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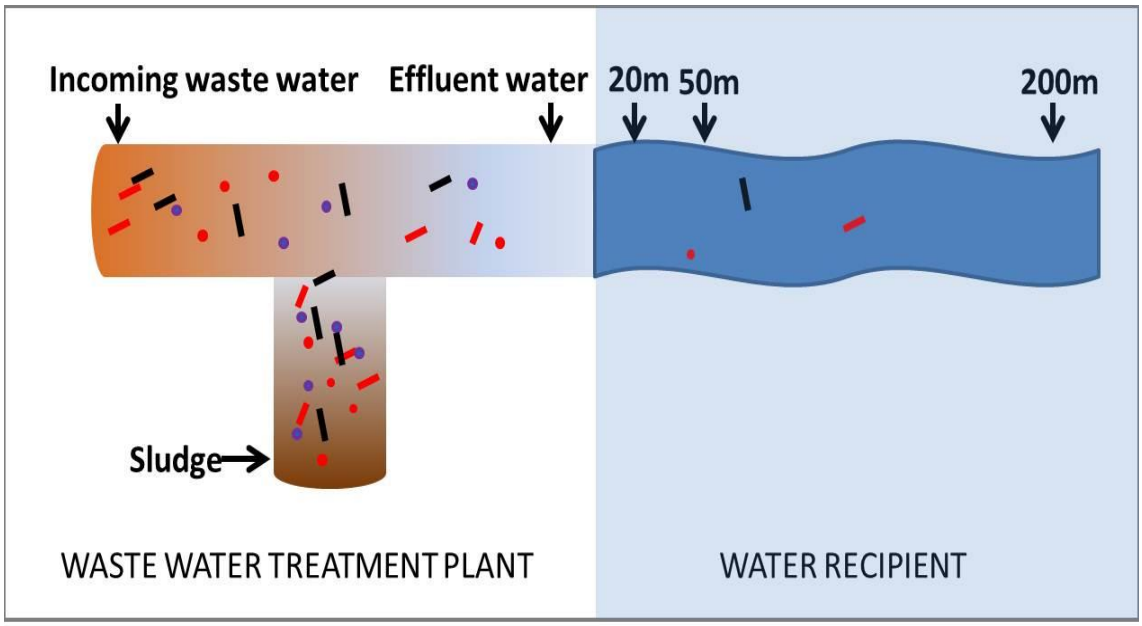
Screening of microplastic particles in and down-stream a wastewater treatment plant



Sampling of microplastic litter particles in a waste water treatment plant and in the water recipient outside the mouth of the waste water effluent tube.

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Summary
The role of waste water treatment plants (WWTPs) as entrance routes for microplastic particles to the sea was evaluated. Sampling was done at a small WWTP (14 000 population equivalents) with effluent water being discharged into the sea. Microplastic particles ≥300 µm were analysed in influent and effluent water, sewage sludge and in recipient water outside the effluent tube. Background levels were from a location not directly affected by the WWTP effluents. All sampling was done during the course of one day.

WWTP concentration in incoming water was 15 000 microplastic particles per m^3, resulting in an inflow of 3 200 000 particles per hour. Retention in sewage sludge was > 99 %, and 1 770 microplastic particles per hour left the WWTP with the effluent water.

The microplastic concentration in the recipient of the effluent tube was elevated compared to background levels; 1.1 - 1.8 plastic particles m^{-3} were found in the effluent plume compared to 0.45 m^{-3} in the reference area. Higher particle concentrations were found close to the mouth of the tube compared to 200 m downstream.

The study demonstrates that the supply of microplastics from WWTP effluents to the marine environment may be substantial, but their relative importance in relation to other source is difficult to estimate due to the general lack of quantitative studies.

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Table of Content

Summary

This project aims at evaluating the role of waste water treatment plants (WWTPs) as entrance routes for microplastic particles to the marine environment, and is completed within the scope of the Swedish EPA screening programme 2014. Sampling was done at Långeviksverket in Lysekil, a relatively small WWTP with a load of 14 000 population equivalents (pe), and with effluent water being discharged into the sea. Analyses were performed on microplastic particles collected on a filter with a 300 µm mesh size, both in the actual WWTP (incoming and effluent water, and sewage sludge) and in the recipient water. Background levels of microplastics were obtained by analysing seawater from a location not directly affected by the effluents from Långeviksverket. All the sampling was done during the course of one day.
It is not obvious to give an exact definition of the size of the collected particles, e.g. plastic fibres with a diameter smaller than 300 µm might either be caught on the filter or slip through it. Still, in this report the collected material is referred to as *microplastics ≥300 µm*, even though it would have been more accurate to define it as *the microplastics collected on a 300 µm filter*.

WWTP incoming water was found to have a mean concentration of 15 000 microplastic particles ≥300 µm per m^3, which resulted in an inflow of 3 200 000 microplastic particles per hour. More than 99 % of the particles were retained in the WWTP sludge and the concentration in effluent water was 1 770 microplastic particles per hour. The retention rate was affected by the shape of the particles, and plastic fibres were retained to a higher degree than particles of other shapes.

The microplastic concentration in the recipient of the effluent tube was elevated compared to an area presumed to not be directly affected by the effluent; 1.1 - 1.8 plastic particles m^{-3} were found in the effluent plume compared to 0.45 m^{-3} in the reference area. Higher particle concentrations were found close to the mouth of the tube compared to 200 m downstream. No other plastic particles but plastic fibres were found in the recipient.

The study demonstrates that the supply of microplastics from WWTP effluents to the marine environment may be substantial, but their relative importance in relation to other sources/entrance routes is difficult to estimate due to the general lack of quantitative studies.

Sammanfattning

Inom ramen för Naturvårdsverkets screeningprogram 2014 har i detta projekt avloppsreningsverkens betydelse som introduktionsväg för mikroplastpartiklar till havet utvärderats. Provtagning gjordes på Långeviksverket i Lysekil, ett relativt litet avloppsreningsverk med en belastning på 12 000 person ekvivalenter (pe), och med en avloppstub som mynnar i havet. Analyser av mikroplastpartiklar ≥300 µm utfördes dels i själva reningsverket (inkommande och utgående vatten samt i slam), dels i recipientvattnet. Bakgrundshalter av mikroplaster analyserades i havsvatten på en lokal som bedömdes vara opåverkad av Långeviksverkets utsläpp. Alla provtagningar gjordes under loppet av en och samma dag.
Det är inte heller självklart att exakt definiera storleken på de uppsamlade partiklarna. t.ex. kan en plastfiber med en diameter mindre än 300 µm antingen fastna på filtret eller åka igenom det. Trots detta har vi valt att kalla det uppsamlade materialet för *mikroplastpartiklar ≥300 µm*, även om det egentligen hade varit mer korrekt att definiera det som *de mikroplastpartiklar som fångats med ett 300 µm-filter*.

I inkommande vatten uppmättes en genomsnittlig koncentration på ~15 000 mikroplastpartiklar ≥300 µm per m^3 vilket innebar inflöde av ~3 200 000 mikroplastpartiklar per timme. Över 99 % av partiklarna avskiljdes till reningsverksslammet och mängden som lämnade verket med utgående vatten var ~1 770 mikroplastpartiklar per timme. Formen på de analyserade partiklarna påverkade i vilken utsträckning de avskiljdes i reningsverket och plastfibrer var en grupp som i högre grad än partiklar av andra former återfanns i slamfasen.

Koncentrationen av mikroplastpartiklar i recipienten var förhöjd i plymen utanför avloppstubens mynning jämfört med ett referensområde som inte var direkt påverkat av utsläppsvattnet; 1.1 - 1.8 plastpartiklar m^{-3} i plymen jämfört med 0.45 m^{-3} i referensområdet. Högre partikelkoncentrationer uppmättes närmast tubens mynning jämfört med 200 m nedströms. I recipienten detekterades inga andra typer av plastpartiklar än plastfibrer.

Undersökningen visar att volymen av mikroplastpartiklar som tillförs havet via utgående vatten från avloppsreningsverk kan vara substantiell. Eftersom det fortfarande har gjorts mycket få kvantitativa studier av källor/tillförselvägar till marint mikroskräp är det dock svårt att bedöma avloppsreningsverkens relativa betydelse.

1 Introduction

1.1 Background

Litter has been internationally recognized as a serious problem to the marine environment and has recently become one of eleven descriptors defining a Good Environmental Status (GES) of the marine environment in the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC). EU member states are thus obliged to monitor litter (including microlitter), in coastal areas, and if necessary take measures to reduce the input at least to levels where "Properties and quantities of marine litter do not cause harm to the coastal and marine environment" (EC, 2010). Strategy plans for how to reduce the amount of marine litter in the North-East Atlantic and the Baltic Sea are also being developed within HELCOM and OSPAR.

Whereas visible marine litter has been considered as a serious environmental problem for a long time microlitter, and in particular microplastics, has received attention only the past decade. A few reports on findings of plastic pellets in the sea were published already in the early 1970's (Carpenter & Smith, 1972; Colton *et al.*, 1974), but the debate really took off after a ground breaking article by Thompson et al 2004 (Thompson *et al.*, 2004), where data on microplastics in zooplankton samples from the Atlantic were presented. Since then an increasing number of studies of marine microlitter from all parts of the world have been published (Ng & Obbard, 2006; Claessens *et al.*, 2011; Faure *et al.*, 2012; Cózar *et al.*, 2014; Magnusson, 2014).

Although the number of reports and scientific articles on marine microplastics has increased dramatically over the past decade surprisingly little effort has been spent to identify the sources. Waste water treatment plants (WWTPs) have been suggested to function as important entrance routes to the marine environment for many kinds of anthropogenic particles, including microplastics. The WWTPs receive waste water from households, institutions, commercial establishments and industries, and sometimes also rainwater run-off from urban areas. The treatment includes physical, chemical and biological processes, and is mainly focused on the elimination of large objects and on reducing the concentrations of nutrient and organic material in the waste water. There are also WWTPs where the effluent water before being discharged undergoes a final treatment, e.g. disc filter or Membrane Bio Reactor (MBR), which probably reduces the amount of particulate material in the effluent water. However, many Swedish WWTPs lack this kind of final treatment of the waste water.

The harmful effects of microplastic litter to marine organisms may be linked to mechanic disturbance by the plastic particles, leachage of toxic plastic monomers (e.g. bisphenol A from polycarbonates and expoxy, or styrene from polystyrene) or toxic

plastic additives (e.g. brominated flame retardants and phtalates). But plastic particles also constitute a surface to which organic pollutants in the surrounding water may adsorb (Koelmans *et al.*, 2013). This may be of great concern in the WWTP environment since waste water can contain relatively high concentrations of harmful compounds originating from e.g. pharmaceuticals, household and personal care products and cleaning products (Carballa *et al.*, 2004; van Beelen, 2007).

1.2 Aim and limitations of the study

The overall aim of the study was to investigate the importance of WWTPs as an entrance route for microplastics ≥300 µm to the marine environment, and to estimate the efficiency by which microplastics in incoming waste water are retained within the plant. The study was limited to one sampling occasion where all matrices were sampled within one day; incoming water, sewage sludge, effluent water and recipient water around the mouth of the effluent tube.

2 Description of the selected WWTP

The study was carried out at Långeviksverket in Lysekil at the Swedish west-coast, This WWTP is adapted for a population equivalent (pe) of 45 000 but in practise has a load of 12 000 pe. The waste water is treated mechanically, chemically and biologically. Effluent water is discharged into the sea through a ~850 meter long tube (Ø ~700mm) that ends at 22 meters depth on an erosion bottom (sea shell gravel and pebbles with grain size 1 mm – 10 mm). The outlet of the tube is located in an area that is very exposed to the westerly winds.

3 Methods

Analysis of microplastics was done on incoming, effluent and recipient water, and on sewage sludge. The incoming water was sampled before the grid, and the effluent water was sampled *after* all treatment steps (Figure 1). Number of replicates and sampled volumes/weight of water and sediment is presented in Table 1.

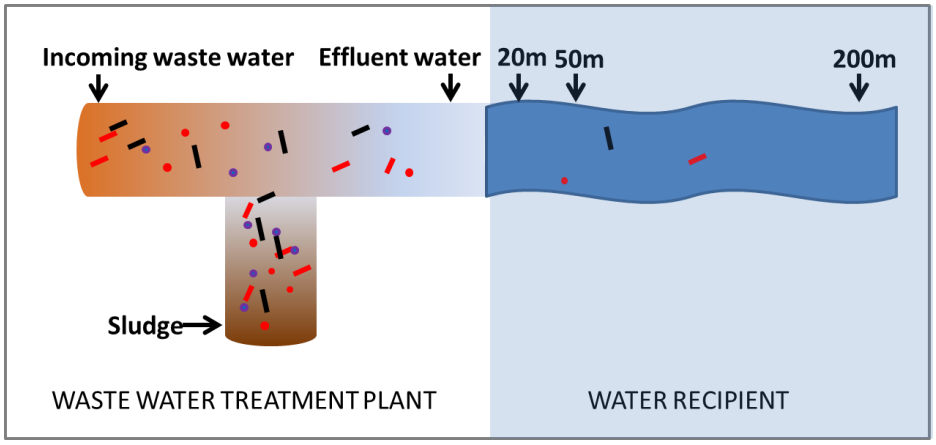

Figure 1 Schematic picture of the fate of microplastic litter particles in the investigated WWTP. Sampling points are marked with arrows. Samples were also taken from a reference site in the recipient

Table 1. The matrices sampled for analyses of micro plastics, the number of replicates and the volume/weight of the replicates.

Sample	Number of replicates	Volume/weight of each replicate
Influent water	3	2 litres
Effluent water	4	1 m^3
Sewage sludge	4	~25 g wet weight (=~1.1 g dry weight)
Recipient water (20, 50 and 200 m from the effluent tube + unaffected reference site)	2 at each location	6.6 m^3

3.1 Sampling of microplastics in the WWTP water and sludge

Since the influent water contained considerably more organic material than the effluent, different methods were used for sampling at the two locations. Influent water had a high content of organic matter and only a few litres could be filtered until the filters were completely clogged. Effluent water had a considerably lower content of organic material and it was therefore feasible to filtrate volumes in the range of m^3. It was also presumed that the effluent water would contain fewer microplastics than influent water as the particles where supposed to become caught in the sludge, and it would therefore be advisable to sample a larger volume.

Incoming water was sampled with a Ruttner sampler (a water sampler made up by a cylinder which is lowered into the water and closed with a plummet). The water was poured into a filter holder of stainless steel fitted with a filter cut out from plankton net

and with a mesh size of 300 µm (Ø 80 mm). The water was sucked through the filter by vacuum filtration using an aspirator connected to the water tap.

Effluent water was sampled by fitting the same filter holder used for incoming water to a tube connected to a suction pump. The filter holder was lowered into the effluent water, and the water was sucked through the filter by vacuum filtration. A flow meter was fitted to the pump to measure the sampled volume.

Samples of sewage sludge were taken from slightly dewatered sludge. The sludge dry weight (dw) was estimated by drying aliquots of wet sediments at 70°C to constant weight and was found to be 4.5 %.

Filters were kept in petri dishes and sewage sludge in new, carefully cleaned polyethylene storage boxes before getting analysed. All samples were stored in the dark at room temperature.

3.2 Sampling of microplastics in the WWTP recipient

Water samples in the recipient where taken at 20, 50 and 200 meter downstream the effluent tube. Samples were also taken at a reference station 3 500 meters away from the water plume. The plume of effluent water was followed using a current cross with a mounted GPS logger. The survey boat (MV Oberon) followed the current cross and stopped at the selected sampling distances (20, 50 and 200 m from the tube) using a high precision GPS on board. There was no visible stratification in the water mass during the sampling. At all stations the stratification was measured before sampling using a SSV-75M CTD and the results were similar between the stations (Fig 2).

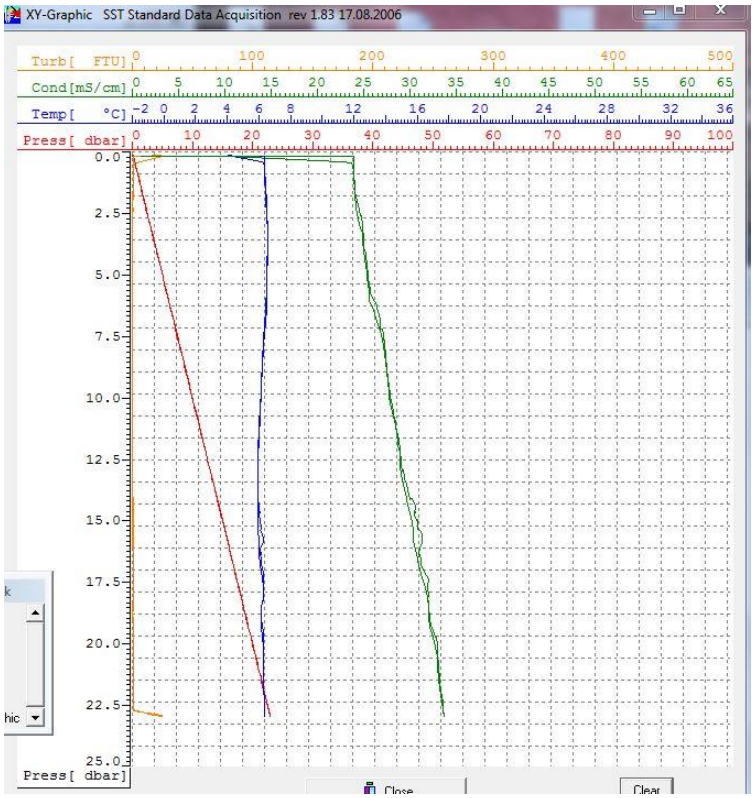

Figure 2 Conductivity -Temperature-Depth (CTD) profiles at the outlet point of the pipe. The CTD profile is representative for all three stations. Green line indicates conductivity (mS m-1), blue is temperature (°C) and red is depth (m). The y-axel indicates water depth (m).

Sampling was done with zooplankton net with a mesh size of 300 µm that was towed horizontally from the bottom (rising from 22 m by the mouth of the effluent tube to 18 m 200 meters away from the tube) to the surface while the survey boats was in a fixed position. Each replicate consisted of three tows, which added up to a sampled volume of 6.6 m^3. After sampling the net was rinsed from the outside using surface water to collect all material in the cod-end of the net. The cod-end was emptied from the bottom and poured onto a 300 µm filter (Ø 80 mm) mounted on a stainless steel filter holder. The filters had been pre-examined prior to sampling and all particulate matter removed. All handling was done with the aim to minimize contamination from air and surfaces.

3.3 Analyses of microplastics

3.3.1 Analyses of water samples

The filters with the collected material from incoming and effluent water were studied under stereo microscope (50 times magnification) and all detected plastic particles were counted and placed into one of the categories fibre, fragment or flake. *Fragment* was used for all microplastics with an obvious three dimensional shape, whereas *flakes* were very thin particles. The terms *microparticles* and *particles* refer to all three categories.

It was generally easy to differentiate between anthropogenic and natural particles simply by observing the morphology. However, occasionally it was difficult to distinguish between plastic and non-synthetic anthropogenic fibres, e.g. textile fibres made of cotton. In those cases the fibres were placed on an object glass and heated over the flame of an alcohol burner. Fibres and particles made of plastics would melt, whereas the non-synthetic anthropogenic ones would not.

3.3.2 Analyses of sewage sludge

In order to reduce the amount of fresh organic material in the sewage sludge, which would hamper the detection of microplastics, aliquots of wet sediment (~25 g) were carefully sieved through filters with 300 µm mesh size, which were cut out from plankton net. The sludge samples were then analysed in the same way as the water samples.

3.4 FTIR analyses

To receive more specific information on what material the collected microplastics were made of, individual particles were picked out for analyses with Fourier transform infrared spectroscopy (FTIR). With this technique the analysed particles are exposed to infrared radiation and a spectrum is obtained where characteristic peaks correspond to specific chemical bonds between atoms. This makes it possible to identify the exact composition of the particle. All analyses were performed at Swerea IVF with a Bruker FTIR Tensor in Attenuated Total Reflectance (ATR) mode. The ATR was equipped with a diamond crystal. The analysed microplastics were selected either because they were commonly occurring in the samples or because they were considered to be of particular interest.

4 Results

4.1 Microplastics in WWTP and recipient water

The total amount of microplastics ≥300 µm (number m-3) was 1 800 times higher in incoming water than in effluent, ~1 500 particles compared to 8 (Table 2). In the recipient microlitter concentrations were elevated compared to the unaffected reference site. There was also a clear declining trend along the water plume from the mouth of the effluent tube and moving downstream.

Table 2. Microplastics in influent and effluent water, in the water recipient outside the effluent tube, and in sewage sludge. Samples were also taken at a recipient reference site presumed to be unaffected by the WWTP effluent water. Data is given as number of particles m^{-1} (water samples) and number of particles kg-1 (sludge). Figures are mean values ±SE (influent water: n=3; effluent water: n=4; recipient: n=2; sludge: n=4).
Ww = wet weight; dw=dry weight.

Sampling point	Plastic fibres	Plastic fragments	Plastic flakes	ΣMicroplastics
Influent water (number m^{-3})	$10.7\pm0.39\cdot\cdot10^3$	$2.67\pm0.77\cdot10^3$	$1.78\pm0.80\cdot10^3$	$15.1\pm0.89\cdot10^3$
Effluent water (number m^{-3})	4.00±0.58	3.75±1.25	0.50±0.50	8.25±0.85
$Recipient_{20m}$ (number m^{-3})	1.82±0.45	0.08±0.08	0.08±0.+8	1.97±0.30
$Recipient_{50m}$ (number m^{-3})	1.29±0.68	0	0	1.29±0.68
$Recipient_{200m}$ (number m^{-3})	1.14±0.38	0	0	1.14±0.38
Recipient reference (number m^{-3})	0.45±0	0	0	0.45±0
Sludge, ww (number kg^{-1})	521±76	146±45	53±4	720±112
Sludge, dw (number kg^{-1})	$12.1\pm1.23\cdot10^3$	$3.37\pm0.94\cdot10^3$	$1.28\pm0.17\cdot10^3$	$16.7\pm1.96\cdot10^3$

It could be presumed that the microplastics not ending up in the effluent water would be found in the sewage sludge. A way to verify this was to compare concentrations of microlitter based on in the solid material in incoming water, with concentrations in the sludge. Solid material in waste water is measured as *suspended solids* (SS) and is determined in a different way than the dry weight (dw) of the sewage sludge. Whereas dw of SS in the influent water is determined from the material collected on a glass fibre filter with a mesh size of 1 µm, the dw of sludge is determined without any manipulating. Still, as a rough estimate, SS (dw) and sludge (dw) could be considered as comparable units. There were no measurements of SS in influent water the day of the sampling. However, it is measured on regular bases, i.e. the 25th of June, 6 days prior to the sampling day (1 July), it was found to be 520 mg l^{-1} and the 10th of July 490 mg l^{-1}. This was a period of dry weather, and it is therefore likely that SS content in incoming water July 1st was in the same range as at the other two dates, i.e. ~500 mg l^{-1}. SS in effluent water is always very low compared to incoming water (usually in the order of 10 mg l^{-1}), which means that almost all SS is deposited in the sludge. When comparing the microplastic concentration in 500 mg SS in influent water with 500 mg sludge (dw) it was found that the microplastic concentration in sludge was somewhat lower but still within the same range as in the water (Table 3). Since, as discussed previously, the microplastic concentration in SS in influent water can be presumed to be slightly higher than the concentration in sludge, simply due to differences in how the two units are determined, the similarity between microplastic concentration in incoming water and sludge could be expected to be more similar than indicated by the figures in table 3. There are uncertainties, e.g. the amount of SS was an estimated value, there were only three replicates of influent water and the measurements were only made at one occasion. Still, the results indicate that it is possible to get a good estimate of microplastic concentrations in sewage sludge by measuring concentrations only in incoming water.

Table 3 Comparison between the number of microplastics in 1 m^3 of incoming water, which is estimated to contain 500 g dw of suspended solids (SS) and 500 g dw of sewage sludge. Figures are mean values ±SE (Influent water: n=3; Sludge: n=4)

	Plastic fibres	Plastic fragments	Plastic flakes	ΣMicroplastics
Influent water (number m-^{3})	10.7±0.39··10^3	2.67±0.77·10^3	1.78±0.80·10^3	15.1±0.89·10^3
Sewage sludge (number 500 g dw^{-1})	6.04±0.62··10^3	1.69±0.47·10^3	0.64±0.082·10^3	8.36±0.98·10^3

4.2 Retention of microplastics in WWTP

The retention capacity of microplastics ≥300 µm in Långeviksverket, was calculated as

([Incoming water]-[Effluent water] / [Incoming water]) x 100

The retention was very high, over 99.9%, for all microplastic categories (Table 4).

Table 4. Retention of microplastics in Långeviksverket, calculated from the difference between incoming and effluent water. Figures are based on mean values.

Plastic fibres	Plastic particles	Plastic flakes	ΣMicroplastics
99.96%	99.75%	99.63%	99.90%

4.3 Partitioning between different shapes of microplastics

The relative distribution (in numbers) between different kinds of microplastics (fibres, fragments and flakes) was found to differ between influent and effluent water (Fig. 2). Plastic fibres were more efficiently retained in the sewage sludge than the plastic fragments and plastic flakes. In the incoming water and in the sewage sludge the fibres made up around 70 % of the total microplastics, and in effluent water 49 %. The relative proportion of plastic flakes (probably deriving from paint) was the same in all three matrices, influent water, sludge and effluent water.

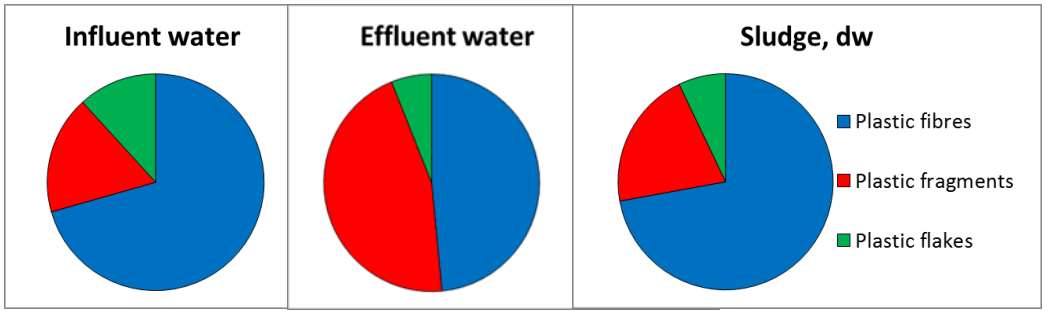

Figure 3 Partitioning between different categories of microplastic particles in influent and effluent water, and in sewage sludge. The distribution is based on number of particles.

4.4 Amount of particles coming into and going out from WWTP per hour

The average flow rate of waste water through Långeviksverket between 9 am and 14 pm the day of the samplings was 215 $m^3 h^{-1}$. That means that 3.25 million microplastic fibres, fragments and flakes entered the WWTP per hour and a little less than 2 000 left with the effluent water (Figure 5) on this particular day.

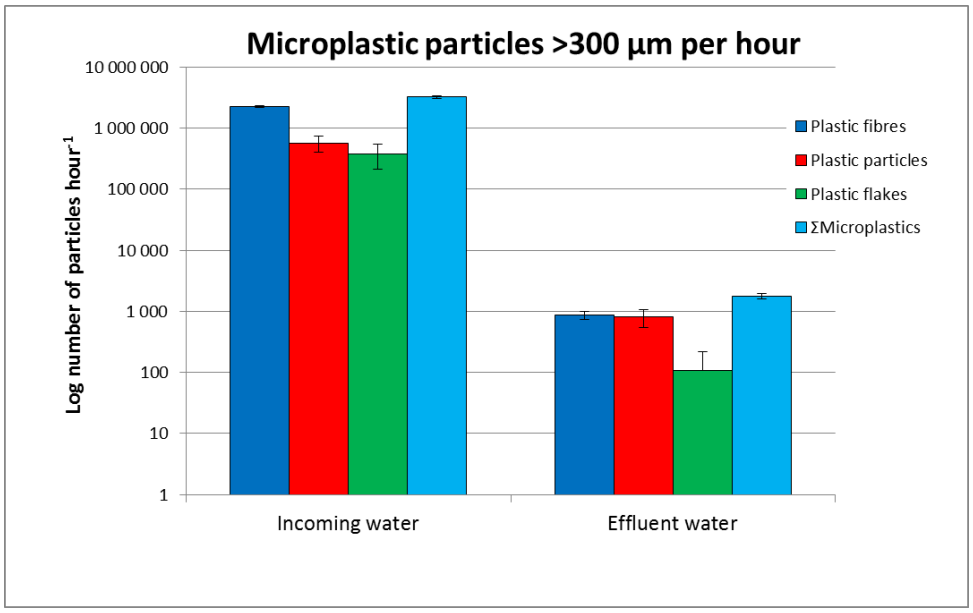

Figure 4 The number of microplastics ≥300 µm coming into and leaving Långeviksverket per hour. The table displays values for each category of microplastics as well as the sum of them. Figures are mean values±SE (Incoming water: n=3; Effluent: n=4). Note log scale!

4.5 FTIR-analyses of microplastic particles

Good FTIR spectra were obtained from several plastic fragments and plastic flakes. However, due to problems with the FTIR spectrometer it was not possible to get spectra from any plastic fibres. Some of the fragments and flakes were worn and threaded, which also resulted in spectra that were hard to interpret. A selection of the successful analyses from the FTIR analyses is presented in table 6.

Table 6 Results from the FTIR analyses of a selection of microplastic particles ≥300 µm in a WWTP. Photos of the particles are shown in Figure 4.

Description of the particle	Origin	Results from the FTIR
White plastic fragment	Influent water	Thermoset plastic based on aliphatic polyester resin. Chalk identified in (or on) sample
Red plastic fragment	Influent water (Fig. 4B)	Thermoset plastic based on aliphatic polyester resin.
Semi-transparent, irregular plastic fragment	Effluent water (Fig. 4B)	Polyethene
Blue plastic fragment	Effluent water	Polyethene
White plastic fragment	Effluent (Fig. 4A)	Polypropene

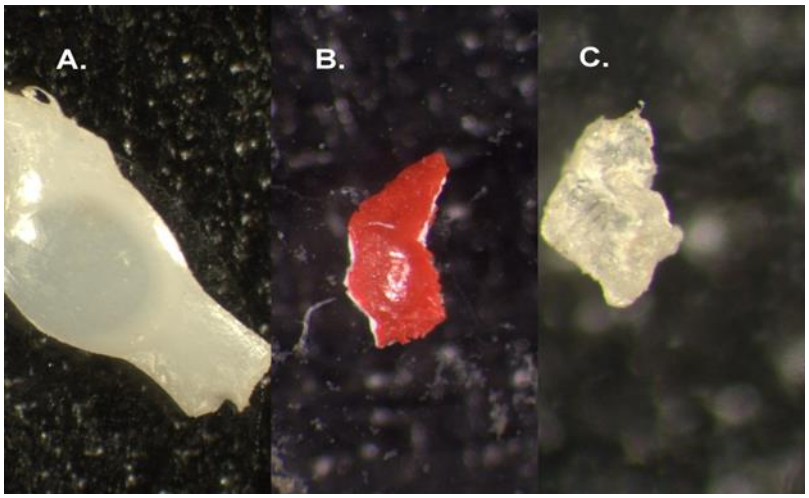

Figure 5 Particles from influent and effluent water from Långeviksverket. A) Fragment of polypropene (lenght~1 mm); B) Fragment of thermoset plastic based on aliphatic polyester resin (lenght 0.5 mm); C) Fragment of polyethene (length ~0.3 mm).

5 Discussion

5.1 General discussion

The amount of microplastics entering the investigated WWTP (Långeviksverket) at the day of the sampling amounted to 3 250 000 particles ≥300 µm per hour, and of these the vast majority, >99 %, were retained in the sewage sludge. Still, 1 500 microplastics in this size range entered the recipient water via the effluent tube every hour. Långeviksverket is a relatively small WWTP serving only ~12 000 pe, implying that larger WWTPs will contribute with considerably more microplastics through their effluents. Microplastics in influent and effluent water from WWTPs were measured in a previous study where Långeviksverket along with two larger WWTPs, Henriksdal in Stockholm with 750 000 pe and Ryaverket in Gothenburg with 740 000 pe, were included (Magnusson & Wahlberg, *in press*). In that study the load of microplastics >300 µm from Långeviksverket was found to be 1.5 % of that from Henriksdal, ~13 600 microplastics per hour from Långeviksverket compared to ~880 000 per hour from Henriksdal. Ryaverket is similar in size to Henriksdal but here the waste water passes through a disc filter with a mesh size of 15 µm before being directed to the recipient, which seemed to have had a reducing effect on the amount of microplastic in the effluent water. The amount of microplastics ≥300 µm in effluents from Ryaverket was found to be considerably lower (~100 000 microplastics per hour) than in effluents from Henriksdal.

The amount of microplastics in the effluent from Långeviksverket observed in the present study was found to be an order of magnitude lower than in the study by Magnusson and Wahlberg. Retention in the sewage sludge was similar in the two studies so this cannot explain the differences, but most likely it demonstrates that there are large temporal variations in the amount of microplastics entering the plant.

In the present study both incoming water and recently formed sewage sludge were analysed for microplastics. The data showed that it was possible to get a good estimate of the sludge content by analysing the incoming water and relate the amount of microplastics to suspended solids (SS) content.

FTIR of a selection of particles revealed that a kind of frequently occurring transparent fragments consisted of polyethene. The plastic flakes analysed with FTIR were composed of thermoset plastic based on aliphatic polyester resin, which indicates that that they are paint flakes. No fibres could be analysed with FTIR due to technical problems. The shape of the micro plastic particles seemed to have an effect on the retention efficiency. In the incoming water and the sludge 70 was composed of plastic fibres whereas this category only made up 49 % in the effluent water

The concentration of microplastics in the recipient water, 20 meters from the mouth of the effluent tube, was four times as high as at a reference site. No other category of particles but plastic fibres were detected in the recipient samples, even though there were an almost equal number of plastic fibres and plastic fragments in the water right before entering the effluent tube (Fig. 3). Sampling was done from the depth of the mouth of the effluent tube, all the way up to the water surface, so it is difficult to explain why not all categories of particles found in the effluent water before leaving the WWTP were also found in the recipient.

5.2 Reflections on the applied methods

5.2.1 Sampling

Sampling was performed with a filter with 300 µm mesh size. This size was selected because the first findings of microplastics in the sea that received attention were in zooplankton samples collected with trawl nets of this size. There are still very few studies where it has been evaluated whether this really is the most appropriate mesh size when looking for microplastics. In previous studies of Swedish and Russian WWTPs, sampling was conducted also with smaller mesh sizes, 100 and 20 µm, and considerably higher microplastic concentrations were detected (Magnusson and Wahlberg, in press)(Talvitie & Heinonen, 2014). This demonstrates that the choice of sampling methods has a profound effect on the result. To use 300 µm filters when sampling microlitter has become a common practice among many scientists and organizations concerned with marine microlitter, and within governmental agencies it is often suggested to be used when monitoring microplastics in sea water in the EU. It would however be advisable to do parallel sampling with both 300 µm filters and filters of smaller mesh sizes so that the results could be compared before proposing a standard method.

5.2.2 Analyses

There are at present no standard procedures for handling of matrices like sediment or sewage sludge when looking for microlitter. It is however necessary to remove or at least reduce the amount of fresh organic material in the samples. Since there was no time for method development within the present study, the wet sediment was just gently sieved through a filter with a 300 µm mesh size. In theory there are many different kinds of chemicals that could be applied, but there is always a risk that they will also remove some of the microplastics.

6 Conclusions and recommendations for the future

The investigated WWTP is small, only 12 000 pe, but still the number of microplastics ≥300 µm was substantial. This shows that the WWTPs are contributing to the content of microplastics in the sea. Still, there are very few studies on the quantitative input of microplastics from different sources so it is not yet possible to estimate the *relative* importance of WWTPs compared to other sources or entrance routes for marine microplastics.

There are large temporal variations in the amount of microplastics entering the WWTPs with the influent water, probably both on a short term scale like over a day but also between seasons. To get a full picture of the quantities of microplastics entering the sea these variations should be studied in more detail.

The retention of microplastics in the WWTP was very high, >99 %, so further studies on the fate of microplastics in sewage sludge are needed.

Since the crucial findings of microplatics in the sea made by Thompson et al (2004) it has become common to sample microplastics in seawater with trawls with a mesh size of 00 µm (sometimes also 330 µm), which is the common size used for zooplankton sampling. The advantage of continuing to use this particular mesh size is the possibility to compare results with previous studies. But we suggest that before settling for a standard method for monitoring, parallel sampling should be carried out with 300 µm filters and with filters of smaller mesh sizes so that the results could be compared.

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