VA-teknik Södra

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Microplastics

Report from an IWA Sweden conference and workshop in Malmö, November 8-9, 2017

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Foreword

In recent years, microplastics in the environment has become an issue of growing concern. At the same time, the knowledge about sources and effects of microplastics is very limited, and thus a field with increasing research activity. This includes methods for analysis of microplastics, which are associated with considerable difficulties and not yet possible to standardise.

These above mentioned were the main motives behind two events arranged in Malmö, Sweden, in November 2017.

The IWA Sweden Microplastics Conference took place on November 8. It was organised by IWA Sweden, Sweden Water Research, the Swedish Agency for Marine and Water Management and the Swedish Water and Wastewater Association. The conference gathered more than 150 delegates from nine different countries.

The day after the conference, a workshop was held for researchers, organised by Sweden Water Research and VA-teknik Södra. The workshop was attended by 36 persons from universities, research institute and water companies.

We wish to convey our sincere appreciations to Susanne Tumlin, Gryaab, moderator of the conference and author of this report that summarises the conference talks, the panel discussion and the outcome of the workshop. Our gratitude also goes to the lecturers and the participants at the conference and workshop.

December 2017, the programme committee:

Hans Bertil Wittgren, Sweden Water Research (chair)
Anders Finnson, Swedish Water and Wastewater Association
Bengt Fjällborg, Swedish Agency for Marine and Water Management
Emma Fältström, Sweden Water Research
Daniel Hellström, IWA Sweden - Governing Member Sweden of International Water Association
Karin Jönsson, VA-teknik Södra
Ann Mattsson, Gryaab

Summary

Marine littering is one of the biggest environmental problems today and plastics are identified as the most common litter in the oceans. Intake and accumulation of plastics has been observed for filter organisms, invertebrates, fish, mammals and birds. There is a risk of plastic particles binding toxic substances in the environment. However, it is not possible to quantify the risks due to insufficient amount of data and lack of knowledge.

Analysis of microplastics is a major challenge. Plastic is produced using different types of polymers and no single analytical method can detect all polymer types. There is a need for a suite of methods to completely analyse a sample. Without proper analytical methods, the amount of microplastics in the environment cannot be assessed, which results in an inability to distinguish which are the most important sources, and to quantify their impacts.

There are many pathways identified for the transport of microplastics from land based sources to the aquatic environment. In Sweden, the main pathway of microplastics to water bodies has been identified as stormwater runoff.

Microplastics from tyres is estimated as the biggest land based source in Sweden, Norway, Denmark and the Netherlands. However, it was not possible to quantify how much reaches waterways, lakes and oceans. The second largest source of microplastics to the environment is considered to be artificial turf pitches because of the loss of rubber granules used as in-fill. There are a lot of uncertainties regarding magnitude of loss of the granules, the content of hazardous substances and pathways to the environment.

It is important to identify and implement actions near the source where microplastic particles are generated to prevent them from being further transported in the environment. However, there is very little clarity regarding the responsibility for stormwater and an investigation regarding legislation concerning stormwater is suggested in Sweden.

Wastewater treatment plants (WWTPs) are not identified as a major pathway of plastics to water. Initial studies have showed that up to 99 % can be removed from the wastewater during the conventional treatment processes. Most of the microplastics are retained in the WWTP and it is indicated that most of that ends up in the sludge.

Regarding the effects of microplastics on terrestrial ecosystems, a lab scale study of earth worms in soil, where microplastics and plant litter were added was presented. An effect was observed on mortality and growth with a quantity above 28 % of microplastics content in the added plant litter. Above 7 % of microplastics in the added plant litter, an accumulation in the cast was measured which present an environmental risk. Promising results from the study showed that the concentration of microplastics is decreased to some extent by bacteria in the worm's gut. There is on-going research on how microplastic effect the soil-plant system.

The workshop after the conference identified the most urgent research issues. The four most important, with the highest uncertainty came out as:

- Evaluation of the risk of microplastics in the environment
- Standardise analytical methods and sampling of microplastics
- Establish mass balances and pathways of microplastics
- Prevent release of microplastic by source control

Sammanfattning

Marin nedskräpning är ett av vår tids största miljöproblemen och plast har identifierats som den vanligaste sortens skräp i haven. Upptag och ackumulering av plast har observerats för filtrerare, ryggradslösa djur, fisk, däggdjur och fåglar. Det finns en risk att plastpartiklar binder toxiska substanser i miljön. Det är dock inte möjligt att kvantifiera riskerna på grund av otillräcklig mängd data och brist på kunskap.

Att analysera mikroplast är en stor utmaning. Plast kan bestå av flera olika typer av polymerer och ingen av dagens analysmetoder kan detektera alla polymertyper. Det behövs en rad olika metoder för att få en fullständig analys av ett prov. Utan tillförlitliga analysmetoder kan inte mängderna plast i miljön fastställas vilket leder till att det inte heller går att avgöra vilken källa som är viktigast och vilken inverkan de har.

Flera olika tillförselvägar har identifierats som kan transportera mikroplast från land till vattenförekomster. I Sverige har dagvatten identifierats som den huvudsakliga tillförselvägen för mikroplast till vattenförekomster.

Mikroplast från däck har uppskattats vara den största landbaserade källan i Sverige, Norge, Danmark och Holland. Det har dock inte gått att kvantifiera hur mycket som når vattenvägar, sjöar och hav. Den näst största källan av mikroplast till miljön anses vara fyllnadsmaterialet i konstgräsplaner. Det är stora osäkerheter förknippat med hur mycket fyllnadsmaterial som spills, riskabelt innehåll och spridningsvägar i miljön.

För att kunna hindra mikroplastpartiklar att spridas vidare i miljön är det viktigt att identifiera och implementera åtgärder nära källan där mikroplastpartiklarna genereras. Det är dock väldigt oklar ansvarsfördelning för dagvatten och en utredning om lagstiftning kring dagvatten har föreslagits i Sverige.

Avloppsreningsverk har inte identifierats som en betydande spridningsväg av mikroplaster till vattenförekomster. De första studierna har visat att upp till 99 % av mikroplasterna avskiljs från avloppsvattnet i en konventionell reningsanläggning. Den största delen av mikroplasterna kvarhålls i reningsverket och troligen avskiljs de mesta av mikroplasterna till slam.

En studie presenterades som analyserat effekter på daggmaskar i jord då mikroplast och växtavfall i olika koncentrationer tillsatts jorden. En effekt på dödlighet och tillväxt observerades när mikroplastmängden i det tillförda växtavfallet överskred 28 %. Vid en mikroplasthalt på över 7 % i det tillförda växtavfallet ackumulerades mikroplast i maskarnas avföring vilket utgör en miljörisk. Lovande resultat från studien visar att mikroplast till viss del bryts ner i maskarnas magar. Forskning pågår om hur mikroplast påverkar jord-växt systemet.

Workshopen i anslutning till konferensen identifierade de mest brådskande forskningsfrågorna. De fyra viktigaste med högst osäkerhet var:

- Utvärdering av riskerna med mikroplast i miljön
- Standardisering av provtagning och analysmetoder för mikroplast
- Upprätta massbalanser och fastslå spridningsvägar för mikroplast
- Förhindra spridning av mikroplast vid källan

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Introduction

The conference was organised in five different themes covering the issues identified by the program committee. At the end of the day, a panel discussion was held with five of the lecturers to discuss the questions raised at the conference.

The five themes were:

- Theme 1: What is the problem with microplastics and where do they come from?
- Theme 2: What are they and how do we know they are there?
- Theme 3: What can be done about microplastics in stormwater?
- Theme 4: What happens at the wastewater treatment plant, in sludge and soil?
- Theme 5: What results can be expected from ongoing research?

The lecturer’s presentations are available online:
http://www.svensktvatten.se/utbildning/konferensdokumentation/svenskt-vatten/microplastic/

The day after the conference a workshop was held for researchers. The aim of the workshop was to follow up on the themes of the conference, in terms of identifying urgent issues for further research.

Theme 1: What is the problem with microplastics and where do they come from?

~ During the first theme of the conference the representative from the Swedish Environmental Protection Agency (EPA), **Anna-Maria Sundin**, gave a summary of the Swedish Government Commission on microplastics and the EPA's proposal on measures.

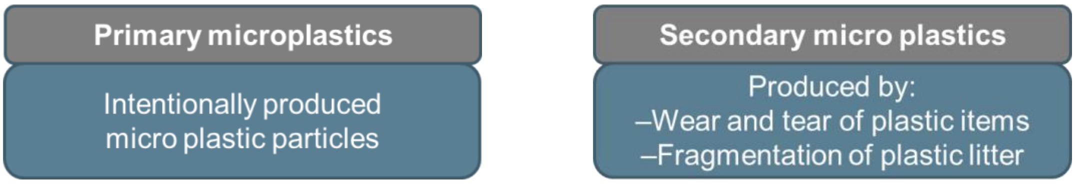
Marine littering is one of the biggest environmental problems today and plastics are the most common litter in the oceans (60-90 %). One of the global Sustainable Development Goals (SDG), number 14 "Life below water", is to "By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution".[1]

Microplastics are found everywhere in the environment. Intake and accumulation of plastics has been seen for filter organisms, invertebrates, fish, mammals and birds. There is a risk of plastic particles binding toxic substances in the environment. However, it is not possible to quantify the risks due to knowledge and data gaps.

Definition of microplastics

In the Swedish governmental commission microplastics are defined as particles smaller than 5 mm. "Particles" are defined as solid particulates for example, fibres, fragments and flakes. "Plastics" is a broader definition which includes synthetic polymers from petroleum products, but also non-synthetic polymers like natural rubber and polymer modified bitumen. The size, shape and density of the particles are important factors for the possible pathways in the environment.

Most common is to divide microplastics into primary microplastics and secondary microplastics based on their origin:



Swedish governmental commission

The Swedish government has recognized challenges with microplastics in the aquatic environment and has given a governmental commission to the Swedish EPA: "Identify sources and pathways and suggest measures to reduce the amount of microplastics in the aquatic environment".

The report was delivered in June 2017 and summarises best available technology for removal of microplastics in wastewater treatment plants (WWTP) and gives an overview of international activities and possible actions in the EU and international arena. [2]

[1] http://www.un.org/sustainabledevelopment/oceans/
[2] http://www.naturvardsverket.se/978-91-620-6772-4

Key sources and pathways in Sweden

There are many pathways identified that bring microplastics from land based sources to the sea, for example: air deposition, stormwater runoff, wastewater treatment plants, sewage sludge and snow deposits. For many of these pathways there are only estimations, the challenge today is to find out what amount that reaches oceans, lakes and waterways. The key sources of microplastics identified in the Swedish EPA report are:

- Industrial production and management of primary plastics
- Roads- and tyres
- Artificial turf pitches
- Wastewater from washing of synthetic textiles
- Boat hull paint
- Littering

Microplastics from road wear and tyres is estimated as the biggest land based source in Sweden, where the biggest contribution comes from tyres. However, it was not possible to quantify the amount that reaches oceans, lakes and waterways. The Swedish EPA has proposed a commission to the National Road and Transport Research Institute and suggests that measures should be taken to prevent particles being formed by wear and tear in parallel to preventing particles from spreading to the environment.

The second largest source of microplastics to the environment is artificial turf pitches because of the loss of rubber granules used as in-fill. There are a lot of uncertainties regarding magnitude of loss of the granules, the content of hazardous substances and pathways to the environment. Operators have a great responsibility for maintaining the facilities to avoid spreading of plastics. Measures suggested are education programmes for the personnel responsible for managing the turf pitches, as well as using dedicated hard surfaces for storing of snow scraped from the pitches.

The main pathway of microplastics to water bodies was identified as stormwater runoff. Stormwater can no longer be seen only as a hydraulic issue. It is important to find actions near the source where the particles are generated to prevent them from being further transported in the environment. A Swedish government commission about stormwater was delivered in September 2017: *Analysis of the state of knowledge of stormwater challenge.*[3] However, there is very little clarity regarding the responsibility for the stormwater and an investigation regarding the legislation concerning stormwater is suggested.

Proposed actions concerning microplastics in stormwater and wastewater

- Harmonized definitions and measurement
- Research on microparticles
- Demand for plan for prevention of unwanted substances (“upstream work”)
- Stormwater overflows – guidance for increased control
- Technology development of advanced treatment of stormwater and wastewater
- Pre-procurement purchaser´s group

The Swedish EPA suggest possible research call on microplastics with the aim to continue the building of a knowledge base. The autumn 2017 budget proposition puts focus on plastics in oceans, for

[3] http://www.naturvardsverket.se/upload/miljoarbete-i-samhallet/miljoarbete-i-sverige/regeringsuppdrag/2017/analys-kunskapslaget-dagvattenproblematiken.pdf

example stormwater runoff treatment.[4] There is a governmental investigation (SOU) about the environmental effects of plastics that will be presented 1 October 2018. [5]

What can be done on an international level?

- Regional action plans of HELCOM and OSPAR
- Nordic plastic strategy
- EU circular economy – strategy for plastics
- Together with the Swedish Energy Agency:
  - Investigate the EUs energy labelling of tyres – possible to include tire durability?
  - Developing eco-design rules for washing machines
- Synergies when implementing the marine directive, water framework directive and wastewater directive

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~ During the second presentation of the first theme, **Satu Reijonen** from the Nordic Council of Ministers presented the Nordic program to reduce the environmental impact of plastics

The Nordic Council work with how to share and combine the effort in terms of knowledge production, political discussions and actions at Nordic countries' level. They developed a Nordic programme to reduce the environmental impact of plastics 2017-18. The budget is limited but there is a great will to put political focus on this topic with the development of a vision on plastic management.

Example of action of the Nordic Council: they sent a letter to European Commissioner Karmenu Vella (Commissioner for Environment, Maritime Affairs and Fisheries) to urge him to deliver the work on plastics.

Examples of actions in the Nordic countries:

Norway:

- Miljødirektoratet: Program on reduction of marine littering - 60 million for projects that reduce marine littering. Budget for 2018 not yet approved.
- Current investigation on mandatory sorting (at source) of plastic waste from households and service business. This will come as a regulation by summer of 2018.

Sweden:

- Proposed 78 million in 2018.
- Procurement group for reduced environmental impact from artificial turf pitches.
- Ongoing governmental investigation[6]

Finland:

- 8 projects on marine littering, focus on sources and effects on marine life[7]
- New policy brief on microplastics published this spring[8]
- New smaller project finalized where SYKE analysed 3D printing's ability to reduce the environmental impact of production.

[4] http://www.regeringen.se/pressmeddelanden/2017/05/regeringen-foreslar-insatser-mot-plast-i-haven/
[5] http://www.regeringen.se/rattsdokument/kommittedirektiv/2017/06/dir.-201760/
[6] http://www.regeringen.se/pressmeddelanden/2017/09/asa-stenmarck-utreder-plastens-miljoeffekter/
[7] http://www.syke.fi/meriroskat
[8] https://helda.helsinki.fi/handle/10138/177568

Denmark:

- Plans a national work plan against the environmental impacts of plastics
- Financing two projects on better design of plastic packaging.

The Nordic Council works with 6 strategic areas:

1) Prevention of plastic waste and support for design that promotes greater reuse, longer lifetime and recycling
2) Effective waste-management systems and increased recycling of plastic waste
3) Co-operation on measures to stop plastic waste in the seas and find cost-effective clean-up solutions
4) Advancing knowledge of MPs and identifying measures to cut emissions of MPs to the environment
5) Advancing knowledge of the environmental impacts of bio-based alternatives to plastics and biodegradable plastics
6) Advancing knowledge of problematic substances in recycling of plastic

Focus of the on-going projects has this far been predominantly on the marine aspects. As well as challenges regarding harmonisation of measurement methods.

Examples of on-going projects sponsored by the Nordic Council:

- Micro-, meso- and macroplastic in the commercially important marine species in the Nordic waters. [9]
- Microplastic in the demersal fish and animals between coast and sea areas in the Nordic Region, including the effects on the blue bioeconomy (chairmanship project / Norway)
- Optimization and harmonization of microspectroscopic methods of identification of microplastic in marine samples

[9] https://www.diva-portal.org/smash/get/diva2:1141513/FULLTEXT02.pdf

Theme 2: What are they and how do we know they are there?

~ During the second theme of the conference, **Jes Vollertsen** from Aalborg University gave an overview of methods and challenges for microplastic analysis.

Analysis of microplastics is a major challenge. It can be summarised with the following citation from the BASEMAN project: "*Although microplastics (MP) are recognized as an emerging contaminant in the environment, currently neither sampling, extraction, purification nor identification approaches are standardized, making the increasing numbers of MP studies hardly -if at all- comparable*." [10]

The BASEMAN project strives to tackle the problem of analysis by harmonising the measurement methods. The project is on-going (January 2016 – December 2018).

Without proper analytical methods, the amount of microplastics in the environment cannot be assessed, which results in an inability to distinguish which are the most important sources, and quantify their impacts. The scientific community does not yet have the final answer to how microplastics should be analysed.

Size and mass

Particle size is an important factor, however, larger particles will fractionate into numerous smaller particles. So, a particle number and size cannot be used to establish balances like "which source is the most important". The traditional wisdom is however that microplastic toxicity increases with decreasing size. A challenge during the sampling procedure is to maintain the size of the original particle.

Mass is a good measurement because it is a consistent measurement but it is not enough because different materials have different properties and different effects. Each measurement method has its limitation (mass evaluation but not size; or not product). No analytical method can detect all polymer types. There is a need for a suite of methods to completely analyse a sample (Figure 1).

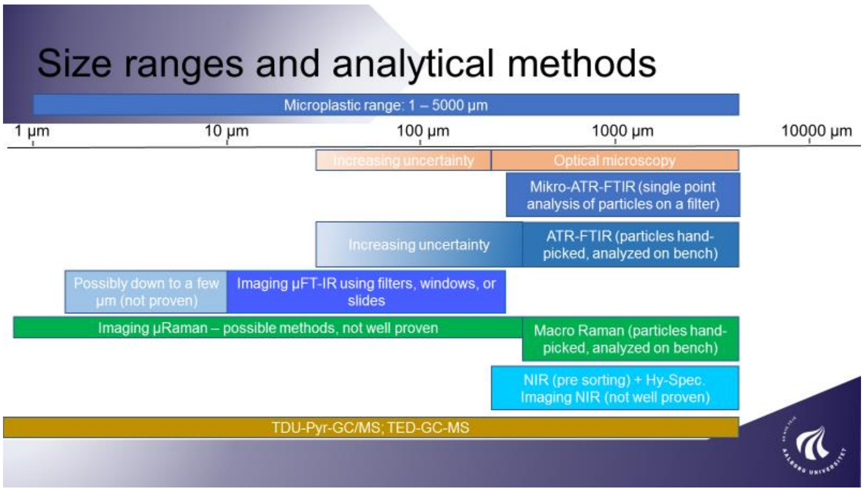

Figure 1. Size ranges and analytical methods.

[10] http://www.jpi-oceans.eu/baseman/main-page

~ A more detailed presentation on analysis with FT-IR and image software was given by **Alvise Vianello** from Aalborg University.

Infrared (IR) molecular spectroscopy is the most used instrumental technique to identify polymer particles in environmental samples.

FTIR = Fourier Transform Infrared Spectroscopy is a vibrational spectroscopy method that relies on the interaction of IR light with matter (sample). IR vibrations are characteristic for each chemical bond, they “occupy” precise regions of the IR spectrum (specific wavenumber ranges). This makes it possible to identify a wide range of substances. FTIR is the most promising analytical technique for microplastic (ID, quantification). Figure 2.

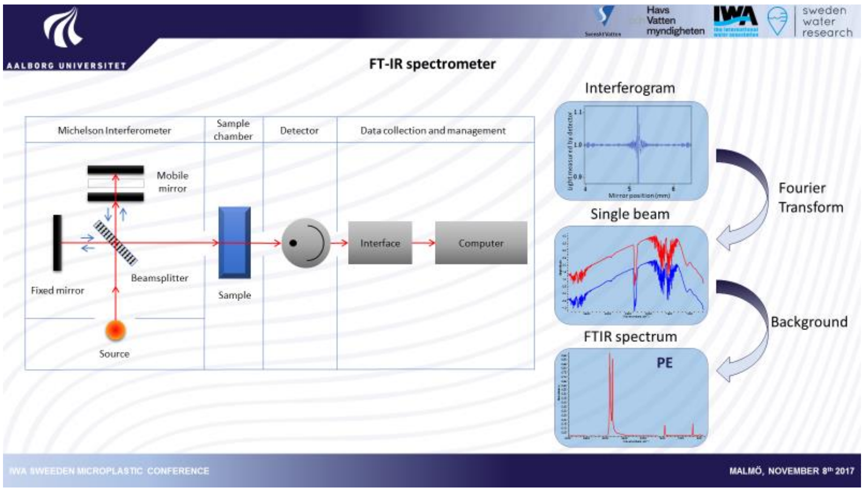

Figure 2. How a FT-IR spectrometer works.

Sample preparation is very important (and time-consuming) since manual handling is needed to prepare and sort the particles before the analysis with FTIR.

Imaging-µFT-IR is the most suitable technique for small microplastics analysis, avoiding manual pre-sorting. A full automatization (or semi-automatization) of the data analysis is important to increase the accuracy and precision of the analysis (Figure 3).

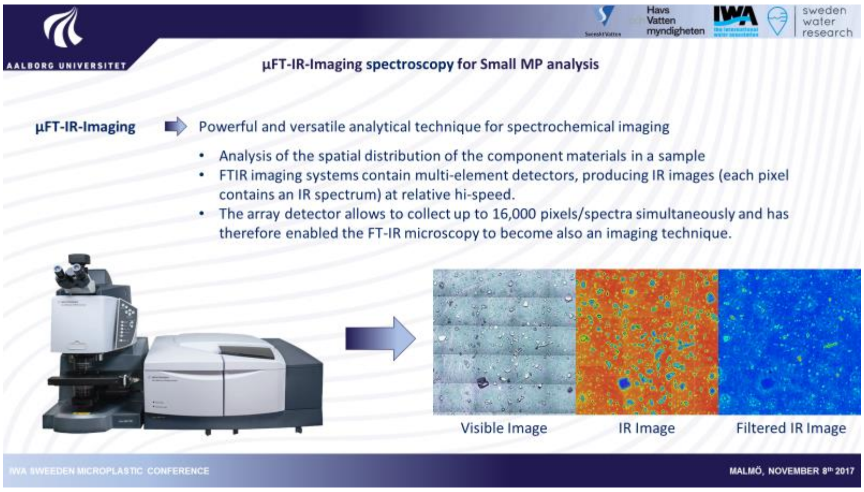

Figure 3. µ-FTIR-Imaging spectroscopy for small microplastic analysis.

Theme 3: What can be done about microplastics in stormwater?

~ First speaker during the third theme of the conference was **Fan Liu**, from Aalborg University, who presented results from an investigation about microplastics in stormwater ponds.

Five stormwater ponds in Denmark were investigated. They had different size catchment areas and different types of catchments (residential, industry, highway, commercial). Both water samples and sediment samples were taken. At the time of the conference only results from the water samples were available.

Microplastics were found in all ponds. Polypropylene, polyethylene and PVC were the most common polymers found. Which pond that contains most microplastics depends on if the results are expressed as number of particles per litre or microgram per litre. Catchment type and area can affect the abundance and type of MP retained in stormwater pond. Density is not the only factor that governs the transport of MP in water phase.

~ The second presentation during the third theme was given by **Daniel Venghaus** from Technical University of Berlin: Optimized materials and processes for the separation of microplastics in road runoff.

Big challenges remain for defining the pathways of plastics and microplastics to the aquatic environment.

One of the on-going projects presented was OEMP[11] that will run until end of September 2018. The project aims at analysing the performance of decentralised devices implemented in the gully to remove microplastic from the stormwater. These devices seem to work well for light and moderate rain (90-98 %) but less for heavy rain (62-78 %).

Figure 4. Pathways for microplastic in road runoff.

The other project presented, RAU[12], will run until the end of July 2020. It involves "street sweeping" analysis, which so far has revealed the diversity of particle distribution with weight concentrated

[11] http://www.siwawi.tu-berlin.de/menue/forschung/oemp/parameter/en/
[12] http://www.siwawi.tu-berlin.de/menue/forschung/rau/

from 125µm to 500µm. This range fraction is however the least associated to organic matter. Regarding microplastics their presence was detected, polyethylene (PE), polystyrene (PS), polypropylene (PP), but for the moment, no quantification has been performed.

There is a correlation between the results of the street sweeping analysis and the intensity of traffic but they are working with the analysis and yet there are no clear conclusions

Abrasion of tyre wear in the aquatic environment will be investigated in a future project.

Theme 4: What happens at the wastewater treatment plant, in sludge and soil?

~ **Julia Talvitie** from Aalto University and the Finnish Environment Institute (SYKE) started of theme four with her presentation on removal of microplastics in wastewater treatment plants.

Wastewater treatment plants are considered as one of the pathways for microplastics to the aquatic environment. First studies have showed that up to 99 % can be removed from the wastewater during the conventional treatment processes. In or before primary settlers, up to 80 %, and a further 20 % in secondary treatment. A microplastic balance of the WWTP indicates that most is retained in the WWTP and there are strong presumption that most of microplastic ends up in the sludge. It is not quantified how much microplastics are retained in the screenings.

The purpose of the presented study was to look at removal efficiencies of specific tertiary treatment processes. Disc filter (DF), biological active filters (BAF), flotation (DAF), rapid sand filters (RSF) and membrane bioreactor (MBR) were the technologies tested. The water was filtered through different meshes and the particles visually sorted. Pre-selected particles were analysed with imaging FTIR. All particles more than 20 µm were included in the study.

Order of performance: MBR (99.9 % removal), RSF (97 % removal), DAF (95 % removal), DF (40 – 98.5 %), BAF (no removal). The microplastics were made of 13 different polymers, with the majority determined as polyether sulfone (PES) and polyethylene (PE). The knowledge of the sources gives a possibility to source control of the microplastics pollution before they enter the WWTPs.

Sampling a greater volume helps to better capture the diversity of the particles (effluent is better defined than influent). The smallest size fraction (20-100µm) and textile fibres were the most common microplastics present before and after the treatments.

Microplastic pollution should in the future be taken into consideration, when designing and implementing wastewater treatment technologies.

The polymers used for dewatering the sludge do not count as microplastics since they are in liquid form rather than particle form.

~ The second presentation during the fourth theme was given by **Márta Simon** from Aalborg University on microplastics in wastewater and soil.

The presented case study from 2016 included sampling from ten of the largest WWTPs in Denmark. The study analysed particles smaller than 500 µm. Measurement of quantities within the sludge proved to be challenging and there was no attempt to do a mass balance across the plant.

Results from the wastewater showed 98 % removal efficiency by mass and 99 % by particle number. The main conclusion of the study was that WWTPs are not a major pathway of plastics to water.

- **Esperanza Huerta** from Wageningen University gave the last talk during theme four on plastic in the terrestrial environment.

An overview of different sources of microplastics in the environment was presented. In some parts of the world there are huge problems with plastic soil cover (mulch) that when not collected properly after use, release a lot of microplastics that will be absorbed in the ground.

The study looked at microplastics uptake by soil invertebrates (earthworms). Microplastics smaller than 150 µm were mixed in with plant debris on the surface of the soil. The earth worms were exposed to microplastics in litter at concentrations of 7, 28, 45 and 60 % dry weight, percentages that, after bioturbation, translate to 0.2 to 1.2 % in bulk soil. When there was a lot of plastics on the surface, the faeces of the worms contained more plastic. However, there is a loss of plastics and it is assumed that bacteria in the worm contribute to degrading plastics.

There was an effect seen on mortality and growth with a quantity above 28 % of microplastics in the soil, yet no effect was observed on reproduction. However, above 7 % of microplastics in the soil, an accumulation in the cast was measured which present an environmental risk.

Promising results from the study showed that the concentration of microplastics is decreased to some extent by bacteria in the worm's gut. The decay was 60 % in 21 days. An interesting question that requires further research is if nanoplastics are created from microplastics.

The plastic added was new plastic, it is unknown if the loss consisted of easily degradable components of the plastic, for instance phthalates. It was suggested that old/used plastic may contain less degradable components and thus not be degraded to the same extent as new plastic.

A field study in Mexico was presented were microplastics were concentrated in the food chain. Chickens that ate earth worms and plastic debris in home gardens accumulated plastics in crop and gizzard.

There is on-going research on how microplastic affect the soil-plant system at the Wageningen University.

Theme 5: What results can be expected from ongoing research?

~ The project MICROPOLL[13] (Multilevel assessment of MPs and associated pollutants in the Baltic Sea) was presented by **Christian Baresel** from IVL Swedish Environmental Research Institute.

This project runs from July 2017-June 2020. It is a multilevel assessment of microplastics and associated pollutants in the Baltic Sea. The plan is to include assessment of status quo, assessment of measures and policy implementation.

There are six work packages (WP):

1. Marine microplastics sampling and processing
2. Vector function of microplastics for organic contaminants and biofilms, degradation
3. Impacts of MP, associated contaminants and biofilms on Baltic biota
4. Eco-technological approaches for efficient wastewater treatment.
5. Modelling, sources, transport, pattern and fate of microplastics
6. Policy advice and implementation

WP4 was in focus of the presentation. This WP includes going through existing data on WWTP as a pathway for microplastics to the Baltic Sea, and looked at combined sewer overflows. This WP also includes investigating resource efficient removal technologies how much impact micropollutant removal might have at WWTPs (for example filter technologies). This will lead to recommendations of holistic strategies.

~ The project IMPASSE[14] (Impacts of MicroPlastics in AgroSystems and Stream Environments) was presented by **Martyn Futter** the Swedish University of Agricultural Science, SLU.

This project runs from 2017 to 2020.

The research work plan is framed around two pillars: pillar 1 is devoted to analysis of exposure and impacts of microplastics in agricultural systems. In pillar 2 this information will be used to assess environmental and economic impacts of possible management actions.

The project includes a combination of field, laboratory and modelling studies to estimate the fate and environmental effects of microplastics in agricultural soils. Field studies including soil, water and sludge sampling are being conducted in Canada, Spain and Sweden. Methods for separation and quantification of microplastics in sludge using FTIR/Raman spectroscopy are being developed in Norway. Laboratory studies of microplastic effects on soil invertebrates are being conducted in the Netherlands and Sweden. Modelling of microplastic transport in the environment and investigations of the impact of applying sewage sludge on land are also included.

Furthermore, assessments of the risk for transfer of hazardous substances in microplastics to crop and dairy products will be performed.

[13] https://www.bonusprojects.org/bonusprojects/the_projects/blue_baltic_projects/micropoll
[14] http://www.waterjpi.eu/index.php?option=com_content&view=article&id=589:impasse&catid=156:joint-calls

Panel discussion: What more can be done and who should do it?

The panel consisted of five lecturers representing Sweden, Denmark, Germany, Finland and the Netherlands:

- Anna-Maria Sundin from the Swedish Environmental Protection Agency
- Jes Vollertsen from Aalborg University, Denmark
- Daniel Venghaus from Technical University of Berlin, Germany
- Julia Talvite from Aalto University and the Finnish Environment Institute
- Esperanza Huerta from Wageningen University, the Netherlands

The panel first discussed the behavioural patterns in society and that almost all human activities today will generate microplastics. Society needs to change and think about which legacy that is left to coming generations.

The plastic producers should have more responsibility according to the "polluter pays principle". Co-operation among stakeholders is also very important.

Pathways and sources

To map the pathways and sources properly the mass balances need to be closed, look at mass flows and identify and quantify different pathways/sources. Also, there is a need to determine which components that are discussed and what effect they have. There is a need to know what to measure to be able to do proper risk assessments. Some plastics may not harm the environment. Maybe the additives could be more problematic?

Analytical methods

The BASEMAN project will not give all answers about standardised methods, the BASEMAN consortium has agreed on three size fractions: ~20 µm, ~100 µm, ~1mm. Hence, small paint and rubber particles will not be included since they are often smaller than 20 µm.

The lower limit for size determination seems to be 1 µm, for smaller particles than that it is only possible to determine mass weight. There is a risk of contamination of samples. There is a great challenge to monitor the dispersal of microplastics. Extraction of microplastics from sludge is also problematic but not impossible.

Stormwater

With today's knowledge, it seems like stormwater is an important pathway of microplastics to water bodies (in Sweden, Norway, Denmark and the Netherlands) and in some cases also CSO (combined sewer overflow). When addressing stormwater there is also a need to look at other micropollutants.

At the WWTP

Some first investigations at the WWTP shows over 90 % microplastic removal with preliminary and primary treatment, and up to 99 % if activated sludge is included. However, it is still unknown what happens at the screening step/steps and if the microplastics are degraded in the WWTP processes or converted to nanoplastics. Monitoring series of microplastics in the influent to WWTP could give good information.

Probably, a big share of the microplastics will end up in the primary sludge. It is also unknown if the digestion process affects microplastics. Perhaps changes could occur regarding the size and shape of the microplastics, but it is very difficult to measure in the sludge. Is there a need to treat primary sludge separately? Thermal hydrolysis processes (THP) as pre-treatment before digestion might affect the microplastic content of the sludge.

Should every WWTP monitor its microplastic emissions or should it be just environmental monitoring of receiving waters? However, no monitoring program is relevant until methods and measurement and quantification have been agreed upon.

In soil

There is currently an on-going study in Sweden considering microplastics in farmland fields that have had sludge applied/not applied for more than 35 years. Results from this study will contribute to fact-based decisions and how to prioritize the issue.

Bio based plastics instead of fossil plastics in the soil are not good either. The biodegradability is the most important.

If most of the plastics coming to the WWTP end up in the sludge, should they be maintained there and not spread on farmland? A balance must be found between positive and negative aspects when the decision to recycle sludge is considered. The precautionary principle should not be based on gut reactions, it should be based on well-grounded research of good quality.

Comments from the audience

- Inform the public more on this problem.
- Work with minimizing the sources
- Reduce traffic, make it more expensive to buy gas, park, go through city centres.
- Prohibit scrubs with microplastics and put filters in washing machines.
- Implement maintenance instructions for artificial turfs.
- Increase ocean and beach clean-ups to prevent larger plastics to breakdown into microplastics.
- Determine which pathways are most important.
- Define easy, quick and cheap methods to measure the level of microplastics in sludge.
- Standardize sampling, sample preparation and analytical test methods by co-operation among different sectors (researchers and authorities).
- Innovative solutions for stormwater treatment are needed, combine with other needs to treat stormwater.
- Make clear how much plastic is removed at what stages at the WWTP.
- Focus on simple treatments of sludge so that recycling of sludge as a fertilizer can continue.
- Have a clear picture of the size of the problem in WWTP and sludge, compare it to other threats and take science based decisions. R&D needed.

Workshop

The workshop, held the day after the conference, had 36 participants from universities, research institutes and water companies. The day was divided into two sessions. During the morning session, the task was to identify urgent research issues and during the afternoon to discuss projects that could address the urgent research issues.

The morning session started off discussing research needs in five groups that each had a theme:

1. Sources and sinks
2. Prevention
3. Analytical methods
4. Treatment
5. Fate in recipient

Related to the five themes, nine urgent research issues were identified, see Figure 5.

A ranking of these nine urgent research issues was done by the participants in two aspects: importance and uncertainty. The discussions included eight of the nine issues (number nine ranked as the least important). The four most important, which also all was regarded as having high uncertainty came out as:

- Evaluation of the risk of MP in the environment
- Standardise methods and sampling
- Mass balance and pathways
- Source control

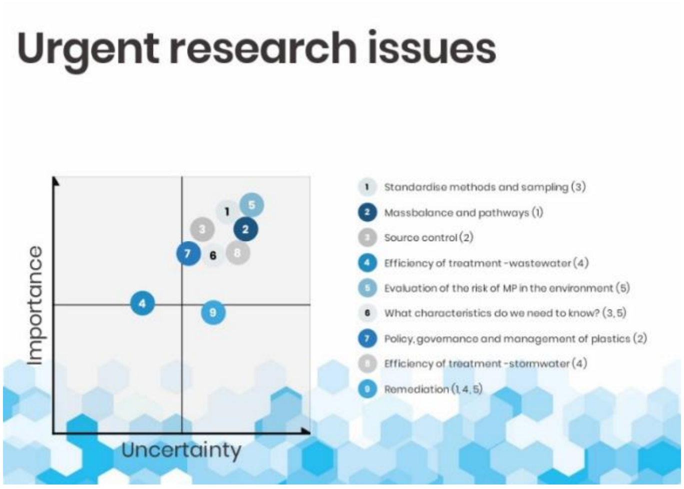

Figure 5. Identification and ranking of urgent research issues. The figures within brackets refers to the five themes (1) Sources and sinks, (2) Prevention, (3) Analytical methods, (4) Treatment, (5) Fate in recipient (water and soil).

Urgent research issues

A fragment of the discussions held during the day is presented below.

Standardise sampling, pre-treatment and analytical methods:

- Standardised sampling and pre-treatment is needed to reduce issues with contamination of samples, to increase the possibility to compare results. There is a need to know what happens to the particles during sample preparation.
- This must be achieved through condensation of knowledge over time and consensus within the people working with this type of analysis.
- There must be more thought put into creating standards for cross analysis between different labs. There have been unsuccessful trials with this. Perhaps focus on weight rather than number of particles and to keep within a realistic range.
- Documentation and sharing experience is important to avoid a risk that clusters of researchers are being created with many standards depending upon the matrix.
- Identification of soft sensors/surrogate parameters for microplastics identification could be interesting to provide affordable alternatives for analysing microplastics.

Mass balance and pathways:

- There is a need to know where the particles are originating from, how much and what happens to them in order to identify measures.
- It is unknown what happens to emitted particles. Do they reach surface water, and to what extent? What happens to the ones that do not reach surface water?
- The relation between different sources of microplastics, how much do these contribute?

Source control

- Source control, polluter pays principle and extended producer responsibility is very important to prevent release of microplastics in the environment.
- Prevention can be done by legislation, recirculation initiatives and other economic- and information instruments.
- How can people’s behaviour change to decrease the amount of microplastics spread in the environment?

Efficiency treatment – wastewater

- There is a need to identify removal of microplastics in the different WWTP processes.
    - How much microplastics is removed at the preliminary treatment (screens) and doesn’t end up in sludge?
    - It would be interesting to compare removal efficiency for pre-filtration processes and conventional primary sedimentation processes.
    - What happens to microplastics in the digesters at the WWTP? Different at different temperatures?
    - What are the sources to the microplastics in sludge, mostly from wastewater or from external food waste/grease traps etc?
    - During other treatment steps, do the microplastics become nanoplastics or are they degraded?

Evaluation of the risk of microplastics in the environment

- There is a need to address the risk – is microplastic dangerous?
- Evidence of clear problems is lacking.
- What are the known suspects – sizes, toxicity, surface, vector effects, processes, water- air- or soil bound?
- Is the possible creation of nanoplastics a problem?
- Microplastic in sludge is another knowledge gap.
- The "farmland perspective" is important, where do the microplastics found on farmland origin from and which pathway brought them there?

What characteristics do we need to know?

- There is a need to establish what is most important to know about the microplastics:
  - Mass
  - Size
  - Composition
  - Type of plastics
  - Additives
  - Morphology

Policy, governance and management of plastics

- Ban on cosmetic beads is important, low hanging fruit.
- Focus on air and soil as well.

Efficiency of treatment – stormwater

- There is a need to analyse road dust and road runoff.
- The efficiency of storm-water ponds/gardens as microplastics traps is unknown.
- Combine microplastics analysis with measurement of turbidity, suspended solids and heavy metals to find correlations with microplastics. Generalise to be able to predict results from other ponds based on simpler analyses. Very important to find ponds with suitable construction. They should allow for accurate flow measurements and sampling.