released into the marine environment, there is widespread ignorance of the sources that contribute most. In an attempt to identify point sources of emissions and study the dispersion of microplastic, a screening study was conducted in 2017 on behalf of the Swedish EPA on microplastic from Lake Mälaren to the Baltic Sea (Rotander & Kärrman, 2019a). The study was conducted in Södertälje, and water samples and sediment cores were taken upstream of Södertälje in Lake Mälaren and then downstream, out into the Baltic Sea. In addition to the population, the area is also affected by different types of industries. Södertälje bay is well defined and has few sources of inflow except from runoff from the city and industrial areas.

The level of microplastics in surface water did not increase significantly from the background level in Lake Mälaren to the beginning of Södertälje bay. A certain increase in microplastics in surface water was discernible downstream of downtown Södertälje in the Igelstaviken area with its major industries and in Södertälje harbour. The content of microplastics subsequently decreased downstream and out into the Baltic Sea. The results indicate that there are point sources linked to Igelstaviken and Torpaviken. However, the importance of the point sources for the total emission of microplastics from land to water could not be established. Both boat traffic, industries, and heating plants are linked to the areas. There are no known plastic manufacturers in the areas, so the amount of microplastics released from other manufacturing industries should be investigated.

Dispersion through wastewater treatment plants and storm water

In the Swedish EPA's report on the previous government commission in 2017, it was noted that knowledge of how microplastics are dispersed through various pathways was limited, even very limited, with the exception of dispersion through the sewage system. Knowledge of how microplastics disperse from source to sea, lakes and watercourses remains limited. This describes the current state of knowledge for microplastic dispersion through wastewater treatment plants, including sewage sludge, and storm water.

Dispersion of microplastics through sewage treatment plants

The emission of microplastics from wastewater treatment plants in treated wastewater have been estimated at about 1–19 tonnes of microplastics (Magnusson et al., 2016). According to Baresel et al. (2017) and Ljung et al. (2018), the contributions from wastewater treatment plants are actually at the lower end of the range, i.e. closer to one than 19 tonnes.

Microplastics transported through wastewater treatment plants come from connected households and industries. Microplastics can also be transported to wastewater treatment plants via storm water. However, in Sweden only a small part of storm water, about 13 %, is transported to wastewater treatment plants.[11]

MICROPLASTIC IN WASTEWATER

The degree of separation of microplastics is high in wastewater treatment plants: from 95 % and higher for microplastic particles larger than 300 µm (Baresel et al., 2017). This high degree of separation is verified by a study by Sjölunda's wastewater treatment plant in Malmö conducted between 2016 and 2018 (Ljung et al., 2018). The study showed that the removal of microplastic particles of the purified wastewater was 99 %.

MICROPLASTICS IN SEWAGE SLUDGE, DEBRIS REMOVAL, GREASE AND SAND

The separation of microplastic in wastewater treatment plants means that the microplastics end up not only in the sewage sludge but also in other waste fractions. In the past, it was assumed that the microplastics separated in the treatment process are mostly found in the sludge. However, the 2018 study by Ljung et al. on Sjölunda's wastewater treatment plant suggests that about 60 % of the microplastic is "lost" on the way and that the separation of microplastics into the sludge fraction is closer to 40 % after the cleaning screens.[12] According to the same study, this could be a result of microplastics being removed at the time of debris removal and separation of grease and sand (Ljung et al., 2018). The results can also be explained by large uncertainties in measurements from sampling.

ADVANCED PURIFICATION

Technical solutions for further separation of microplastics and other undesirable substances in wastewater are available as complementary treatment steps to the existing wastewater treatment[13]. Ultrafiltration (UF) is today the only

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[11] Storm water enters the wastewater network in areas with combined sewerage systems and where storm water leaks into the sewerage network in various ways. In combined sewerage systems, storm water is diverted to the purification plants in the same pipes as sewage water and drainage water. Combined sewerage systems are mainly found in older urban areas built in the mid 20th century. The combined sewerage systems account for about 13 % of the sewerage network in Sweden (Svenskt vatten, 2016a). In more recently built urban areas, with separated or duplicate systems, storm water is drained separately and thus does not burden the wastewater treatment plants.

[12] Wastewater treatment plants are cleaned mechanically, chemically and biologically. First, the wastewater passes through a cleaning screen that traps objects larger than 3–6 millimetres, such as tampons and tops. The wastewater then passes to a sand trap. This filters out sand and other heavier particles. Anything heavier than water sinks to the bottom. The sand is pumped from the bottom into a sand dehydration system. The sand is dehydrated before being transferred to a container. Remaining wastewater is filtered and led back to the sand trap and then flows to primary sedimentation.

[13] Read more about advanced purification techniques in the Swedish EPA's report 6772 in the best practices section.

available technology that can provide a complete removal of microplastics from wastewater but the more common disc filters with a pore size < 1 µm are considered to provide almost complete removal (Baresel et al., 2017).

Development and trials of technologies that provide more complete separation of microplastics and other undesirable substances are currently in progress. For example, two of the world's largest MBR plants will be installed at Henriksdal's wastewater treatment plant and Himmerfjärdsverket, both in Stockholm. Several Swedish wastewater treatment plants, such as Ryaverket in Gothenburg, have disc filters installed to achieve more extensive phosphorus removal, which also results in additional microplastic separation. Ultra- and microfiltration (pore size dependent) removes microplastics and provide good pre-purification prior to advanced purification technologies, such as ozone or the use of activated carbon, for the removal of pharmaceutical residue and other contaminants.

DISPERSION OF MICROPLASTICS THROUGH SEWAGE SLUDGE

The microplastics transported to the environment are mainly contained in sewage sludge. Sewage sludge produced at Swedish wastewater treatment plants is used for soil production (27 %), for fertilizer on agricultural land (34 %) and for landfill cover (22 %) (SCB, 2016).

The microplastics that can be assumed to be remaining in debris and fat goes to incineration. It is possible that microplastic can accompany waste sand, which, compared to sludge, accounts for a relatively small proportion of the waste that leaves wastewater treatment plants.

THE DISPERSION OF MICROPLASTIC THROUGH OVERFLOW WASTEWATER

As microplastics are largely separated at wastewater treatment plants, the proportion of microplastics from overflow wastewater is a significant part of the total emission of microplastic from wastewater treatment. During heavy rainfall, wastewater is discharged completely unpurified or incompletely purified to the recipient water.

Instead of letting untreated water pass through, an overflow water treatment can be applied, which mainly separates phosphorus and organic matter. Similar to the efficient separation of particles and microplastics in conventional chemical-precipitation wastewater treatment plants, overflow water treatment should be a means of reducing pollution not only of phosphorus and organic matter, but also of microplastic.

ASSESSMENT OF NEEDED MEASURES FOR REDUCING DISPERSION OF MICROPLASTIC EMISSIONS THROUGH WASTERWATER TREATMENT PLANTS

Based on the current understanding of microplastics, it is doubtful whether additional requirements for the separation of microplastics in wastewater treatment plants can be justified based on the environmental code or other legisla-

tion.[14] This is because microplastics are, for the most part, already separated in a conventional wastewater treatment plant. The water and drainage industry, however, is in a phase where many operations are given new, more stringent environmental permits. Many plants have been in operation since the 1960s and 1970s and are now undergoing renovation and rebuilding. Synergies between nutrient purification, other pollutants and microplastics should lead to increased knowledge of processing technology and increased separation of microplastics as wastewater treatment plants are converted to meet increased purification requirements. The Swedish EPA has also begun to consider choice of technologies when adapting processes for a wastewater treatment plant in connection with assessing environmental permits.

Ongoing measures for advanced wastewater treatment

Development and trials of technologies that provide a more extensive separation of microplastics and other undesirable substances are currently in progress. For example, the Swedish EPA has initiated a pre-purchase procurement group to further develop advanced wastewater treatment for the separation of pharmaceutical residue, microplastics and other undesirable substances. This group, which consists of some 20 representatives of Swedish wastewater treatment plants, aims to review the state of knowledge, advice and guidelines for the industry as a whole and to facilitate exchanges of experience between stakeholders about to conduct procurements and use of advanced treatment technologies. The pre-purchase procurement group will finalize the report in early autumn 2019.

The Swedish EPA has also been commissioned by the Government to allocate investment grants for technologies that remove pharmaceuticals in wastewater treatment plants. These technologies also contribute to reducing microplastic emissions. In addition to the environmental benefits, the treatment plants that now choose to go ahead and apply for investment grants before legislation is in place will also serve as important reference facilities, both nationally and internationally. This offers the opportunity to demonstrate both Swedish knowledge and Swedish technology in water treatment.

Concerning the pre-purchase procurement group, the Swedish EPA estimates that there will still be a need for some form of industry coordination when implementing new technology for advanced purification of all micropollutants after 2019, and this need will likely increase in the coming years as facilities that have been, or will be, granted investment grants in the 2018 and 2019 call for pharmaceutical purification are completed between 2020 and 2021.

[14] As with many other sources of and pathways for microplastics, the problem is relatively new and there is no regulation currently defining requirements for the emission of microplastics from sewage or sludge from wastewater treatment plants. See the Swedish EPA's report 6772, chap. 10, for a review of the regulations controlling emissions from wastewater treatment plants.

In summary, there are clear synergies between the pre-purchase procurement group's work and the investment grant for pharmaceutical treatment. Investment grants for treatment of pharmaceuticals and the pre-purchase procurement group together constitute a package of instruments that will contribute in the long term to significant improvements to the impact of wastewater treatment plants on marine and aquatic environments. For this reason, the Swedish EPA would like to take this opportunity to highlight the benefits of continuing grants for investments in advanced purification after 2019 and the possibility of funding the continued work of the pre-purchase procurement group for advanced purification or a similar function, such as a knowledge platform.

Reduced dispersion through sludge and upstream work

Related to the dispersion of microplastics through sewage sludge, an inquiry is ongoing on *Giftfri och cirkulär återföring av fosfor från avloppsslam [Non-toxic and circular return of phosphorus from sewage sludge]* (Dir. 2018:67). A special investigator has been assigned the task of proposing how to formulate a requirement for phosphorus removal from sewage sludge and a ban on spreading sewage sludge. The commission also includes investigating whether there is a need for start or investment grants for the technical solutions required to recycle phosphorus from sewage sludge. The investigator will also propose how to ensure continued upstream efforts to reduce emissions close to the source after a ban on the spread of sewage sludge has been introduced. A report on the commission will be submitted by 10 January 2020.

The Swedish EPA's assessment is that it is not relevant to present proposals for measures at present, Instead, it will await the proposals from the inquiry. However, the Swedish EPA wants to take this opportunity to stress the importance of efficient and broad upstream work.

The Swedish EPA has previously proposed that the Agency be authorised to produce instructions defining in more detail what a plan for preventive measures should contain. One measure could be to include microplastics (Swedish EPA, 2017). The background to the proposal is that a draft statute was presented in a government commission on sustainable phosphorus removal: *Förordning om produktion, saluhållande, överlåtelse och användning av avloppsfraktioner, biogödsel och kompost [Ordinance on production, marketing, transfer and use of sewage fractions, biofertilizer and compost]* (Swedish EPA, 2013). In addition to the rules on the use of sludge, bio-fertiliser and compost, the draft statute also included wording on the need for documented preventive measures to improve the quality of fractions. This was proposed to occur by the operator establishing a plan that describes the preventive measures taken to minimise the presence of metals, organic substances and other undesirable substances in the fractions. However, microplastics were not included in that proposal. Depending on what the inquiry proposes for upstream work, the proposal that the Swedish EPA be authorised to produce instructions on what a plan for preventive measures should contain may be updated.

Dispersion through storm water

In itself, storm water is not a source of microplastics but can act as a dispersion pathway for microplastics and other pollutants that storm water can carry to seas, lakes and watercourses.[15] In short, wear and outdoor activities that use plastic materials are sources of microplastic where storm water is a significant dispersion pathway. According to IVL's survey of sources of microplastic pollution and dispersion pathways (2016), storm water is the main pathway for microplastics from road and tyre wear, AGPs, industrial production and handling of primary plastics, surface treatment and painting of buildings, and litter. Storm water not only carries plastic and rubber particles caused by wear and tear to the sea, but can also carry larger pieces of plastic, i.e. larger than 5 mm. The larger pieces of plastic may then be broken down into microplastic in the environment. There are still considerable knowledge gaps about the presence of microplastics in storm water, which is why it is uncertain to what extent microplastics from these sources are dispersed to other aquatic environments.

For a detailed description of how the storm water system works in Sweden, see the recently submitted report on the government commission to propose intermediate targets for storm water (Swedish EPA, 2019b).

SUMMARY OF THE STATE OF KNOWLEDGE

There is still a lack of knowledge about the amounts of microplastics dispersed through storm water from various sources to seas, lakes and watercourses. There are also still uncertainties about methods of measuring and analysing microplastics in storm water. For example, more measurements on existing storm water ponds with sedimentation at the inlet and outflow would be needed to improve knowledge of microplastics in storm water and its dispersion to surrounding environments and recipients (Ejhed et al., 2018).

Luleå University of Technology is conducting research on sources, sinks and flows of microplastics in the urban environment, within the framework of the Swedish EPA's research programme on microplastics, for which the final report will be submitted in 2021. The Swedish EPA believes that it is important to continue research, surveying and acquiring knowledge to improve understanding in this area and that the results are utilised.

Purification technology

The need for storm water purification varies according to the pollution it contains, which in turn depends on the catchment area and the sensitivity of the recipient. Storm water purification technologies can include installation of well filters and technical filter systems. In 2017, the Swedish EPA identified a need to expand knowledge of the effectiveness of current treatment technologies for storm water at removing microplastics. Studies show good removal of

[15] Surface water is understood to mean temporary flows of rainwater, melt water, flushing water, outflows of groundwater and similar.

microplastic particles in storm water ponds and engineered wetlands (Coalition Clean Baltic, 2018; Jönsson, 2016). Maintenance of storm water ponds is an important aspect that is regularly highlighted in source materials (Swedish Transport Administration, 2015; Road Administration, 2008). This needs to be explored further to determine the most effective treatment possible.

Report no. 193 from Svenska MiljöEmissionsData (SMED) (Norén et al., 2016) presents a series of treatment techniques for the removal of debris from wastewater and storm water, ranked by cost-effectiveness and utility. The top-rated cleaning techniques were street cleaning and emptying waste bins. The report highlights dry vacuum cleaning as the most efficient form of street cleaning, and it also proved to reduce the particle content in air.

ASSESSMENT OF NEEDED MEASURES TO REDUCE DISPERSION OF MICROPLASTICS VIA STORM WATER

The Swedish EPA sees a continuing need to reduce pollution such as microplastics and substances that impact the environment, such as metals, oils and PAHs, and eutrophication substances from storm water, its recipients and beyond to the sea.

The Agency also notes that it is still important to develop new cost-effective treatment techniques. To develop new technologies, particular attention should be given to methods suitable for treatment in environments close to the sources of microplastics, i.e. road traffic storm water and surfaces in urban areas with a lack of space. It is important, however, that these treatment technologies consider not only the problem of microplastics but also other substances impacting the environment.

In this report, we do not propose any specific measures to reduce the dispersion of microplastics through storm water. In March 2019, however, the Swedish EPA submitted the report *Regeringsuppdrag att föreslå etappmål om dagvatten* [Government commission to propose intermediate milestones for storm water]. In the report, the Agency proposes two intermediate targets and measures to promote sustainable storm water management aimed at adapting society to a changing climate, reducing the emission of pollutants and nutrients, and using water as a resource. Microplastics are not explicitly addressed in the report, but the report's proposals for intermediate targets and measures deal with reducing pollution, which includes microplastics.

To clarify that microplastics are included in the intermediate targets, the Swedish EPA intends to issue guidance on this, assuming that the intermediate targets are adopted. This applies, in particular, to the proposed Intermediate Target 2: By 2025, municipalities with water resources at risk of significant impact from storm water from existing buildings will have conducted a survey and developed measures for sustainable storm water management. The implementation of actions under the measures should also have started.

In this context, the Swedish EPA intends to issue guidance that the source survey of microplastic particles should be included in the survey of sustainable storm water management. The results of the microplastic particle survey

will also be highlighted in the measures to be developed under the proposed Intermediate Target 2.

The Swedish EPA has also received the government commission of awarding grants for investments in technology or other measures aimed at removing microplastics and other pollutants from storm water, or otherwise reducing the dispersion of microplastics and other pollutants through storm water.[16] The grants were awarded for the first time in the autumn of 2018. There are no results yet to be reported, but the agency's assessment is that the grant clearly signals that storm water needs to be cleaned. The grant together with the proposals for intermediate targets and measures constitute a package of instruments that will contribute to significant long-term improvements to storm water impact on the marine and aquatic environments. As such, the Swedish EPA would like to take this opportunity to highlight the benefits of continued funding for storm water treatment after 2019 together with the proposed intermediate targets.[17]

Dispersion of microplastics through the air

Airborne particles are one of the pollutants that cause the greatest health problems in urban areas. Emissions are mainly from combustion and from road traffic. Road traffic, including exhaust gases and tyre, brake and road surface wear, is a source of particulate matter in urban air. According to Grigoratos & Martini (2014), about 3–7 % of PM2.5 is made up of tyre particles (Grigoratos & Martini, 2014).

Microplastics from road traffic are to a certain extent dispersed through the air (Magnusson et al., 2016). We have a better understanding today of dispersion to surrounding soil and aquatic environments than we had a few years ago. In a Swedish study, tyres have been tested in a machine to measure the particles released. The results show the dispersion of some ultra-fine particles less than 5 mm in size. These slightly finer fractions can travel far and clump together with other particles, later landing in the surrounding soil and aquatic environments (Dahl et al., 2005). VTI , the Swedish National Road and Transport Research Institute, has been given a special commission to look at dispersion from road surfaces in more detail. In the Swedish EPA's research call concerning microplastics, projects are also under way to study dispersion through water.

Sampling and measurement methods

Measuring microplastics in the environment is challenging, and since the field of research is still relatively young, there are still no standardised methods for sampling, sample processing and analysis of microplastics. This means that

[16] Read more at http://www.naturvardsverket.se/Stod-i-miljoarbetet/Bidrag/Utslapp-via-dagvatten-2019/
[17] The grant for 2019 may be used for measures to be completed by 2021 at the latest.

there is a lack of reliable quantitative data and that it is difficult to compare results from different studies. However, data on the presence, dispersion and levels, especially in the aquatic environment, is increasing rapidly. Research is developing new methods for measuring and categorising microplastics, and work is underway to develop common methods for monitoring microplastics within, for example, the OSPAR and HELCOM marine conventions. The UN expert group GESAMP has made recommendations on monitoring programmes and methods for marine debris at a global level (GESAMP, 2019).

Measuring microplastics in the environment is time-consuming and expensive. The smaller the particles, the harder they are to measure even though the number of particles increases the smaller the particles are. In the field, microplastics are often measured in surface water, but it is difficult to take representative samples because the distribution is uneven and is affected by the weather and wind. Information on levels, trends and geographical distribution of microplastics is important for tracing sources and pathways and, thus, for the implementation of appropriate measures. The ability to categorise microplastics according to size, shape, type of plastic and chemical content is critical.

In 2017, the Swedish EPA and the Marine and Swedish Agency for Marine and Water Management commissioned researchers from the universities of Gothenburg and Örebro to investigate the difference between different sampling methods for microplastics in water (Karlsson et al., 2018).

Manta microplastics sampling trawl net and pumps, which are two common methods for sampling microplastic over 300 µm in water, were compared under winter conditions at the same location in Gullmarsfjorden for one day. The pump samples contained between 0 and 8 microplastic particles which, by volume, produced an average of 0.17 MP/m^3. The trawl samples gave a significantly higher concentration than the pump samples. The variations in measurement uncertainty between the methods are considered mainly related to sample volume differences, since the sample volume of the trawl was three times larger than that of the pump. The composition of the microplastics also differed between the sampling methods. For example, a higher concentration of cellular plastic was measured using the trawl. Cellular plastic is light and floats on the surface, which means that the pump, which takes samples just below the surface, misses these to a greater extent. Weather and wind conditions affect sampling with a trawl as it makes it difficult to estimate the volume of water sampled. The study shows the difficulties in monitoring microplastics in the environment and that there are many factors that affect the results. The purpose of the monitoring needs to be clear, and it, in turn, has to determine what to monitor and how to do so to make it meaningful and that the results are useful as supporting data and for follow-up of measures.

As a significant proportion of the microplastics in the sea will sink, sediment is also a relevant matrix to analyse. Measuring microplastics in sediment or soil is challenging and requires effective sample processing and extraction. Generally, independent of matrix, sufficient volumes of samples are required to produce any statistically significant data. The size of the fraction measured

will also affect the result, as the number of particles per sample increases as they become smaller. An accurate description of how sampling, sample treatment, processing and analysis are carried out is essential for the use and comparison of results between studies.

When measuring microplastics near the source or at the point of emission, sampling and measurement methods should be chosen based on needs. Various methods can be useful, depending on the purpose of the survey, the type of microplastic (such as pellets from the plastic industry, textile fibres from textile laundry or rubber granules from AGPs), and the relevant matrix (such as soil or sludge). Within the framework of the Swedish EPA's pre-purchase procurement group for artificial grass, the Agency has financed a project to investigate available analysis methods that are suitable for measuring the dispersion of microplastics in water from artificial grass (Ecoloop, 2018). The project shows that there are several analysis methods feasible for measuring microplastics from artificial grass, but that at present there is no single method that works for all types of filling materials and artificial grass. Further development of methodologies is therefore required.

Awareness of the presence of plastic nanoparticles in the environment is increasing, but there are no available methods for sampling and analysing nanoplastics in the environment. Nanoplastics could be formed from degradation of microplastics or wear of plastic products. Improved knowledge of nanoplastics is desirable since they probably behave differently in the environment and have completely different, and likely more potent, effects than microplastics.

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Annex 1. Impact assessment of notification requirement proposal

1 Description of issue

Artificial grass pitches (AGPs) and other facilities using plastic materials are a source of dispersion of microplastic particles into the environment. The problem analysis shows that the way an AGP is constructed, managed and maintained determines how much microplastic is shed from the pitch. Apart from guidances, there are currently no specific incentives for this area, and the Government has instructed the Swedish Environmental Protection Agency to investigate the potential for regulating these with general requirements for installation and maintenance or requiring notification and permits. The legal analysis shows that the requirement to report can be a possible incentive for getting operators to take preventive measures during construction, maintenance and upkeep.

2 Baseline

What happens if the proposal is not implemented? A great deal has happened regarding AGPs, such as the Swedish EPA's guidance, pre-purchase procurement group and active municipalities (see also chapter on AGPs and other outdoor facilities). Many municipalities have adopted or are in the process of adopting preventive measures on a voluntary basis. However, in the case of equestrian arenas and installations using moulded granulate material, it is assumed that few or no protective measures will be taken without further governance.

3 The proposal

The proposal means that operators of AGPs, equestrian arenas and outdoor facilities larger than 200 m^2 using moulded granulate have a notification requirement. The following is a description of the consequences for operators of the various installations.

4 Consequences for AGPs

Which stakeholders are affected by the proposal?

The proposal will mainly affect those municipalities that have not already taken note of the issue and taken preventive measures.

Operators

The proposal affects operators who own and operate AGPs, mainly municipalities. There are about 1,300 large AGPs and an unknown number of smaller pitches. New facilities are directly affected by the notification requirement. Changes to facilities will also be affected if the change is significant in

terms of disrupting operations.[18] Existing facilities will be affected in the long term when the notification requirement also becomes applicable to them.

Regulatory authorities
The regulatory authorities are affected by the need to spend time on applications and to exercise supervision. However, they can charge full cost coverage for this work. For this reason, only the costs for operators are described below.

How are operators affected?
Administrative costs
Costs of submitting an application. 8 hours x SEK 390 (SCB) = SEK 3,100 one-off cost.

Costs incurred by the regulatory authority paid for by the operator:

- Costs of processing the application including orders to take precautions and preventive measures approx. 5 hours x SEK 1,180 per hour (Stockholm City's rate for 2019) approx. SEK 6,000, one-off cost.
- Costs of supervision. Depending on how much supervision the municipality assesses the pitch to require. We estimate this to about SEK 3,000 per year.

Costs of preventive measures
Costs of any precautionary and preventive measures the regulatory authority chooses to impose will be covered by the operator. Examples of potential protective measures that have been identified for AGPs are the construction of a designated site for cleared snow, the installation of granule traps/microplastic filters in storm water drains and brush stations for the players, as well as creating a hard surface around the facility. It is not currently known how many have already taken protective measures, but based on the IVL study in 20 municipalities, there already seems to be some ambition to take measures. Common measures among these municipalities were granule traps and snow clearance sites.

The following briefly describes these measures and estimates the costs, benefits and number of stakeholders expected to be required to take the measures when the notification requirement is introduced, compared to the zero option. The costs are estimated for full-size (11-player teams) football pitches.

Brush stations for players
Description: Off-pitch brush stations that players can use to brush off granules and fibres as they leave the pitch.

Benefit: Uncertain how much microplastic the brush stations will collect. Difficult to predict how many stations are being used.

Cost: SEK 5,500.

[18] See Chapter 1, Section 11 of the Swedish Ordinance on Environmental Licensing.

Granule trap
Description: Granule traps are installed in storm water drain wells.

Benefit: Ensures that microplastic does not reach waste water treatment plants and recipients via storm water.

Cost: SEK 2,600 each. The total cost is dependent on the number of storm water drain wells installed at the pitch. 5 wells per pitch SEK 13,000.

Microplastic filter
Description: Filters installed in storm water drain wells.

Benefit: Also traps smaller particles that pass through the granule trap. Can be combined with separation of metals and PAH.

Cost: approx. SEK 3,500 each, 5 wells per pitch SEK 17,500.

Hard surfaces outside the pitch
Description: surface areas around the pitch

Benefit: Granule dispersion to the surrounding area can be collected and returned to the pitch.

Cost: An asphalt surface is estimated to cost around SEK 500,000, although costs may be lower for other hard surface options, such as extending the surface of the artificial grass beyond the touch lines of the pitch.

Snow storage site
Description: A designated area with a hardened surface or use a part of the field where snow is placed after clearing the field.

Benefit: Since the greatest emissions occur during snow removal, providing a depot spot for the snow radically reduces emissions.

Cost: Cannot be estimated as it is site-specific and depends on the potential for the pitch and adjacent area.

Costs for training, maintenance plan and self-inspection
Training: Costs/time for training of staff on how to manage the tracks to minimize emissions of microplastics. 8 hours x SEK 390 (SCB) = SEK 3,100

Maintenance plan: The time required to produce the care and maintenance plan. 8 hours x SEK 390 (SCB) = SEK 3,100.

Self-inspection: The time required for documentation, procedures, lists etc., according to the Regulation on self-inspection by operators will have to be met. 8 hours x SEK 390 (SCB) = SEK 3,100.

Total costs for an artificial grass pitch

We do not know how many of the existing pitches have begun with these measures or how many will have to begin if the notification requirement is introduced. The estimated total cost of preventive measures for a newly laid full-size pitch taking all the above precautions is SEK 536,000. The administrative costs amount to SEK 9,100 in one-off costs plus approximately SEK 3,000 per annum. Other costs are estimated at approximately SEK 9,300 per year.

5 Consequences for equestrian arenas

Which stakeholders are affected by the proposal?

Owners and operators of equestrian arenas are local authorities, the Swedish Equestrian Federation and riding clubs. It is unclear how many equestrian arenas using plastic or rubber substrate there are in Sweden. There are 450 riding schools affiliated with the Swedish Equestrian Federation. Of these, 40 state that they have used plastic in the substrate. New facilities are directly affected by the notification requirement. Changes to facilities will also be affected if the change is significant in terms of disrupting operations.[19] Existing facilities will be affected in the long term when the notification requirement begins to apply also to them.

How are operators affected?

Administrative costs
The same as above for AGPs.

Costs of preventive measures
Costs of any precautionary and preventive measures the regulatory authority chooses to impose will be covered by the operator. We do not know how many facilities currently use a substrate with a plastic or rubber mix, but there are about 40 among Equestrian Federation facilities. If the same distribution applies for the whole country, approximately 10 % of all arenas will be affected. No measures have yet been adopted at these equestrian arenas.

Closed retaining bank or fence
Description: Reduce the dispersal of microplastic particles from the riding track in wind and rainfall.

Cost: Depends on selection of materials. A typical riding track is 20 x 60 metres, i.e. a total of 160 m of fencing. Wooden fencing @ SEK 60 per metre = SEK 9,600 Concrete fencing approx. SEK 360 per meter = SEK 57,600. (Swedish Equestrian Federation)

Fibre trap
Description: Fibre traps installed in storm water drain wells.

Benefit: Ensures that microplastic does not reach waste water treatment plants and recipients via storm water.

Cost: approx. SEK 2,600 each. Approximately 5 wells per facility. SEK 13,000.

Microplastic filter
Description: Filters installed in storm water drain wells.

Benefit: Traps even smaller particles

Cost: approx. SEK 3,500 each, approx. 5 traps per facility. SEK 17,500.

[19] See Chapter 1, Section 11 of the Swedish Ordinance on Environmental Licensing.

Costs for training, maintenance plan and self-inspection
Training: Costs/time for training of staff on how to manage the tracks to minimize emissions of microplastics. 8 hours x SEK 390 (SCB) = SEK 3,100.

Maintenance plan: The time required to produce the care and maintenance plan. 8 hours x SEK 390 (SCB) = SEK 3,100.

Self-inspection: The time required for documentation, procedures, lists etc., according to the Regulation on self-inspection by operators will have to be met. 8 hours x SEK 390 (SCB) = SEK 3,100.

Total costs for an equestrian arena

There will be an estimated total cost of preventive measures for an equestrian arena taking all the above precautions of between SEK 40,100 and 88,100. The administrative costs amount to SEK 9,100 in one-off costs plus approximately SEK 3,000 per annum. Other costs are estimated at approximately SEK 9,300 per year.

6 Consequences for facilities with moulded granulate surfaces

Which stakeholders are affected by the proposal?

Operators who own and operate facilities using moulded granulate. These are mainly municipalities, but there are also private operators. The number of facilities is unknown. New facilities are directly affected by the notification requirement. Changes to facilities will also be affected if the change is significant in terms of disrupting operations.[20] Existing facilities will be affected in the long term when the notification requirement begins to also apply to them.

Consequences: How are operators affected?

Administrative costs
The same as above for AGPs.

Costs of preventive measures
Costs of any precautionary and preventive measures the regulatory authority chooses to impose will be covered by the operator. It is not known how many facilities have taken these measures today, but there are probably few.

Granule trap
Description: Granulate traps installed in storm water drain wells.

Benefit: Ensures that microplastic does not reach waste water treatment plants and recipients via storm water.

Cost: approx. SEK 2,600 each. The total cost is dependent on the number of storm water drain wells installed at the pitch. Approximately 5 wells per facility SEK 13,000.

[20] See Chapter 1, Section 11 of the Swedish Ordinance on Environmental Licensing.

Microplastic filter
Description: Filters installed in storm water drain wells.

Benefit: Also traps smaller particles that pass through the granule trap. Can be combined with separation of metals and PAH.

Cost: approx. SEK 3,500 each, approx. 5 traps per facility SEK 17,500.

Hardened surfaces
Description: Hard surface around fall protection or running lanes to reduce the dispersion and to be able to more easily capture the microplastic particles that have been dispersed.

Benefit: Reduces the dispersion of microplastic to surrounding areas.
Cost: It is not possible to estimate because it depends on the design and location of the facility. Most facilities are supposed to have this already, especially in urban areas.

Costs for training, maintenance plan and self-inspection
Training: Costs/time for training staff on care to minimise loss of microplastic. 8 hours x SEK 390 (SCB) = SEK 3,100.

Maintenance plan: The time required to produce the care and maintenance plan. 8 hours x SEK 390 (SCB) = SEK 3,100.

Self-inspection: The time required for documentation, procedures, lists etc., according to the Regulation on self-inspection by operators will have to be met. 8 hours x SEK 390 (SCB) = SEK 3,100.

Total costs for a facility with moulded granulate

There will be an estimated total cost of protective measures for a facility taking all the above precautions of SEK 30,500 + any costs for the hardened surface. The administrative costs amount to SEK 9,100 in one-off costs plus approximately SEK 3,000 per annum. Other costs are estimated at approximately SEK 9,300 per year.

Annex 2. Microplastics in EU and international policy work

Annex 3 to the Swedish Environmental Protection Agency's report on microplastics from 2017 describes in detail the relevant regulations and processes within the EU and internationally. Some of what has happened since then is described here. For more detailed information, please refer to Annex 3.

EU's PLASTIC STRATEGY

In January 2018, a Communication was issued on the EU's plastic strategy that will focus on the entire plastic value chain and the negative environmental impact of plastic on the various stages.[21]

The first area where proposals for measures are presented is plastic recycling. The emphasis is on the importance of designing plastic products and packaging for recyclability.

Concerning the prevention of plastic waste and litter, the Commission emphasises measures relating to the use of disposable plastic articles. Another area covered is fishing gear abandoned at sea.

A comprehensive literature study forms the basis for the development of the EU's plastic strategy and research-based policy advice on the impact of plastic on the environment and health. The studies provide a comprehensive picture of the challenge of plastic and (marine) litter in Europe, specifying the occurrence and distribution in different environmental fractions, as well as possible impacts and suggested measures.[22]

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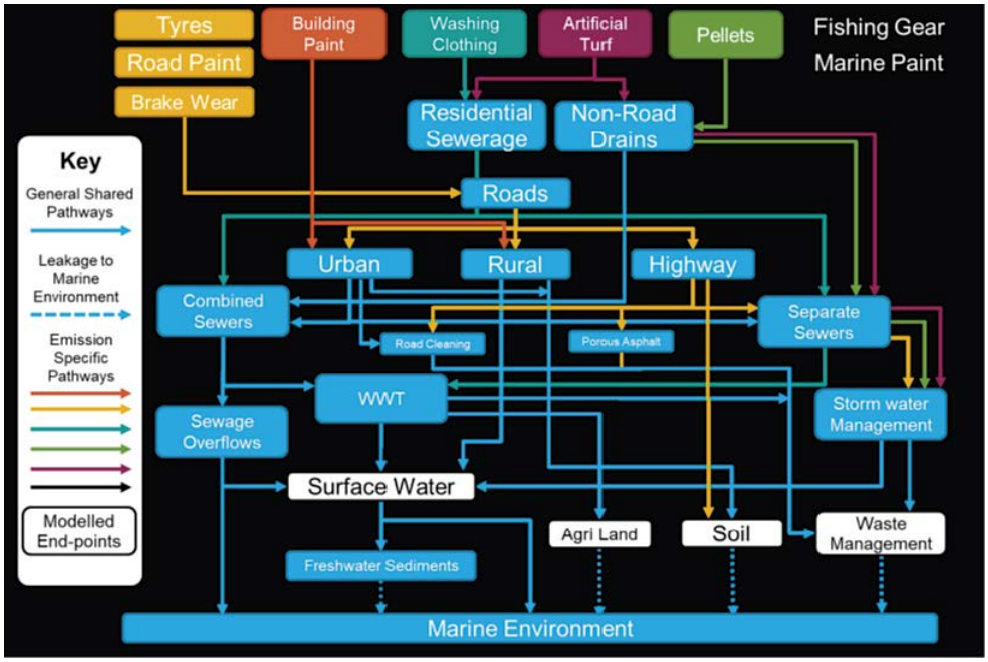
[21] https://eur-lex.europa.eu/resource.html?uri=cellar:2df5d1d2-fac7-11e7-b8f5-01aa75ed71a1.0013.02/DOC_1&format=PDF

[22] Hann/Sherington et al. (2018): Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products. European Commission Scientific Advice mechanism, 2018: Microplastics pollution – the policy context, background paper. Eunomia (2016) https://www.eunomia.co.uk/reports-tools/plastics-in-the-marine-environment/https://ec.europa.eu/research/sam/index.cfm?pg=pollution
Commission's Group of Chief Scientific Advisors endorsed the SAPEA Evidence Review Report https://ec.europa.eu/research/sam/index.cfm?pg=pollution
A scientific perspective on microplastics in nature and society, Science Advice for policy by European Academies, SAPEA, January 2019.
https://www.sapea.info/topics/microplastics/https://www.sapea.info/wp-content/uploads/microplastics-conclusions.pdf https://ec.europa.eu/research/sam/pdf/topics/mp_statement_july-2018.pdf#view=fit&pagemode=none



Source: from Hann/Sherington et al. (2018): Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products.

Prohibition of disposable plastic articles

On 27 March 2019, the European Parliament adopted a new directive on the use of disposable plastic articles (the SUP Directive).[23] The disposable plastic directive is based on existing EU waste legislation but goes further by placing even more stringent demands on the types of products and packaging that are among the ten most prevalent items on European beaches. This also includes abandoned fishing gear.

The new rules enter into force in 2021 and prohibit the use of certain disposable plastic products where alternatives are available. Cutlery, plates, various products of oxo-degradable plastics, cups and food packaging of expanded polystyrene are examples of products that are banned. The measures for abandoned fishing gear are mainly aimed at strengthening producer responsibility, whereby the manufacturers of fishing gear will have to pay for removal of fishing gear that has been washed up onto the shore.[24] In the context of the new Directive, the Commission launched a campaign to ban disposable plastic articles, 'Be Ready to change – the seductive power of single use plastics'.[25]

[23] http://europa.eu/rapid/press-release_IP-18-6867_en.htm

[24] https://www.consilium.europa.eu/en/press/press-releases/2018/12/19/single-use-plastics-presidency-reaches-provisional-agreement-with-parliament/pdf

[25] https://www.bereadytochange.eu/en/

Tyre labelling

Work on tyre labelling in the EU[26] started on 1 May 2018. The regulation states the need to regulate unintended release of microplastic particles from tyres, including information requirements such as labelling and minimum tyre requirements.

EU DRINKING WATER DIRECTIVE

The On 1 February 2018, the European Commission published a proposal to revise the Directive on the quality of water intended for human consumption (Drinking Water Directive).[27]

The proposal treats microplastic particles as a growing problem. However, in the Council's revision of the Drinking Water Directive, published in February 2019, microplastics have been removed from the proposal.[28] A general orientation on the Drinking Water Directive will first be developed at the Council meeting in June and negotiations cannot be started before the end of 2019.

INDUSTRIAL EMISSIONS DIRECTIVE

Under the Industrial Emissions Directive (IED), there are reference documents describing best available technology (BAT) for manufacturing in a given industry, so called BAT Reference Documents or BREF. Binding BAT conclusions contain mandatory basic requirements for a production facility. Microplastic could be addressed as one aspect of these documents. The BREF documents are revised by industry according to a rolling schedule of approximately 10-year intervals.

In 2017, a review of BREF for the textile industries was initiated. However, at the June 2018 start-up meeting, it was stated that microplastics would not be included as key environmental indicators (KEI) and that data about microplastics would not be collected. On the other hand, it was agreed to treat microplastic as an environmental aspect of BREF and to begin to collect information from existing microplastic studies, to be included in the revised textile BREF. National reports on microplastics in textile production will be submitted by Austria, Sweden, EURATEX and the European Environmental Bureau. Sweden has submitted a report from SWEREA, now RISE, on a new method for measuring microplastic emissions from textiles.[29]

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[26] COM(2018)296 REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the labelling of tyres with respect to fuel efficiency and other essential parameters and repealing Regulation (EC) No 1222/2009.

[27] http://ec.europa.eu/environment/water/water-drink/pdf/revised_drinking_water_directive.pdf

[28] https://data.consilium.europa.eu/doc/document/ST-6876-2019-INIT/en/pdf

[29] https://www.mdpi.com/2071-1050/10/7/2457/htm

REACH

In line with the objectives of the EU's plastic strategy and REACH procedures aimed at limiting substances that pose a risk to the environment or health, ECHA, at the request of the Commission, examined the need for an EU-wide restriction of "intentionally added" microplastic particles in products or uses that "intentionally release" microplastic particles into the environment at EU level.

ECHA evaluated the health and environmental risks of intentionally added microplastics in products and, in mid-January 2019 they presented a proposal to the Commission to ban intentionally added microplastics in products released on the EU market.[30] If the ECHA's restriction proposal were to be adopted in its current form, it is estimated that this could lead to a reduction in microplastics emissions of around 400 thousand tonnes over 20 years.

AQUATIC AND MARINE MEASURES

EU water legislation is undergoing a comprehensive review[31] to assess whether the current regulatory framework is fulfilling its purpose in accordance with the Better Regulation Guidelines.

THE WATER DIRECTIVE

Currently there are no good status parameters relating to litter or microlitter, including microplastic, in the Water Directive. A review of the framework directive will be conducted in 2019, and the Commission will make proposals for any changes.

THE URBAN WASTE WATER TREATMENT DIRECTIVE

A review of the EU's Urban Waste Water Treatment Directive was launched in October 2017 with a roadmap and the publication of the 9th report on the implementation of the EU's Urban Waste Water Treatment Directive in December of the same year.

Publication of the report was followed by a consultation on public comments of Council Directive 91/271/EEA. This consultation ended in October 2018.

MARINE STRATEGY FRAMEWORK DIRECTIVE

The Marine Strategy Framework Directive is the only EU legislative instrument in which microplastics are explicitly and directly mentioned.

On 17 May 2017, the European Commission adopted criteria and methodology standards for good environmental status in marine waters.[32] These

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[30] https://echa.europa.eu/documents/10162/82cc5875-93ae-d7a9-5747-44c698dc19b6

[31] Evaluation and Fitness review plan
https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-5128184_en

[32] C (2017)2901
http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm

provide that each Member State is to set thresholds for the presence of microlitter, including microplastic, in relation to the risk of damage to the coastal and marine environment by July 2018 or as soon as possible thereafter.

COLLECTION OF WASTE FROM SHIPS

According to a provisional agreement of December 2018[33, 34], ships are required to pay an indirect charge allowing them to unload their waste at a port. This charge must be paid regardless of whether or not the actual emission of waste takes place. The charge will also apply to fishing ships and leisure craft. Finally, the new Directive adapts EU legislation to the International Convention for the Prevention of Pollution from Ships (Marpol).

RESEARCH AND OTHER COLLABORATION WITHIN THE EU

European Network of the Heads of Environment Protection Agencies (NEPA)[35]

The Interest Group Plastics, a working group, was created in 2016. Sixteen countries participate in the group, including Sweden. The main focus of the group is to prevent plastic litter from reaching the environment. The group exchanges information on ongoing research and policy development in Member States. In September 2018, the group published a report on biodegradable plastics with a number of recommendations that Sweden also endorsed. The report shows the biodegradation of various types of plastics and the degradation time of biodegradable plastics in various environments, such as fresh water, seawater and soil. With the exception of France and Italy, no EU countries have regulations on biodegradable plastics in place.

Sweden participates in JPI Oceans, a collaborative organisation for EU countries aimed at making better use of national research resources in certain strategic areas.

Since 2016, four research projects have been ongoing in a specific initiative targeting microplastics in the European marine environment:

- BASEMAN – Defining the baselines and standards for microplastics analyses in European waters.
- EPHEMARE – Ecotoxicological effects of microplastics in marine ecosystems.
- PLASTOX – Direct and indirect ecotoxicological impacts of microplastics on marine organisms.
- WEATHER-MIC – How microplastic weathering changes its transport, fate and toxicity in the marine environment – Plastics as a planetary boundary threat.

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[33] https://www.consilium.europa.eu/media/37649/st15183-re01-en18.pdf

[34] https://www.consilium.europa.eu/sv/press/press-releases/2018/12/19/eu-tackles-plastic-and-other-waste-ending-up-in-the-sea-council-approves-agreement-on-port-reception-facilities/

[35] https://www.eea.europa.eu/about-us/who/epa-network

The results were presented in November 2018 and final reports will be published shortly.

JPI Oceans launched a new call on microplastics in the marine environment in 2018. This joint multidisciplinary call focuses on increasing knowledge of relevant microplastic sources, analysis methods for the identification of microplastics and nanoplastics, monitoring of their distribution and presence in marine systems, and their impact on these, and action concepts to reduce the emission of plastic into the marine environment.[36]

Sweden is contributing with funding. The call has awarded up to EUR 9.5 million.

International conventions

IMO

On 22–26 October 2018, the International Maritime Organisation's (IMO) Marine Environment Protection Committee (MEPC) adopted an action plan to deal with marine plastic litter from vessels. This will improve the existing regulatory framework and introduce measures to reduce and prevent marine plastic litter being thrown or dumped into the seas from ships.

International organisations and partnerships

THE UN AND ITS' BODIES

Awareness of the global nature of microplastics and its associated problems is increasing, as demonstrated by international initiatives on marine litter, such as the UN Global Partnership on Marine Litter[37] and the G7 and G20 countries' action plans[38]. Plastic pollution was also identified as one of the most serious pressures on healthy seas at the UN Oceans Conference[39] in June 2017. The UN Environment Assembly adopted a resolution on marine litter and microplastic in December 2017.[40]

United Nations Environment Assembly, UNEA

An Ad Hoc Open-ended Expert Group was established in 2017 under Resolution 3/7 at UNEA's third meeting (UNEA 3) on marine plastic litter and microplastics.

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[36] http://www.jpi-oceans.eu/calls/proposals/microplastics-marine-environment

[37] ttps://www.unep.org/gpa/what-we-do/global-partnership-marine-litter

[38] https://www.g7germany.de/Content/EN/_Anlagen/G7/ 2015-06-08-g7-abschluss-eng_en.html and https://www.g20.org/Content/DE/_Anlagen/G7_ G20 /2017-g20-marine-litter-en.html?nn=2186554

[39] UN 'Our Oceans' conference, June 2017 https://oceanconference.un.org/coa

[40] For UNEP/EA.3/L.20 see: https://papersmart.unon.org/resolution/uploads/k1709154.docx

The group was mandated to submit proposals to the fourth UNEA meeting on 11–15 March 2019 (UNEA-4)[41] for potential national, regional and international measures to combat marine litter and microplastics, particularly with regard to land-based sources, for possible further analysis.[42] The mandate of the group was extended to UNEA-5 to identify ongoing measures, including the reduction of microplastic emissions, financial and technical resources to address emission problems at Member State level and to analyse the effectiveness of measures and response mechanisms.

WORLD HEALTH ORGANIZATION

In March 2018, the UN World Health Organisation announced plans to carry out a review of the presence and risks of microplastics in drinking water plastic bottles.

FAO

In 2018, the UN Food and Agriculture Organisation (FAO) published a report entitled Microplastics in Fisheries and Aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety.[43] The document will help to ensure that policy decisions on the management of microplastics in fisheries and aquaculture have a scientific basis. It provides information on the most likely sources and pathways, as well as the presence of microplastics in both the marine food chain and seafood value chains. It also provides a framework for assessing the risks that may affect commercial fish stocks and consumers. The report reviews current practices and limitations on microplastic sampling techniques. In July 2018, the FAO Committee on Fisheries discussed a comprehensive list of policy recommendations to address the challenge of the presence and impact of microplastics in fisheries and aquaculture, as well as the safety and health aspects of food from the sea.[44]

GESAMP – Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection)

The focus of WG 40 for 2017–2018 was to develop guidelines covering terminology and methods for sampling and analysis of marine macro- and microplastics, more specifically: size and shape definitions for particulates. It is considered necessary to coordinate work with a large number of regional maritime conventions and other regional organisations to ensure that the guidelines are relevant to the organisations responsible for the monitoring and assessment of plastics and microplastics. The guidelines were published in spring 2019.[45]

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[41] http://web.unep.org/environmentassembly/node/40724

[42] https://papersmart.unon.org/resolution/uploads/k1900897.pdf

[43] http://www.fao.org/3/a-i7677e.pdf

[44] http://www.fao.org/3/MX201EN/mx201en.pdf

[45] http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean downloaded 13 May 2019.

REGIONAL MARINE CONVENTIONS

OSPAR

An extensive monitoring programme has been conducted within the framework of OSPAR. As part of its monitoring and evaluation programme, OSPAR currently uses marine litter on beaches[46], seafloor[47] and plastic items in the stomach of fulmars as common indicators[48].

OSPAR is working to develop new indicators of microplastic particles in sediments and marine litter absorbed by turtles, which could be monitored from 2021.

HELCOM

In 2015, HELCOM adopted a regional action plan to reduce the presence and release of marine litter to the Baltic Sea. The plan will be reviewed and revised in 2021.

HELCOM is a partner in the INTERREG FanpLESStic-Sea project. The project will contribute to a revision of HELCOM's recommendations for waste water and storm water management. It intends to include specific requirements for the prevention of microplastic in the recommendations.

HELCOM's Baltic Sea Action Plan (BSAP) will be revised in 2020/2021. The revised action plan will better reflect the current working areas under HELCOM, such as marine litter, and facilitate the implementation of the UN sustainability goals (SDG), Aichi targets and MSFD descriptors.

THE NORDIC COUNCIL OF MINISTERS

In May 2017, the Nordic Environment Ministers launched a two-year Nordic plastic programme 2017–2018, which set the direction for efforts to reduce the environmental impact of plastic in the Nordic countries.[49]

The proposals in the programme have been included in the Nordic Environment and Climate Action Programme 2019–2024, adopted in August 2018.[50] The action programme notes that Nordic cooperation has contributed to limiting pollution and litter entering the sea, not least plastics and microplastics. The following are proposed:

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[46] OSPAR (2017a). *CEMP Guidelines for monitoring marine litter washed ashore and/or deposited on coastlines (beach litter) (OSPAR Agreement 2017-05)*: OSPAR Commission.

[47] OSPAR (2017b). *CEMP Guidelines on Litter on the Seafloor (OSPAR Agreement 2017-06)*: OSPAR Commission.

[48] OSPAR Commission (2015). *CEMP Guidelines for Monitoring and Assessment of plastic particles in stomachs of fulmars in the North Sea area*: OSPAR Commission.

[49] http://norden.diva-portal.org/smash/get/diva2:1092150/FULLTEXT01.pdf

[50] https://www.norden.org/sites/default/files/session_documents/885904233B%20322_holdbart.pdf/B_322_holdbart.pdf

- Efforts should be made to stop the inflow of plastics and microplastics to the sea.
- Initiatives to combat the inflow of litter, including plastics and microplastics, to the sea and on the coast are to be reinforced.
- Contribute to the implementation of the UNEP process of evaluating options for action to better combat marine litter and microplastics, as well as to the review of the UNEP Global Programme of Action (GPA) for land-based pollution to the ocean.

Highlight the importance of coordinated implementation of the OSPAR and HELCOM action plans on marine litter and actively contribute to the EU's efforts to reduce the environmental impact of plastics.

ARCTIC COUNCIL

In 2017, the PAME (Protection of the Arctic Marine Environment) working group initiated work on marine litter, including microplastics.

A literature study is being conducted from 2017 until 2019. In February 2019, the report was discussed at the PAME review and approval meeting of experts.[51] The study will serve as a basis for developing an action plan within the Arctic Council for reducing litter in the Arctic.[52] The final version of the status report is expected to be published in the context of the Arctic Council ministerial meeting in Finland in May 2019.

CROSS-BORDER PROJECTS

A study is ongoing in the BONUS EEIG programme on the presence of microplastics in the Baltic Sea and another study is ongoing on removing microplastics in polluted waters. Sweden is active in both studies, which will submit reports during 2020.

EU INTERREG brings together several projects, including the FanpLESStic-SEA about removing microplastics.

EU COUNTRIES

In addition to a range of collaboration both internationally and within the EU on microplastics, countries are also taking action nationally. The following is a selection such initiatives, focusing on other Nordic countries and the Netherlands, the UK and Germany.

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[51] Desktop Study on Marine Litter including Microplastics in the Arctic, Final revised draft (12 Feb 2019-CLEAN

[52] https://pame.is/images/03_Projects/Arctic_Marine_Pollution/Litter/Workshop/ML_Workshop_summary_report.pdf

FINLAND

New Finnish roadmap for plastics

Finland has been the first country to have drawn up a road map for a sustainable plastic economy.[53] The Finnish government has selected measures to help improve plastic handling from more than a hundred proposals. Included in the roadmap's proposals are:

- A plastic tax inquiry.
- Increased number of waste collection points for plastics.
- Increased consumer information.
- Cities and event organisers agree to reduce the use of single-use packaging and avoid unnecessary packaging of goods.

One of the objectives of the roadmap is to better identify plastics in buildings and to improve the sorting of plastic waste at construction sites. Another objective is to improve recycling of agricultural and garden plastics and to replace plastics with biodegradable materials.

As early as 2017, Finnish SYKE published a policy briefing on environmental challenges of microplastics and proposals for measures to reduce the release of microplastics into the environment.[54] It states that microplastics pose a high risk to both the aquatic and terrestrial environments and that effective measures to combat the dispersion of microplastics in the environment should be developed and improved as a matter of urgency. Three specific action proposals were put forward on how to address the emission of microplastics in the environment:

- Develop appropriate financial and legal instruments and information measures. These measures should also encourage innovation and new business models.
- The use of sewage sludge from waste water treatment plants must be carefully planned in terms of their possible environmental impact. The aim should be to find safe and effective ways of utilising nutrients in the sludge, for example by finding ways of extracting valuable nutrients and processing it into innovative fertiliser products.
- The amount of microplastics that are emitted to the sea from built-up areas can be reduced by sustainable drainage planning and the use of new technologies.

[53] http://www.ym.fi/download/noname/%7B628D8103-91AD-470C-9906-8C5D1463FB61 %7D/140645

[54] Syke policy brief – microplastics 2017, https://helda.helsinki.fi/bitstream/handle/10138/177568/SYKE_PolicyBrief_mikromuovi_ENG_web.pdf?sequence=1&isAllowed=y

DENMARK

The government's Plastics Action Plan was published in December 2018. [55] The strategy is set out the path to establishing a system for circular plastic use in Denmark. In addition to a ban on microplastics in cosmetic products, the issue of microplastics is mentioned several times in various contexts.

The March 2017 report *Microplastic in Danish Waste water – Sources, occurrences and fate*, published by the Danish Environmental Protection Agency,[56] recommends shifting the focus from the presence of microplastics in waste water treatment plants to the presence in sludge. According to the report, almost all microplastics end up in the sludge and thus also on agricultural land where sludge is used as fertilizer.

Water from industrial textile washing machines will be purified from microplastics in an experiment. With resources from the MUDP scheme, the Danish Ministry of the Environment is supporting a project that will develop a method for capturing microparticles and testing purification using chemical-mechanical filtration.[57] The project is a collaboration between the Danish Technology Institute, Aarhus University School of Engineering, Berendsen Textile Service and AL2-Teknik, Dankalk.

A report from the Danish Environmental Protection Agency has previously stated that textile washing accounts for about two per cent of the microplastics that reach the aquatic environment in Denmark.[58]

NETHERLANDS

Circular economy strategy 2050

Plastics (macro and micro) are the five policy areas/sectors in the circular economy programme most relevant to the Dutch economy, but they are also considered to have the greatest impact on the environment. At the same time, it is believed that there is great potential for a transition to a circular economy.[59]

A large and multifaceted data set was published in 2017 in *Environmental International*. The data show that plastic pollution is found in significant concentrations in large Dutch rivers, treated waste water, Amsterdam canals and in estuaries and sea sediments off the Dutch coast.[60]

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[55] https://mfvm.dk/fileadmin/user_upload/MFVM/Miljoe/Plastikhandlingsplan/Regeringens_plastikhandlingsplan_web_FINAL.pdf

[56] https://www2.mst.dk/Udgiv/publications/2017/03/978-87-93529-44-1.pdf

[57] https://mfvm.dk/nyheder/nyhed/nyhed/vand-fra-tekstilvask-skal-renses-for-mikroplast/

[58] https://www2.mst.dk/Udgiv/publications/2017/03/978-87-93529-44-1.pdf

[59] A circular economy in the Netherlands by 2050, The NL Government, 2016
https://www.government.nl/topics/circular-economy/documents/discussion-documents/2017/01/24/national-agreement-on-the-circular-economy

[60] Leslie HA, SH Brandsma, MJM van Velzen, AD Vethaak. 2017 Microplastics en route: Field measurements in the Dutch river delta and Amsterdam canals, waste water treatment plants, North Sea sediments and biota.Environment International 101, 133–142.
https://www.sciencedirect.com/science/article/pii/S0160412017301654

The report *Potential measures against microplastic emissions to water*[61] provides an overview of potential measures to address microplastic contamination in Dutch waters. Uncertainty about the impact of microplastics on humans and ecosystems is considered to be high. Therefore, it is considered that the precautionary principle should prevail when developing measures to reduce emissions of microplastics. RIVM has taken note of the advantages and disadvantages of various potential measures. This study focuses on three sources: tyre wear (the largest source), paint and microplastics added to hygiene and cleaning products.

NORWAY

The Norwegian Environmental Agency has proposed several measures to prevent and reduce emissions of microplastics.[62] This includes:

- Stimulate the choice of methods for road washing in densely populated areas, which contributes both to better air quality and to less emissions of microplastic particles.
- Investigate the possibilities of removing microplastics in run-off from the busiest roads in a cost-effective way.
- Investigate environmentally friendly alternatives to rubber granules on artificial grass pitches:
  - Consider recycling requirements for rubber granules.
  - Observe facility requirements for the operation of artificial grass in separate regulations.[63]
- Require the prevention of emissions of microplastics and environmental pollution from marinas in separate regulations.
- Conduct a test project on hull washing of small boats to reduce the use of anti-fouling paint on leisure craft.
- Examine the volumes of microplastic particles that are present in sewage sludge used as fertiliser and how this can affect the terrestrial environment.
- Possibly create a local authority subsidy system for measures to combat the emission of microplastic particles and marine litter.
- Examine the possibility of filtering microfibres from washing machine waste water.
- Cooperate with the plastics industry to stop the emission of plastic pellets.
- Compile the state of knowledge of microplastic particles to identify areas when more knowledge is needed.

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[61] RIVM Report 20 17-0193., AJ Verschoor I E. de Valk

[62] http://www.miljodirektoratet.no/no/Nyheter/Nyheter/2017/Januar-2017/Slik-far-vi-ned-mikroplastutslippene/

[63] In July 2018, the Norwegian Environmental Agency presented a national regulation to regulate release of microplastic from artificial grass pitches.

The Norwegian Institute for Water Research (NIVA) issued a report on properties, dispersal pathways and measures related to microplastic/micropollutants in road dust.[64]

In December 2017, SINTEF Oceans AS[65] issued the report *Microplastics in Global and Norwegian Marine Environments* on behalf of the Norwegian Environment Agency. This comprehensive study highlights the presence, distribution, degradation and transport of microplastics in the marine environment.

Within the framework of the WaterJPI project IMPASSE[66], Norwegian NIVA has published several reports on microplastics in the soil.
The April 2018 report from the Norwegian Environment Agency[67] uses a scientific calculation model that shows that "sludge is a significant source of plastic in both marine and land-based ecosystems".

UNITED KINGDOM

In the UKs 25-year plan for the environment, microplastics are only mentioned in connection with biodegradable plastics. In this context, cooperation with researchers will be established to develop standards for biodegradable plastic bags.[68]

One study on waste water treatment plants as a source of microplastic particles in catchment areas measured microplastic particles in catchment areas and identified potential sources of pollution. Waste water treatment plants are important sources of microplastic in river basins, although there are also other important sources. These can include sewage sludge used on agricultural land, diffuse release of secondary microplastics and atmospheric deposit. The composition of microplastics varies geographically and over time but is dominated by fibres, fragments and flakes, as opposed to grains and pellets. It is believed that measures for reducing microplastic concentrations in lakes, rivers and seas need focus on a wide range of different sources.[69]

GERMANY

The Federal Ministry of Education and Research (BMBF) has launched a research programme focusing on "Plastic in the environment – sources • sinks". In the period 2017–2021, 18 cooperation projects and a scientific support project will be funded with approximately EUR 35 million. More than 100 research, industry and business partners are involved in the world's largest focus area in research on the environmental effects and impacts of plastic.

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[64] NIVA, TOI, 2018: Microplastics in road dust – characteristics, pathways and measures http://www.miljodirektoratet.no/Documents/publikasjoner/M959/M959.pdf

[65] https://www.sintef.no/en/ocean/initiatives/clean-ocean/plastic-in-oceans/#Ourprojectsonmicroplastics

[66] http://www.waterjpi.eu/joint-calls/joint-call-2016-1/impasse

[67] http://www.miljodirektoratet.no/no/Publikasjoner/2018/April-2018/Mapping-microplastics-in-sludge/

[68] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

[69] Waste water treatment plants as a source of microplastics in river catchments Environmental Science and Pollution Research; April 2018; https://doi.org/10.1007/s11356-018-2070-7

In 2017, Germany amended its national sludge and fertiliser regulations[70] and became, after Switzerland, the only country in Europe to have a clear restriction on the use of sewage sludge on agricultural land and legal requirements for phosphorus removal.

According to the German Environment Agency (UBA), sewage sludge is a mixture of many substances. While heavy metals and certain pollutants are clearly regulated in the legislation, many organic pollutants and new chemicals are not subject to regulation. According to UBA, little is known about their environmental effects and impacts. By applying sewage sludge to or on the ground, such as in the form of agricultural fertilisers, these pollutants may disperse to the environment. Despite the legal provisions of the new sludge and fertiliser regulation, the UBA states that it cannot be excluded that individual substances may enter the environment.[71]

[70] http://www.gesetze-im-internet.de/abfkl_rv_2017/AbfKl%C3 %A4rV.pdf

[71] https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/2018_10_08_uba_fb_klaerschlamm_bf_low.pdf

Annex 3. Measures considered

In accordance with the commission, measures are presented here that the Swedish EPA has considered but chosen not to proceed with. They are accompanied by a brief explanation.

ARTIFICIAL GRASS

Investment grants for sustainable artificial grass pitches

Investment grants could be beneficial if there are solutions with significantly reduced environmental impact that are not used because they are more expensive than conventional solutions. However, there are currently no material concepts that meet the three criteria that the Swedish EPA considers central: that the materials are based on fossil-free raw materials; that they do not contain hazardous substances; and that they do not contribute to microplastic emissions. An investment grant would therefore have no effect.

Targeted support for research and innovation on artificial grass and granules

The Swedish EPA judges that there is no need for new targeted initiatives for research and innovation. Funding of the pre-purchase procurement group for artificial grass provides good potential for the participants to be able to start development projects and new collaborations using existing funding offers from Sweden's innovation agency, Vinnova, and others.

Alternative materials for artificial grass or moulded granulate surfaces

One way of reducing the emission of microplastics could be to use alternative materials. Organic filler materials (e.g. bark, cork and coconut) are an alternative to plastic and rubber granules. Other options are granules made of bio-based plastics or wood raw material. Material development is also underway for moulded rubber granulates.

The Swedish EPA currently believes that it is not our role to recommend one specific material over another available on the market. The responsibility for safe use of materials should lie with companies. This type of steering mechanism could also inhibit the development of new materials.

International collaboration

The development and production of artificial grass is mainly done by large companies in such countries as the USA, Germany and China. International input is needed to stimulate faster development of new material concepts. One hope is that the participants in the initiatives supported by the Swedish EPA can find relevant partners in the EU and this can enable continued development funding, for example via Horizon2020. Another possibility is to support cooperation between the prospective purchasers in the Nordic countries so that they can better communicate their common needs to international suppliers. One possible source of funding for this type of activity is the Nordic Council

of Ministers. In 2019, the Swedish EPA will work actively to strengthen international cooperation to speed up the development of new material concepts. For this reason, it has decided not to present the proposal here.

TEXTILE LAUNDRY

Consumer information on how microplastic emissions can be reduced during laundry

The results from verification of consumer information have been transferred to the information efforts that are part of the Swedish EPA's government assignment on consumer information on sustainable textiles.

Development of eco-labels for textiles

Eco-labelling is one way to help consumers make more sustainable choices. The EU's Textile Labelling Regulation establishes rules on textile fibre names and related labelling and labelling requirements, including country of origin. There is also a harmonised European standard for which washing symbols may be used on textile products. Producers can also provide the customer with information that can be removed after purchase.

It is not considered possible to introduce eco-labelling for microplastic textiles since there is unknown how much microplastic is emitted from different textiles and such labelling would likely be contrary to the EU regulation and standard on harmonised labelling. More knowledge and EU coordination are therefore needed before the measure can move forward.

Pre-purchase procurement group for textile laundry

The Swedish EPA has considered setting up a pre-purchase procurement group for textile laundry, but this need is expected to be filled through guidance combined with other measures that stimulate market introduction, the use of filter solutions and the development of documentation that facilitates the introduction of the Ecodesign Directive.

Procurement criteria

Procurement and the introduction of criteria limiting microplastic emissions remain an important measure.

The National Agency for Public Procurement's sustainability criteria for laundry and textile services will be updated during the first part of 2019 and the issue of how laundries manage microplastics will be addressed. Because of this, the Swedish EPA does not propose any measures.

Annex 4. Governmental assignment to the Swedish Environmental Protection Agency

The public service agreement for 2018 (dnr M2017/03180/S and others) gives the Swedish Environmental Protection Agency the following assignment:

Measures on the release of microplastics into the aquatic environment
The Swedish Environmental Protection Agency is to continue its work of identifying and addressing more important sources of microplastic emissions to aquatic environments in Sweden, based on previous assignments (dnr M2015/2928Ke). Different risk management tools should be considered, such as support for procuring authorities, changes in regulations and guidances, increased supervision and dialogue with relevant industries. The Swedish Environmental Protection Agency (the Swedish EPA) is to also analyse various options for regulating the release of microplastics into the aquatic environment. This analysis must cover the potential for legislative proposals on regulating emissions, including requirements for facilities and maintains of artificial grass pitches (AGPs) and other outdoor sports and play facilities that risk microplastic emissions. The analysis must also include whether the above-noted facilities might constitute environmentally hazardous activities that should be subject to notification requirements or permit requirements. Socio-economic impact assessments should form the basis for the proposals and for the more important measures considered by the Agency but not chosen to propose. These analyses must be included in the report. The assignment report is to be submitted to the Government Office (Ministry of Environment and Energy) by 31 May 2019.

Microplastics in the Environment 2019

Report on a government commission

REPORT 6957

SWEDISH EPA
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In 2017, the Swedish Environmental Protection Agency presented the report from the first government commission on sources of microplastics and proposals for measures to reduce emissions.

This report presents results from the second government commission. It was published in Swedish in 2019 and contains new findings and proposed measures.

The proposed measures target important quantified sources, such as artificial grass and microfibres from laundering of textiles.

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