Technical report on technologies for litter reduction from waste- and storm water and supply

Disclaimer: *"This report represents a technical output contributing to the delivery of RAP ML Action 42 and does not represent the views or position of the OSPAR Commission or its Contracting Parties"*

RAP ML Action 42 refers to "Investigate and promote with appropriate industries the use of BAT and BEP to develop sustainable and cost-effective solutions to reduce and prevent sewage and storm water related waste entering the marine environment, including microparticles.

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Executive summary and conclusions

The intention of this document is to provide an overview and indication of micro-litter sources that will end up in and/or be discharged from waste- and stormwater systems. In addition it identifies the most common existing measures that can be put in place to reduce discharges. However, over time, it is recommended that treatment processes should be considered where appropriate and addressing microlitter sources directly should be given priority in order to reduce the possibility of micro-litter discharges from waste- and stormwater systems.

As data in this area is limited, we have provided general examples of microlitter sources that may considered significant. These may be considered by each OSPAR Contracting Party to assess their relevance in the context of national waste- and stormwater systems, meteorological, hydrogeographical and other relevant circumstances. Upgrading and maintenance of waste- and stormwater systems is a continuous and costly process and measures to reduce discharge of microlitter must be implemented in the overall action plans.

It is acknowledged that the circumstances for each country within OSPAR differ greatly and hence the relevant measures required to address micro-litter in waste- and stormwater will vary accordingly. However, it is hoped that the examples described and measures recommended will represent a useful starting point in the development of national based action plans.

Our main recommendation is that each country develops their own action plan in order to reduce the discharge of micro-litter from stormwater and wastewater treatment plants to the sea. In such plans the following measures should be considered:

Wastewater:

- Construction of treatment plants for untreated discharges (or connection to a sewerage system already connected)
- Consideration of primary measures to reduce plastic micro-fibre inputs from washing machines in industries and private homes such as the installation of filters or improved fabric technologies reducing wear
- Separation of the combined system. This will reduce overflow from the network and increase the treatment efficiency. It may however increase the number of particles to environment as the storm water may be a more significant micro plastic source.
- Upgrading of poor quality pipes in order to reduce uncontrolled leakages to the environment. Such losses may be discharged to surface water through storm water pipes or trenches.
- Implement treatment connected to overflow weirs

Storm water:

- **Better** design and run-off protection from sport facilities (pitches, running tracks, etc) with artificial surfaces to reduce losses of rubber granulate
- **Improved procedures for cleaning/sweeping of roads and streets** in order to collect more particulate litter from tyre wear, wearing of road paints and asphalt/concrete particles
- Improved collection systems for all kinds of construction works
- Installation of filters connected to combined sewer overflows

- Infiltration or other treatment of storm water run-off, especially from roads with heavy traffic and urban areas

1.1 Introduction

1.1.1 The task

The scope for this activity is to produce a list of BATs for reduction of litter in waste and storm water to be accepted by the OSPAR member states and their respective industries, municipalities etc. Thus the partners in the OSPAR task group need to agree on the work ahead and on how the work should to be partitioned among participants.

Activities:

- Review of waste and storm water treatment techniques currently applied in the OSPAR member states (national and regional similarities/dissimilarities).
- Compilation of available data on litter quantity (micro-plastic and – particles) and quality in wastewater and storm water within the OSPAR region.
- Compilation of knowledge on state of the art treatment techniques and their reduction efficiencies as well as treatment costs.
- Compilation of treatment techniques under development, their reduction efficiencies as well as their treatment costs.
- Contact with manufacturers of purification systems, municipalities, wastewater treatment plants, industries, relevant researchers etc. within and outside the OSPAR region.
- Present recommendations

1.1.2 Background

Previously litter was generally perceived as large clearly visible items discarded throughout the environment. However, it is now increasingly recognised that litter exists in all scales from large visible items to micro and nano litter particles that may not be immediately visible to the naked eye. Large items may be fragmented into smaller particles through the combination of UV-light and wear from vehicles, pedestrians, waves etc. Such litter may have been disposed of intentionally but may also have been blown away by the wind from open or full litter bins, recycling stations, waste deposit plants and litter transport vehicles. *Litter* is essentially any improperly discarded or disposed of solid human made material including (but not limited to) items made of plastic, paper, wood, glass and metal, and can consist of for example plastic bags and bottles, glass bottles, food containers, cigarette butts, chewing gum etc.

Wastewater from industries and households can contain substantial amounts of microlitter particles originating from industrial processes, cleaning products, textiles etc. Current studies[3] indicate that the greatest contribution, however, may come from roads and paved surfaces in urban areas.

From studies in the open sea of the Northeast Atlantic[4], the concentration of microplastic (in that study the size range was 250 micrometres to 5 mm) is above 2 particles/m^3, while in coastal waters of the Skagerrak it could be tens or hundreds per litre. In beach and sediment surveys in the North Sea area concentrations of several hundred microscopic plastic particles per kg sand has been recorded.

Wastewater is generally fed to Waste Water Treatment Plants (WWTPs) where most of the solid material, including microlitter, is retained in sewage sludge and hence does not get released in treated water outflows. Nevertheless, a certain amount of litter particles may pass through the plant and enter the environment via WWTP outflows / effluent water. However, WWTPs are designed to reduce the amount of particles, nutrients and organic matter inputs into the environment from wastewater.

Treatment of storm water from roads and urban areas has been the subject of research programs and national studies[3]. Storm water runoff has been found to contain both large litter items and microlitter. In many countries, storm water is often combined with wastewater flows to WWTPs.

This can be problematic in situations of heavy rainfall or during snow melting when sewage pipes can overflow and, as a result, large volumes of untreated wastewater can be discharged into the environment. The trend is therefore to have separate systems for wastewater from households/industries and storm water. Where this is not possible for technical or economic reasons the trend is to improve the storm management capacity of the wastewater collection and treatment system.

There are differences in how storm water is treated. In some municipalities substantial efforts have been made to construct systems with trenches, channels and ponds to handle flooding water, whereas in others the storm water is allowed to enter the freshwater and coastal environments untreated.

1.1.3 Sources

Litter items consist by definition of a wide array of different materials such as plastic, rubber, paper, metal, glass and textile and a combination of these materials. Among them, plastic is considered the most problematic. The size, shape and, in the case of plastic, the composition of the marine litter affect its distribution in the environment, the ultimate fate of the items and the potential harm it may cause.

The microplastics found in the North Sea and probably in the whole OSPAR region come predominantly from the region itself and not from the surrounding sea areas ("Indicator development for microplastics on the Dutch Continental Shelf" presented by the Netherlands at the ICG-ML-meeting in Copenhagen 8th to 10th of November 2016).

Globally marine litter is considered to be dominated by land-based sources; especially since the adoption of the MARPOL Convention, the London Convention and the Oslo Convention (OSPAR) regulating dumping at sea, though there are regional differences.

Marine litter from land based sources reach the North Sea by discharge of storm water, waste water, littering or atmospheric deposition, either directly to the North Sea or in its catchment area and further transported by rivers and other water ways to the sea. Whereas the sources to marine litter, and to some extent also the quantities of litter released from these sources, are well investigated, information on the relative importance of the different pathways is still limited.

The by far biggest source is run-off from roads. Tyres, road wear and road paint represent more than 50% of the total land based source, according to different Nordic studies.

From different Nordic surveys[1,2] the concentration of microlitter in the influent water may vary between 100.000 and 300.000 particles/m^3 > 300 µm and between 100.000 and 6 million for particles > 20 µm.

2 Wastewater

2.1 Collecting systems

Collecting systems for wastewater may be designed as a:

- Combined system (sewerage and storm water in the same pipe)
- Separate system, two pipes (separate pipes for wastewater and for storm water)
- Separate system, one pipe for wastewater and one for storm water, or storm water being infiltrated or discharged directly to surface water

In many countries combined systems are often the predominant system used in urban areas. These systems will normally have overflow systems that will discharge a combination of wastewater and storm water during heavy rainfalls. The amount will often vary from minimal volumes up to 15% of the total flow over a year.

Separated systems do normally not have overflow discharges in the same way, except in emergency situations. Collection systems can have problems such as accidental cross-connections and leakages The wastewater may leak into surrounding soil, or depending on the design, ex-filtrate from the wastewater pipe into a stormwater pipe. The leakages could vary from very little to a significant part of the total load. The impact will vary, depending in the designed system and distance to the nearest receiving waters.

In some countries a significant share of the population is connected to sewerage systems with untreated discharges.

With this in view, we have identified four different ways of reducing the discharge from the collecting system:

- Construction of treatment plants for untreated discharges (or connection to a sewerage system already connected)
- Separation of the combined system (this action may however increase the number of particles to environment)
- Upgrading of poor quality pipes in order to reduce leakages
- Implement treatment for overflow weirs
- Make sure plastic based biomedia cannot escape the treatment plants

2.2 Wastewater treatment technologies

Most wastewater in the OSPAR region is treated in municipal wastewater treatment plants, even although the performance and technology vary substantially within the region.

European and most OSPAR countries are regulated by the Urban Waste water Treatment Directive (91/271/EEC) since 1991. This largely determines the performance standard and in turn the design of European wastewater treatment plants. The aim of the Directive is to protect the environment from the negative effect of the discharge of untreated urban wastewater. In the Directive urban waste water means domestic waste water or a mixture of domestic wastewater, industrial wastewater and/or run off rain water. The specific substances that are regulated within the Directive are organic load and nutrients. The regulated discharge concentrations, or the reduction levels (%), are coupled to the number of persons (population equivalent; PE) within an area (called an agglomeration in the directive) from which wastewater is discharged, the type of receiving environment into which the treated wastewater is released and the classification of that environment. The terms used to characterise the different treatment levels of wastewater within the Directive are: primary treatment, secondary treatment, appropriate treatment and more stringent treatment. These treatment levels are not tightly coupled to specific techniques but rather to the quality of the discharged water or the degree of pollutant reduction.

Emission- and reduction levels have to be followed for discharged water to be compliant with the Directive. Consequently stricter applications are thus beyond the requirements of the UWWT Directive. Each member state may however set stricter national requirements on the discharge of wastewater. For discharge to sensitive areas used as drinking water sources nitrate have to be removed and for discharge to waters classified as sensitive areas under other directives such as the Water Framework Directive, the Natura Directives or Bathing Waster Directive. Further treatment may consist of the removal of for example pathogens or toxic substances.

Wastewater sources include domestic wastewater, storm water, and industrial wastewater. The data is very scarce concerning the litter content of wastewater from these different sources even although it is likely that storm water sources may have the highest litter content as they receive direct run-off from roads and pavements.

Litter content in industrial wastewater depends on the nature of the industry generating the wastewater.

Untreated and treated municipal wastewater can contribute substantial amounts of litter to the aquatic environment. Studies carried out in Sweden[1], Finland[1], Norway[4] and Germany have shown that in waste water treatment plants (WWTPs) with chemical and/or biological treatment of the waste water more than 90% of the litter particles in the influent water are retained in the sewage sludge and will therefore not be released with the effluent water.

Different cut off size were used in the different studies, and the observed concentrations of microplastics ≥300 µm were around 10 - 40 per m^3 , for particles ≥20 µm 2 600 – 5 600 particles per m^3 and for particles ≥10 µm 86-13 659 per m^3. In those studies where the flow rate of the wastewater was known it was possible to estimate the total load of microplastics to the treatment plant and discharge to the receiving waters. The discharge load is of course closely connected both to how efficiently the microlitter particles are retained in the WWTP and to the number of people connected to the plant.

Plastic microbeads used in personal care products (PCPs) are one form of microplastics reaching the aquatic environment via wastewater effluents. It was estimated that the total volume of microbeads used in liquid soaps in the countries within the North Sea catchment area in 2012 amounted to 2 - 300 tonnes per year. Liquid soaps are considered to constitute the largest category of PCPs contributing to this output, which makes them interesting when studying the fate of microbeads in the environment. It should however be emphasised that there are also several other categories of PCPs, cosmetics and other products such as certain household cleaning agents that contain plastic microbeads that may be rinsed into wastewater systems.

It is roughly estimated that between 80% and 100% of the population of the North Sea states are connected to urban WWTPs and between 30 and 100% of the WWTPs in these countries are equipped with tertiary treatment of the wastewater. There still are untreated discharges of wastewater among the North Sea States. This is, as an illustration, the case for around 5% of the Norwegian plants and slightly below 20% of the Belgian ones. There is no available information on the capacity of WWTPs from other European countries but those mentioned earlier (Sweden, Norway, Finland, Germany and Iceland) to retain microplastics in sewage sludge. However, since the plants with tertiary treatment were found to retain more than 97% of the microplastics ≥300 µm, the average value for all North Sea countries should be somewhat lower. The average size of microbeads in liquid soap was around 450 µm so the retention found for particles ≥300 µm should be valid also for them. A very rough guess would be that an average of around 75% of liquid soap microbeads should be retained in the WWTPs of the North Sea countries.

Microlitter in domestic sewers can be presumed to be mainly composed of synthetic particles from personal care products and household cleaning products, and fibres from household dust and from washing machine effluents. Particle characteristics like polymer composition, morphology and colour can give important information on their origin. Analyses have shown that polyethylene and polystyrene are particularly common among microplastics particles in wastewater. No real effort has been done to connect characteristics of microscopic litter to the source of the wastewater.

The reduction through a treatment plant will vary greatly, depending on technology, from less than 10% up to 99%.

2.2.1 Pre treatment

The pre-treatment stage is normally included in a treatment plant to remove constituents that may affect the operation of the plant negatively by clogging and possibly breaking pipes and pumps. During this stage large objects such as paper, plastics, pieces of rags, sand and grit are removed. In this stage screens of different sizes are used which remove some microlitter depending on the screen mesh size and design. To a certain degree also floatables such as oil and fat is removed which also should remove floating micro litter. This could reduce the quantity of micro-plastic by between 5 and 30%.

2.2.2 Primary treatment

According to the directive BOD_5 has to be reduced by at least 20% before discharge and total suspended solids by at least 50%. This stage usually consists of filtration/settlement with or without chemical additions. With filtration, removal of total suspended solids is 30–60% whereas the use of polymers may increases this up to 50-75%.

2.2.3 Secondary treatment

This stage involves biological process in order to reduce organic matter. Bacterias consume and degrade the organic material within the water and up to 95% of organic matter can be removed. 90-99% of the microlitter may be removed after sedimentation/flotation or filtration following such treatment.

2.2.4 More stringent treatment

The requirement for this step depends on the nature of the receiving waters. It can be used to reduce phosphorous and/or nitrates. In order to fulfil requirements for discharge to waters sensitive to the addition of nutrients advanced biological processes are used to reduce the discharge of nitrates.

In order to reduce phosphorous levels chemical precipitation is the most common technology. This will remove 90-98% phosphorous and 95-99% of the microlitter from the discharges and hence, be incorporated in the sludge.

2.2.5 Conclusions on wastewater

The efforts made within the OSPAR member states to reduce the discharge of untreated wastewater and to include conventional primary and secondary treatment of the municipal wastewater generally also have a substantial effect in reduction of the marine litter.

Wastewater treatment plants (WWTPs), incorporating biological and/or chemical treatment of the wastewater will retain >95% of microlitter≥300 µm and generally >80% of litter particles ≥20 µm in the sewage sludge[1,2].

Inlet screens remove between 5-10% of the suspended solids. Primary treatment removes approximately 30-65%, secondary treatment removes approximately 85 % and chemical treatment removes about 95% of total suspended solids. This treatment efficiency can be used as a proxy also for microlitter removal rates, which are included in the total suspended solids.

Additional techniques such as soil infiltration, integrated constructed wetlands, ultra-filtration and even membrane filtration would improve the treatment efficiency in terms of containing and removing microlitter particles. Such measures could further reduce the discharge concentrations from 20 – 300 microplastic particles/l towards zero.

Even after removing 95% of the particles from the wastewater, a discharge from 500.000 pe could represent a flow of 1-4 m^3/s or 5 – 50 million particles pr. day. This is still a significant number of particles.

3 Storm water

In the context of channelized flows, Storm water effects all urban areas and therefore the history of storm water drainage management is as old as the history of human settlement. The structure and purpose of today's systems and the technological terminology vary within and both different countries and over time.

Storm water occurs when precipitation or melting snow runs off from impervious, semi-impervious or saturated surfaces. Large volumes of water can rapidly arise with heavy rainfall in urban areas and cause flooding and transport of debris, including litter. Due to climate change, precipitation patterns are changing and flood intensity and frequency caused by storm water overflows are predicted to increase in northern Europe and North-western Europe. The increased prevalence of paved surfaces in urban areas the 20th Century has led to increased run-off from storm events and the subsequent increased loadings on stormwater systems.

According to a thesis by Robert Jönsson, November 2016 (Mikroplast i dagvatten och spillvatten. Avskiljning i dagvattendammar och anlagda våtmarker) storm water can contain 5 – 20 microparticles/l or 2-5 times discharge concentrations from wastewater discharges. Ponds will remove > 90% of particles > 20 µm. A thesis by Alicia Jannö, University of Gothenburg (May 2016) found that run-off from highway roads can contain 10 – 400 particles/l.

Joel Svalin, University of Gothenburg (May 2016) studied run-off from football-pitches and found more or less the same level, of 27 – 123 particles/l depending on precipitation levels. This corresponded with a total discharge from each of three pitches of 150.000 to 13 million particles/d. He discusses measures that could be taken to reduce this, including that construction of a small barrier or establishment of interceptiontraps could be effective.

Different studies apply different techniques and methodologies. This makes study results difficult to compare.

3.1 Sources

Storm water run-off is formed as precipitation flows over impervious, semi-impervious and saturated surfaces. If the rainfall is heavy enough this leads to a suspension of litter and wash-off from these surfaces and the further transport of litter through the storm-water drainage systems. The interval between precipitation events, along with their intensity and duration, leads to variations in wash-off efficiency, in litter concentrations in the initial runoff (i.e. "first flush") and in the litter load reaching the storm water system. Storm water is either diverted into the sewage system and treated in a waste water treatment plant ("combined system"), or transported separately to the receiving water with or without storm water treatment ("separate systems").

Important sources of micro-litter in storm water are considered to be wear caused by traffic, such as from tyres and worn road markings, particulate litter created during the maintenance of infrastructure, boats and cars, industrial storm water, microlitter from artificial sport arenas, and atmospheric deposition. Losses occurring during production and handling of industrial plastic pellets is still considered to be a large source of micro-plastic litter. These pellets may also be transported by storm water, depending on the location of the spill. Although there still are uncertainties about micro-litter sources, levels of data on quantities of litter emitted from these particular sources are improving. However, there are few studies on the transport of litter by storm water, reduction of litter by storm-water treatment technologies and final load of litter on the marine environment from storm water.

Micro-litter particles caused by traffic may be deposited on roads and eventually be rinsed off by rainwater. They may be deposited in the close vicinity of the road or they may be dispersed in the atmosphere for deposition further away from the road. In areas with a sewer system rinsed off particles may end up there.

Based on data from a study by Sörme and Lagerqvist (2002) on traffic dust in the city of Stockholm, Lassen et al. (2015) estimated that in areas with a sewerage system, 30-50% of the emitted traffic dust particles could be expected to end up in such systems. Particle size seems to be the most important factor determining whether the particles will be airborne or remain on the ground. In the case of the dust particles generated by traffic, it has been shown that abrasion particles from break lining generally are relatively small (<10 µm) and hence more prone to be airborne than for example, the larger particles derived from wear of tyres.

Due to the limits in available data, and likely regional variations, it is very difficult to generally estimate the quantities of micro-litter in storm water. It has however been found that litter concentrations are elevated in water in urban areas with paved surfaces where the run off from land is facilitated. For example in the harbour of Malmö concentrations of microplastics ≥300 µm in surface water amounted to around 50 particles per m^3 compared to levels between 0.08 and 0.69 per m^3 outside the harbour area. In Gothenburg harbour sampling of microplastics ≥300 µm was done both during a long period of dry weather and during a period of rain. The microplastic concentration was found to be considerably higher during periods of rainfall, on average 2.9 microplastic particles per m^3 compared to 0.9 microplastics per m^3 lower during the dry period. The extra load of plastic particles most likely had reached the water in the harbour via run-off from land.

In Northern Europe the dumping of snow that has been collected in urban environments is another pathway for litter to the sea. This snow will contain not only litter of all sizes but also toxic emission particles from car exhausts and from heating of houses. As snow is dumped into the water it will cause an exposure peak of all these potential harmful particles and compounds to the aquatic organism in the area. Dumping of contaminated snow in water bodies is therefore banned in many countries.

European cities in general have a large proportion of combined sewage drainage systems, but these vary widely in from across different countries and even cities. This variance applies to stormwater treatment and handling as well. Combined systems are however, sensitive to weather conditions and changes in urban land use. More paved areas lead to faster hydrologic response and higher pike flows. Moreover, storm water can contain heavy metals that risk impairing the treatment process and deteriorating the sludge quality.

If a sewer system lacks capacity to carry all the wastewater, controlled or uncontrolled overflows will take place, meaning that untreated or moderately treated wastewater will be released into the receiving water bodies, increasing litter load on the environment.

There are only few scientific studies published on techniques to reduce litter of any size in storm water and also very limited information on the cost of investment and maintenance of such facilities. Many technologies are primarily designed to reduce large litter inputs but may nevertheless, have an effect on microlitter inputs as well. When preparing this report, no studies were identified indicating concentrations of microlitter in storm water or potential techniques to reduce microlitter quantities in storm water.

It is important to underline that particle size distributions are seldom analysed in tests and evaluations of storm water treatment systems. This may be a reasons why the performance of different systems varies among studies, as the size and the density of particles determines settlement velocity and sedimentation is the main treatment mechanism for many systems.

The most commonly used storm water treatment technology is wet-basin ponds. This is considered to provide relatively high reduction efficiency with regard to total suspended solids, up to 65 % reduction. Wet basin ponds are used in all types of storm water producing environments; roads, urban environment, industrial areas, and recreational environment. However, wet basin ponds are poor at reducing dissolved and colloidal pollutants. Large litter and microlitter with a density >1 kg/dm^3 are therefore likely to be retained efficiently in wet ponds, while microlitter with lower density is likely to pass through ponds and other detention systems.

Storm water management technologies focusing on removing dissolved and colloidal substances are also efficient in reducing litter of all sizes.

Emerging green and blue value technologies for use in storm water management systems are expected to further reduce marine litter as more run-off will be infiltrated rather than discharged into surface water. Increased water retention in these systems will also lead to more efficient reduction of microscopic litter and dissolved pollutants.

Rivers are often efficient pathways for litter to ocean. There are still only a limited number of studies on the amount of micro-plastics reaching the North Sea via rivers. In a study of the Rhine, which is the largest river in the region, the average concentration in surface water[5] was found to be ~890 000 micro-plastics particles ≥300 µm per km^2, with concentration peaks of 3.9 million micro-plastics particles per km^2. This was estimated to correspond to an average of 17 micro-plastics particles ≥300 µm per m^3. The concentration was high compared to micro-plastic data reported from the Seine in France (0.3-0.5 micro-plastics ≥330 µm per m^3, and 3 -108 micro-plastic particles ≥80 µm per m^3) and Göta älv in Sweden (0.9 – 2.9 micro-plastics ≥300 µm per m^3)[6]. When using the field data on micro-plastic particles concentrations in the Rhine to estimate the input of micro-plastics particles to the North Sea it was found to be around 190 million ≥300 µm per day. To estimate the mass of plastic particles into a weight it was assumed that the average particle was spherical, with a diameter of 1 000 µm and a density of 1 kg/dm^3. The Rhine would hence discharge ~100 kg of micro-plastics per day, or 36 tons per year to the North Sea. It was however pointed out by Mani et.al. that the figures for the River Rhine transport are probably an underestimation of the true contribution since the calculation only included microplastics found on the surface layer of the river.

Sources producing litter of different sizes that risk ending up in the storm water are shown in figure 1. A series of reports on the national sources for microplastics to the environment, including the sources to microplastics found in storm water, have been presented in Norway, Denmark, Germany and Sweden.

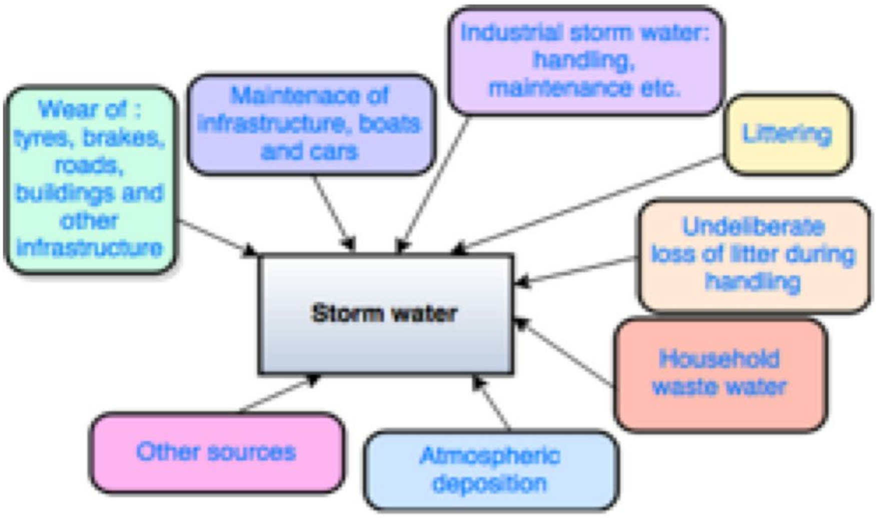

Figure 1. Sources of litter to storm water

3.1.1 Wear caused by road traffic

Road traffic gives rise to microscopic litter mainly from tyre wear, road abrasion (asphalt and road marking) and break wear. The potential amount of micro-particles originating from traffic has given rise to concern, but they have not generally been depicted as litter. The particle sizes that so far have been of major interest from a research and a societal perspective are the very small airborne particle fractions with a diameter of less than 10 µm (PM_{10}) that can enter the human respiratory system and cause negative health effects. Therefore, the concentration of particles less than 2.5 µm wide ($PM_{2.5}$) and PM_{10} is often regulated. Particles in this size range are also produced by traffic through both combustion and wear from tyres, road surfaces and marking and brakes. The scale of particles that can be airborne is between a few nanometres to 100 micrometres.

It has been estimated that the loading of total suspended solids (TSS) on motorways and major roads can be between 815-6 289 kg/ha/year (based on European data), which makes it very important to analyse how much of the TSS that consists of anthropogenic particles and how much consists of natural dust.

Three recent Nordic reviews and one German, on sources of microlitter have pointed out road wear as being the most important. Car tyres are made up of numerous different rubber and other polymeric compounds, many types of carbon black, fillers like clay and silica, and chemicals, minerals added to allow or accelerate vulcanization. About 35% of the thread part of the tyre consists of rubber polymers and approximately 20% of the weight of a tyre wears away as micro-plastic particles during the life of a wheel. Rubber emissions from tires in Sweden have been evaluated in a study for two vehicle classes; cars where the wear is supposed to be 0.05 g rubber per vehicle per kilometre, and buses where the wear is 0.7 g rubber per vehicle per kilometre.

The Swedish emissions of rubber particles from wear of tyres were estimated to 13 000 metric tons per year, the Danish emissions to be 4 200 – 6 600 metric tons, the Norwegian emissions to be 4 500 tons and emissions in the UK to be 53 000 tons per year.

The total abrasion of asphalt is estimated to create 110 000 tons per year in Sweden. Bitumen is the binder used in asphalt. In the normal asphalt the binder content is typically about 5-6% by weight corresponding to about 10% by volume. In order to improve the construction of asphalt, polymers are added to some bitumen. The emissions of polymers from the Swedish road network were estimated to be 15 metric tons per year, assuming that the concentration of polymers is the same in road wear as in new asphalt.

Another source of microplastics from roads is abrasion of road marking. These are partly thermoplastic, partly polymer paints. The content of road marking is mainly fillers but the typical thermoplastic elastomer content is about 1-5%. Estimations made in Denmark indicate that 110–690 tonnes of thermoplastic road marking material is emitted as micro-plastic particles due to wear per year. The report used the elastomer content of 0.5-2% according to Danish manufacturers and abrasion factor of road marking of 15-43%, and estimated the micro-plastic elastomer emissions are 4-50 tons per year for Denmark. Calculating on Denmark road length year 2010, which was 73 574 km, emission factors thus became:

- 0.05-0.68 kg per year and kilometre road.

The Swedish emissions inferred from the total yearly consumption of road markings using Norwegian emission data and based on Sweden road length, 579 567 km, resulted in the following emission factor:

- 0.87 kg per year per kilometre road.

The emission of micro-plastic elastomer in Sweden would hence be 504 tons per year.

3.1.2 Artificial surfaces on sport pitches

Run-off of rubber granulate from sport arenas may be a significant source of microlitter in some regions. The number of sport pitches in Norway covered with artificial surfaces, has increased from 100 to more than 1.000 the last 15 years. The rubber used on the pitches is, mainly made by old rubber tires.

Each pitch contains around 100 tons rubber granulate and will have to be replaced by ca. 10 tons per year, due to, run-off and attached to clothes and shoes, and in some regions, mechanical snow removal.

3.1.3 Maintenance of infrastructure, boats and cars

Cleaning of infrastructure, paved surfaces etc. can be undertaken by using high and low water pressure washing as well as blasting with particles of different materials. Structures such as roads, tunnels, bridges, roofs and facades are regularly cleaned causing additional wear on these surfaces and the possible creation of microlitter. In Norway building repair was estimated to create 270 tons of micro-plastic pollution per year, but only part of this is likely to end up in storm water. The Swedish total emission of micro-plastics from protective coatings and decorative paint were estimated to 128-251 tons per year. Activities like cutting and fitting of plastic objects, such as pipes for different uses, may also produce microlitter in the form of swarf. Some of the microlitter from these different sources might eventually end up in the storm water.

3.1.4 Industrial storm water

Industrial storm water may contain particles created during outdoor washing and blasting of cars, ships and structure. Outdoor handling of products or raw materials consisting of micro-plastic particles may lead to accidental spills and thereby also to possible releases of micro-plastics to the storm water system.

Historically, plastic pellets have been considered a major source of marine micro-plastics. There has been evidence of considerable point source inputs of plastic pellets or powders near to plastic processing plants. However, over the last decades the amounts of plastic pellets have decreased by approximately 75%[7]. In spite of the decreasing trend, emissions of primary plastic pellets still continues, evident for example by the very high water concentration of pellets in an industrial harbour outside a large manufacturing plant in Sweden where peak values of 102 000 per m^3 were detected.

3.2 Storm water treatment

To date, very few scientific papers are available on techniques to reduce different size classes of litter in storm water. The information forming the base for reduction of microscopic litter has been compiled from non-peer-reviewed reports and a survey that was directed to OSPAR-members within the working group for the Regional Action Plan (RAP) on Marine Litter.

Methods studied include various types of Low Impact Development (LID), litter traps, wet-basin ponds, wetlands, filters, detention- and infiltration areas, but also more technical solutions such as hydrocarbon interceptors and hydrodynamic separators. In the scientific literature, practices for street sweeping, emptying of catch pits, installation of grates over catch pits.

Based on general knowledge the following measures could be considered:

- **Better** design and run-off protection from sport pitches with artificial grass to reduce losses of rubber granulate
- **Improved maintenance for cleaning/sweeping of roads and streets** in order to collect more (micro) litter from tyres, road paints and asphalt/concrete particles
  Improved collection systems for all kinds of construction works
- Installation of filters connected to combined sewer overflows
- Infiltration of storm water run-off, especially from roads with heavy traffic and urban areas

3.3 Conclusions on storm water:

The information on transportation of litter from source to storm water, and from storm water to the sea is sparse and relies on screening studies based on few samples.

Most storm water in the OSPAR region is currently not treated at all, so installation of storm water treatment facilities in exposed areas should be considered. Conventional treatment systems like gulleys and graitings followed by wet-ponds would reduce the litter load from storm water to sea substantially. To improve the reduction of microlitter in storm water additional filtration may be needed.

Where feasible storm water should not be treated in municipal wastewater treatment plants where high flow variability and heavy metals will impair the treatment and deteriorate the sludge quality.

Low impact development mimicking the natural hydrology in urban area has a good potential to reduce the load of litter to the sea. The storm water volumes will be reduced, and the increased visibility of the storm water in the urban environment is likely to reduce the deliberate and accidental littering by the public. Moreover, the extended retention time and the infiltration of storm water will lead to a reduction in peak pollutant concentrations in the receiving waters.

4 Recommendations

4.1 Wastewater

All countries should develop action plans for reduction of discharges from wastewater systems.

For many countries, construction of treatment systems or secondary treatment, is still pending. By enforcement of existing plans and implementing the Wastewater Directive many countries will reduce the discharge of microlitter significantly.

Improved purification beyond secondary treatment will most probably have little effect and will be of very high cost.

For cities or urban areas where combined systems exist, screening and filtration of overflows may be a feasible measure and should be considered.

Measures to be considered:

- Construction of treatment plants for untreated discharges (or connection to a sewerage system already connected)
- Installation of filters in washing machines in industries and private homes
- Separation of the combined system (this action may however increase the number of particles to environment)
- Upgrading of poor quality pipes in order to reduce leakages and reduce infiltration/inflow which will increase overflows and reduce treatment capacities
- Install treatment for overflow weirs
- Make sure plastic based biomedia cannot escape the treatment plants

4.2 Storm water

All countries should develop action plans for reduction of discharges from wastewater systems.

The major part of micro-plastic will be transported by storm water. As more storm water will be separated from the sewage pipes, measures that prevent litter to enter pipes should be considered.

In addition, infiltration or percolation of storm water would reduce the transport to rivers or sea.

There are some point sources that should be considered, like sport fields and run off to rivers/ streams from roads with heavy traffic.

Measures to be considered:

- **Better** design and run-off protection from sport pitches with artificial surfaces to reduce losses of rubber granulate
- **Improved procedures for cleaning/sweeping of roads and streets** in order to collect more (micro) litter from tires, road paints and asphalt/concrete particles
  Improved collection systems for all kinds of construction works
- Installation of filters connected to combined sewer overflows
- Infiltration of storm water run-off, especially from roads with heavy traffic and urban areas

5 References

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5. Mani, T., et al., *Microplastics profile along the Rhine River.* Scientific Reports, 2015. **5**: p. 17988
6. Magnusson, K., et al., *Microlitter in sewage treatment systems. A Nordic perspective on waste water treatment plants as pathways for microscopic anthropogenic particles to marine systems*. 2016. p. 56.
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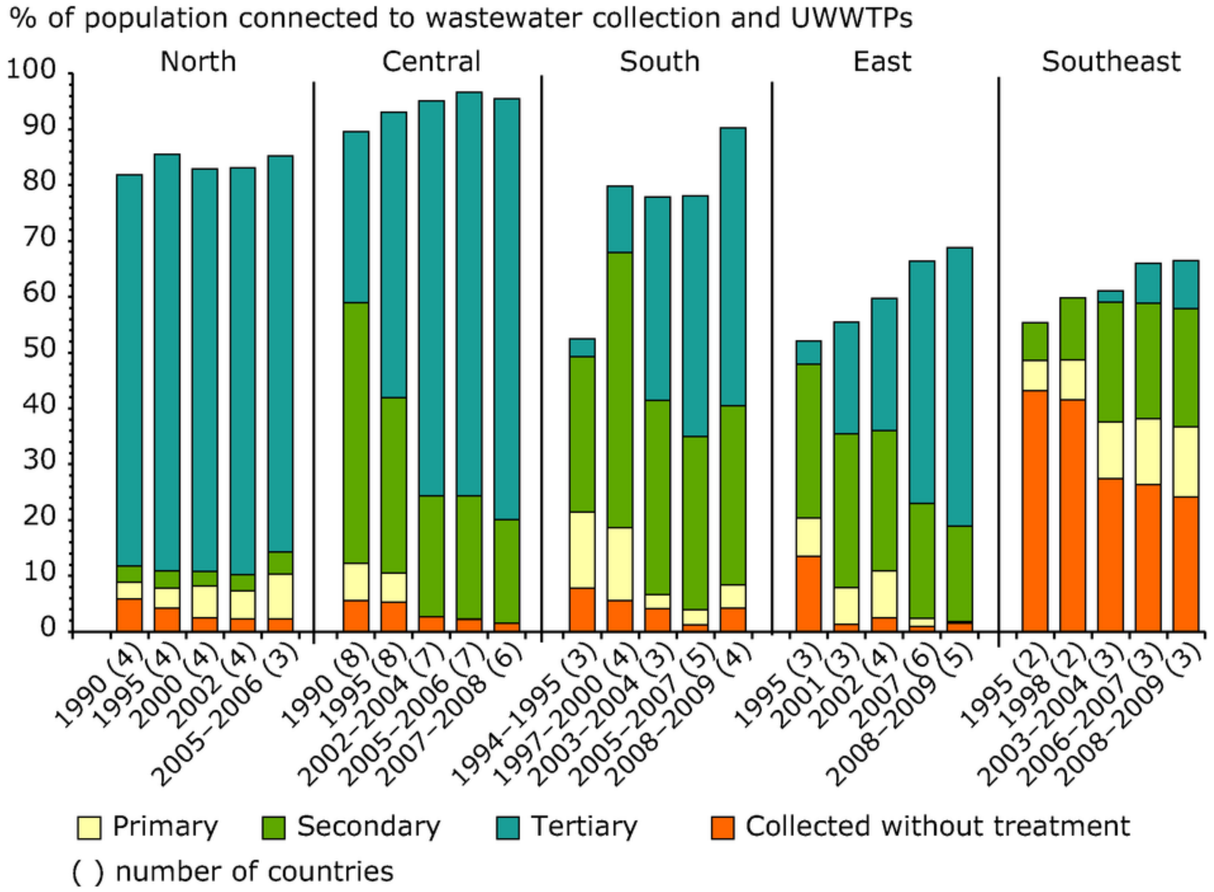
6 Appendix 1. Wastewater treatment in Europe

Fig. 1: Changes in wastewater treatment in regions of Europe between 1990 and 2012 Source: (eea.europe.eu/data-and-maps/figures)



North: Norway, Sweden, Finland and Iceland
South: Cyprus, Greece, France, Malta, Spain and Portugal
Central: Austria, Denmark, England and Wales, Scotland, Netherlands, Germany, Switzerland, Luxembourg, Ireland
East: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovenia, Slovakia
South-East: Bulgaria, Romania, Turkey

More stringent treatment was in place for 89% of the load for EU-15 and for 27% of the generated load for EU-12. In summary, charts 1a (EU-15) and 1b (EU-12) illustrate the waste- water infrastructure in place in 2007/2008. (http://ec.europa.eu/enviroment/water)

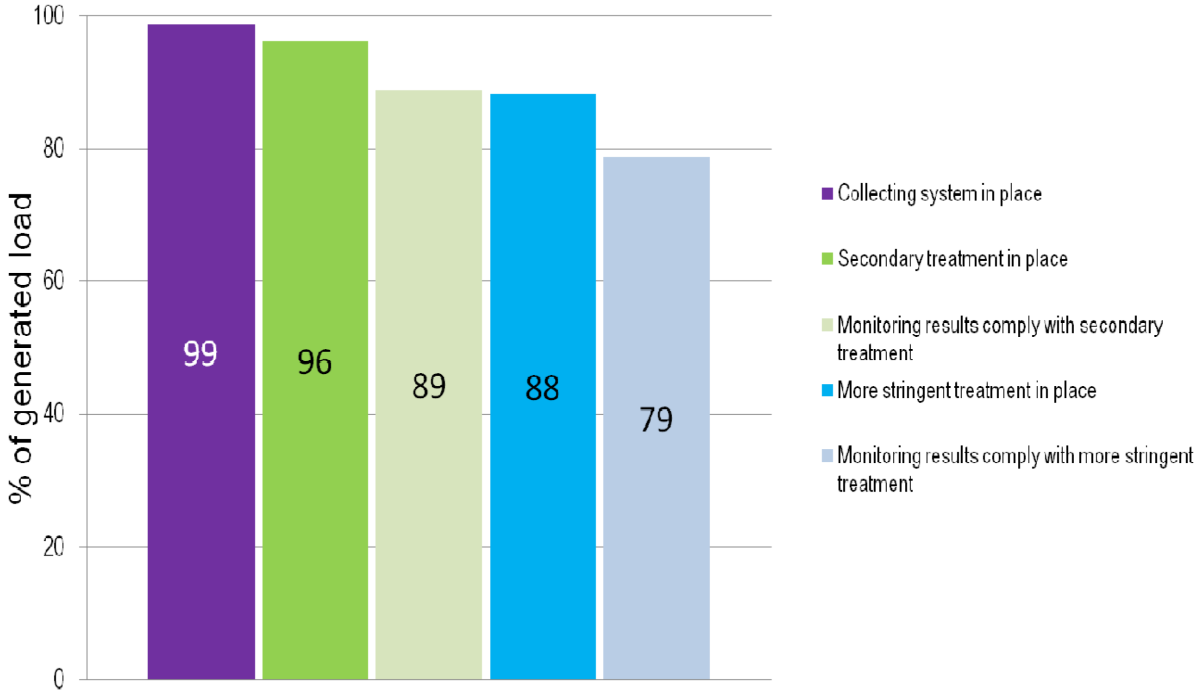


Chart 1a: Average share of generated load collected in collecting systems, treated by secondary treatment and more stringent treatment for EU-15.

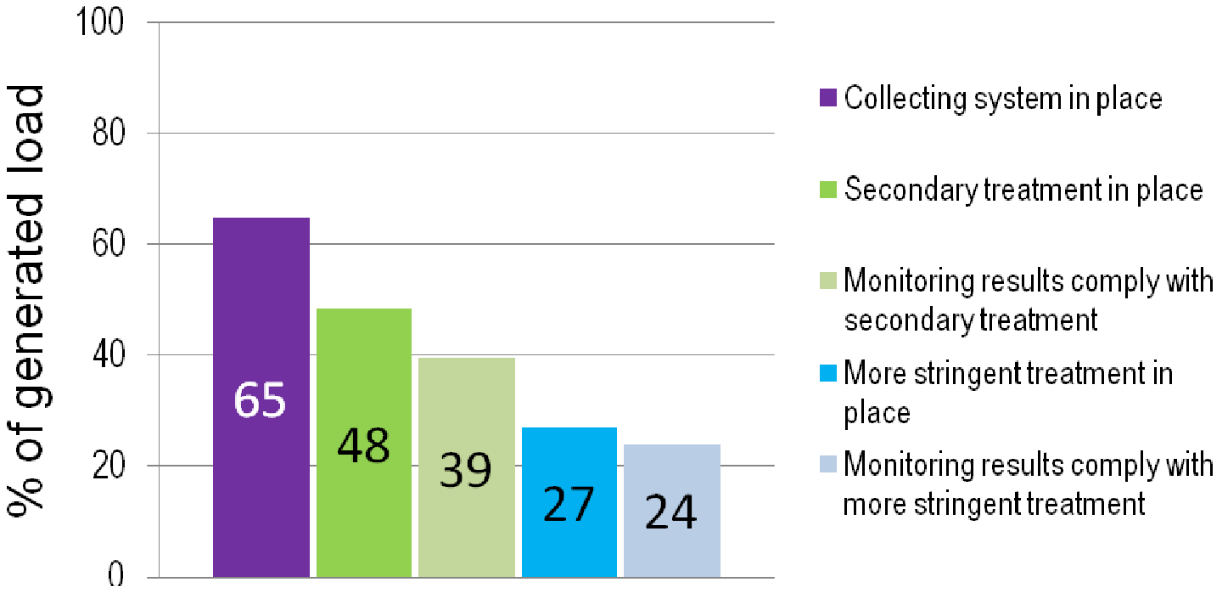


Chart 1b: Average share of generated load collected in collecting systems, treated by secondary treatment and more stringent treatment for EU-12

EU-15 refers to Member States which joined the EU before the 2004 enlargement: Austria, Belgium, Denmark, Germany, France, Finland, Greece, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden, The Netherlands and United Kingdom; however it should be noted that, on what regards this Summary, EU-15 does not cover United Kingdom, referring therefore to 14 Member States only.
EU-12 refers to Member States who acceded to the EU in 2004 and 2007 enlargements: Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria and Romania.