BASE Project - Implementation of the Baltic Sea Action Plan in Russia

Baltic Marine Environment Protection Commission

Preliminary study on

Synthetic microfibers and particles at a municipal waste water treatment plant

Pilot Activity	Preliminary study on synthetic microfibers and particles at a municipal waste water treatment plant
Implemented by (Main Consultant)	Helsinki Region Environmental Services HSY
Implemented in cooperation with	State Unitary Enterprise “Vodokanal of St. Petersburg”
Authors of the report	Julia Talvitie, Mari Heinonen
Report compiled by	Julia Talvitie, Mari Heinonen
The following people and organizations have participated in the compilation of this report	Julia Talvitie, Mari Heinonen Helsinki Region Environmental Services HSY
For bibliographic purposes this document should be cited as	HELCOM 2014, BASE project 2012-2014: Preliminary study on synthetic microfibers and particles at a municipal waste water treatment plant
Design and layout	HELCOM Secretariat and HSY
Cover photos	Julia Talvitie
Back cover	Johanna Laurila

Implemented in the framework of:

Project	Implementation of the Baltic Sea Action Plan in Russia (BASE)
Funded by	EU
Implemented by	HELCOM Secretariat and St. Petersburg Public Organization ‘Ecology and Business’

ABSTRACT

Public and scientific interest in micro-sized plastic waste in marine environment has increased considerably in recent years, but relatively little is known about the sources of microplastics. Also the lack of standardized methods of sampling and analyzing microplastics has complicated the comparability of results gained from the few studies carried out. Helsinki Region Environmental Services Authority HSY has developed a microplastic sampling method targeted at wastewaters and was willing to share its knowledge and experience of microplastic research with colleagues at the State Unitary Enterprise Vodokanal of St. Petersburg in this HELCOM BASE project.

The objective of this project was to study the amount of microplastic litter arriving at the Central Wastewater Treatment Plant (WWTP) of St. Petersburg and the effect of the purification process. The study was performed in co-operation with HSY and Vodokanal of St.Petersburg. The procedures and methodology for studying microplastics in wastewaters were presented to Vodokanal employees for Vodonakanal of St. Petersburg to continue microplastic research independently. In addition, all of the equipment acquired for this study was left in the possession of Vodokanal.

The amount of microplastic was studied by sampling the wastewater at the beginning of the process and during and after the purification process. In the sampling process, water was filtered through different mesh-sized filters using a specific filter device. All samples were inspected under a light microscope and microplastics were identified and counted. The methodology has been successfully used in a pilot study at Viikinmäki WWTP (in 2012 and 2013).

The results of this study show that the WWTPs may operate as a point source of microplastic litter into the aquatic environment. However, the reduction of the microplastic load is also remarkable in scale. Due to the preliminary status of this project, results gained in this study are only indicative. In order to evaluate the actual role of WWTPs on the total micoplastic load of the marine environment, a more detailed investigation is needed into the amount and types of microplastic litter in wastewaters and in natural waters. Furthermore, extensive studies of other possible sources are needed.

CONTENTS

1 INTRODUCTION

Annual global plastic production exceeds 280 million tonnes and is expected to increase by 4% per year (Plastic Europe 2011). With growing plastic production, plastic litter in the environment is increasing. This causes an accumulation of plastic litter in various environments, including marine habitats (Andrady *et al*. 2011). It is estimated that marine litter consists of 60 – 80% of plastics and most of it is very small (< 5 mm), termed as microplastics (Thompson *et al*. 2004, Barnes *et al*. 2009).

Plastic litter in the marine environment causes a threat to wildlife. Animals may ingest or get entangled in plastics. Ingested plastics can cause internal damage, reduce feeding, disturb the digestive enzyme system or hormone balance and have an impact on reproduction (Derraik 2002). Plastics can contain harmful additives such as phthalates and flame retardants, and they may also absorb hydrophobic pollutants, such as PCBs and DDE from the surrounding water (Mato *et al*. 2001). The ingestion of plastics may thus potentially transfer environmental pollutants to marine food webs. Entanglement in plastic litter can drown an animal, reduce its fitness, cause external injuries, or impair its ability to catch food and avoid predators. Plastics may also transport species far away from their origin (Derraik 2002).

Over the past decade, there has been increased awareness of micro-size plastic litter found in the marine environment. Experimental studies have shown that many marine invertebrates such as bivalves, echinoderms, amphipods and zooplankton ingest microplastics (Browne *et al*. 2008, Graham & Thompson 2009, Cole *et al*. 2013) and ingested microplastics can be transferred in the food chain from prey to predator (Setälä *et al*. 2014). In a study conducted in the North Sea, microplastics have also been found in fish gut (Foekema *et al*. 2013). The main concern is that the plastics enter the food chain at the end of which are humans.

Marine microplastic litter is derived from a variety of sources, such as traffic, industry, fragmentation of larger plastic particles and wastewater treatment plants (WWTPs). Processed municipal wastewaters contain, for example, synthetic textile fibers from washing of clothes and abrasive plastic fragments from cleaning agents (Browne *et al*. 2011).

The aim of this project was to perform a pilot study on the amount of microplastic litter arriving at the Central WWTP of Vodokanal of St. Petersburg with the effluents, and to examine the effect of the purification process. The study was performed in co-operation with the Helsinki Region Environmental services Authority HSY and SUE Vodokanal of St. Petersburg.

2 METHODS

2.1 Composition of the research team

The actual research work was performed in collaboration with HSY, Vodokanal of St. Petersburg and Water Research and Control Center during 3 – 7 March 2014. The sampling of microplastics was conducted in the Central WWTP of St. Petersburg (Fig. 1) and the microscopic analyses of the samples were carried out at the Water Research and Control Center. Despite the relatively short time period reserved for this study, the sampling and analysis methods were successfully introduced to Vodokanal employees. After this project, it is possible for Vodonakal to carry out microplastic research using this common method. In addition, all the equipment acquired for this study, provided by HELCOM BASE Project, was left in the possession of Vodokanal.

Figure 1. Picture of the Central Wastewater Treatment Plant of Vodokanal of St.Petersburg

2.2 Research methods

2.2.1 Construction of the filter device

A specific filter device has been designed for microplastic sampling from wastewater. The device consists of three transparent plastic tubes (diameter 60 mm) and screw-on plastic connectors attaching the tubes to one another (Fig. 2). Round (diameter 80 mm) filters are placed into the filter device between the connectors and tubes are screwed tightly together with rubber o-rings (Fig. 3). Round filters are cut from different mesh size plankton nets. The largest mesh size filter 300 µm is placed on the top of the device, 100 µm filter in the middle and 20 µm filter at the bottom. In this order (300 µm → 100 µm → 20 µm) the sample is filtered through the device. If the filter is blocked during sampling, connectors can be crewed open and the filter can be changed.

Before placing the filters, it is important to rinse them carefully to avoid contamination. In addition, all equipment (including filter device) has to be rinsed thoroughly prior to sampling. When studying microplastic litter in wastewater, a risk of contamination of the samples is fairly high. Contamination in this context means that the micoplastics found in the samples (e.g. fibers) do not originate in the wastewater but come from another source. Potential sources of contamination include room dust and fibers from the clothing of sampling staff.

Figure 2. Picture of the filter device

Figure 3. Filter is placed between the screw-on connectors

2.2.2 Sampling the wastewater

Purified wastewater was collected manually straight from the stream into the pre-cleaned plastic containers. From the containers, the sample was poured into the filter device using a measuring glass (Fig. 4). 50 liters of purified wastewater were filtered through 300 and 100 µm filters and 1 liter through the 20 µm filter (a larger volume blocks the 20 µm filter). Three (3) replicates of 20 µm filtering were taken during one sampling and the sampling was repeated three (3) times.

Microplastic concentration in wastewater varies depending on time and place. In order to get more exact information on how much microplastic litter ends up in the environment with wastewater, seasonal and intra-day variation should be taken into account. This requires using 24-hour composite samples with automatic samplers. Furthermore, samples should be taken in different seasons.

The microplastic litter inflow into the WWTP and the effect of the purification process were studied by sampling 24-hour composite samples at the beginning of the process (incoming wastewater), during (after mechanical purification) and after the process (from purified, discharged wastewater). The volume of the filtered samples depended on the purification level of the water and varied from 100 ml (incoming wastewater) to 8 litres (purified wastewater). It is important not to filter too large volumes of wastewater through the filters, as wastewater contains organic solids that will block the filters and complicate the later microscopic analyses of microplastics.

Figure 4. Employer of Vodokanal filtering the sampled wastewater in the laboratory of the Central WWTP of St. Petersburg

2.2.3 Sample analyses

After the sampling, the filters were collected into the petri dishes with tweezers and the petri dishes were carefully sealed to avoid contamination (Fig 5). Samples were inspected under a light microscope (magnification x 50) and microplastics were identified and counted. Microplastics were classified according to their shape into particles and fibers. Where possible, the microplastics were identified through the transparent lids of the petri dishes but, especially when analyzing the particles from the 20 µm filter, the particles were so small that the lid had to be removed to improve the lighting.

Microplastic litter and other anthropogenic inorganic particles were divided into the form of particulate and fibrous pieces and the colors of black, blue and red. White, transparent, green and brown litter was excluded from the study as it is difficult to identify them as inorganic material using only a light microscope. High-gloss black particles were included in the study. Inorganic anthropogenic oil-based particles have a specific shiny blue-black appearance, which separates them from other dark particles. Dark, matt particles were not included as it is impossible to know or even estimate the material.

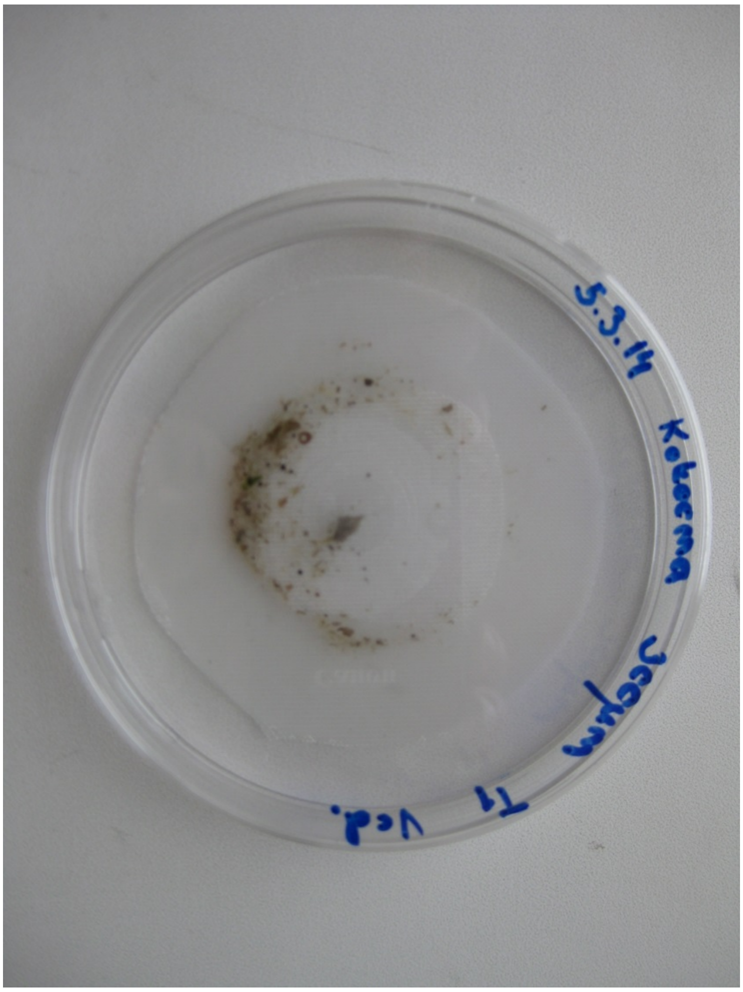


Figure 5. Samples ready for microscopic analyses

3 RESULTS AND DISCUSSION

3.1 Collaboration and sharing the knowledge

The co-operation between Helsinki Region Environmental services Authority HSY, Vodokanal of St. Petersburg and the Water Research and Control Center of St. Petersburg was successful and we were able to gain preliminary results concerning microplastics in wastewaters at the Central WWTP of St. Petersburg.

3.2 Microplastics in wastewater

Microplastics were found in large numbers in all analyzed samples taken from the Central WWTP of Vodokanal of St. Petersburg. However, the concentration decreased substantially during the purification process. The incoming wastewater contained 467 fibers, 160 synthetic particles and 3,160 black particles per liter of wastewater. After mechanical purification, the corresponding figures were 33 fibers, 21 synthetic particles and 302 black particles. At the last sample point, after the purification process, 16 fibers, 7 synthetic particles and 125 black particles were found per liter of wastewater (Fig. 6, Table 1). It seems that microplastics settle or are captured into the sludge during the processes, but some of them also pass the treatment and end up in the water environment with the purified wastewater. These figures, however, are for illustrative purposes only as they are only based on a one-day sampling.

The smallest black particles found in the samples were excluded, because it is impossible to say whether they are organic or inorganic material using only the light microscope. In all steps, wastewater contained more small dark black particulate litter than is shown in these results.

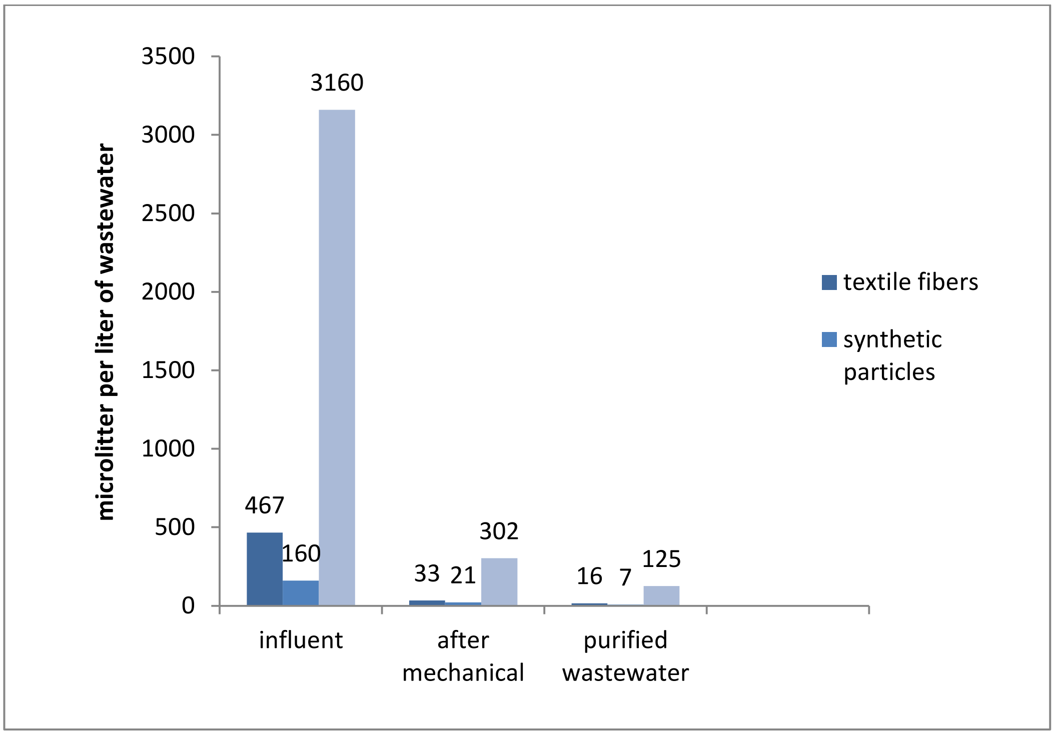


Figure 6. The quantities of textile fibers, synthetic particles and black particles per liter of incoming wastewater (influent), after mechanical purification and in purified wastewater when using 24-hour composite samples

Table 1. Purification percentage of microlitter at the Central WWTP of Vodokanal when using 24-hour composite samples

Litter type	Influent	After mechanical	After purification	Purification %
Textile fibers	467	33	16	96,57
Synthetic particles	160	21	7	95,63
Black particles	3160	302	125	96,04

The Central WWTP of Vodokanal of St. Petersburg purifies about 350 million cubic meters of waste water per year so the amount of microplastic litter in effluent water can be considerable. The results from this pilot study imply that WWTPs can act as a point source of marine microplastic litter. To evaluate the more specific role of WWTPs in the total micoplastic load of the marine environment would require much more detailed investigation into the amount and types of microplastic litter in wastewaters and natural waters.

The microlitter included in this study was assumed to comprise anthropogenic inorganic fibers and particles. In addition to plastic fibers and inorganic particles, the wastewater includes organic litter. For example, some of the fibers analyzed here as plastic fibers may have been dyed cellulose (cotton, wool) fibers. These fibers do not accumulate in the water environment but will biodegrade over time. However, these non-synthetic fibers can potentially also be harmful to natural water environments as cotton clothes are often treated with various hazardous chemicals to get different properties (e.g flame retardants) for clothes.

A more precise analysis of the litter material found in samples would give a better estimate of the amounts and quality of plastics entering marine environments with the effluents. Analyses can be performed for example with FTIR (fourier transform infrared spectroscopy) or EDX (energy-dispersive X-ray spectroscopy) analyses. Within the scope of this study, it was not possible to perform material analyses. All the samples have, however, been stored carefully for possible further studies. Samples were left in the possession of Vodokanal.

4 SUMMARY

The aim of this project was to study the amount of microplastic litter arriving at the Central WWTP of Vodokanal of St. Petersburg with the effluents, and to examine the effect of the purification process. The main task was to present the procedures of studying microplastics in wastewaters to Vodokanal employees, so that after this project it will be possible for Vodonakal to continue the microplastic research independently. In addition, all the equipment acquired for this study was left in the possession of Vodokanal.

The amount of microplastic litter inflow to the wastewater treatment plant and the effect of the purification process on the total amount of microparticles were studied by sampling at the beginning of the process (incoming wastewater), during (after mechanical purification) and after the process (from purified wastewater). In the sampling process, water was filtered through different mesh-sized filters: 300, 100 and 20 µm, respectively. The water volume filtered depended on the used filter size and purification level of the wastewater. All samples were inspected under a light microscope and microplastics were identified and counted. Microplastics were classified according to their shape into particles and fibers.

Considerable amounts of microplastics were found in all analyzed samples taken from the Central WWTP of Vodokanal of St. Petersburg. However, the concentration decreased substantially during the purification process. The incoming wastewater contained 467 fibers, 160 synthetic particles and 3,160 black particles per liter of wastewater. After mechanical purification, the corresponding figures were 33 fibers, 21 synthetic particles and 302 black particles. After the purification process, 16 fibers, 7 synthetic particles and 125 black particles were found per liter of wastewater. It seems that the microplastics settle or are captured into the sludge during the processes, but some of them also pass the treatment and end up in the water environment with the purified wastewater.

The results gained from this pilot study imply that WWTPs can be a source of marine microplastic litter. The Central WWTP of Vodokanal of St. Petersburg purifies about 350 million cubic meters of waste water per year so the amount of microplastic litter ending up in the natural water environment can be considerable. The evaluation of the role of WWTPs in the total microplastic load of the marine environment, however, needs further investigations.

5 REFERENCES

Andrady A.L. 2011. Microplastics in the marine environment. Mar. Pollut. Bull. 62:1596–1605

Barnes, D. K. A., Galgani, F., Thompson R. C., Marlaz, M. 2009. Accumulation and fragmentation of plastic debris in global environments. Phil. Trans. R. Soc. B 27 vol. 364 no. 1526

Browne, M. A., Dissanayake, A., Galloway, T. S., Lowe D. M., Thompson, R.C. 2008. Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, Mytilus edulis (L.) Environmental Science & Technology 42, 5026−5031

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T. S., Thompson, R. C. 2011. Accumulation of microplastic on shorelines woldwide: sources and sinks. Environ. Sci. Technol. Nov. 1, 45(21):9175-9

Cole, M., Lindeque, P., Fileman E, Halsband C, Goodhead R, Moger J, Galloway T. S. 2013. Microplastic Ingestion by Zooplankton. Environmental Science & Technology 201347 (12), 6646-6655

Derraik, J. G. B. 2002. The pollution of the marine environment by plastic debris: a review. Mar. Pollut. Bull. 44, 842–852

Foekema, E.M., De Gruijter, C., Mergia, M.T., Andries van Franeker, J., Tinka A., Murk, J., Koelmans A.A. 2013. Plastic in North Sea Fish. Environmental Science & Technology 2013 47 (15), 8818-8824

Graham, E.R., Thompson, J.T. 2009. Deposit- and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. Journal of Experimental Marine Biology and Ecology. Vol 368:1, 22–29

Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., Kaminuma, T. 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environmental Science and Technology 35(2): 318-324

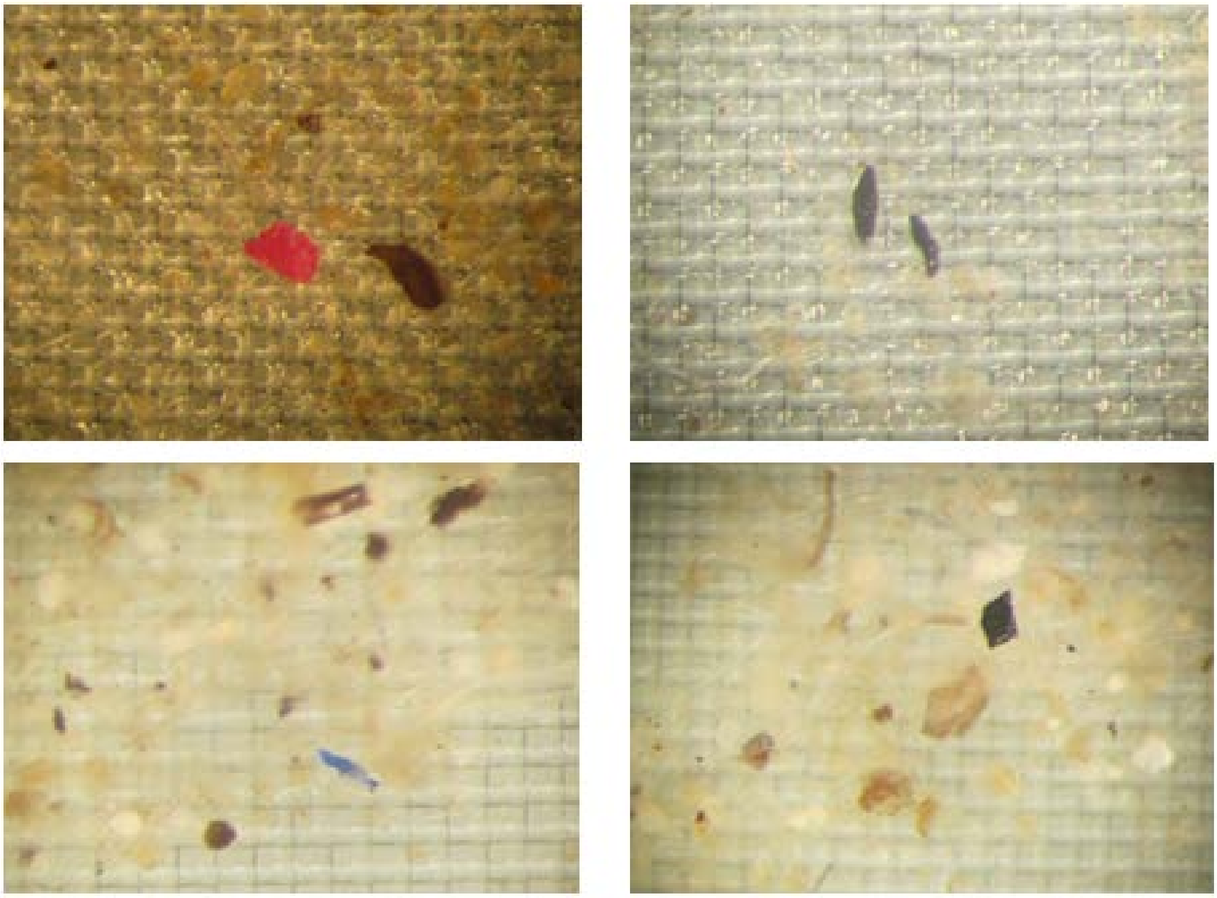
Plastic Europe 2011 http://www.plasticseurope.org/information-centre/press-room-1351/press-releases-2012/first-estimates-suggest-around-4-increase-in-plastics-global-production-from-2010.aspx - 24.4.2014

Setälä, O., Fleming-Lehtinen, V. & Lehtiniemi, M. 2014. Ingestion and transfer of microplastics in the planktonic food web. Environmental pollution Vol 185, Feb, 77-78

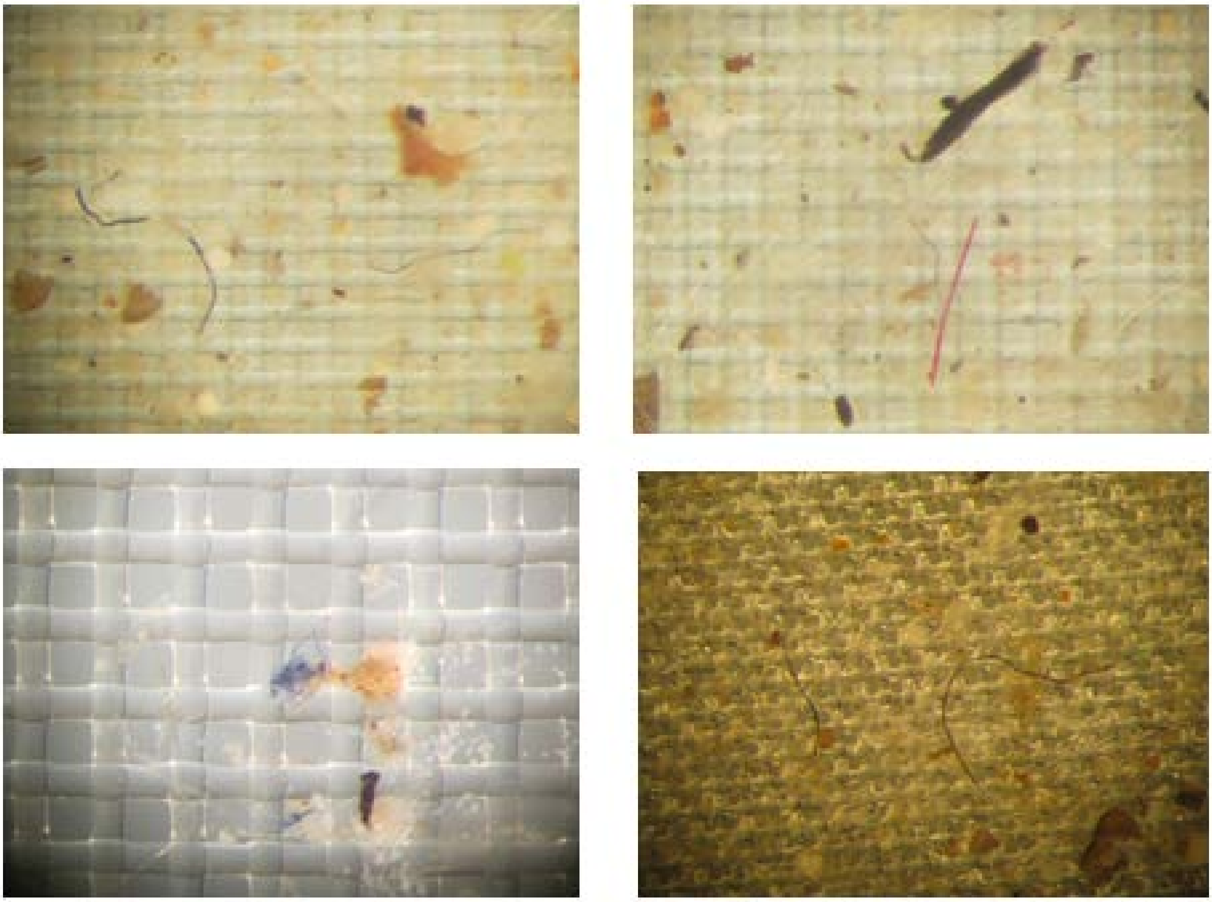
Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S. J, John, A. W. G., McGonigle, D., Russell, A. E. 2004. Lost at sea: Where is all the plastic? Science 304:838–838

6 ANNEXES

Annex 1. Pictures of particulate micro-size litter found in wastewater



Annex 2. Pictures of fibrous micro-size litter found in wastewater



HELCOM

www.helcom.fi