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Background

HELCOM Regional Action Plan on Marine Litter (RAP ML) adopted by the Contracting Parties in 2015 calls for:

- assessing the importance of the contribution of upstream waste flows to the marine environment and, if needed, identifying suitable actions (RL8, led by Poland);
- compilation of available techniques as well as research and developing additional techniques in WWTPs to prevent micro particles entering the marine environment (RL7, co-led by Sweden and Finland);
- improvement of stormwater management in order to prevent litter, including microlitter, to enter the marine environment from heavy weather events (RL4, Sweden is willing to contribute).

Under these actions, HELCOM should:

- by 2017 - assess of importance of sewage related waste coming from upstream waste flows;
- by 2018 - share the assessment with River and River Basin Commissions, identify missing elements, and present measures including the implementation of related regulations, and guidelines for improvement;
- by 2018 at the latest - compile information to give guidance on improvements of stormwater management on a local level to prevent and reduce stormwater related waste (including micro litter) entering the marine environment, taking into consideration similar action within OSPAR.
- by 2018 - compile information, and prepare a report on micro particles removal in waste water treatment plants taking into account similar action within OSPAR.

If appropriate according to findings of the activities and other relevant information, HELCOM may consider amending Recommendation 28E/5 on municipal wastewater treatment.

Further on, at the national level, Contracting Parties are invited to clarify and, if needed, carry out research on the importance of sewage related waste in the upstream waste flows (i.e. sewage treatments applied, efficiency of the treatments, existence of untreated sewage, storm water influence, etc).

CCB has been working with urban and rural sanitation systems, as well as upstream storm- and sewage water flows since quite a while in close cooperation with WRS AB, however with a stronger focus on nutrient removal and provision of cost-efficient wastewater treatment solutions. Since both marine litter and pharmaceutical issues emerged at environmental agenda, CCB have also started looking whether the same technical solutions may provide wider synergistic effect. The attached policy brief provides an overview of concrete ways to reduce microplastics in stormwater and sewage. It is based on an expert inputs from Swedish academia and water consultants' team and represents a compilation of conclusions of a research project addressing the efficiency of wetlands as final stage in treatment of both storm- and sewage water flows in trapping micropalstics particles, along with other contaminants. Simultaneously, CCB stresses the priority of source-reduction measures before any, even cost-efficient end-of-pipe solutions are applied.

NB: the attached document can't be distributed freely before 28.10.2016 as it forms part of MSc Thesis.

Action requested

The Meeting is invited to take note of the attached policy brief and its conclusions. The Meeting is also invited to consider in addition to potential revision of HELCOM Recommendation 28E/5 the needs for update of Recommendations 23/5 and 18/4, respectively addressing stormwater management systems and use of wetlands, with a view to promote BAT/BEP and application of ensure synergistic and cost-efficient solutions.

Concrete ways to reduce microplastics in stormwater and sewage

Concerns about the microplastic pollution caused by sewage and stormwater

There are growing concerns about microplastic (MP) pollution in the marine environment. Some even call it our potentially largest upcoming environmental threat and there are indications that today's levels of MP concentration in the marine environment could cause great harm to fish[2,13]. When MPs are released to e.g. the Baltic Sea they can stay there for up to hundreds of years due to their slow degradation and the low water exchange with the North Sea[7,12]. Due to the growing use of plastic products[19], the MP concentrations in the oceans will only get higher if actions are not taken. MPs are constantly released via sewage streams and though the waste water treatment plants (WWTPs) are capable of removing a relatively high percentage of incoming MPs the large flows of sewage make the number of MPs released from WWTPs considerable. Due to for example heavy rains, overflows are known to sometimes occur in the WWTPs which means that large amounts of untreated sewage can be released[12]. This not only results in large releases of MPs to the recipient waters, but also greater releases of heavy metals and eutrophicating nutrients[8].

Most of the MPs removed in the WWTPs end up in the sewage sludge. The sludge is often used as fertilizer in agricultural soils due to its phosphorus content[12]. Long term studies have shown that plastic covered in soil could take hundreds of years to degrade[18]. Today there is little known about the effects of MPs in the soil when spread via sludge. There is also little known about how much MPs are released to recipient waters from agricultural runoff[12]. This doesn't mean that sewage sludge should stop being used as fertilizer, but it's a good reason to take action towards reducing upstream sources of MPs.

Depending on both climate and the imperviousness of urban surfaces, the amount of stormwater can be greater than the amount of sewage. Often stormwater is released untreated and studies have shown that the concentrations of MPs in stormwater can actually be higher than those found in treated sewage from WWTPs[4,9,10]. This mostly unexplored MP pathway could potentially pose a great threat to the marine environment.

Land-based sources of microplastics in marine environments

Several countries have made attempts to quantify the amounts of MPs released to the oceans. Due to lack of data, the reports stress the importance of more research and describe the amounts as rough estimates. Table 1 displays some of the land based sources and pathways for MPs to the marine environment from Sweden, Denmark and Norway. Bear in mind that only part of the emissions are actually transported to the marine environment. Some are accumulated in the soils near their sources or on the way to the oceans[12,15,21]. As seen in the table, some of the largest sources have stormwater as their pathway, which is often untreated[4].

Table 1. Pathways and estimated emissions of some land based sources of MP pollution. The table only shows initial emissions at the sources, not the final quantities ending up in the oceans (data source[12,15,21])

Land based source	Pathway	Swedish emissions[15] [t/year]	Danish emissions[12] [t/year]	Norwegian emissions[21] [t/year]	Remarks
Tyres and road wear	Stormwater, sewage, air	13 520	4 310-7 290	4 500	DK: only tyre wear + road markings NO: only tyre wear
Rubber granulates from artificial turfs etc.	Stormwater	2 300-3 900	450-1 580	n/a	
Laundry of textiles	Sewage	180- 2 000	200-1 000	700	
Paints and building materials	Stormwater, sewage, air	130-250	232-1 297	500	DK: paints + building materials NO: paints + building repair SE: protecting and decorative coatings etc.
Footwear	Stormwater, air	n/a	100-1 000	n/a	
Personal care products	Sewage	60	9-29	40	
Littering	Stormwater, sewage, air	n/a	n/a	n/a	

Additional microplastic reduction by tertiary treatment in WWTPs

As mentioned above not all MPs are removed in conventional WWTPs and those that are removed are often suspended in the sludge. The large flows make the percentages of MPs not removed a considerable amount[12]. Additionally, tertiary treatment can be used in WWTPs for effluent polishing. Today however, there are only a few studies to be found on their ability to remove MPs.

One study has been done for anthropogenic microlitter reduction in four Swedish WWTPs. The microlitter was defined as both MPs and non-synthetic fibers e.g. cotton fibers larger than 20 micrometer (20 µm).Three of the studied WWTPs use a tertiary treatment step and one of them (Sjöstadsverket) is a pilot WWTP fitted with a membrane bio reactor (MBR) as tertiary treatment. Prior to the tertiary treatment the water in all of the WWTPs had been treated with mechanical, chemical and biological treatment. The sand filter in Henriksdal showed no palpable removal effects and in some cases it even added particles to the water. The disc filter in Ryaverket showed a reduction of microlitter >300 µm, but not for the smaller fraction. The pilot WWTP with the MBR was fed with the same incoming water as the Henriksdal WWTP. It ended up showing the best reduction results. It was able to reduce the microlitter content to a tenth of the concentrations measured in the effluents of the other WWTPs[16]. It is thus important to note that the measures tested so far are inconclusive, expensive or simply not working well enough across the relevant size range of MPs.

A win-win-win solution is already available

Another kind of tertiary treatment that can be used is a constructed wetland placed after the WWTP. Studies of two free water surface (FWS) wetlands in Sweden indicate removal efficiencies of close to 100 percent for MPs >20 µm[10]. The study is summarized in the next chapter. In addition to the MP reduction, well designed wetlands have a number of other benefits;

- They are efficient in removing eutrophicating nutrients[11]
- They work as an effective barrier for untreated sewage reaching the recipient waters in case of overflows in the WWTPs[20]
- They show efficiency on reducing pharmaceuticals[1]
- They cost-efficiently contribute to ecosystem services[5]

Microplastic reduction in stormwater ponds and in constructed wetlands for tertiary sewage treatment – short summary

With the aim to determine possible MP reduction a study was conducted for two stormwater ponds and for two constructed FWS wetlands located in Sweden. One of the wetlands also received a minor inflow of stormwater. This was sampled but its MP content was not added to the concentration for the incoming sewage stream due to its low inflow. The year of construction for the facilities varied between the mid-20th century to year 2000. During the spring and early summer samples were collected from the facilities influents and effluents by pumping water through 20 µm and 300 µm filters. Additional sampling was carried out by collecting minor water samples for later filtration through 20 µm filters in a laboratory. The latter sampling was done for easier quantification of particles found in large concentrations. All quantification was performed manually by counting MPs using a microscope. Some of the detected MPs were analyzed with FTIR spectroscopy to better determine their material content[10]. Collecting MP samples in water by pumping water through filters is not a new method and has been used with satisfactory performances in different studies for almost a decade[3,16,17]. Table 2 below summarizes the background information for the different treatment facilities.

Table 2. Summary of information for the different facilities (data source[10])

Facility	Unit	Örsundsbro wetland	Wetland Alhagen	Tibbledammen	Korsängen vattenpark
Type		FWS wetland (1 430 pe)	FWS wetland (13 000 pe)	Stormwater pond	Stormwater pond
Area	[ha]	0.8	28	5.7	9
Mean flow	[m³/d]	667	5 100	4300	3440
Theoretical residence time	[d]	3.5	11.5	2	5-10
Reduction - Suspended solids	[%]	99	86	82	89
Reduction – Total phosphorous	[%]	68	91	66	39
Reduction – Total nitrogen	[%]	43	78	47	18

Results and discussion

The results from the MP sampling showed about 4 objects/liter for the sewage inlet of wetland Alhagen and about 950 objects/liter for the inlet of Örsundsbro wetland. The MPs in Örsundsbro wetland were mostly polyethylene or polyamide particles[10]. Wetland Alhagen's inlet concentration corresponds well to other studies of WWTPs effluents, but the concentration in Örsundsbro is far greater than others studies results for untreated sewage. No cause could be found for the larger concentration. For the three stormwater inlets the MP concentrations varied between 5.4 and 10 MPs/liter[10]. This is more than what has been detected in several other WWTPs effluents[14], including the incoming water to wetland Alhagen. The number of particles >300 µm was almost non-existent in relation to particles >20 µm. In all the main inlets a large number of black particles and red particles were detected. From their looks both particle types were similar to particles found in Swedish coastal waters[10]. Their exact sources are unknown but there are suspicions that the black particles come from car tyre wear and combustion of fossil fuels. The red particles may come from either anthropogenic or non-anthropogenic sources. One of the analyzed red particles showed indications of polyethylene content[10,17]. In Figure 1 concentrations for the facilities influents and effluents are summarized. It demonstrates the abundance of the black particles. All the facilities showed a distinct reduction for all the detected types of particles and in most cases about 90-100 %[10].

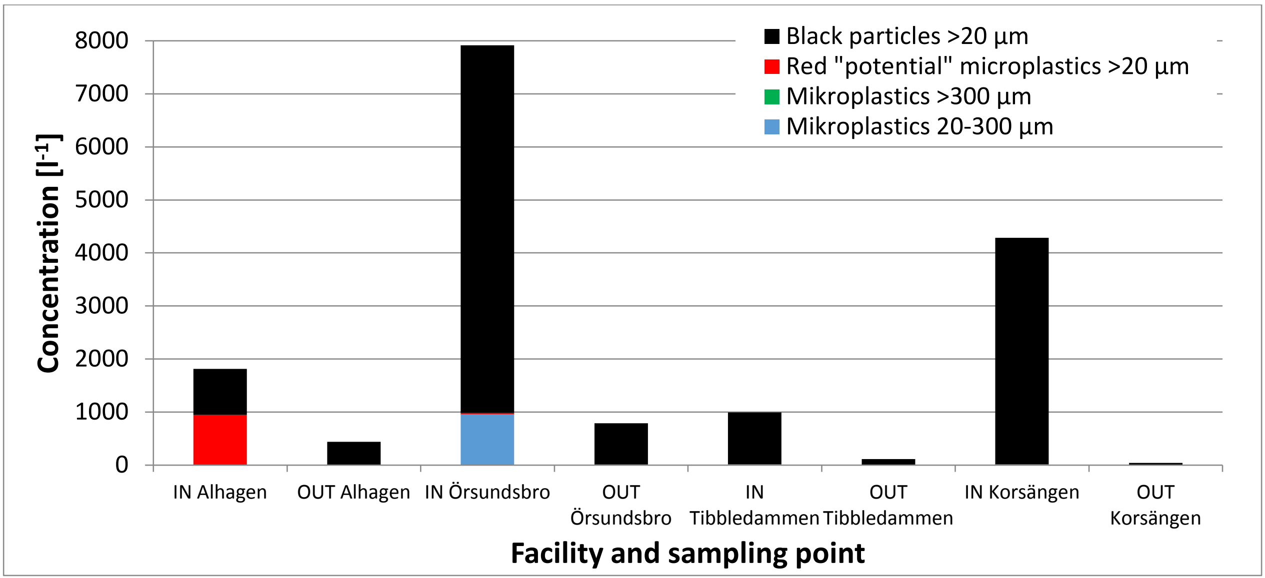

Figure 1. Summary of quantified particles in the influents and effluents of two wetlands and two stormwater ponds. The figure is modified after Jönsson (In press)[10].

Cost examples for wetlands constructed for sewage treatment

To illustrate the cost of constructed wetlands, some examples are given in Table 3. All the examples are taken from a review of a number of Swedish FWS wetlands constructed for tertiary treatment. The costs apply to 2008 and are displayed in the current value of 2008. A significant part of the larger costs for wetland Alhagen is due to the pumping of water from the WWTP to the wetland, initial inspections and environmental impact assessments[6]. In the years 2008-2016 the value of 1 € has fluctuated between 9.1 and 11.5 SEK[22].

Table 3. Cost examples for five Swedish wetlands constructed for tertiary sewage treatment. All costs are displayed in one million Swedish crowns, for the year of 2008 and in the current value of 2008. (data source[6])

Facility	Size [ha]	Mean flow [m^3/d]	Investment cost [MSEK]	Operating costs [MSEK]
Vagnhärad	2.3	1 442	7	0.14
Trosa	5.3	1 703	12	0.21
Magle	20	12 369	11	0.25
Brannäs	23	4 396	8	0.10
Alhagen	28	5 218	20	0.40

Conclusions made from the study

- Constructed free water surface wetlands of varying shapes, age, flow rates and sizes can be very efficient in reducing microplastics from effluents of WWTPs to the water bodies. These new results adds to their already known benefits, such as e.g. pharmaceutical removal, nutrient removal and protection for unwanted releases of untreated water.
- The high MP concentrations found in urban stormwater call for concerns due to the often large and untreated stormwater volumes released to recipient waters.
- Stormwater ponds used as end of pipe solutions show good removal efficiency for microplastics.
- There are relatively simple and verified methods for sampling and analyzing microplastic contents in water.
- If microplastics are to be analyzed for stormwater or sewage it's very important to include particle sizes smaller than 300 µm, due to their abundance.
- More research is needed regarding the effects of microplastics spread in soil via sewage sludge.

Policy recommendations

Based on the findings and conclusions presented in the above study, Coalition Clean Baltic suggests that the following HELCOM Recommendations would need to be revised/updated in order to fit for the purpose of implementing HELCOM RAP ML:

- 18/4 "Managing wetlands and freshwater ecosystems for retention of nutrients"
  - adopted in 1997, addresses mostly diffuse nutrient inputs and nature conservation;
- 23/5 "Reduction of discharges from urban areas by the proper management of storm water systems"
  - adopted in 2002, should have been reconsidered in 2007, addresses contamination by oil, lead and suspended solids, does not set any quantitative targets/limits, except for overflows;
- 28E/5 "Municipal wastewater treatment"
- 28E/6 "On-site wastewater treatment of single family homes, small businesses and settlements up to 300 person equivalents (p.e.)"
  - Both of those recommendations were adopted as a part of the HELCOM BSAP and hence only cover reduction of nutrient inputs
  - Use of wetlands as a tertiary step in municipal wastewater treatment and as a potential main treatment technology for rural areas and smaller settlements could be included in both recommendations, taking also into account the synergistic effects in trapping other contaminants.

References

1. Breitholtz, M., Näslund, M., Stråe, D., Borg, H., Grabic, R., Fick, J., 2012. An evaluation of free water surface wetlands as tertiary sewage water treatment of micro-pollutants. Ecotoxicol. Environ. Saf. 78, 63–71. doi:10.1016/j.ecoenv.2011.11.014
2. Depledge, M.H., Galgani, F., Panti, C., Caliani, I., Casini, S., Fossi, M.C., 2013. Plastic litter in the sea. Mar. Environ. Res. 92, 279–281. doi:10.1016/j.marenvres.2013.10.002
3. Enders, K., Lenz, R., Stedmon, C.A., Nielsen, T.G., 2015. Abundance, size and polymer composition of marine microplastics ≥10μm in the Atlantic Ocean and their modelled vertical distribution. Mar. Pollut. Bull. 100, 70–81. doi:10.1016/j.marpolbul.2015.09.027
4. EPA, 2016. Stormwater Discharges from Municipal Sources [WWW Document]. EPA US Environ. Prot. Agency. URL https://www.epa.gov/npdes/stormwater-discharges-municipal-sources#overview (accessed 9.26.16).
5. European Commission DG, 2015. Science for Environment Policy - Benefits of Constructed wetland ecosystem services worth more than double the costs.
6. Flyckt, L., 2010. Reningsresultat, drifterfarenheter och kostnadseffektivitet i svenska våtmarker för spillvattenrening (Master Thesis). The Department of Physics, Chemistry and Biology, Linköping University.
7. HELCOM, 2010. Ecosystem Health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment (No. 122), Baltic Sea Environment Proceedings.
8. Henze, M. (Ed.), 2008. Biological wastewater treatment: principles, modelling and design. IWA Pub, London.
9. Jannö, A., 2016. Förekomst av mikroplast i dagvatten från väg och trafik i Göteborg - Provtagning och analysering (Bachelor Thesis). The Department of Biological and Environmental Sciences, University of Gothenburg.
10. Jönsson, R., In press. Mikroplast i dagvatten och spillvatten - Avskiljning i dagvattendammar och anlagda våtmarker (Master Thesis). The Department of Earth Science, Uppsala University.
11. Land, M., Granéli, W., Grimvall, A., Hoffmann, C.C., Mitsch, W.J., Tonderski, K.S., Verhoeven, J.T.A., 2016. How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. Environ. Evid. 5. doi:10.1186/s13750-016-0060-0
12. Lassen, C., Foss Hansen, S., Magnusson, K., Norén, F., Bloch Hartmann, N.I., Rehne Jensen, P., Gissel Nielsen, T., Brinch, A., 2015. Microplastics: occurrence, effects and sources of releases to the environment in Denmark. Danish Environmental Protection Agency.
13. Lonnstedt, O.M., Eklov, P., 2016. Environmentally relevant concentrations of microplastic particles influence larval fish ecology. Science 352, 1213–1216. doi:10.1126/science.aad8828
14. Magnusson, K., 2014. Mikroskräp i avloppsvatten från tre norska avloppsreningsverk (No. C 71). IVL Svenska Miljöinstitutet, Stockholm.
15. Magnusson, K., Eliasson, K., Fråne, A., Haikonen, K., Hultén, J., Olshammar, M., Stadmark, J., Voisin, A., 2016. Swedish sources and pathways for microplastics to the marine environment - A review of existing data (No. C 183). IVL Svenska Miljöinstitutet.
16. Magnusson, K., Wahlberg, C., 2014. Mikroskopiska skräppartiklar i vatten från avloppsreningsverk (No. B 2208). IVL Svenska Miljöinstitutet.
17. Norén, F., Ekendahl, S., Johansson, U., 2009. Mikroskopiska antropogena partiklar i Svenska hav. N-Research.
18. Ohtake, Y., Kobayashi, T., Asabe, H., Murakami, N., 1998. Studies on biodegradation of LDPE — observation of LDPE films scattered in agricultural fields or in garden soil. Polym. Degrad. Stab. 60, 79–84. doi:10.1016/S0141-3910(97)00032-3
19. PlasticsEurope, 2015. Plastics – the Facts 2015.
20. R. Kampf, R.M.van den Boomen, 2013. Waterharmonica's in the Netherlands (1996 - 2012), natural constructed wetlands between well treated waste water and usable surface water. doi:10.13140/2.1.3930.1128
21. Sundt, P., Schulze, P.-E., Syversen, F., 2014. Sources of microplastics-pollution to the marine environmnet (No. M-321). Mepex for the Norwegian Environment Agency (Miljødirektoratet).
22. Trading Economics, 2016. EURSEK Exchange Rate [WWW Document]. Trading Econ. URL http://www.tradingeconomics.com/eursek:cur (accessed 9.27.16).