OSPAR COMMISSION

Review of BAT and BEP in Urban Wastewater Treatment Systems focusing on the reductions and prevention of stormwater related litter, including micro-plastics, entering the Marine Environment

Environmental Impacts of Human Activites

2019

Review of best available techniques (BAT) and best environmental practices (BEP) in urban wastewater treatment systems in accordance with the URBAN Waste Water Treatment Directive (91/271/EEC) and other relevant standards, with a focus on reduction and prevention of stormwater related litter (including microparticles) entering the marine environment

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l'Allemagne, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume- Uni de Grande Bretagne et d'Irlande du Nord, la Suède, la Suisse et l'Union européenne

Acknowledgement

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Sponsors: Department of Housing Planning and Local Government Ireland, Dónal Cronin & Conall O'Connor

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Executive Summary

The scope and the objective of this project is to compile a report containing information, from across the OSPAR area, on the best available techniques (BAT) and best environmental practices (BEP) in urban wastewater treatment systems, with a focus on stormwater related litter (including microparticles) entering the marine environment, as part of the OSPAR Regional Action Plan for the Prevention and Management of Marine Litter, Action 42.

Performance standards

This background document reviews environmental performance standards within the OSPAR area for the handling of stormwater in combined urban wastewater systems and combined sewer overflows (CSOs). The authors note that there is no single piece of legislation regulating all aspects of CSOs. Information analysed during the review demonstrates that while many countries within OSPAR have made significant efforts to address CSOs in accordance with the requirements of the Council Directive 91/271/EEC Urban Waste Water Treatment Directive (UWWTD), it is not possible to quantitatively determine the effectiveness of these performance standards in preventing litter, including micro particles, entering the marine environment without undertaking further studies. The lack of information relating to spill frequency, spill duration and duration rates is of particular concern and points to a need for monitoring and reporting of the performance of CSOs. In addition, it is noted that there is a need to revise the UWWTD to include microplastic thresholds as the effectiveness of existing Waste Water Treatment Plants (WWTPs) and CSO treatment systems cannot be quantitatively assessed based on existing performance standards.

Systems and Technologies

This background document also reviews existing processes, techniques, technology and systems for the removal of stormwater related waste from combined urban wastewater systems. The review finds that policy makers and environmental managers aiming to achieve a reduction in stormwater related waste entering the marine environment can:

- Adopt source based measures which attempt to prevent litter entering the sewer and avoid or minimise the presence and creation of microplastics in the sewer; and/or
- Adopt pathway based measures which attempt to remove litter at the CSO, thereby removing or restricting the pathway for litter to enter the marine environment.

The review highlights the important role which the public's attitude to marine litter and consumer awareness will play in preventing the entry of plastics into the environment. The report finds that it is only with public understanding of the impact on the environment, including the marine environment, of their decisions regarding the selection of sustainable consumables and/or clothing products and the proper disposal of litter that the full impact of any of these measures can be realised.

Recommendations

In this background document a number of critical knowledge gaps are identified and the following recommendations are formulated to address these knowledge gaps:

- **Increase monitoring:** There is a need to establish monitoring so that the effectiveness of existing WWTPs and CSO treatment systems in the removal of microplastics can be quantitatively assessed;
- **Research:** There is a need for research to be carried out to evaluate management systems (i.e. disintegration technologies) so that the potential impact on the environment is minimized.

- **Increased Reporting Requirements:** There is lack of information pertaining to technologies used to treat CSO discharges throughout the OSPAR region.

Legislation: It is also noted that there exists the need to revise the UWWTD to include microplastic thresholds.

Récapitulatif

La portée et l'objectif du présent projet sont l'élaboration d'un rapport comportant des informations, pour l'ensemble de la zone OSPAR, sur les meilleures techniques disponibles (BAT) et la meilleure pratique environnementale (BEP) appliquées au traitement des eaux usées urbaines, insistant plus particulièrement sur les déchets liés aux eaux pluviales (notamment les microparticules) pénétrant le milieu marin, dans le cadre de l'Action 42 du Plan d'action régional OSPAR pour la prévention et la gestion des déchets marins.

Normes de performance

Le présent document de fond passe en revue les normes de performance environnementale, au sein de la zone OSPAR, portant sur le traitement des eaux pluviales dans les systèmes des eaux usées urbaines combinés et les systèmes des débordements d'égout combinés (CSO). Les auteurs indiquent qu'il n'existe aucune législation réglementant tous les aspects des CSO. L'analyse des informations réalisée au cours de la revue démontre que nombre de pays au sein d'OSPAR ont fait des efforts considérables pour aborder la question des CSO conformément aux exigences de la Directive relative au traitement des eaux urbaines résiduaires (DERU). Il est cependant impossible de déterminer, du point de vue quantitatif, l'efficacité de ces normes de performance lorsqu'il s'agit d'empêcher les déchets, notamment les microparticules, de pénétrer le milieu marin sans entreprendre des études supplémentaires. L'absence d'information portant sur la fréquence des déversements, leur durée et leur débit cause en particulier des inquiétudes et indique qu'il y a lieu de surveiller et de notifier la performance des CSO. Il est de plus indiqué qu'il y a lieu de réviser la DERU afin d'inclure des seuils pour les microplastiques car l'efficacité des usines de traitement des eaux usées et des systèmes de traitement CSO existants ne peut pas être évaluée quantitativement par rapport aux normes de performance.

Systèmes et technologies

Le présent document de fond passe également en revue les processus, techniques, technologies et systèmes existants pour l'élimination des déchets causés par les eaux pluviales provenant des systèmes des eaux usées urbaines combinés. Cette revue révèle que les décideurs politiques et les gestionnaires de l'environnement, ayant pour objectif de parvenir à réduire les déchets liés aux eaux pluviales pénétrant le milieu marin, peuvent:

- adopter des mesures, basées sur les sources, visant à empêcher les déchets de pénétrer les égouts et à éviter ou réduire la présence et la création de microplastiques dans les égouts, et/ou
- adopter des mesures, basées sur les voies de pénétration, visant à éliminer les déchets dans les CSO, retirant ou limitant donc la voie de pénétration des déchets dans le milieu marin.

La revue souligne le rôle important que joue le comportement du public envers les déchets marins et celui que jouera la sensibilisation du consommateur dans la prévention de l'entrée des plastiques dans le milieu marin. Le rapport révèle que l'une quelconque de ces mesures ne pourra avoir un effet maximum que si le public est conscient de l'impact sur l'environnement, notamment le milieu marin, des décisions portant sur la sélection de produits de consommation et/ou vestimentaires durables et l'élimination correcte des déchets.

Recommandations

Le présent document de fond identifie un certain nombre de lacunes importantes dans les connaissances et comprend les recommandations suivantes permettant d'aborder ces lacunes:

- **augmentation de la surveillance:** il y a lieu de mettre en place une surveillance permettant d'évaluer quantitativement l'efficacité des usines de traitement des eaux usées et des systèmes de traitement CSO existants dans le cadre de l'élimination des micropastiques;
- **recherches:** il y a lieu de faire des recherches afin d'évaluer les systèmes de gestion (c'est-à-dire technologies de désintégration) pour minimiser les impacts potentiels sur l'environnement.
- **Augmentation des exigences de la notification:** absence d'informations portant sur les technologies utilisées pour traiter les rejets des CSO dans l'ensemble de la zone OSPAR.

Législation: il indique également qu'il y a lieu de réviser la DERU afin d'inclure des seuils pour les microplastiques.

Glossary

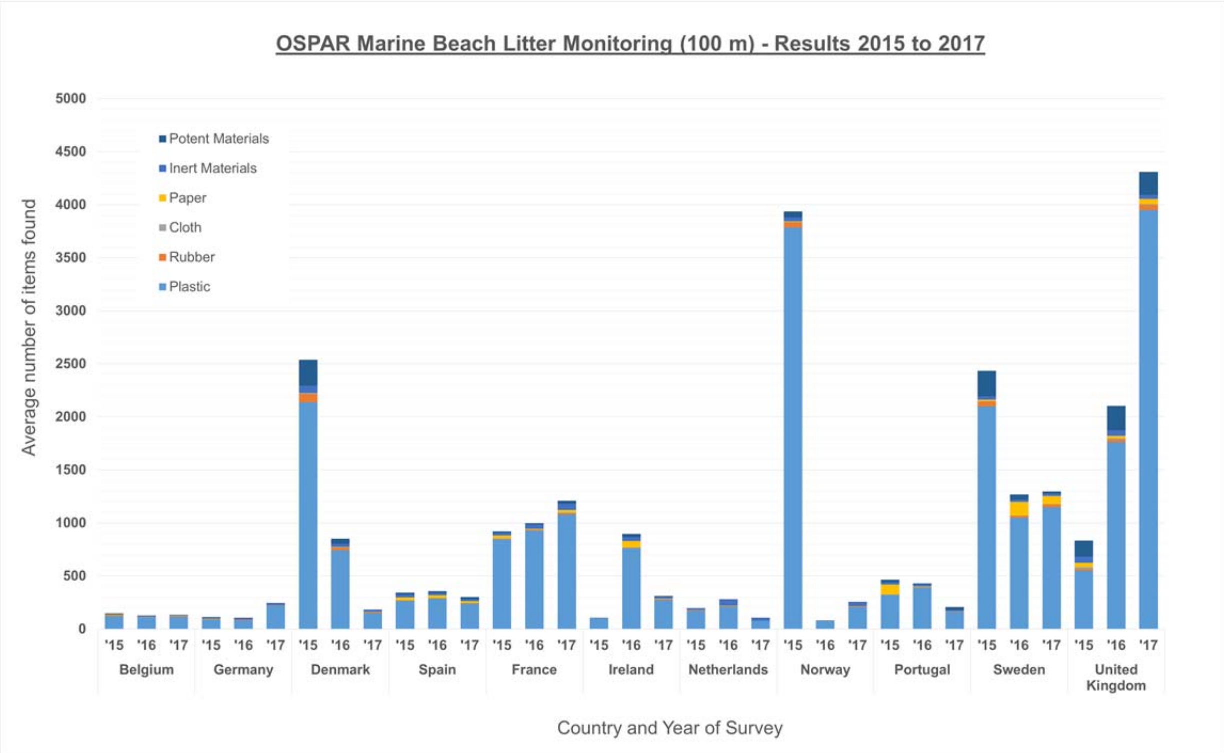
Best Available Technology (BAT)	The latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste (OSPAR, 2018).
Best Environmental Practice (BEP)	The application of the most appropriate combination of environmental control measures and strategies (OSPAR, 2018).
Combined Sewer Overflow (CSO)	Combined sewer overflows are structures which allow combined sewer systems to overflow to a receiving watercourse when the hydraulic capacity of a combined sewer network, or stormwater storage capacity at a WWTP, is exceeded during extreme rainfall events.
Combined sewer system	Networks of underground pipes that convey domestic sewage, industrial waste water and storm water runoff in the same pipe to a centralised treatment facility.
Domestic waste water	Waste water from residential settlements and services, which originates predominantly from the human metabolism and from household activities (OJEC, 1991).
Emergency Overflow (EO)	Emergency overflows are overflow mechanisms constructed as part of pump sump infrastructure, whereby a power failure, essential maintenance or other similar interruption in normal operations results in a discharge of untreated waste water from the sump as a consequence of the pumps being disabled.
European Commission (EC)	The European Commission is an institution of the European Union, responsible for proposing legislation, implementing decisions, upholding the EU treaties and managing the day-to-day business of the EU.
European Economic Area (EEA)	The European Economic Area is the area in which the Agreement on the EEA provides for the free movement of persons, goods, services and capital within the European Single Market, including the freedom to choose residence in any country within this area.
Good Environmental Status (GES)	Good Environmental Status is a qualitative description of the state of the seas that the European Union's Marine Strategy Framework Directive requires its Member States to achieve or maintain by the year 2020.
Industrial waste water	Industrial waste water means any waste water which is discharged from premises used for carrying on any trade or industry, other than domestic waste water and run-off rain water (OJEC, 1991).
Low Impact Development (LID)	Low impact development comprises urban drainage systems which are designed to mimic natural hydrology, minimising runoff and encouraging attenuation and storage of stormwater so that it can be discharged gradually to the environment.
Marine litter	Any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. It also includes materials transported into the marine environment from land by rivers, draining or sewage systems or winds. It includes any persistent, manufactured or processed solid material (OSPAR, 2018).
Marine Litter Regional Action Plan (RAP)	The Regional Action Plan is designed as a flexible tool providing a set of actions to address marine litter which has been adopted by OSPAR Contracting Parties as an OSPAR Other Agreement.
Membrane Filtration	Membrane filtration systems use pressure or concentration gradients to separate particles through a semipermeable membrane.
Microparticles	A microparticle is a particle which is between approximately 1 and 1000 micrometers in size.
Microplastics	Microplastics are small pieces of plastic that pollute the environment. While there is

	some contention over their size, the U.S. National Oceanic and Atmospheric Administration classifies microplastics as less than 5 mm in diameter.
OSPAR	The mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic. OSPAR started in 1972 with the Oslo Convention against dumping and was broadened to cover land-based sources and the offshore industry by the Paris Convention of 1974. These two conventions were unified, up-dated and extended by the 1992 OSPAR Convention. The new annex on biodiversity and ecosystems was adopted in 1998 to cover non-polluting human activities that can adversely affect the sea.
Overflow	Release of untreated or moderately treated waste water to the environment due to a hydraulic overload in the sewer system or in the WWTP.
Population Equivalent (PE)	Population equivalent (in waste-water monitoring and treatment) refers to the amount of oxygen—demanding substances whose oxygen consumption during biodegradation equals the average oxygen demand of the waste water produced by one person (OECD, 2001). PE is also referred to as unit per capita loading.
Separate sewer systems	Networks of underground pipes that are designed to convey waste water and storm water in separate pipes.
Source control	The use of site design and a deliberate choice of building material to reduce pollution.
Storm water	Water from rain or melting snow that runs off urban surfaces. Storm water is either drained into the sewage system and treated in a waste water treatment plant (“combined system”), or drained into a dedicated storm water system from where it is transported to the receiving water with or without storm water treatment (“separate sewer systems”).
Storm Water Overflow (SWO)	See definition for combined sewer overflow (CSO)
Sustainable Drainage Systems (SuDs)	See definition for Low Impact Development (LID)
Total solids (TS)	Measurement of the total solids in a water or wastewater sample.
Suspended solids (SS)	Measurement of the total solids in a water or wastewater sample that are retained by filtration (normally 1.5-micrometer pore size).
Urban waste water	Urban waste water (often just waste water) is domestic waste water or the mixture of domestic waste water with industrial waste water and/or storm water (OJEC, 1991).
Waste water treatment plant (WWTP)	A facility where waste water is treated. It normally includes mechanical (primary treatment), biological (secondary treatment), and chemical (tertiary treatment) processes to remove contaminants and produce environmentally safe treated effluent water. A by-product of sewage treatment is a semi-solid waste or slurry, called sewage sludge, which has to undergo further treatment before being suitable for disposal or land application.

1 Introduction

1.1 Marine litter – General Overview

Marine litter is any manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Marine litter comprises of plastics, wood, metals, glass, rubber, clothing, paper etc. The spatial distribution and accumulation of litter in the ocean is influenced by hydrography, geomorphological factors, prevailing winds and human activities. Hotspots of litter accumulation include shores close to populated areas, particularly beaches, but also submarine canyons, where litter originating from land accumulates in large quantities (Pham et al., 2014). Globally it is accepted that plastic accounts for the majority of marine litter found in oceans (Barnes et al., 2009) and it is borne out within the OSPAR region by analysis of data from beach litter monitoring carried out in 11 OSPAR countries over three years between 2015 and 2017 (OSPAR, 2015, 2016 and 2017), as shown in Figure 1 below.



*potent materials: medical, sanitary and faeces; inert materials: glass, metal, wood and pottery.

Figure 1 OSPAR Marine Beach Litter Monitoring (OSPAR, 2015, 2016 and 2017)

Single Use Plastic (SUP) items represent about half of all marine litter items found on European beaches by counts. The 10 most commonly found SUP items represent 86% of all SUP items (constituting thus 43% of all marine litter items found on European beaches by count) (EC, 2018a). It is estimated that between 3.4 and 5.7 million tonnes of plastic, which are a source of microplastics, is disposed of annually to the world's oceans (Essel et al., 2015). In general, larger plastic fragments can be effectively removed from CSO discharges using screening. Microplastics, which are generally described as particles smaller than 5mm, are significantly smaller and as a result pose a much greater challenge to remove from sewerage and CSO discharges. Microplastics make up the majority of micro particles throughout the world's oceans (MSFD, 2013) and for the remainder of this background document the two terms are considered to be interchangeable.

1.2 Microplastics

Microplastics are classified as either primary or secondary. Primary microplastics are intentionally engineered and added to products or used in production processes, while, secondary microplastics are created intentionally or unintentionally during the production, use or waste phase of plastic items. All plastic products are a potential source of microplastics with between 6 and 10 percent of global plastics production ending up as marine litter (Verschoor et al., 2015). The release of microplastics to the environment is a function of the methods used to produce, transport, utilise and ultimately dispose of plastic products (Verschoor et al., 2015). A comprehensive review of sources of microplastics in OSPAR countries carried out by the OSPAR Commission in 2015 found that the distribution and abundance of microplastics in the environment followed a similar trend to larger fragments of marine litter. The authors presented preliminary estimated annual emissions of microplastics to surface water from 6 different sources in OSPAR countries (see Table 1 below), measured in tonnes/year (Verschoor et al., 2015).

Microplastic sources	Microplastic type	Emissions (tonnes/year)
Detergents	Secondary	39.6
Cosmetics	Primary	2,825
Synthetic turf	Primary	326
Tire wear	Secondary	54,508
Paints	Secondary	8306
Laundry fibres	Secondary	11,160

Table 1 Preliminary estimated annual emissions of microplastic to surface water from 6 different sources in OSPAR countries in ton/year (Verschoor et al., 2015)

The adverse impacts of plastic litter in the marine environment are well established with plastic products responsible for entanglement of animals, causing injuries to the alimentary tract, preventing digestion or blocking the intake of food to the point that the animal starves if ingested (Werner et al., 2016; Rochman et al., 2013). Marine litter also causes damage to habitats and acts as vector for non-native species to proliferate (Werner et al., 2016).

In addition to causing injury and impairment to fish and animals in the same way as larger plastic fragments, microplastics can be toxic to animals or cause endocrine disruption (Rochman et al., 2013). Microplastics are persistent in nature (Anderson et al., 2015) and there is evidence that marine organisms swallowing microplastics may potentially ingest higher doses of persistent organic pollutants which have been absorbed to the surface of these microplastics (Teuten et al., 2009). Through this mechanism microplastics can also facilitate bioaccumulation of persistent organic pollutants in the food web (Mattsson et al., 2015; Wieczorek et al., 2018).

1.3 Stormwater Overflows

The purpose of this study is to look at the nature and quantum of microplastic material entering the marine environment from combined sewerage systems, via stormwater overflows in the systems. Traditionally, there are two types of sewer systems; (i) combined sewer system which is designed to convey sewerage and surface water runoff and (ii) separated sewer systems which are designed to keep sewerage and surface water runoff completely separate. From an engineering perspective, separated sewer systems are the preferred option as they minimise the volume of water which must be treated at wastewater treatment plants (WWTPs), in addition to reducing the risk of dilution of influent to the plant interfering with the treatment process, however, it is not always practical or economically feasible to upgrade existing sewer networks so as to completely separate sewerage and surface water runoff. It is also worth noting that combined sewers are advantageous in some regards, for example they provide for treatment of sewage and stormwater in the one facility (Bromback et al., 2005).

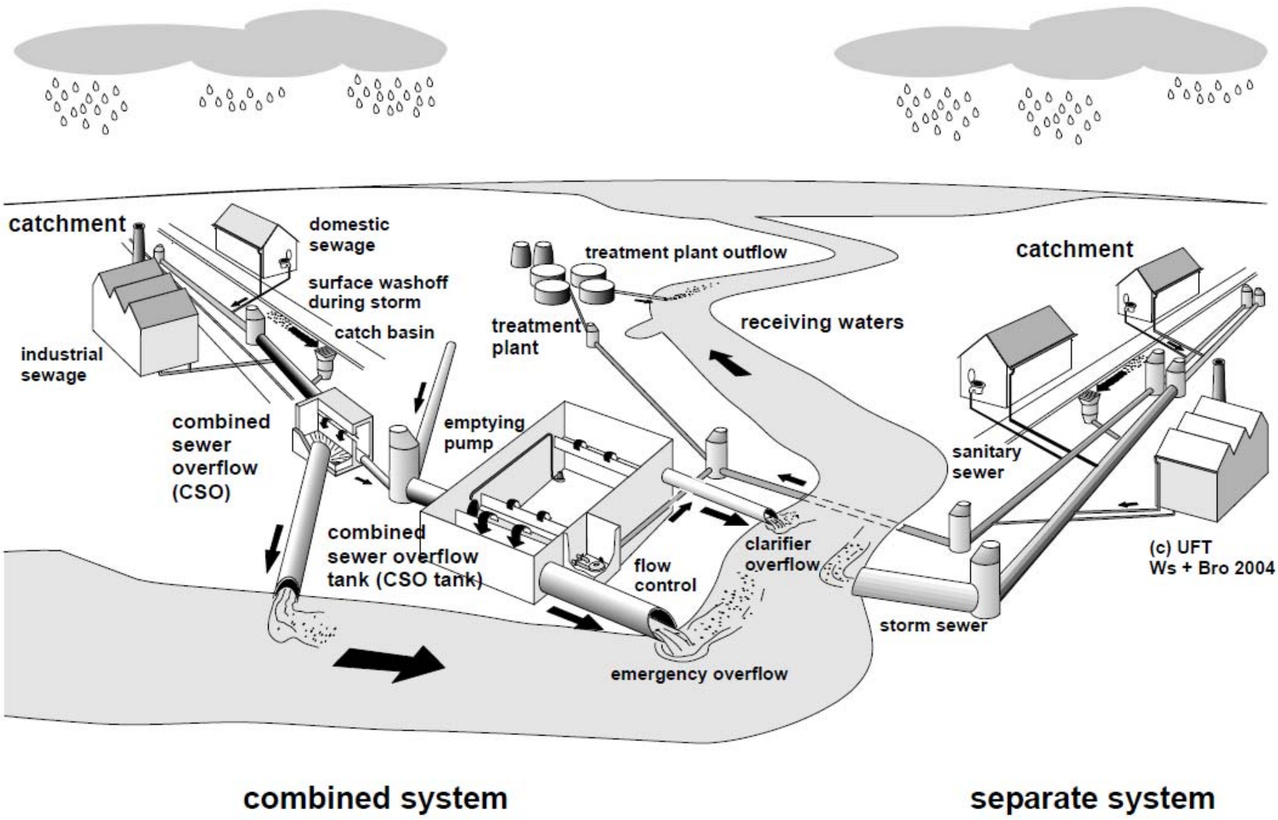


Figure 2 Traditional combined (left) and separate (right) sewer systems (Bromback et al., 2005)

There are two types of storm water overflow in sewer networks.

i. Combined sewer overflows (CSOs) which occur when the capacity of a combined sewer network, or storage at a WWTP, is exceeded during extreme rainfall events; and
ii. Emergency overflows (EO) which occur when there is a mechanical or electrical failure at a WWTP or pumping station and can occur on combined and separate sewers.

It should be noted that both CSOs and EOs are only used in sewerage networks, pumping stations or WWTPs as an emergency relief, and that they are not designed to spill runoff or sewerage on a regular basis. Both EOs and CSOs present the same challenges for the environment with the difference being that CSOs are designed to discharge during operation (extreme events). This document will focus on CSOs, however, the discussion and findings may also be applied to EOs.

1.4 Combined Sewer Overflow (CSO) Discharges

CSO discharges contain a mixture of raw sewage and stormwater and are thus a source of microbial pathogens, oxygen-demanding substances, suspended solids, toxic substances, pharmaceutical chemicals, nitrogen, phosphorus, human waste and wrongfully disposed sanitary products (Baralkiewicz et al., 2014). CSOs also contain waste materials that are washed into the combined network from the area being drained, as surface runoff collects debris from road and other impermeable areas before it enters the combined system. The runoff waste collected includes hydrocarbons, sediment and microplastics released due to tire wear and tear and depends on a number of factors including tire composition, type of road surfaces, slope (mountains), climate and driving behavior (Verschoor et al., 2015). Typically, between 1%

and 15% of total wastewater load can overflow during extreme events (Morgan et al., 2017). The findings of a European Commission (EC) fact sheet are included below to highlight the number of agglomerations in the EU which may contain CSOs (EC, 2018b).

Statistic	EU 28
Total number of agglomerations (having the load of more than 2,000 PE)	23,569
Total number of agglomerations 2000-10000 PE	15,011
Total number of agglomerations >10000 PE	8,558
Number of big cities / big dischargers (having generated a pollution load of more than 150 000 PE)	662
Total Load discharged from agglomerations	588 million PE
Total load discharged from agglomerations 2000-10000 PE	68 million PE
Total load discharged from agglomerations >10000 PE	519 million PE
Total load discharged from big cities discharging >150 000 PE	277 million PE

Table 2 Agglomerations in EU28 and the generated organic pollution load that they discharge (EC, 2018b)

While there is no definitive information on the number of CSOs within the OSPAR countries, or information regarding typical CSO design, an EC report from 2016 provided information relating to the general prevalence of CSOs in the OSPAR region (Moreira et al., 2016). The report demonstrates that CSOs occur in all of the countries which provided information, including Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom (see Table 3 below). Information from the remaining OSPAR countries, i.e. Iceland and Norway is compiled in Table 4, having been gathered during this study from publically available information (Reykjavíkur, 2008; Statistics Norway, 2017). No data was available for Switzerland.

Counties	Separate sewers	Combined sewers	Risk of overflows*	No. of storm overflow (SO) structures (Note: where region name included in brackets the number is not a total and is a region only)
Belgium	7.7%	92%	+++	12,382 SOs (Brussels, Flanders, Walloon)
Denmark	50%	50%	++	17,548 SOs (4873 CSOs)
Finland	c.95%	c.a. 5% Helsinki: 30%	++	No. overflows not provided.
France	68%	32%	++	No. overflows not provided.
Germany	57%	43%	++	18,425 SOs (North Rhine-Westphalia & Bavaria)
Iceland	Not included in Moreira et al., 2016 study.			
Ireland	76%	16%	+	1,900 SOs
Luxembourg	10%	90%	+++	No. overflows not provided.
Netherlands	27%	68%	+	13,700 SOs
Norway	Not included in Moreira et al., 2016 study.			
Portugal	66%	33%	+	6,432 SOs
Spain	87%	13%	+	No. overflows not provided.
Sweden	88%	12%	+	No. overflows not provided.
Switzerland	Not included in Moreira et al., 2016 study.			
United Kingdom	30%	70 %	+++	19,049 CSOs.

Table 3 Percentage of types of sewage pipes in terms of length, risk of overflows and number of overflows in OSPAR countries (excl. Iceland, Norway and Switzerland) (Moreira et al., 2016)

Undertaking a thorough review of all of the raw data provided to the Moreira et al. (2016) study is outside of the scope of this background document. We are of the opinion however that the figures reported for Ireland stand out as being out of line with our expectation based on our extensive knowledge of working on Ireland's wastewater systems. As part of this background document a review on the figures quoted in the above table relating to the position in Ireland was carried out. Initial indications were that the estimated percentage of separate sewers quoted in the table seemed high for the national position in Ireland. An interrogation of the factsheet completed by Ireland, and used as a basis for the data quoted in the table, showed that there was no quantitative information available relating to the length of each type of sewer and number of CSOs. In the absence of data, the authors conducted an interview a nominated CSO expert and the figures quoted are an extrapolation based on GIS data from 2014. The authors included stormwater sewers as separate sewers when calculating the percentage of each sewer type. Recalculating the figures we found that 65% of sewers were separated and 23% combined. Having found this issue we believe that it reasonable to assume that there may be similar issues with information provided from other countries. In 2018, Demark provided updated sewer type figures (i.e. 60% separated and 40% combined sewers) and total number of sewers (19,773 SOs (4,880 CSOs)) (Lone Munk Söderberg, *pers. com.)* which were significantly different to those reported by Moreira et al. (2016). Notwithstanding these limitations, the Moreira et al. (2016) report contains the best information available relative to CSO data and as such is useful reference for those examining CSOs in OSPAR countries.

The authors of the Moreira et al. (2016) report noted there was a 'diverse set' of data available with some counties demonstrating an advanced understanding of CSOs (e.g. Flanders (Belgium), Denmark, Ireland, Sweden and England (United Kingdom)) and others demonstrating a lack of awareness. The authors also noted that CSO information was rarely found as part of the desk study research and was generally gathered from interviews conducted with nominated CSO experts in each country. The authors indicated that (1) some information may be available that the researchers were not able to collate and highlighted (2) the risk of differences in interpretation regarding interview questions.

Counties	Separate sewers	Combined sewers	No. of overflow structures (where region name included in brackets the number is not a total and is a region only)	Reference
Iceland		70%	No. overflows not available.	Reykjavíkur, 2008
Norway	81%	19%	3,346	Statistics Norway, 2017
Switzerland				Not available.

Table 4 Percentage of types of sewage pipes in terms of length, risk of overflows and number of overflows in Iceland, Norway and Switzerland

1.5 Regional Actions

The OSPAR Convention for the protection of the environment of the Northeast Atlantic is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Union, cooperate to protect and conserve the marine environment. In 2014 the OSPAR Commission agreed to implement a Marine Litter Regional Action Plan (RAP). This plan seeks to address the sources, pathways and impacts of marine litter including microparticles on the marine environment in the North East Atlantic. The OSPAR Marine Litter Action 42 calls for the '*Investigation and promotion with appropriate industries the use of BAT and BEP to develop sustainable and cost-effective solutions to reduce and prevent sewage and stormwater related waste entering the marine environment, including microparticles*' and is being co-led by Ireland, Norway and Sweden. Ireland, Norway and Sweden are currently working on the development of an OSPAR background document to support Action 42.

1.5.1 Background within the OSPAR

In 2016 and 2017 a partial background document was developed (OSPAR, 2017) which collected information on best available technologies (BAT) and best environmental practice (BEP) for the collection and treatment of urban waste water and how this addressed the problem of litter including microparticles entering the marine environment (including through riverine inputs). However, this document did not contain any substantial information on how combined collection and treatment systems handle stormwater related litter and prevent it entering the marine environment.

This study document aims to address that knowledge deficit by reviewing BAT and BEP in urban wastewater treatment systems in accordance with the Urban Waste Water Treatment Directive (91/271/EEC, OJEC, 1991) and other relevant standards, with a focus on reduction and prevention of stormwater related litter (including microparticles) entering the marine environment. The review also addresses other relevant standards arising from including the Water Framework Directive, Natura 2000 Directives, Marine Strategy Framework Directive and Bathing Water Directive.

The OSPAR Convention defines BAT as 'the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste' and BEP as 'the application of the most appropriate combination of environmental control measures and strategies'.

1.5.2 Focus of this background document

This background document aims to provide information on existing storm water handling practices in the OSPAR region, specifically, how CSOs performance standards, and best available processes, technologies and systems can be employed to minimise stormwater related litter, and particularly microplastics, entering the marine environment. Marine litter is a complex issue with a wide range of land- and sea-based sources and pathways contributing to marine litter impacts (Veiga et al., 2016). This document focuses on a land based source, specifically marine litter, and microplastics which has entered the marine environment through CSOs. Figure 3 below shows the source – pathway – impact which is considered in this document.

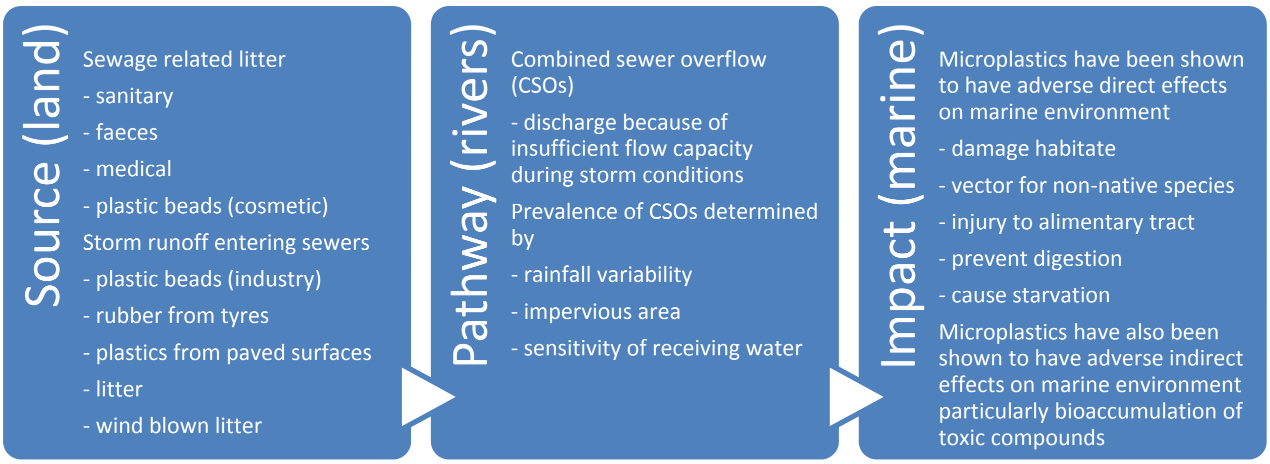


Figure 3 Source, Pathway and impacts of land based marine litter entering the marine environment via CSOs

The specific objectives of this background document are as follows:

1. Review the environmental performance standards within the OSPAR area for the handling of stormwater in combined urban wastewater systems.
2. Review existing processes, techniques, technology and systems for the removal of stormwater related waste from combined urban wastewater systems.
3. Review of the effectiveness of the performance standards and the existing systems in preventing litter including microparticles entering the marine environment, including through riverine inputs.

2 Review of Performance Standards

This section comprises a review of the environmental performance standards within the OSPAR area for the handling of stormwater in combined urban wastewater systems and marine litter reduction.

2.1 Legislative Context

A review of EU legislation was undertaken to determine environmental performance standards within the OSPAR area, for the handling of stormwater in combined urban wastewater systems. All Contracting Parties are EU members with the exception of Norway, Switzerland and Iceland, which, while not EU members Norway, Switzerland and Iceland have agreed to fully implement EU environmental legislation in accordance with the European Economic Area (EEA) agreement.

2.1.1 Legislation specific to the control of Intermittent Discharges including SWOs

There is no legislation at EU level which specifically regulates CSOs, their impacts on the environment and on human health. Directive 91/271/EEC, the Urban Waste Water Directive (UWWTD) (OJEC, 1991)) is the only piece of EU legislation that refers expressly to the control of intermittent discharges including storm water overflows.

The UWWTD requires collection and secondary treatment for all discharges from agglomerations with greater than 10,000 population equivalent (PE), and for discharges to fresh waters and estuaries for agglomerations greater than 2000 PE. Wastewater entering collection systems shall be provided with appropriate treatment for discharges to fresh waters and estuaries for agglomerations less than 2000 PE and for discharges to coastal waters for agglomerations less than 10,000 PE. Tertiary treatment must be provided for discharges to sensitive receiving waters for agglomerations with greater than 10,000 PE. The directive also requires pre-authorisation of all urban wastewater discharges, and monitoring and reporting of the performance of the treatment plant and of the receiving water quality.

Storm water overflows are referenced in the UWWTD as follows:

- Annex I.A (3) asks to “limit the pollution of receiving waters due to storm water overflows”.
- Footnote 1 of Annex 1 recognises “that it is not possible in practice to construct collecting systems and treatment plants in a way such that all waste water can be treated during situations such as unusually heavy rainfall" and asks Member States to "decide on measures to limit pollution from storm water overflows. Such measures could be based on dilution rates or capacity in relation to dry weather flow, or could specify a certain acceptable number of overflows”.

The directive allows Member States to adopt specific national rules regarding the treatment of water during heavy rainfall recognising that it is not practicable to prevent all storm water overflows. It should be noted that the UWWTD is currently being updated and it is not yet known if further guidance/standards around SWOs will be included in the updated version (EC, 2018a).

2.1.2 Legislation specific to protecting receiving waters

In addition to the UWWTD, there are several other European environmental directives and regulations which address these issues both directly and indirectly. The Water Framework Directive 2000/60/EC (OJEC, 2000a) is the key policy driver in the water sector and is aimed at protecting receiving waters. The WFD has resulted in the enactment of new measures and strengthening of existing legislation with the aim of achieving at least good ecological status in all waters of Member States. Additional legislation aimed at protecting waterbodies include the Habitats Directive (OJEC, 1992), Groundwater Directive (OJEC, 2006a), Floods Directive (OJEC, 2007), Marine Strategy Framework Directive (OJEC, 2008a), Birds Directive (OJEC, 2009a) and the Bathing Water Directive (OJEC, 2006b).

While these directives do not specifically reference storm overflows they do contain quality objectives for waterbodies to achieve or maintain a quality status or establishing standards for the concentration of certain pollutants. Meeting these targets will in most cases require storm water overflows to be managed and controlled.

The Marine Strategy Framework Directive (MSFD) is the most ambitious of the Directives listed above in terms of its objectives for the protection of marine biodiversity. It is the first EU legislative instrument related to the protection of marine biodiversity and aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. The Directive adopts the ecosystem approach to the management of human activities having an impact on the marine environment, integrating the concepts of environmental protection and sustainable use and establishes European marine regions and sub-regions on the basis of geographical and environmental criteria. The Directive lists four European marine regions – the Baltic Sea, the North-east Atlantic Ocean, the Mediterranean Sea and the Black Sea – located within the geographical boundaries of the existing Regional Sea Conventions. Member States are required to develop a marine strategy which must be kept up-to-date and reviewed every 6 years for marine waters in order to achieve GES by 2020. Each Marine Strategy much include:

- The initial assessment of the current environmental status of national marine waters and the environmental impact and socio-economic analysis of human activities in these waters.
- The determination of what GES means for specific national marine waters.
- The establishment of environmental targets and associated indicators to achieve GES by 2020.
- The establishment of a monitoring programme for the ongoing assessment of performance against targets and the regular update of targets.
- The development of a programme of measures designed to achieve or maintain GES by 2020.

2.1.3 Legislation/policy specific to marine litter

There are a wide range of EU policies and legislation which relate to marine litter, addressing both its sources and impacts. This includes EU environmental legislation relating to waste management (Waste Framework Directive (OJEC, 2008b), Landfill Directive (OJEC, 1999), The Packaging and Packaging Waste Directive (OJEC, 1994)) urban wastewater (UWWTD (OJEC, 1999)) or pollution from ships (Ship-source Pollution Directive (OJEC, 2009b) and Port Reception Facilities Directive (OJEC, 2000)[1]. Waste management legislation should be seen in the broader context of enhanced resource efficiency, now a key cross-cutting policy goal. The EU's resource efficiency policy, which is best demonstrated in the Europe 2020 flagship initiative "A Resource Efficient Europe" (EC, 2012) should have a beneficial upstream impact by influencing the use and design of plastic products and particularly of packaging. In terms of legislation dealing with the impacts of marine litter on the coastal and marine environment, the EU Integrated Maritime Policy (IMP) and the Marine Strategy Framework Directive as its environmental pillar address the development of sea-related activities in a sustainable manner.

[1] This directive is currently being revised.

On 1 September 2010, the European Commission adopted Decision (2010/477/EU) outlining the criteria to be used by Member States in the context of the MSFD to assess the environmental status of their seas (OJEC, 2010). The two criteria and four indicators relating to marine litter are:

10.1 Characteristics of litter in the marine and coastal environment

- Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)
- Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)
- Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)

10.2 Impacts of litter on marine life

- Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1).

Recently the European Economic and Social Committee and the Committee of the Regions have put forward a European Strategy for Plastics in a Circular Economy. The appended Annex 1 provides a list of future EU measures. Among these is an ongoing evaluation of the Urban Waste Water Treatment Directive, specifically, assessing effectiveness as regards microplastics capture and removal (EC, 2018a).

2.2 Performance Standards

There is no definition of storm water overflows in EU law. Although the term is used twice in the UWWTD, no definition is provided. It is noted that there exist no performance indicators for microplastics in terms of emissions (UWWTD) and water quality (WFD, etc.) directives. In order to address the knowledge gap which existed regarding the implementation of storm overflow regulation at a national level the European Commission engaged Milieu Ltd. (Belgium) to carry out an assessment of the impact of storm water overflows from combined waste water collection systems on water bodies (including the marine environment) in the 28 EU Member States (Moreira et al., 2016). This report provides the most comprehensive review of EU and national legislation concerning storm water overflows currently available.

National experts from each member state were required to complete fact sheets which gathered basic information, legal and policy framework information and available data relevant to storm water overflows. The study found that “National standards on storm water overflows range from non-existent to comprehensive and are found in both legislation and national guidance documents”. In general member states national guidance and standards refer to the number of overflows and dilution rates. The report found that only 19 of the 28 member states examined have developed national standards on storm water overflows. It was noted that several EU Member States, including Croatia and Luxembourg, have adopted, at least in practice, standards based on German documents, while other Member States are of the opinion that storm water standards are sufficiently addressed in other standards including water quality measures. While almost every member state has transposed Section A of Annex I to the UWWTD into national legislation, in reality for the majority of members (23 out of 34 cases), transposition remains only a literal translation, with the collection system requirements directly translated without specifying for example how stormwater overflows will be controlled.

The assessment undertaken by Moreira et al. (2016) found that while the majority of Member States (27 out of 34) have at least some guidance document concerning water management at national level only 14 have documents which specifically made reference to the management of CSOs. These 14 countries include the following 9 OSPAR countries: Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, Spain and United Kingdom. While France provided documents but these contained no specific reference to management of CSOs. The detail provided by each of the 9 countries varies considerably making comparison difficult. The following specific references were found in these factsheets:

- Sewer separation *(Belgium, Denmark)*
- Remediation of CSOs *(Belgium)*
- Guidance of level of treatment for CSOs at WWTPs *(Denmark)*
- Capture of "first flush" of stormwater runoff containing the majority of sediments *(Denmark)*
- Settlement tank construction expensive and challenging in densely populated areas *(Denmark)*
- Information provided relating to number of storm water basins and percentage of combined and separate sewers *(Germany)*
- Spill frequency and volume guidance *(Ireland, Luxembourg, Spain, United Kingdom)*
- Screening to prevent the escape of visible debris *(Ireland)*
- Frequency of operation or number of overflow events in a specified period is the preferred trigger for corrective action *(Ireland)*
- Replacement of CSOs with settlement tanks/basins *(Luxembourg)*
- Guidance to limit the number of CSOs *(Netherlands)*

Interestingly, while there was significant variation in specific references to CSOs almost all of the 9 countries acknowledged that CSOs cause pollution of surface waters. The observed variation may point to the need for high level guidance relating to Storm Water Management across OSPAR countries.

3 Removal of stormwater related litter from CSOs

This section comprises a review of the existing processes, technology and systems for the removal of stormwater related litter from CSOs.

3.1 Stormwater related litter reduction strategies

CSOs pose a threat to water quality and human health as they act as a pathway for raw and partially treated sewerage and stormwater related litter to enter the environment. Removal of stormwater related litter and microplastics is a complex problem and there are variety of approaches and strategies which policy makers may adopt in order to achieve reductions in litter loss/leakage from urban areas to the marine environment. It should be noted however that there are many limitations including political, economic, social and environmental restrictions, placed on policy makers and environmental managers when forming and implementing policy that reduces "plastic leakages" (Axelsson and Sebille, 2017).

Policy makers and environmental managers aiming to achieve a reduction in stormwater related waste entering the marine environment can:

(1) attempt to prevent litter entering the sewer at
(2) source and avoid or minimise the presence and /or creation of microplastics in the sewer and/or
(3) remove litter at a point or points along the sewer (at the CSO) removing or restricting the pathway to the marine environment

Existing processes, technology and systems associated with both of these options are discussed in sections 3.3 and 3.4 below.

3.2 Composition and physical properties of stormwater related litter

Litter comprises a wide range of materials (and combinations of materials) not limited to plastic, rubber, paper, metal and textiles (MSFD, 2013). Litter occurs in a wide range of sizes with micro particles defined as litter items in size between 1µm and 5mm (Norén et al., 2016). In addition to litter size, density and shape affect how litter is transported downstream. Litter and micro particles with a density <1 kg/dm^3 can float in water while denser litter can be carried below the water surface. When considering the CSO treatment alternatives we must consider the composition and physical properties of stormwater related litter.

3.3 Source based stormwater related waste reduction

The public's attitude and behaviours play a significant role in the routes of entry for plastics into the sewer and ultimately the marine environment (Anderson et al., 2015). When proposing measures to decrease the entry of plastics into the environment we must consider social aspects as it is only with public understanding and acceptance that the full impact of any measure can be realised. Marine litter has been a concern for environmentalists for many decades. The discovery of the Great Pacific Garbage Patch in 1997, which in is the largest accumulation of marine litter in the world and is located between Hawaii and California, resulted in publicity which raised public awareness of the problem. The first scientific publication which focused solely on the microplastics was published by Science in May 2004 (Thompson et al., 2004) and this publication received media coverage with over 50 stories referencing the article in traditional media (Anderson et al., 2015). Anderson et al. (2015) conducted an analysis of UK newspapers between 2004 and 2014 and noted that there has been an increase in references to microplastics in recent years which was consistent with Google Trends data analysed.

In recent years there have a number of TV documentaries including Blue Planet II produced by the BBC Natural History Unit which have captured the imagination of the public and marine litter and microplastics are very much to the fore in terms of the public's environmental concerns. Social Media platforms including Twitter, YouTube and Facebook now allow people to learn about the issue and the level of support shown for initiatives such as the "Sky Ocean Rescue" indicate that there is significant support for measures to protect the marine environment form marine litter.

Before discussing technologies used to remove litter from CSOs we must first examine source based control initiatives and technologies as these can significantly reduce the amount of litter and micro litter entering the combined sewer network, thereby reducing the need for downstream removal. Upstream (at source) approaches have been shown to be the most cost effective means of reducing litter in CSOs, however, it is acknowledged that these measures alone will not remove all litter (Norén et al., 2016). In this sub-section we briefly explore methods to reduce the amount of litter and micro litter entering the sewer and methods to minimise the formation of additional secondary microplastics in the sewer.

3.3.1 Prevent litter entering the sewer at source

Flows from CSOs comprise contributions from domestic dwellings, industry and storm runoff, and consequently, there are a wide range of sources of litter. Measures to directly reduce litter entering the combined sewer include:

- Improving awareness of the general public to minimise the wrongful disposal of litter which cannot be treated at the WWTP;
- Improving waste management thereby decreasing the volume of litter being washed into the sewer with stormwater;
- Usage of catch basins in domestic and industrial applications to prevent litter entering combined sewer systems.

When implemented correctly these source control measures have the potential to significantly reduce the volume of litter entering combined sewer networks (Sherrington et al., 2016). It should be noted that none of these measures address specifically the issue of microplastics in wastewater.

3.3.2 Prevent microplastics entering the sewer at source

Increased awareness of microplastics in wastewater both from public and regulatory bodies (MSFD, 2013) has resulted in efforts to reduce the microplastics load entering the sewer. Recent efforts to remove microplastics from sewerage have focused on (1) developing filters which remove laundry fibres at source (washing machine effluent) and (2) removing microbeads from cosmetic and personal care products. Laundry fibres and personal care products account for 35% (Boucher and Friot, 2017) and 4.1% (Sherrington et al., 2016) of global release of primary microplastics to the world's oceans, respectively.

3.3.2.1 Laundry Fibres

Washing of synthetic textiles is a constant source of plastic microfiber emissions into the environment (Pirc et al., 2016; Boucher and Friot, 2017). A recent EU LIFE project has recommended that textile manufacturers have a major role to play in tackling the problem of microfiber release to the environment (Mermaids, 2017). The study concluded that the release of microplastics from clothes is controlled by fibre length, yarn twist, linear density, fabric density and textile resistance to abrasion (Mermaids, 2017). These are physical characteristics of synthetic textiles which could in future be engineered to minimise the release of microplastics. Mermaids (2017) report recommended setting of maximum microfiber emission thresholds for synthetic textiles.

Laundry fibres can also be controlled at the source (i.e. at the washing machine) using propriety innovations such as the Cora Ball and the GuppyfriendTM washing bag. The Cora Ball is a ball that is put in with laundry which captures microplastics in it for later removal, it has an efficiency of approximately 35% (Anis & Classon, 2017). The GuppyfriendTM is a bag made from specially designed micro filter material into which synthetic clothing is placed before a wash. The manufactures claim that 99% of fibres are retained in the bag for removal and disposal after the wash (GuppyfriendTM, 2018).

3.3.2.2 Cosmetic Products

Microbeads used in cosmetic and personal care products have been targeted for reduction or elimination by regulators worldwide. Many countries including the United States, Canada, and OSPAR countries France, Ireland, Sweden, and the UK have implemented bans on use, manufacture and sales of microproducts some details on which are summarised in Table 5. Several countries have banned the use of microbeads in cosmetics. This growing trend has caused large international cosmetic brands to announce that they will be phasing out the use of these microbeads in cosmetics on a voluntary basis (Abbing, 2017). While the exact impact of these bans on microbeads is hard to pinpoint it stands to reason that this source reduction measure will reduce the overall amount that will end up in receiving water bodies, and eventually the marine environment.

Country	Proposed/implemented ban of Micro beads rinse-off cosmetics – effective date	Ban on importation & manufacture – effective date	Sales ban – effective date	Note	Reference
Canada	18-May-15	1-Jan-18	1-Jul-18	Microbeads in natural health products and non-prescription drugs banned on July 1, 2018.	(Marchildon, 2018)
France	6-Mar-17	1-Jan-18	1-Jan-18		(France, 2017)
Ireland		Before the end of 2018	Before the end of 2018		(Flynn, 2018)
Italy		1-Jan-20	1-Jan-20	Ban on plastic, non-biodegradable and non-compostable ear cleaning sticks from 1 January 2019.	(Stringer, 2018)
New Zealand	16-Jan-17	1-Jul-18	1-Jul-18		(Abbing, 2017)
Sweden	1-Feb-18	1-Jul-18	1-Jan-19	Sales ban applicable only on products purchased before the ban came into effect.	(HKTDC Research, 2018)
Taiwan	1-Aug-17	1-Jan-18	1-Jul-18		(Zhang , 2018)
United Kingdom	9-Jan-18	19-Jun-18	19-Jun-18		(Barr, 2018)
United states		1-Jul-17	1-Jul-18	Plastic particles added to cosmetics and some drugs will also be phased out by 2019.	(Trager, 2016)

Table 5 Countries that have banned or are proposing to ban production, use and sale of microbeads

3.3.3 Minimise in-stream process potentially increasing generation of microplastics in sewerage

In addition to dealing with microplastics entering the sewer network, it is possible to create further microplastics within the sewer network when using disintegration equipment (macerators and similar) to break down litter and solids which could cause blockages in the network. In some instances disintegration equipment such as macerators and comminutors are installed to cut any solids or material passing through the sewer. Any plastic litter passing through these units will be converted into smaller particles some of which may be smaller than 5mm (i.e. microplastics). Macerators and comminutors are typically used at (1) the inlet to WWTPs where plant layout may making screening impractical and (2) small and isolated/difficult to access pumping stations (Tchobanoglous et al., 2003).

3.3.3.1 Use of Macerators and Comminutors at WWTPs

Use of macerators or comminutors at the inlet to WWTPs is relatively uncommon (Tchobanoglous et al., 2003) but where they are used their primary purpose is to protect the pumps in the WWTPs. When used at WWTPs macerators and comminutors are typically found downstream of primary screening and are designed to sheer cut any solids or material that flows into the WWTP before the start of the treatment process. Heavy debris removal traps are sometimes also provided at the inlet to WWTPs, as macerators are not designed to cut hard solids like rocks and metal (Peters, 2017). It should be noted that macerators and comminutors can also be installed with no screening. This can be advantageous to WWTP managers because while screens are an economical means of removing solids from a wastewater stream some waste may escape the screen causing pumps to become blocked. In addition screens require regular cleaning maintenance, thereby adding to the task schedule and therefore manpower requirement within every plant. By macerating these solids they can be diverted to the excess sludge management processes in the WWTP i.e. removing solids which would need to be disposed of. Typically disposal is by means of landfill, landspreading or incineration, however if landspreading is the chosen option the pathway potential exists for these microplastics to re-enter the environment. This lack of information regarding mobility of microplastics following land application is identified in section 3.4. In smaller remote installations macerators or comminutors may be installed to minimise the need for maintenance. While screens with effective automatic cleaning processes are available there is always the risk of causing blockages and localised flooding when using screens. This risk is increased at unmanned pumping stations and WWTP's.

3.3.3.2 Use of Macerators and Comminutors within the Sewer Network

Macerators and comminutors are more commonly used within the sewer network than at WWTPs. Within the sewer network their purpose is to protect the pumps in the network pumping stations which pump wastewater from local collection sumps to the main sewer. In unmanned pumping stations, solids and litter (i.e. rags) in the wastewater stream would lead to blockages and therefore downtime of the pumps thereby generating additional labour costs. For this reason the use of macerators and comminutors is quite common at such sites.

3.3.4 Potential role of gulley pots in capture of tyre and road surface microplastics

As shown in Table 1 of this report, microplastics originating from the wear and tear of tyres is a substantial source of microplastics entering the marine environment. This element of stormwater derived microplastics was outside of the scope of this background document, however we note it was addressed as part of the OSPAR RAP against marine litter Action 42.

3.4 Pathway based stormwater related waste reduction technologies

In OSPAR countries the vast majority of WWTPs provide secondary treatment which has been shown to achieve up to 90% removal efficiency of microplastics in sewerage (Verschoor et al., 2015). Additional filtration and use of membrane technologies can result increase removal efficiency up to 98% (Talvite et al., 2017). It follows that maximising the volume of wastewater treated at WWTPs (and minimising CSOs which can account for up to 15% of total flow (Morgan et al., 2017)) would significantly reduce the loss of microplastics to the environment. It must be noted that the majority of microplastics captured in WWTPs are retained in the sludge and there is a lack of information available regarding mobility of microplastics following land application (Mahon et al. (2017). There has been a decrease in the land spreading of sewerage sludge in recent years with less than 1 million tonnes of sewerage sludge land applied in the EU (27% of sludge produced) in 2015, compared to over 4 million tonnes in 2010 (47% of sludge produced) (Eurostat, 2018a). While, the trend is towards reduced sludge application there is a lack of knowledge regarding the fate of microplastic contained in legacy and ongoing sewerage sludge applications (Mahon et al. (2017).

There are two options available to designers asked to remove the need for CSOs in sewer networks, which are (1) sewer separation and (2) low impact development (LID) also known as Sustainable Drainage Systems (SuDS).

3.4.1 Separation of Sewerage and Stormwater

The majority of OSPAR countries have a significant proportion of sewerage network which is combined with the stormwater collection network (as detailed in Section 1 of this report). Separation of these systems so as to have a network dedicated only to sewerage and a second dedicated only to stormwater would be of benefit in reducing the volume of stormwater runoff entering the sewer network and decrease the incidence of discharges from CSOs. However, it is not always practical to replace existing combined sewers with separate sewers and stormwater systems, primarily on economic grounds. In addition, it is important to remember that EOs still occur where such separated systems exist and therefore separating sewers will not completely reduce the risk of litter being transported through drainage infrastructure to the marine environment. For this reason it is clear that sewer separation alone will not address the issue of CSO discharges acting as pathway for litter to enter the marine environment. It has been highlighted that unless stormwater treatment is provided when separating foul and storm sewers there may be an increased risk to the environment as in most cases existing combined sewer networks provide for treatment of a certain amount stormwater removing heavy metals and suspended solids (Bromback et al., 2005). The authors note that as new systems are typically separate, the percentage of separate systems will increase with time as new systems are built, thus reducing the percentage of sewers which are combined. This change to separate sewers will bring challenges for wastewater managers and policy makers with dedicated stormwater treatment facilities to remove hydrocarbons, suspended solids and litter from stormwater required to ensure that installation of separated systems does not have an adverse impact on the environment.

3.4.2 SuDS

If CSO improvement is considered in the context of the whole sewer system, the range of improvement options increases and in addition to measures such as source control, and the separation of storm and sewage flows, discussed above, the encouragement of Sustainable Drainage Systems (SuDS) also known as Low Impact Development (LID) measures to reduce the volume of stormwater entering the sewer system (CIRIA, 2015) must also be examined.

SuDS comprise urban drainage systems which are designed to mimic natural hydrology, minimising runoff and encouraging attenuation and storage of stormwater so that it can be discharged gradually to the environment. In addition clean runoff water is collected, stored and allowed to drain from underground storage tanks to groundwater, recharging groundwater. Some examples of SuDS include:

- rainwater harvesting
- permeable pavements
- filter drains
- infiltration trenches/ soakways
- bio-retention
- trees
- swales
- detention basins/ retention ponds
- stormwater wetlands

These measures act to reduce the volume of stormwater generated during and immediately after a storm event, thereby reducing the peak volumetric load at the WWTP, enabling stormwater to be treated in WWTPs in combined sewer systems that might otherwise be discharged untreated through the CSOs. Reducing the volume of storm runoff reduces both the frequency and volume of spills at CSOs in combined sewers.

3.4.3 CSO Treatment

In this section available technologies which can used to remove litter and micro particles (mostly comprising microplastics) from CSO discharges are reviewed. Treating CSO discharges is challenging because their design purpose as safety valves within the sewer system CSOs mean they typically operate infrequently, on a responsive rather than a planned basis and only for a short period of time. This difficulty is further compounded by the fact that CSOs are frequently located in roadways and areas with space, access and power supply restrictions.

Morgan et al., (2018) found that the design of CSOs throughout the EU is very inconsistent (Austria, UK, Germany and Spain examined as part of a review of technologies for monitoring CSOs). Scherrenberg's (2006) review of available technologies for treatment of CSOs in Denmark concluded that effective CSO treatment technologies must be capable of:

- surviving long periods without influent
- handling wide variations in flow rate and loading rate due to the first flush effect
- starting up within a couple of minutes
- capable of advanced removal of suspended sediment
- operating with minimal chemical dosage
- being placed within a small footprint
- operating effectively with low maintenance costs

The treatment technologies available for providing primary and secondary treatment and disinfection at CSOs are discussed below in addition to an option for treatment downstream of CSOs.

3.4.3.1 CSO Treatment Technologies – Preliminary Treatment

3.4.3.1.1 Baffles

Baffles are used extensively to remove solid waste and floatables from CSO discharges. They are inexpensive, simple to install and have little maintenance requirements. In theory baffles retain floatables during high flows, and then release the floatables to the treatment plant when flow returns to normal (US EPA, 1999a). Studies have shown that baffles can retain between 10 and 90% of litter depending on design and flow regime (Newman II., 2001). Newman II, (2001) noted that once horizontal velocities exceed 0.35m/s removal efficiencies reduce to 10%. It is reasonable to assume that microplastics with a density less than 1 kg/dm^3 would be retained by the baffle provided that the velocity in the sewer is sufficiently low.

3.4.3.1.2 Screening

Screening is an economical way to remove solid waste and floatables from CSO discharges and are the most commonly used treatment for CSOs. Generally placed as the first unit in a CSO they remove solids and floatables by two principal mechanisms (1) direct straining of partials larger than the bar spacing and (2) filtering of smaller particles by straining flow through the mat of solids already deposited on the screen (US EPA, 1999b). A schematic of a vertical screen is shown in Figure 5 below. Water flows through the screen and litter is trapped on the bars. There are a wide variety of screens and screening devices in all manner of configurations, aperture sizes and applications available to designers. Screens are generally classified as vertical bar screens or horizontal bar screens and screens, can be coarse or fine and can be cleaned manually or mechanically.

Provided that screens are maintained (i.e. blockages removed and screen kept clean) screens have been shown to be very effective at solids removal with up to 98.5% removal for 6mm screen (US EPA, 1999b). It should be noted however that screens have limitations and the smaller the aperture size the more frequent the cleaning and the greater the likelihood of blockages resulting at CSOs or localised flooding which is undesirable.

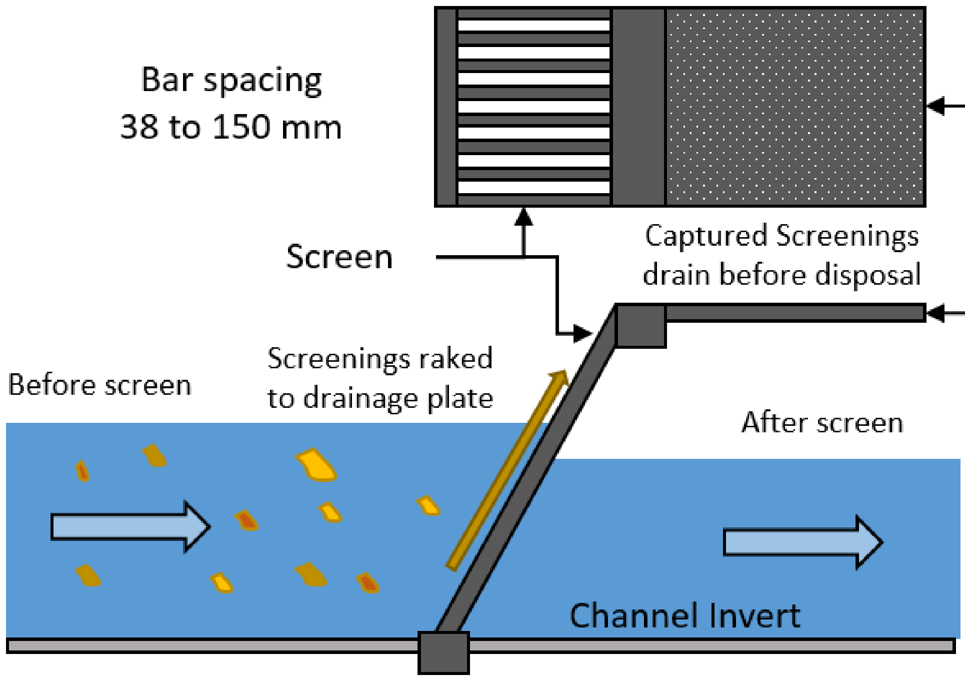


Figure 5 Vertical bar screen

In a review of WWTP technologies used to remove litter from WWTP influent and stormwater Norén et al. (2016) reported that there were few studies which published microplastics removal performance. Norén et al., (2016) proposed that suspended solids be used as a proxy for microplastics as they largely behave in a similar manner. Fine screens are capable of removing 25 to 45% of total suspended solids (Tchobanoglous et al., 2003). However, installation of such fine screens at CSOs is not likely to be practical due to the risk of blockages occurring.

Table 6 contains a schedule of aperture size and efficiency rates for a range of screen types for comparison purposes.

Screen	Openings	Efficiency	Note
Trash Rack	40 to 80 mm	25-90 % of the total solids[1]	Remove only very large objects from the flow stream
Manually Cleaned Bar Screen	25 to 50 mm	30 to 35 %[1,2]	The bars are set 30 to 45 degrees from the vertical and the screenings are manually raked onto a perforated plate for drainage prior to disposal.
Mechanically Cleaned Bar Screen	6 to 25 mm		
Horizontal BAR Screens	4mm	98.5% of floatables[1]	The ROMAG™ screen partitions the flow, sending screened flow to the CSO discharge point, while keeping solids and floatables in the flow directed towards the sanitary sewer.
Band screen (stepped screens)	3 to 6 mm	30 % with 6mm; 50 to 56% with 3 mm[2]	
Continuous Belt Screens with Plastic Elements	6 mm	71%[2]	Replacement of the plastic elements – expensive and time consuming

Table 6 Types of screens by typical aperture size and efficiency ranges

[1]US EPA, 1994; [2]Brodwell (2017)

3.4.3.2 CSO Treatment Technologies – Secondary Treatment

3.4.3.2.1 Storage in settlement tanks/basins

When the capacity of the sewer is exceeded stormwater flows via the CSO to a storage tank, and, once the capacity of the storage tank is reached the CSO spills. Storage tanks provide sedimentation for (1) flow that will be treated later and (2) overflows from the storage tank in the event that the storage capacity is exceeded before the end of the storm event.

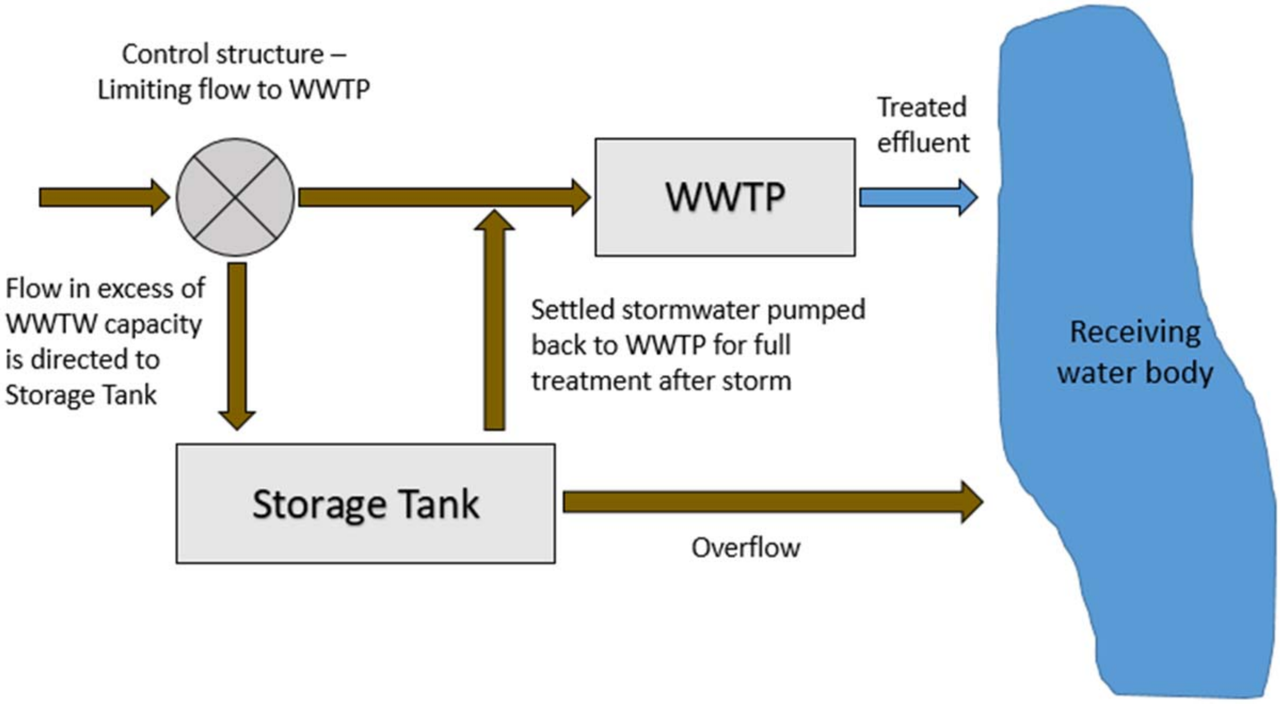


Figure 6: CSO discharge to settlement tank

In Ireland stormwater storage tank design is based on the SDD Method (DoEHLG, 1995) which was first used in the UK. Using this method, the volume of storage required is determined based on the dilution factor available at the receiving water body with stormwater holding tank volume determined based on an estimate of the minimum overflow setting (Formula A which is approximately 6 DWF) less flow to full treatment with a two hour storm duration. Once the storm event has subsided and the downstream WWTP has capacity, stormwater held in the storage tanks is pumped to the WWTP for full treatment (see Figure 5).

Traditionally WWTPs are designed to accept a hydraulic load of up to 6 times the dry weather flow (DWF). The DWF refers to the “baseline” wastewater flow in a sewer system during periods of dry weather with minimum infiltration of groundwater to the system. Where flows in excess of 6 DWF reach the WWTP, they are spilled to the receiving waters using CSOs at the WWTP. Similar to WWTP CSOs, network CSOs spill when the flow in the network exceeds the network’s hydraulic capacity.

In general the national guidance and standards around CSO performance of the EU member states refer to the number of overflow events which occur annually and dilution rates (Moreira et al., 2016). The critical dilution rate is the dilution rate between storm water flow (i.e. CSO spill flow) and receiving water dry weather flow (i.e. low flow in receiving water body, the critical flow being that which is equaled or exceeded at least 95% of the time). Stormwater storage may be required both at WWTP and within the combined sewer network to meet spill frequency and dilution limits set by each country.

There are no allowable dilution rates set by the EU and as a result member states have implemented their own dilution rates ranging from 1:4 to 1:12 (Moreira et al., 2016). Some countries apply a single value dilution rate while others provide a range of dilution rates which are used on a case by case basis depending on the location of the CSO (Moreira et al., 2016).

CSO storage tanks significantly reduce the spillage frequency from CSOs during a storm event and have been shown to reduce suspended solid loads between 45% and 60% (Llopart-Mascaro et al., 2015). As suspended solids can be used as a proxy for microplastics it follows that CSO storage tanks can effectively reduce the microplastics load to the environment.

3.4.3.2.2 Vortex separation

Hydrodynamic separators are an alternative to settlement tanks. Hydrodynamic separators are structures which use the characteristics of vortices to remove mainly solids, grit, floatables, oil and grease from waste streams. These structures channel flow through them, directing flow to cause a vortex (US EPA, 1999c). This vortex causes the contaminants to move to the outer side of the structure where they remain until they are removed, allowing “treated” flow to “escape”.

Standard prefabricated units have a relatively small footprint and can be placed inside traditional manholes. In larger applications units are specifically designed and go up to a radius of 12 m (US EPA, 1999c). Due to the lack of moving parts minimal maintenance is required. It is however recommended that regular inspections are conducted (once a month) in the first year of installation to allow the determination of the rate of accumulation of floatables and solids for future cleaning. There are a wide range of options available with suppliers reporting total solid removal efficiencies of between 50 and 90% (US EPA, 1999c). While microplastics removal rates are unavailable removal rates for microplastics can be reasonable assumed to fall within this range. However further research would be required to determine microplastic removal rates with this technology.

3.4.3.2.3 Constructed Wetlands (Soil Filters)

Vertical flow constructed wetlands (VFCWs), called retention soil filters (RSFs) in Germany, have been proposed as an economical and ecologically feasible way to treat effluent from CSOs (Meyer et al, 2013). Particulates and solutes are retained and reduced by filtration, adsorption and biochemical degradation (Brunsch, 2015). Studies conducted on several of these RSFs have shown that besides reducing solids by filtration, RSFs have good chemical and biological cleaning capacities for a variety of parameters (Knorz et al., 2018). In a field test concluded by the Coalition Clean Baltic (2017) it was shown that constructed wetlands of varying shapes, age, flow rates and sizes can be very effective (82 to 89%) at removing suspended solids and from a stormwater waste stream. In the same test microplastic analysis showed that microplastics removal efficiency was between 90 and 100%.

3.4.3.2.4 Micro Strainers (Drum filter/Disc filter)

Micro screens (micro strainers/filters) involve the use of slowing revolving drums which are continuously being backwashed under gravity-flow conditions. Water flows into a drum that either has vertically mounted discs with filter media on each side or the drum itself is covered with filter media. As particles build up on the filter media flow is impeded, causing a rise in water level until a certain point when a backwash process is initiated, during which the screens are sprayed with nozzles, thereby rinsing off the solids onto a catchment trough (Ljunggren, 2006). This is a continuous screening process that is not stopped during backwashing.

The design of micro screens are influenced by factors including clogging rate, rotational speed of the drum or disk, area of submergence, backwash efficiency, applied head and the water characteristics. These screens operate with a relatively low head loss when compared to other filtration processes (Ljunggren, 2006). Talvite et al. (2017) examined micro-screen filtration with discfilters (DF) at a WWTP located in Helsinki. Microplastic removal efficiencies of 98.5 and 40% were observed for discfilter with pore size 10 µm and 20 µm, respectively.

3.4.3.2.5 Membrane Filtration

Micro filtration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) are classified as pressure-driven membrane filtration systems. In membrane filtration a physical separation process that uses a semipermeable membrane is used to remove suspended solids from the feed water (SAMCO, 2017). Talvite et al. (2017) examined a membrane bioreactor at a WWTP, located in city of Mikkeli, South-East of Finland and found that microplastics (>20 µm) removal efficiency of 99.9% was achieved.

3.4.3.3 CSO Treatment Technologies – Disinfection

CSOs can be disinfected by adding a disinfectant at the outlet pipe or before a storage tank. The amount of disinfectant required will depend on the strength of CSO and the available residence time in the system. The most common options are disinfection using chlorine compounds, ozone, and UV. There are significant differences between disinfection of CSO and wastewater. CSO events occur a few times per year maximum while wastewater discharges continuously. In addition, CSO composition can change rapidly during a CSO event, necessitating a disinfectant that is robust enough for water quality changes and facilities to allow for rapid change of disinfectant dose (Tchobanoglous et al., 2003).

It should be noted however that disinfection will not impact on the microplastics load discharged from the CSO, and could adversely impact the environment in that there is potential that some microplastics could adsorb disinfectants and disinfection byproducts before being discharged. Also, microplastics, like other suspended solids, can shield pathogens thereby increasing the disinfection requirement of a wastewater.

3.4.3.4 CSO Treatment Technologies – Downstream of CSO

3.4.3.4.1 Netting

Netting systems can be installed as in line units or as floating units. At CSOs floating units, flow is funneled through a series of nets. As water flows through the system floatables, trash, litter and debris are contained within the nets. The design of the nets depends on the type and volumes of floatables to be captured and are typically replaced after each storm event (US EPA, 1999d). These nets need to be placed quite far downstream from the outflow, allowing floatables entrained in the turbulent CSO flow to rise to the flow surface and be captured. Netting systems are available with reusable nets that are able to capture gross pollutants as small as 5 mm (StormX, 2015). It must be noted that the smallest floatable and non-floatable debris captured is reported as 5mm (StormX, 2015; Wodalski, 2010), indicating that microplastics would not be contained within these systems during normal operations. It is however possible that some microplastics and suspended solids might be retained after the nets have been completely or partially filled due to direct straining.

3.5 Review of available technologies

The key performance removal efficiency of the CSO treatment technologies discussed above are tabulated in Table 7 below for ease of reference. Issues relating to costs associated with each of these technologies are dealt with in Section 4.

Treatment Technology	Action	Floatables and Solids (> 5 mm)	Floatables and Solids (< 5 mm)	Micro Plastics
Baffles	Storage and release to WWTP when storm subsides	10 to 90% of litter	Not reported.	Effectiveness depends on particle density and velocities in sewer. Microplastics retained directed to WWTP (shown to achieve up to 98% removal)
Screening				
Trash Rack (Screen)	Screening - 38 to 150 mm	25-90% TS	25-90 % TS	Estimated 5-30% removal microplastics mainly due to entrapment.
Manually Cleaned Bar Screen	Screening - 30 to 50 mm	30 to 35% TS	30 to 35% TS	
Mechanically Cleaned Bar Screen	Screening - 6 to 38 mm			
Band screen (stepped screens)	Screening - 3 to 6 mm	30% TS; 6mm, 50 to 56% TS; 3mm	30% TS;6mm, 50 to 56%TS;3mm	
Secondary				
Storage Tank	Storage, settlement and release to WWTP when storm subsides		45% and 60% TS	All CSO undergoes sedimentation likely to deduce microplastics by up to 60%. Microplastics retained directed to WWTP (shown to achieve up to 98% removal)
Vortex separation	Separation (pre-screened)		50 to 80% TS	Estimated 50-80% removal microplastics based on TS removal efficiency.
Constructed Wetlands (soil filters)	Settlement and filtration (pre-screened)		82 to 89% TS	Microplastic removal efficiency between 90 and 100%.
Micro Strainers	Filtration - 10 to 30µm (pre-screened)		10 to 80% SS	Microplastic removal efficiency of between 40 and 98.5% for 20 µm and 10 µm, respectively.
Membrane Filtration	Filtration - 0.1 to 10µm (pre-screened)			Microplastics (>20 µm) removal efficiency of 99.9%.
Downstream CSO				
Netting Systems	Screening	Yes		

Table 7 Key Performance removal efficiency of the CSO treatment technologies

Note on Table 7: TS: total solids; SS: suspended solids;

4 Review of the effectiveness of performance standards and existing processes and technologies

4.1 Overview

This section comprises a review of the effectiveness of the performance standards and the existing processes and technologies in preventing litter including micro particles entering the marine environment. Current performance standards and existing processes and technologies are discussed in the context of Best Available Technologies (BAT) and Best Environmental Practices (BEP). The OSPAR Convention defines BAT as 'the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste' and BEP as 'the application of the most appropriate combination of environmental control measures and strategies'.

4.2 Review: Effectiveness of performance standards

4.2.1 Legislation regulating CSOs

The review of environmental performance standards within the OSPAR area found that legislation regulating CSO management was divided into three groups: (1) legislation specific to the control of Intermittent Discharges including SWOs (UWWTP); (2) legislation specific to protecting receiving waters and (3) legislation/policy specific to marine litter. The effectiveness of performance standards has been assessed under there three headings below.

4.2.1.1 Legislation specific to CSOs

The UWWTD (OJEC, 1991) is the only piece of EU legislation that refers expressly to control of intermittent discharges including storm water overflows. It is difficult to access the effectiveness of the UWWTD at preventing pollution from CSOs due to the limited data available (Moreira et al., 2016). The recent review carried out by Moreira et al. (2016) provides the best overview of trends and good practices relating to CSO management. The authors reported a lack of data and in an effort to gain an understanding of how effectively the UWWTP was being implemented developed the following indicators:

- Transposition of Annex I.A(3) to the UWWTD
- Transposition of footnote 1 of Annex I to the UWWTD
- Availability of Member State guidance documents concerning storm water overflows
- Availability of technical standards on storm water overflows

These indicators were assessed using a methodology detailed in the Moreira et al. (2016) report and an overall score on the availability of technical standards on storm water overflows was determined qualitatively. Note that the scores have a slightly different meaning for each indicator. Based on this assessment from Table 8 overleaf we can see that the majority of countries examined have incorporated the UWWTP Directive into national guidance and standards. Seven of the twelve OSPAR countries surveyed by Moreira et al. (2016) provided information regarding allowable spill frequency and dilution rates. The lack of information from the other countries is significant in that means that it is not currently possible to know exactly how the UWWTP Directive is being applied with respect to CSOs throughout the EU and within the OSPAR region.

The findings of the Moreira et al. (2016) report demonstrate that while many countries within OSPAR have made significant efforts to address CSOs as set out in UWWTD, it is not possible to quantitatively determine the effectiveness of performance standards in preventing litter including micro particles entering the marine environment without undertaking further studies. The lack of information relating to spill frequency and spill duration is of particular concern and points to a need for monitoring and reporting of the performance of CSOs.

Counties	Transposition of Annex I.A(3), UWWTD	Transposition of the Annex I Footnote, UWWTD	National Guidance	National Standards	Spill Frequency Standards	Dilution Rate
Belgium	Varies between regions				Standards set (max. no. CSO spills and duration spill)	Dilution rate depending receiving on the environment
Denmark*	-	-	++	++	Standards based on define dilution zones	Dilution zones set depending on received environment
Finland	+	-	+	+	NA	NA
France	++	++	+	+	Mandatory Monitoring	NA
Germany	Varies between regions				NA	NA
Iceland	Not included in Moreira et al., 2016 study.					
Ireland	+	-	++	++	NA	NA
Luxembourg	+	+	+	+	NA	NA
Netherlands	+	-	+	++	NA	Dilution zones set depending on received environment
Norway	Not included in Moreira et al., 2016 study.					
Portugal	+	++	++	++	NA	NA
Spain	++	+	++	++	NA	A coefficient of dilution 5-8
Sweden	++	-	++	+	NA	NA
Switzerland	Not included in Moreira et al., 2016 study.					
United Kingdom	Varies between regions				Standards depend on location (max. no. CSOs and duration)	Dilution rate depending received environment

Table 8 Legal and Policy Indicators with description of spill value and dilution rate implementation (Moreira et al., 2016)

Note: The above indicators were assessed using a methodology detailed in the Moreira et al. (2016) report and an overall score on the availability of technical standards on storm water overflows was determined qualitatively; When interpreting Table 8 the reader should note that “-“ denotes no evidence of implementation/availability of information, “+”denotes evidence of some level of implementation/availability of information and “++”denotes evidence of implementation/availability of information; NA denotes cases where no information was provided in the factsheets completed as part of the Moreira et al. (2016) report. *Denmark confirmed that minuses quoted in the above Table are most likely due to missing information and that there are measures to reduce the spill from CSOs (30% of CSOs have basins) and reporting and control take place.

4.2.1.2 Legislation specific to protecting receiving waters

In addition to the UWWTD which controls intermittent discharges directly there is a long list of additional legislation aimed at protecting waterbodies (including WFD, Marine Strategy Framework Directive, etc.) that contain quality objectives to be achieved or maintained for waterbodies. In the context of this background document the overall effectiveness of these performance standards which indirectly regulate CSOs is perhaps best accessed by examining water quality in the EU. In the most recent EEA report it was reported that bathing waters in Europe are of high quality, with 95 % of sites tested meeting minimum water quality standards set out in EU legislation (EEA, 2017). The number of sites rated 'poor' overall in 2016 across the EU, Albania and Switzerland was 1.4% in 2017. Water contamination by faecal bacteria during heavy rains and floods due to sewage overflow, together with runoff from agriculture, were identified as sources of pollution. Thus, at European level CSOs are having a significant impact on water quality. While Bathing Water Directive guidelines are based on faecal coliforms it follows that if CSOs, which give rise to elevated faecal coliforms, may also result in the release of litter and microplastic unless adequate treatment is in place.

The UWWTD does not currently contain thresholds for microplastics and therefore it is noted a need exists to revise the UWWTD to include microplastic thresholds as the effectiveness of existing WWTPs and CSO treatment systems, as they pertain to microplastics, cannot be quantitatively assessed based on existing performance standards.

4.2.1.3 Legislation specific to marine litter

The European Economic and Social Committee and the Committee of the Regions have put forward a European Strategy for Plastics in a Circular Economy. This document provides the state of art regarding marine litter and micro particles in the EU. The document puts forward a proposal which aims to further advance efforts to reduce litter which are already underway in EU Member States as part of the Plastics Strategy (EC, 2018a). This proposal states that there is a need for a review of the UWWTD, specifically, assessing the effectiveness as regards microplastics capture and removal (EC, 2018b). The authors note that while the UWWTD allows for significant removal of pollutants, there is insufficient provision for CSOs capture and treatment. In addition, the authors note that current technologies are not effective at removing single use items commonly disposed of to the sewer network including plastic cotton bud sticks and sanitary products. The proposal seeks to implement upstream measures including raising consumer awareness, increasing producer responsibility and changing labelling requirements for certain single-use plastic products.

4.3 Review: Effectiveness of systems and technologies

4.3.1 Source based stormwater related waste reduction

It is more efficient to capture contaminants at source, i.e. before they enter the sewerage system, rather than to remove them from more dilute water/wastewater streams. Furthermore, it is noted that measures which prevent contaminates entering the environment at source are consistent with the polluter pays principle (Directive 2004/35/EC). In section 3 of this background document two alternative measures aimed at reducing microplastic fibre loads entering sewers were identified. Those measures were: (1) legislation to regulate maximum microplastic fibres loss potential from synthetic clothing and (2) physical units which can be placed in washing machines to trap microplastic fibres before they can be discharged to the sewer. Progress to date regarding the banning of the manufacture, sale and use of microbeads in cosmetics and personal care products is also discussed in Section 3 in addition to the impact that disintegration equipment operating within the sewer network has on the creation of microplastics within the sewer through the breaking up of larger pieces of plastic. This section briefly examines the advantages and disadvantage of these practices in the context of BAT and BEP.

4.3.1.1 Measures to Reduce Laundry Fibres Entering the Sewer

4.3.1.1.1 Legislation Targeting Clothing Manufacturers

Synthetic clothing items typically have an expected life time of up to four years (International Fabricare Institute, 2018). In a review of microplastic pollution from textiles Henry et al. (2018) recommended that further research is required to fully understand the contributions to microplastic pollution from textiles. The study recommended that manufacturers and customers of synthetic clothing should invest in higher quality garments which are more durable. This is in agreement with recommendations of a position paper put forward by Mermaids (2017). However it is noted that manufacturers are unlikely to change their current practices unless there is (1) a demand from the customer for more durable clothing or (2) a regulatory requirement for clothing to meet maximum microfibre emission thresholds. Measures which encourage customers to wear longer lasting, higher quality and more durable clothing will reduce the amount of microplastic fibres lost to the environment. In many instances, however, the customer's decision will be based on price and unless there are regulations controlling the quality of clothing, manufacturers will not change their specifications unless it represents a cost saving.

4.3.1.1.2 Physical microplastic washing machine filters

Washing machines typically have a working life of 10 – 15 years (Janeway, 2018), thus, even if manufacturers are legally obliged to add filters to new washing machine and tumble drier designs it would be over 10 years before the full benefit would be realised. Hernandez et al. (2017) reported that the filter technologies currently being developed may not be capable for capturing the smallest (and most numerous) microplastic fibres released. It must also be noted that the greatest load of microplastic fibres released from an item of clothing occurs during the first wash (Pirc et al., 2016). Release of microplastic fibres during tumble drying may be up to 3.5 times higher than during washing (Pirc et al., 2016). Without a regulatory requirement it is likely that physical units currently on the market will not reduce microplastic fibres loads significantly. It follows that measures which target clothing manufacturers, as set out in section 4.3.1.1.1 above, may be more effective in reducing the amount of microplastic fibres generated and disposed of to the sewer. Verschoor et al. (2015) estimated annual emissions of microplastics contained laundry fibres products to surface water from 7 different sources in OSPAR countries to be in the region of 11,106 tonnes/year.

4.3.1.1.3 Measures to Reduce Microbeads used in Cosmetics Entering the Sewer

As discussed in Section 3 measures to reduce the amount of microbeads used in cosmetics entering sewers are at an advanced stage. Bans on the use, manufacture and sale of cosmetic and personal care products containing microbeads have been implemented is many countries and this will likely reduce the load of microplastics entering the sewer network and from there being discharged to the environment. Verschoor et al. (2015) estimated annual emissions of microplastics contained in cosmetic and personal care products to surface water from 7 different sources in OSPAR countries to be in the region of 2,825 tonnes/year.

4.3.1.2 Measures to Prevent the Creation of Additional Microplastics in the Sewer

There is no information available regarding the impact of disintegration equipment (section 3.3.3) on the generation of microplastics within the sewer, either in terms of sizes and volumes of microplastics generated. Before any recommendation can be made regarding the need to remove or replace such systems research is required on the sizes of particles created by disintegration equipment and the risk these particles pose to the environment. It must be kept in mind that these units do not add litter to the sewer, but rather they break litter up into smaller pieces which are often harder to remove than the original piece of litter. If the litter was not disposed of to the sewer in the first instance then there would not be an issue with the creation of smaller particles using this equipment and therefore the potential of programmes driving social change should also be considered in this context.

4.3.2 Pathway based stormwater related waste reduction technologies

This background document has also highlighted the potential for the use of (1) storm sewer and foul sewer separation and (2) low impact development (i.e. LID/SuDS systems) to reduce the volume of stormwater being discharged from CSOs. Implementing these systems would remove the need for CSOs and prevent stormwater related waste entering the environment.

4.3.2.1 Methods to remove requirement for CSOs

Sewer separation and LID/SuDS systems target the reduction of the volume of stormwater entering the sewerage network. Both measures represent BAT and BEP and provide for the removal of CSOs, in addition to which their implementation would ensure the treatment of the majority of wastewater, however it is likely that implementation throughout the entire OSPAR region would prove cost prohibitive in many older settlements. The advantages and disadvantages of separate sewers and low impact development are shown in Table 9 below.

	Advantages	Disadvantages
Sewer Separation	CSOs not required Flooding risk reduced Increased WWTP efficiency	High capital costs Major disruption in densely populated areas Need for good maintenance to avoid misconnections Increase in pollutants loading to receiving waters if surface run-off not treated
Low Impact Development (LID/SuDS)	CSOs not required Cost can be borne by new developments Reduced volume of stormwater	High capital costs Large space requirements Difficult to retrofit solutions in densely populated areas

Table 9 Advantages and disadvantages of separate sewers and low impact development

Removing all CSOs would ensure that with the exception of EOs all wastewater (and litter) entering the sewer would receive full treatment. Currently, between 74.2 and 96.6% of WWTPs provide secondary treatment or greater (i.e. tertiary) with between 53.4 and 80.1% of WWTPs (Table 10) providing tertiary treatment (Eurostat, 2018b). Thus if all CSOs were extinguished, there is potential for the majority of litter and a significant proportion of microplastics (up to 98% (Talvitie et al., 2017)) to be removed.

Regions (**OSPAR** countries in bold)	Percentage of wastewater collected which receives **No** treatment	Percentage of wastewater collected which receives **Primary** treatment	Percentage of wastewater collected which receives **Secondary** treatment	Percentage of wastewater collected which receives **Tertiary** treatment	Percentage of wastewater collected
Northern Europe: **Norway, Sweden, Finland and Iceland.**	1	5.6	2.3	77	84.9
Central Europe: Austria, **Belgium, Denmark, Netherlands, Germany, Ireland, Switzerland, Luxembourg and United Kingdom.**	0.5	0	16.5	80.1	96.6
Southern Europe: Cyprus**, France,** Greece, Italy, Malta, **Portugal** and **Spain**.	0.1	2.2	21.3	53.4	76.9
Eastern Europe: Czech Republic, Estonia, Hungary, Latvia, **Lithuania**, Poland and Slovenia.	1.1	0.2	13.6	60.6	74.4
South-eastern Europe: Bulgaria, Romania and Turkey.	17.6	16.7	22.8	20.6	60.1

Table 10 Percentage of population connected to urban wastewater collection and treatment systems in European countries (Eurostat, 2018b)

It is generally accepted that it will not be possible to separate all sewers as the cost in many settlements would simply be too great.

4.3.2.2 CSO Treatment Technologies

If microplastics cannot be fully removed at source and all CSOs cannot be extinguished an alternative solution is to ensure that appropriate treatment is provided at CSOs. CSO treatment technology performance data which was collated as part of the review of available technologies (see Section 3) is summarised in Table 11 below. This table also contains information relating to capital costs, power requirements, plan area requirements and maintenance requirements of each technology, the assessment of which is based on a combination of technical review, industry knowledge and practical experience and is categorised as H (relatively high impact), L (relatively low impact) and N (power supply not required) to give an indication the factors which designers much consider when selecting CSO treatment systems. While a full cost comparison is outside of the scope of this background report it is important to consider the cost effectiveness of treatments. In order to be comprehensive such a cost analysis would need to be reflective of the costs within each of the 15 OSPAR countries and include the different currencies, labour and material costs, operational and maintenance costs and budgeting priorities.

Technology	Micro plastics removal efficiency (%)	Power Req.(H/L/N)	Cap. Costs (H/L)	Plan Area (H/L)	Maintenance req. (H/L)	Review against BAT for Litter removal	Review against BAT for Microplastics removal
Baffles	Not Available	N	L	L	L	Shown to be effective in retaining litter during CSO events, provided that velocities are not excessively high	No data available regarding their efficacy in removing microplastics in CSOs.
Screens (manual and automated)	5-30	N/ L/ H	L	L	H	**BAT** as regards litter removal, minimum cost and currently installed in the majority of CSOs.	Shown to be somewhat effective in retaining microplastics
Storage Tanks	60	N	H	H	L	Litter typically retained on screens before wastewater enters storage tanks	Current **BAT** - shown to be effective in retaining microplastics which undergo sedimentation and stored stormwater directed to WWTP receives treatment
Vortex separation	50-80	H	H	L	H	Litter typically retained on screens before wastewater enters vortex separator	Can be expected to be effective in retaining microplastics based on solids removal performance
Constructed Wetlands (soil filters)	90 - 100	L	L	H		Litter typically retained on screens before wastewater enters constructed wetland	Shown to be very effective in retaining microplastics (microplastics remain in the wetland and may be lost if wetland damaged during flooding)
Micro Strainers	40 - 98	H	H	L	H	Litter typically retained on screens before wastewater enters microstrainers	Shown to be very effective in retaining microplastics
Membrane Filtration	99.9	H	H	L	L	Litter typically retained on screens before wastewater enters membrane filters	Shown to be very effective in retaining microplastics
Netting Systems	Not Available	N	L	H	H	Shown to be effective in retaining 93-97% litter (greater than 5mm) during CSO event	Performance data not available

Table 11 CSOs treatment technologies microplastic removal efficiency, capital costs, plan area, maintenance requirements and review against BAT for litter and microplastics removal

Note on Table 11: Capital costs, power requirements, plan area requirements and maintenance requirements of each technology were assessed based on a combination of technical review, industry knowledge and practical experience and are categorised as H (relatively high impact), L (relatively low impact) and N (power supply not required).

Clearly, there are a wide range of established treatment technologies and systems that are already used in wastewater treatment which could be used in CSOs. The technologies identified as BAT in Table 4 above are screening and storage/settlement.

Screening is the most cost effective means of removing litter from CSOs and has been shown to be somewhat effective in removing microplastics (mainly through entrapment). Manual and automated screening options are available and selection of the most appropriate screen for an application is generally based on site specific constraints. Screening is generally included as the first step in CSO treatment systems as it protects pumps and prevents large litter items from clogging systems designed to remove smaller particles.

Storage/settlement tanks are typically placed downstream of a screen. Storage/settlement tanks have been shown to be effective in retaining microplastics, preventing their discharge to the environment. In addition, storage/settlement tanks have the added advantage that stormwater stored in the tank during a storm event can directed to the WWTP for treatment once the WWTP has capacity.

Vortex separation structures are placed downstream of a screen and typically used in WWTPs for grit removal. These structures have the advantage over storage tanks in that they take much up less space. They are expected to be effective in retaining microplastics based on solids removal performance, however, they provide no storage and treated water enters the environment. Constructed wetlands, micro-strainers and membrane filtration are also very effective in retaining microplastics. These have not be have not been widely implemented.

In a review of the 28 Member States, Moreira et al. (2016) collated data from national experts, pertaining to technologies used to treat CSO discharges, a summary of which is included in Table 12. This report conveys the lack of information available to researchers in the area. Three of the twelve OSPAR countries surveyed by Moreira et al. (2016) stated that CSOs receive screening while only two make reference to storage tanks.

Countries	Screening	Storage Tanks	Constructed Wetlands	Vortex Seperation	Micro screen	Membrane Filtration
Belgium	N/A	Standard[7]	N/A	Pilot studies[7]	N/A	N/A
Denmark	N/A	Standard[9]	N/A	N/A	N/A	N/A
Finland	N/A	N/A	N/A	N/A	N/A	*Pilot studies[8]*
France	N/A	N/A	Pilot studies[2]	N/A	N/A	N/A
Germany	N/A	Standard[1 & 6]	Pilot studies[2]	Standard[5 & 6]	N/A	N/A
Iceland	N/A	N/A	N/A	N/A	N/A	N/A
Ireland	Standard[1]	Standard[1]	N/A	N/A	N/A	N/A
Luxembourg	Standard[1]	Standard[1]	N/A	N/A	Standard[1]	N/A
Netherlands	N/A	Standard[1]	N/A	N/A	N/A	N/A
Norway	N/A	N/A	N/A	N/A	N/A	N/A
Portugal	Pilot studies[4]	N/A	N/A	N/A	N/A	N/A
Spain	N/A	Pilot Study	N/A	N/A	N/A	N/A
Sweden	N/A	N/A	N/A	N/A	N/A	N/A
Switzerland	N/A	N/A	N/A	N/A	N/A	N/A
UK	Standard[1]	Standard[1]	N/A	N/A	N/A	N/A

Table 12 Information relating to the use of CSOs treatment technologies in OSPAR countries

[1]Moreira et al. (2016); [2]Meyer et al. (2013); [3]Llopart-Mascaro et al. (2015); [4] Amaral et al. (2013); [5]Brombach et al. (1993); [6]Klepiszewski et al. (2002); [7]Vaes et al. (1999); [8]Talvitie et al. (2017); [9]Krüger. (2014); N/A denotes cases where no information was available.

5 Conclusions

This background document set out to provide information on existing storm water handling practices in the OSPAR region, specifically, how combined sewer overflows (CSOs) performance standards, and best available processes, technologies and systems can be employed to minimise stormwater related litter, and particularly microplastics, entering the marine environment. The findings of this background document relating to (1) performance standards and (2) technologies and systems are as follows:

5.1 Conclusions - Performance Standards

Efforts which encourage upstream measures including raising consumer awareness, increasing producer responsibility and changing labelling requirements for certain single-use plastic products offer the potential to significant reduce litter and microplastic entering the marine environment.

It is not currently possible to fully assess the effectiveness of the UWWTD at preventing pollution from CSOs due to the limited data available. The lack of information relating to spill frequency and spill duration and is of particular concern and points to a need for monitoring and reporting of the performance of CSOs. In addition, there is a need to revise the UWWTD to include microplastic thresholds as the effectiveness of existing WWTPs and CSO treatment systems cannot be quantitatively assessed based on existing performance standards.

5.2 Conclusions - Systems and Technologies (Source Based)

The polluter pays principle should be applied when considering litter and particularly micro particles as the cost of removal of microplastics in particular is significant. Measures which encourage customers to wear longer lasting clothing will reduce the amount of microplastic fibres lost to the environment and should be encouraged through raising awareness and legislation if necessary. Source based measures including laundry microplastic fibre filters require attention and policy makes should consider changing legislation to encourage adoption by manufacturers. It is noted that there is uncertainty around the size of the target microplastic fibres which are being released.

There is a need for research to be carried out to evaluate the potential for disintegration technologies to create microplastics in the sewer network.

5.2.1 Conclusions - Systems and Technologies (Pathway based measures)

Sewer separation and SuDS certainly represent BAT and BEP as regards stormwater management and provide for the removal of CSOs, however, this option is cost prohibitive in many instances. In these instances the provision of CSOs and treatment (if deemed necessary) must be considered but for all new developments a policy of separating storm and sewerage systems should be considered.

Screening represents BAT and BEP as regards litter removal. This is a low cost option and is currently installed in the majority of WWTPs throughout the OSPAR region. Screens have low capital costs, space requirements and can be operated with no power but do increase operation costs for operators and also increase the risk of blockages occurring behind the screens if they are not maintained correctly.

This background document has shown however that screening is not effective at removing microplastics and therefore the potential benefit of widespread installation of screens at CSOs is unproven. Storage tanks which provide settlement represent current BAT for microplastics removal with stored stormwater directed to WWTP for treatment followed by settlement. The settled solids must be managed correctly to ensure that the material does not re-enter the stormwater systems. In general it is noted that there is lack of information pertaining to technologies used to treat CSO discharges throughout the OSPAR region.

6 Recommendations

In this background document a number of critical knowledge gaps which need to be addressed have been identified as follows:

- The total number of CSOs, number of EOs and length of separate and combined sewers in each OSPAR country is unknown;
- There is limited information available regarding standard CSO design criteria including dilution volumes and allowable spill frequencies and spill duration used in OSPAR countries;
- There is limited information available relating to the level of treatment provided and its effectiveness at CSOs OSPAR countries
- There is a lack of knowledge pertaining to microplastic composition and size in effluent from laundry fibres and the impact of physical characteristics of synthetic textiles on the release of microplastics
- This information is needed to determine performance standards for clothing manufacturers and laundry machine manufacturers;
- There is no information available regarding the impact of disintegration equipment on the generation of microplastics within the sewer, either in terms of sizes and volumes of microplastics generated.

It is noted that a revision of the UWWTD is planned and it is therefore recommended that in the updating of this directive consideration should be given to microplastic discharges.

These knowledge gaps can be addressed by undertaking the following steps:

A. **Research:** There is a need for field based research to be carried out to evaluate the potential for disintegration technologies to create microplastics in the sewer network. The following approach may be appropriate:

   - Quantify the potential for disintegration technologies to create microplastics in the sewer;
   - Determine the size distribution and properties of microplastics being created;
   - Determine how effective existing wastewater treatment processes are at removing these microplastics

   In addition there is a need for further research to fully understand the contributions to microplastic pollution from textiles. There has been recent research in this area, however, additional work is required to determine:

   - Determine appropriate maximum permissible microplastic release limits for synthetic clothing and laundry machine manufacturers;
   - Determine how effective existing wastewater treatment processes are at removing these microplastics.

B. **Increase monitoring:** There is a need to establish monitoring so that the effectiveness of existing WWTPs and CSO treatment systems in the removal of microplastics can be quantitatively assessed;

C. **Increased Reporting Requirements:** There is lack of information pertaining to technologies used to treat CSO discharges throughout the OSPAR region. Pilot work to set out what information specifically is required. What technologies are in use and what data set would give us the best quality of information. System then for keeping information up to date. A pilot project would:

- Develop a questionnaire to gather information pertaining to CSOs including:
  i. Number of CSOs, EOs and length of separate and combined sewers in pilot area (region or country);
  ii. CSO design criteria including dilution volumes and allowable spill frequencies, spill duration and duration rates
  iii. Monitoring programmes and maintenance schedules
- Compile and review the data collated:
  i. Determine the critical data which is required to determine the performance of CSOs with a view to litter and microplastic prevention and reduction;
  ii. Determine appropriate level of data required (i.e. CSO scale/ agglomeration scale);
  iii. Determine appropriate reporting frequency;
- Produce a concise questionnaire that could be used across the region to collate data relating to CSO discharges throughout the OSPAR region;
- Utilise GIS data and best available asset management database software to allow for data to be updated annually/quarterly as required.

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ISBN 978-1-911458-72-2

Publication Number: 732/2019