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Study on the feasibility of applying extended producer responsibility to micropollutants and microplastics emitted in the aquatic environment from products during their life cycle

Module 1 – Relevance of EPR for products emitting pollutants to the aquatic environment

FINAL REPORT

January 2020

EurEau

EXECUTIVE SUMMARY

STUDY OBJECTIVES AND SCOPE

EurEau commissioned a study to assess the potential applicability and relevance of extended producer responsibility (EPR) in order to develop clear policy guidance to address emissions of micropollutants and microplastics from products.

The study defines micropollutants as persistent and biologically active substances that are found in water bodies in low concentrations and which can have detrimental effects on humans, the environment and drinking water resources. Secondary microplastics are defined as small plastic parts found in the (aquatic) environment with a diameter of less than 5mm that are formed and released via abrasion or weathering of larger plastic particles, products or debris. The five product categories assessed are pharmaceuticals (human medicinal products), pesticides (plant protection products, biocides (human hygiene/ antibacterial products), textiles (clothing) and tyres.

FROM ENVIRONMENTAL TO ECONOMIC IMPACTS

In addition to the implications for human health and the environment, the presence of micropollutants and microplastics in water bodies throughout Europe also has important economic impacts including the costs to water services both upstream and downstream, affecting drinking and waste water treatment. **Extra treatment to comply with current or future legislative requirements for drinking and waste water regarding micropollutants and microplastics will result in several billion euros per year of investment in advanced water treatment technologies and additional operational costs, unless effective source-control measures are taken**.

Assuming no further action is taken in regard to the current situation, water service providers would have to pass these substantial costs on to water customers and consumers, affecting access to and affordability of water services. These customers are not the root cause of these pollutants and as such should not be required to bear the full costs of their impacts.

MOST RELEVANT POLICY OPTIONS & FRAMEWORK FOR APPLICATION OF EPR

There is–currently no overarching regulatory framework at EU level, which specifically targets the release of micropollutants and microplastics in the aquatic environment. Relevant provisions are laid out in existing cross-cutting legislation such as the Water Framework Directive 2000/60 and REACH Regulation and product-specific legislation e.g. Directive 2001/83 on human pharmaceutical products, Plant Protection Products Regulation 1107/2009, Biocide Products Regulation 528/2012, etc. Against this backdrop, the legislative assessment of implementation of EPR focused specifically on the most relevant provisions on the product categories assessed in respect to potential changes/ amendments required to cover drinking and waste water treatment costs and further contribute to addressing the occurrence of micropollutants and microplastics in the water cycle. The four policy options assessed include:

- **Option A**: Voluntary control-at-source & post-marketing measures (including EPR)
- **Option B**: Mandatory control-at-source measures
- **Option C**: Mandatory control-at-source & post-marketing measures (including EPR)
- **Option D**: Mandatory EPR measures

Control-at-source measures refer to measures applied upstream or early on during the product life-cycle e.g. product design, market authorisation and restrictions, requirements on manufacturing processes; whereas post-marketing measures include the application of

EPR schemes as well as other actions implemented farther down the product life-cycle e.g. information and awareness raising campaigns, end-of-life management, etc.. The comparative analysis of the policy options included parameters such as the implementation approach (voluntary versus mandatory options), estimated timeframe for the implementation of specific measures, coverage of end-of-life/ treatment costs, life-cycle approach, stakeholder support and overall product coverage.

KEY FINDINGS

A key finding of the study confirms that control-at-source measures should be the starting point of mitigation measures. They are usually more effective due to the large number and diffuse nature of emission pathways into the environment. However, the release and presence of these substances continue to be a concerning issue at EU level. This indicates that control-at-source measures are not fully implemented and/or that they alone are not sufficient to effectively address the problem. **Products containing potentially hazardous substances continue to be placed on the market and humans and other living organisms continue to be exposed to their potentially harmful effects.** This demonstrates the urgency of immediate regulatory actions, which is supported by a solid existing knowledge base (including scientific findings) to justify corrective measures; and therefore applying the precautionary principle.

Of the four policy options assessed, Option C (mandatory control-at-source and post-marketing measures, including EPR) and Option D (mandatory EPR measures) are found to be the most effective options. Both options are based on mandatory approaches. It should be noted that the study did not conduct a cost-benefit analysis of these options. Of these two options, a key strength worth noting is that Option C addresses the entire product life-cycle and would be applicable to all products, whereas Option D focuses mainly on post-marketing/ end-of-life stages. As such, it is assumed that there would be a higher level of stakeholder acceptance for Option C compared to Option D since Option C would imply a wider scope and share of responsibility in terms of the potential actors across the supply chain concerned. Furthermore, option C would fully respond to the provisions of article 191.2 TFEU.

The study findings indicate that in addition to control-at-source measures, the existing legislative basis at EU level provides clear opportunities where EPR could be applied in order to more effectively contribute to avoiding and/or reducing micropollutants and microplastics emitted from products during their life-cycle. While EPR holds significant potential to ensure producers take on full physical and financial responsibility of their products, the study concludes that, similar to control-at-source measures, EPR as a stand-alone policy is not the magic solution to solving Europe's water pollution challenges. Instead, only a combination of both upstream and downstream measures would be able to adequately tackle the full extent and scope of the problem.

RECOMMENDATIONS

Some of the main opportunities identified where EPR could be applied in existing EU legislation to ensure producers are held financially and physically responsible for their products throughout their life-cycle, include:

- Defining legal and financial responsibility for the products placed on the market, and consequently a transparent system of traceability;
- Applying appropriate product/substance fees that reflect the full costs of treatment of these products;
- Promoting eco-design by providing incentives to producers to implement more efficient and sustainable product-design and manufacturing practices.

Furthermore, from a practical point of view, EPR is generally more acceptable to society compared to for example a tax imposed to finance downstream measures. EPR is more targeted in that it aims to use collected funds to finance pollution mitigation measures, leaving more flexibility to polluters to decide about the most effective ways to spend these funds. The following key messages and recommendations can be drawn from the study's findings:

- **Control-at-source is key:** Due to the diffuse nature of the occurrence of micropollutants and microplastics in the aquatic environment, measures should be implemented as **early on as possible** in the product life-cycle e.g. substance/product authorisations and restrictions before they can be placed on the market.
- **Develop a clear legislative framework for EPR:** While the polluter-pays principle is enshrined in the TFEU and stipulated in the Water Framework Directive (Recital 38 on use of economic instruments and Article 9 on recovery of costs for water services), these principles are not applied in practice when it comes to micropollutants and microplastics in the aquatic environment. Therefore, there is a need for a clear regulatory framework based on a full life-cycle approach at EU level for the implementation of the polluter-pays principle through EPR. This should build on control-at-source measures and include mitigation measures that could be financed through funds collected under EPR.
- **Traceability and designation of the responsible producers:** The development of a fair and proportionate EPR scheme must address these two points in cooperation with the producers concerned. The experience of existing EU legislation such as waste directives and the Single Use Plastics Directive should be used.
- **Cost-benefit analysis:** An in-depth assessment should be conducted on all possible measures from product design to end-of-life, including mitigation measures that EPR funds could help finance. Other important parameters to evaluate include the impacts on energy consumption and CO_2 emissions, on contributions to the circular economy objectives, the internal market and society, etc.
- **Consideration of local and national specificities:** EPR schemes should be sufficiently flexible to accommodate regional peculiarities such as concentration of 'hotspots', specific local conditions e.g. economic and waste infrastructure systems, material and waste flows, etc.
- **Cross-sectoral stakeholder dialogue:** It is crucial to establish and maintain dialogue between all relevant stakeholders in order to exchange knowledge and best practices, coordinate research and innovation and ensure full application of EU legislation and functioning of the internal market.
- **Boost scientific research**: As scientific understanding of the potential effects of pollutants has increased, so has public and political concern on their potentially hazardous impacts. Public health and environmental concerns, increased scientific knowledge and awareness are important drivers that could further boost innovation, changes to the existing regulatory framework and consumer behaviour.
- **Stay up-to-date on policy evolutions:** National, European and international policy developments should be monitored to avoid potential overlaps, inconsistencies and administrative burden. Likewise, it is essential that policy reflects the latest technological and innovative solutions to anticipate future challenges in regard to new potentially hazardous substances, but also innovative and cost-effective mitigation measures.

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Abbreviations

BAF	Biologically activated filtration
BPR	Biocidal Products Regulation
CSO	Combined sewer overflows
DG ENV	DG Environment
DWD	Drinking Water Directive (Directive 98/83)
DWTP	Drinking water treatment plants
EC	European Commission
ECHA	European Chemicals Agency
EDC	Endocrine disrupting compound
EPR	Extended Producer Responsibility
EQSD	Environmental Quality Standards Directive
EurEau	European federation of national water services
GAC	Granulated activated carbon
IED	EU Industrial Emissions Directive 2010/75/EU
LCA	Life-cycle analysis
PAC	Powdered activated carbon
PCB	Polychlorinated biphenyl
PCP	Personal care products
PE	Population equivalent
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanoic sulfonate
PFASs	Perfluoroalkylated substances
POP	Persistent organic pollutant
PPP	Plant protection product
PP	Polluter pays principle
PRO	Producer Responsibility Organisation
TCS	Triclosan
TF	Tolylfluanid
VMP	Veterinary medicinal products
WFD	Water Framework Directive (Directive 2000/60)
WWF	World Wildlife Fund

Terms and definitions

Aquatic environment: aquatic environments include inland surface water, seas, and ground water, all of which contain diverse microbial populations and microorganisms.

Extended Producer Responsibility: a policy approach under which producers are given a significant financial and/or physical responsibility for the treatment or disposal of post-consumer products. The overarching aim of extended producer responsibility is to provide incentives to prevent wastes at the source, promote product design for the environment and support the achievement of public recycling and materials management goals.

Emerging substances: substances those that have only recently been analysed/ identified in the environment and therefore currently not entirely regulated, which are believed to cause adverse effects on ecosystems and humans.

Final products: A final product is a product that is ready for sale without significant further processing. For example, in the pharmaceutical industry, a finished product would take a final dosage form e.g. a tablet, capsule or solution that contains an active pharmaceutical ingredient, generally, but not necessarily, in association with inactive ingredients.

Intermediary products: An intermediate good or product is a product used to produce a final good or finished product. These goods are sold between industries for resale or the production of other goods. An intermediate product usually requires further processing before it is saleable to the ultimate consumer (or end consumer). This further processing might be done by the producer or by another processor. Thus, an intermediate product might be a final product for one company and an input for another company that will process it further.

Microplastics (secondary): Secondary microplastics are very small particles of plastic material (typically smaller than 5mm) that can be unintentionally formed through the wear and tear of larger pieces of plastic or the degradation of plastic waste in the environment. (ECHA 2018)

Micropollutants: Micropollutants encompass a wide variety of substances that are characterised as small, persistent and biologically active, found in aquatic environments in low concentrations (typically in the range of ng–µg/l) and can have detrimental effects on humans, the environment or drinking water supplies.

Product life-cycle: Refers to all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and end-of-life e.g. disposal, re-use or recycling.

Substance of concern: Any substance, other than the active substance, which has an inherent capacity to cause an adverse effect, immediately or in the distant future, on humans, in particular vulnerable groups, animals or the environment and is present or is used in the manufacturing of product in sufficient concentration to present risks of such an effect.

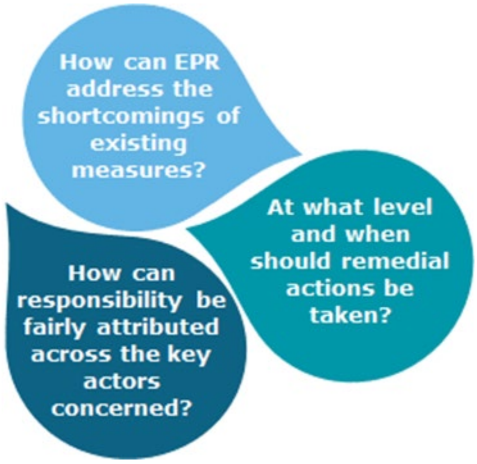
Part I. Study objectives, methodology & scope

1. Objectives

The overall objective of this study is to analyse the feasibility of an effective extended producer responsibility (EPR) scheme on products that release micropollutants and microplastics into the aquatic environment during their life cycle.

The study is organised around four following modules and guiding questions:

- **Module 1**: Relevance of EPR
- **Module 2**: Applicability of EU legislation for EPR on products emitting pollutants to aquatic environments
- **Module 3:** Assessment of the arguments for and against EPR
- **Module 4:** Communication documents



1.1 Module 1 objectives and contents of report

The objective of module 1 is to analyse the **relevance and applicability** of extended producer responsibility for products that release micropollutants and microplastics into the aquatic environment. The module 1 report presents findings of our analysis on the:

- Potential impacts of the continued release and presence of micropollutants and microplastics in Europe's waterbodies (Part II, chapter 4);
- Emission sources & pathways of the products and associated substances assessed (Part II, chapter 5);
- Potential of EPR to address current challenges when existing measures (Part III, chapter 6), such as control-at-source are not sufficient (Part III, chapter 7); and
- Relevance of establishing accountability and responsibility for remedial actions and ensuring compliance (Part III, chapter 8).

Part I of the report summarises the objectives (chapter 1), methodology (chapter 2) and scope of the study (chapter 3). Part IV provides the list of relevant legislation that is assessed in Module 2.

2. Methodology

The findings and analyses carried out are based on a methodology that incorporates in-depth data collection from literature review and stakeholder/ expert inputs.

2.1 Literature review

A comprehensive review of recent and relevant literature allowed the research team to identify and collect necessary information for the analyses. The literature review included over 80 sources, covering a wide range of documents such as scientific articles, guidance and policy reports and stakeholder position papers. Priority sources were reviewed based on their relevance to the study and scientific robustness. In addition, several sources provided by EurEau, for example on costs, were also thoroughly reviewed. The list of references can be found in chapter 8.

2.2 Stakeholder consultation

The stakeholder consultation process included **stakeholder interviews** and a **stakeholder workshop**. **Targeted stakeholder interviews** were carried out to gather key feedback on different stakeholder perspectives – from industry, policy makers, consumer and environmental associations as well as from the drinking and waste water treatment section on the applicability of EPR for the products assessed.

The selection process for the stakeholders invited to participate in the study was based on several aspects, for example ensuring that a diverse range of representative stakeholders, coverage of both proponents and opponents of an EPR scheme, the level of stakeholder interest or role and their presence and participation in initiatives and events such as EU/international/industry working groups and conferences. Priority stakeholder contacts were identified following discussions and agreement with EurEau members.

The results of the stakeholder consultation are summarised in the Module 3 report, presenting the different stakeholder perspectives on the feasibility and applicability of an EPR approach on products that emit micropollutants and microplastics in the aquatic environment.

In addition, a **stakeholder workshop** was hosted by EurEau on 14 February 2019 with the participation of a small number of stakeholders, reflecting EU representatives, international organisations, associations, EurEau and the project team. The goal of the workshop was to further encourage and enhance multi-level and cross-sectoral dialogue on the topic of EPR and micropollutants and to collect useful information for the study.

3. Scope

The scope of the study covers potentially hazardous **micropollutants** and **secondary microplastics**[1] released into the aquatic environment by products during their life-cycle.

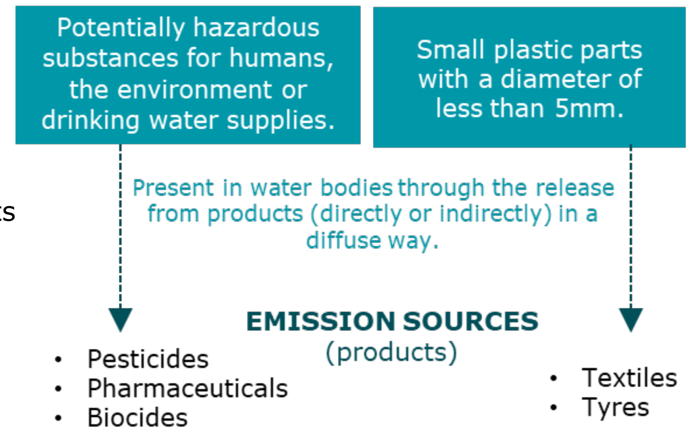
For the purposes of this study, micropolluants are defined as persistent and biologically active substances found in water bodies in low concentrations and which can have detrimental effects on humans, the environment or drinking water supplies. Secondary microplastics are defined as small plastic parts found in the aquatic environment with a diameter of less than 5mm that are formed and released via abrasion or weathering of larger plastic particles, products or debris (ECHA 2018).

The approach employed for the selection of product categories assessed takes into account the representativeness of the manufacturing sectors concerned, while limiting the assessment to the most pertinent products/product categories with regards to the water treatment sector. In other words, substances with properties that have the potential to pollute water sources (drinking water), are technically difficult or costly to remove during drinking water/ wastewater treatment and which can cause detrimental environmental and health effects if left untreated in aquatic environments (see Table 1). Other criteria considered include:

- Anthropogenically produced substances (with the exception of silver, which is used as a biocide in sports wear) that are released directly or indirectly into the aquatic environment in a diffuse way (i.e. no precise discharge point); and
- Evidence that the substance has been detected in Europe's waterbodies at a certain frequency, concentration and occurrence.

The study assesses the following five product categories:

- **Pharmaceuticals**: Human medicinal products
- **Pesticides**: Plant protection products (agriculture)
- **Biocides**: Antibacterial products (human hygiene)
- **Textiles**: Clothing
- **Tyres:** Car tyres

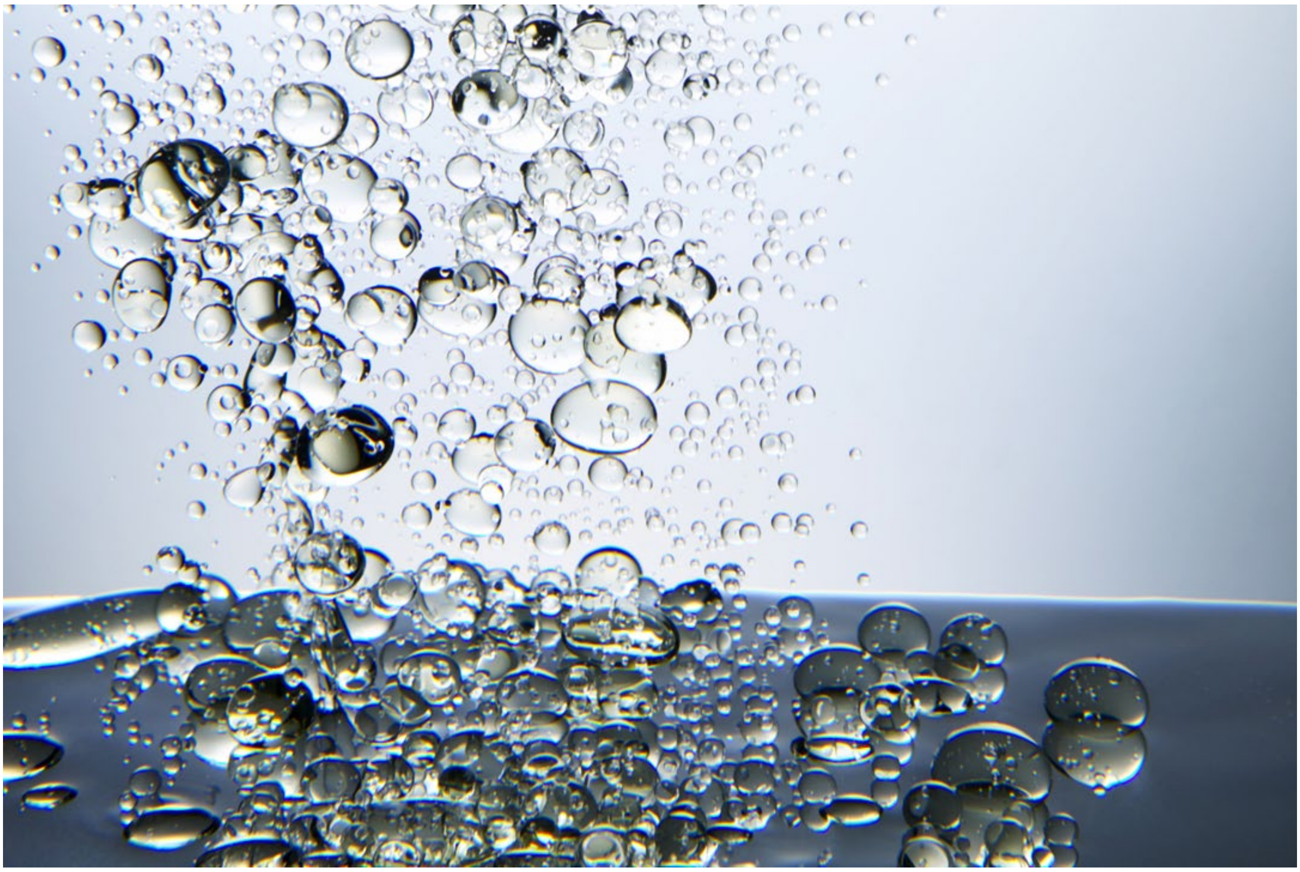


[1] Primary microplastics (i.e. intentionally added to products or deliberately manufactured for a specific purpose) are not covered by the study as they are being addressed by on-going initiatives by the European Commission and European Chemicals Agency (ECHA)

Table 1: Description of product categories assessed

Product group	Description
Emission of micropollutants	
Pharmaceuticals[2]**:** Human medicinal products	Pharmaceuticals refers to medicinal products for human use, which emit potentially hazardous substances e.g. ethinylestradiol, estrone, diclofenac, paracetamol, etc. into the aquatic environment via the consumption phase and incorrect disposal. Macrolide antibiotics are of particular concern, as conventional wastewater treatment plants (WWTPs) cannot fully remove these compounds without the application of more advanced treatments steps (EC, 2016a).
Pesticides[2]: Plant protection products	Pesticides refer to plant protection products used in the agricultural sector, that are intended to protect plants and also their products after harvesting. Plant protection products are considered as pesticides (including herbicides and insecticides). Plant protection products consists of one or more active substances called co-formulates, which can pose potentially hazardous risks to human health and the environment if they are not used or disposed of properly.
Biocides: Products such as antibacterial and disinfectants (human hygiene and cleaning purposes)	Biocidal products refers to products used in a non-agricultural context (to distinguish from the use of biocides for plant protection, which is covered by pesticides) to serve as antibacterial purposes. For example, the use of silver as a biocide in sportswear (socks, jumpers, jerseys, etc.). Silver is a biocide used to "reduce odours" in sportswear; however, is not easily degradable and represents potentially hazardous risks to aquatic organisms and human health.
Emission of secondary microplastics	
Textiles: Clothing	Secondary microplastic particles are released from textile products and tyres into the aquatic environment during use/service life e.g. washing of clothing and carpets and tyre abrasion.
Tyres: Car tyres	

[2] Several of the substances used in pharmaceutical and pesticide products are on the Watch List of substances to be monitored in EU surface waters: https://ec.europa.eu/jrc/en/science-update/updated-surface-water-watch-list-adopted-commission



Part II. Impacts, sources & pathways

4. Impacts of micropollutants & microplastics in the aquatic environment

Amongst the challenges which need to be addressed to improve the quality of the aquatic environment in Europe, tackling microplastics and chemical pollutants in waterbodies has been an increasingly concerning issue in recent years.

Micropollutants refer to persistent and biologically active substances that are of great concern because of the potential adverse effects they can have on organisms (on both humans and other living organisms) at low concentrations. Micropollutants are ubiquitous and are found almost everywhere on earth, particularly in water bodies, but also in soils and even in food destined for human consumption. Micropollutants originate from products manufactured from industries such as pharmaceutics, personal care products, pesticides and industrial chemicals and released by industry, households, or agriculture into the environment and spread throughout the water cycle.

There are many pathways for how micropollutants end up in the aquatic environment. One of them, waste water treatment operations, can only partially remove micropollutants, therefore they are usually not completely eliminated once they enter water bodies. Consequently, micropollutants are ingested by aquatic organisms or humans via contaminated water or food, and transported to different tissues within the organism. Depending on the properties of the micropollutants and the biology of the target species, they may bio accumulate, metabolize or cause adverse effects (Burkhardt, 2011). These effects may translate into alterations on a higher biological level such as disruption of the hormone system, followed by impacts on reproduction, etc.

There is no standardised definition on microplastics at EU or international level. As such, there are no standardised testing, sampling or other analytical methods in order to compare results and data on their affects, quantity, concentration, etc. **Microplastics** found in the environment can either be:

- **Unintentionally formed** through the wear and tear of larger pieces of plastic (secondary microplastics) such as car tyre abrasion from road transport, washing of synthetic textiles; through the degradation of plastic waste / fragmentation of plastic litter in the environment; or unintentionally released through production processes e.g. from spills, leakages or poor storage for example during manufacturing plastic pellets (Eunomia, 2018).
- **Intentionally added** to products or deliberately manufactured for a specific purpose (primary microplastics): Examples include exfoliating beads in facial or body scrubs (ECHA, 2018) or industrial abrasives (Swedish EPA, 2017). It should be noted intentionally added microplastics are not evaluated in this study.

Most currently used drinking water treatment technologies cannot completely remove all micropollutants found in drinking water resources, with removal efficiencies varying widely depending on the type of substance and treatment technology concerned. Certain types of waste water treatment with at least secondary treatment can remove a very high share of microplastics (up to 99% in some cases). However, a significant part of the removed particles end up in sewage sludge, which can potentially affect recycling options.

Findings from two recent reports on microplastics in Norwegian drinking water (Norsk Vann, 2018) and in Danish drinking water (Aarhus University 2018) suggests that the there is no significant concentration of microplastics in certain drinking water resources.

Concern over substances that can resist wastewater treatment and may contaminate water resources, particularly those for drinking water production, has increased in recent years. However, at present, knowledge on many new **emerging substances** is patchy with respect to their effects on humans, animals, and their fate in the environment.

Water pollution in the form of micropollutants with potentially adverse effects will not diminish over time due to certain demographic changes (an aging society consumes more medicine) and economic trends (industrial agriculture still uses large quantities of plant protection products), etc. Therefore, necessary measures should be taken as soon as possible if we are to avoid future damage and costly remedial measures (UBA, 2018). Similar concerns exist regarding microplastics, although more research is needed to determine the extent of their impact on human health and the environment (soil, water, living organisms).

> "**Emerging substances** are those that have only recently been analysed/ identified in the environment and which are believed to cause adverse effects on ecosystems and humans. However, remain insufficiently regulated or entirely unregulated."
>
> \- Murray, 2010

4.1 Environmental and health impacts

The potential impacts of these micropollutants in Europe's aquatic environments on human health and infrastructure, natural habitats and biodiversity are broad, can be quite significant and in many cases unknown. Further, much of the burden in terms ensuring effective treatment of these pollutants falls upon wastewater service providers, drinking water suppliers, environmental protection authorities, regulatory bodies and ultimately tax payers. Figure 1 summarises some of the potential environmental, health and economic impacts of micropollutants and microplastics present in waterbodies.

Figure 1: Impacts of micropollutants & microplastics in the aquatic environment

Environmental impacts

- **Microplastics** can cause physical, mechanical and eco-toxicological hazards
- **Organic chemicals** jeopardise the health of freshwater ecosystems
- **Pesticides** threaten species such as algae and invertebrates, which are important to ensure healthy and well-functioning aquatic ecosystems

Health impacts

Research has shown that human exposure to certain chemicals (e.g. bioaccumulative, endocrine-disrupting properties...) has been associated with genital malformation, impaired neural development and cancer. Further, certain harmful substances could cause inflammation, an immune response to anything recognised as "foreign" to the body, which can cause damage.

Economic impacts

- **Increased costs and investments** for drinking water and waste water treatment plants to ensure compliance with water quality standards and regulations.
- **Increased energy consumption** and use of chemicals associated with certain water treatment techniques.
- **Circular economy solutions** become increasingly difficult to implement in WWTPs due to higher contamination of (new) pollutants in sewage sludge and wastewater.

Of particular concern are the hazardous properties and potential adverse effects of micropollutants and microplastics. For example,

- **Persistent, bioaccumulative and toxic** (PBT): PBTs are a class of compounds that have high resistance to degradation from abiotic and biotic factors, high mobility in the environment and high toxicity.
- **Persistent, mobile and toxic** (PMT): PMTs compounds are highly soluble and therefore difficult to remove in drinking water treatment plants.
- **Endocrine-active or as endocrine-disrupting compounds** (EDC): EDCs are mostly man-made, found in various materials such as pesticides, metals, additives or contaminants in food, and personal care products. EDCs are associated with altered reproductive function in males and females; increased incidence of breast cancer, abnormal growth patterns and neurodevelopmental delays in children, as well as changes in immune function.
- **Persistent organic pollutant** (POP): chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment. This group of priority pollutants consists of pesticides (such as DDT), industrial chemicals (such as polychlorinated biphenyls, PCBs) and unintentional by-products of industrial processes (such as dioxins and furans).
- **Bioaccumulation:** uptake of a chemical by an organism through a combination of water, food, sediment and air, as occurs in the natural aquatic environment.

Microplastics in particular, can persist for long periods in the aquatic environment if not properly disposed of or recycled. Microplastics have been found in wastewater, sewage sludge, freshwater and in the terrestrial environment, and in species of fish and shellfish consumed as food (ECHA, 2018). As reflected in a recent note published by the ECHA (European Chemicals Agency), the concern associated with microplastics is the potential environmental and human health risks posed by their presence in the environment. Microplastics are readily available for ingestion due to their very small (typically microscopic) size and are also very resistant to normal environmental degradation i.e. high resistance towards physical and chemical effects and a low degradability. A recent report from the Danish Environmental Protection Agency indicates that the most abundant microplastic particles in wastewater, sludge and soil samples tested were polyamide/nylon, most likely originating from textiles, clothing and carpets (DEPA 2016).

According to a pan-European study carried out in 2018 by the European Environmental Agency, the majority of Europe's rivers, lakes and estuaries are highly polluted with chemicals and other pollutants – only 38 % of the water bodies evaluated met chemical pollution standards (EEA 2018). The improved performance of metrology and monitoring technologies have led to the identification of new pollutants in waterbodies. This trend reflects the increasing number and types of products that are being put on the market. For example, it is estimated that approximately 100 000 organic chemicals are in regular use in Europe, with 1 000 new ones entering the market each year.

4.2 Economic impacts

In addition to the environmental and health impacts associated with the release and presence of micropollutants and microplastics in water bodies throughout Europe, important economic impacts include the costs of water services both upstream and downstream, effecting **drinking water and waste water treatment**. A discussion on some of the technical limitations of advanced water treatment technologies is provided in section 6.2.1.

4.2.1 Costs of advanced wastewater treatment

Municipal wastewater treatment plants represent a major entry pathway of micropollutants and microplastics to waters, as they are the collection point of urban wastewater and, in the case of combined sewers, of road run-offs. Conventional waste water treatment plants (WWTPs) in the EU were established to comply with the requirements of the Urban Waste Water Directive (UWWTD), which aims to protect the environment from the adverse effects of urban waste water discharges. Accordingly, traditional WWTPs using conventional biological and mechanical processes are not specifically designed to eliminate micropollutants and microplastics – specifically newer and more complex water pollutants that stem from chemicals, products and materials with increasingly new properties and pathways of synthesis (Klaus et al. 2019) – which due to their persistence in the environment, many are able to pass through wastewater biological treatment processes. Although recent innovations in chemicals and materials may promise advantages such as increased efficiency of new products put on the market, the current situation represents both **technical and economic difficulties** for the drinking and waste water sector.

In order to comply with requirements such as those on urban waste water discharges, many WWTPs in the EU must invest in advanced water treatment technologies, which implies increased costs. The additional costs borne by WWTPs to treat waste water is usually being passed on the final consumer, leading to increased water bills. The cost of wastewater treatment depends on several factors such as the condition of the WWTP, its size, the technology that is installed and the quantity and types of pollutants that need to be treated in order to reach the desired water quality. Implementing advanced wastewater treatment is particularly problematic for smaller WWTPs due to the investments costs (including increased energy consumption) and infrastructure required. In most cases, economies of scale and cost effectiveness can be achieved for larger installations as they have more resources to ensure follow-up, process optimisation, and operation and maintenance of the facility. In addition, costs and energy demand per cubic meter are generally lower for larger facilities, and are also likely to decrease as technologies develop and prices drop with increasing market demand. However, if investment requirements come at the wrong moment of the investment cycle, larger treatment plants may also face significant difficulties.

Information on advanced treatment costs are presented in the following paragraphs for Switzerland, Germany, the Netherlands and Sweden. Although some data is available in existing literature, it should be noted that **cost data varies widely depending on the different parameters considered** (e.g. location of the WWTP, local conditions, capacity of the WWTP, measured in population equivalent size, water recharge rate, etc.) as well as differences between Dutch, Swiss, Swedish and German cost and wastewater treatment structures. For example, the design capacity of a WWTP in population equivalents (p.e.) is not calculated in the same way nor are important cost variables such as capital costs, electricity and labour.

Switzerland is one of the first countries to start implementing a national policy to reduce micropollutants in the effluents of municipal sewage treatment plants (STPs). According to a report commissioned by the Swiss Federal Institute of Aquatic Science and Technology, the Institute of Biogeochemistry and Pollutant Dynamics and the Federal Office for the

Environment, the average cost for wastewater treatment including nutrient removal in Switzerland is around 0.61 €/m^3 (0.7 CHF/m^3) wastewater (Eggen 2014). Table 2 summarises the overall investment and capital costs of different types of advanced treatment technologies in Switzerland (Poyroy[3] 2016).

Table 2: Costs of advanced water treatment technologies, Switzerland[4]

Estimated costs	**Advanced water treatment technology** p.e. (population equivalent) = 100 000	
	Ozonation + new filtration	Power activated carbon + new filtration
Total investment sum	10 million € (11.3 million CHF)	10.8 million € (12.3 million CHF)
Capital costs (€/p.e./year)	6.4	6.7
Operating costs (€/p.e./year)	3.2	4.7

Under the Swiss national policy, the total investment costs to upgrade 100 WWTPs (out of approximately 650 WWTPs and covering approximately 50 % of national annual wastewater) are estimated at 1.2 billion CHF (1 billion €), or 130 million CHF (114 million €) per year, over a period of implementation of 25 years (2016-2040)[5]. The planned upgrades to WWTPs are expected to increase the annual costs of urban drainage and wastewater treatment by 6%. Treatment costs are expected to increase by 10−20% for WWTPs serving > 80 000 persons and by 20−50% for WWTPs serving between 8 000 and 80 000 persons (Eggen 2014). **Compared to Germany**, the costs of upgrading 230 large municipal treatment plants (size category 5, covering approximately 50 % of the nationwide annual amount of wastewater) over a period of 25 years are estimated at 10.4 to 10.9 billion €, which would equate to 415 to 435 million € in annual costs for the elimination of micropollutants, including post-treatment (UBA 2018). An earlier report published by the German Environment Agency estimated that the specific costs of advanced waste water treatment in municipal sewage treatment plants range from 0.124 €/m^3 for size class 3 to 0.051 €/m^3 for sewage treatment plants larger than 1 million population equivalents (size class 5). The annual total costs of around 1.3 billion euros (net) are expected when upgrading all the German sewage treatment plants in the size classes 3 to 5 (3 013 in total) to integrate targeted micropollutant removal (UBA 2014).

In Sweden, a government-commissioned report (which based its calculations on the Baresel et al (2017) study) estimates that the advanced waste water treatment costs for facilities larger than 100 000 population equivalents (p.e.) is less than 1 SEK/m^3 (0.09 €/m^3). For smaller facilities (2 000–20 000 p.e.), the costs of advanced treatment technologies are about 5 SEK/m^3 (0.5 €/m^3) (SEPA, 2017). The report breaks down the estimated costs by technology as summarised in Table 3:

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[3] Poyroy is one of the main consulting and engineering companies that has overseen many of the WWTPs upgrades in Switzerland.
[4] Poyroy (2016)
[5] www.water2020.eu/sites/default/files/keynote_adriano_joss_eawag_switzerland.pdf

Table 3: Cost of advanced water treatment technologies, Sweden[6]

	Ultrafiltration	GAC[7]	PAC[8]	BAF[9]	Ozonation
Installation CAPEX (M €)					
2 000 p.e.	9.7–12.4 M€	3.5 M€	0.13 M€	3.5 M€	1.2–4.4 M€
20 000 p.e.	15–22 M€	6.6 M€	0.22 M€	6.6 M€	3–7.9 M€
100 000 p.e.	44 – 66 M€	15.4 M€	0.7 M€	15.4 M€	9.3 – 17.6 M€
Annual capital expenditure CAPEX (M€/year)					
2 000 p.e.	0.7–0.9 M€	0.26 M€	0.008 M€	0.26 M€	0.08–0.35 M€
20 000 p.e.	1.4–1.7 M€	0.44 M€	0.01 M€	0.6 M€	0.26–0.6 M€
100 000 p.e.	3.2–4.8 M€	1 M€	0.05 M€	1.4 M€	0.7-1.3 M€
Operating expenditure OPEX (M€/year)					
2 000 p.e.	0.35–0.4 M€	0.6 M€	0.30 M€	0.6 M€	0.17 M€
20 000 p.e.	0.7–1.4 M€	1.4 M€	1.8 M€	0.79 M€	0.35 M€
100 000 p.e.	3–5.2 M€	6.8 M€	7.5 M€	3.5 M€	1.3 M€
Total cost (€/m^3)					
2 000 p.e.	3–3.9 €	0.88–1.05 €	0.97 €	0.88–1.05 €	0.48–0.8 €
20 000 p.e.	0.6–0.97 €	0.6–0.88 €	0.50 €	0.4–0.7 €	0.20–0.30 €
100 000 p.e.	0.44–0.66 €	0.44–0.6 €	0.50 €	0.30–0.52 €	0.16–0.18 €
Operational electricity consumption (kWh/m^3)					
	0.1–0.5	<0.01	0.01–0.05	<0.01	0.1–0.3

The Swedish study estimates the total costs of upgrading all WWTPs in Sweden (greater than 2 000 p.e.) between 46 million € (41 million kronor) and 2.3 billion € (2.1 billion kronor) per year. This corresponds to approximately 62 - 540 € (55-480 kronor) per household per year (SEPA, 2017).

Another study commissioned by STOWA (Dutch Foundation for Applied Water Research, compared the costs of different advanced water treatment techniques in the Netherlands, Germany and Switzerland (Mulder, 2015). When taking into account the differences in calculation methods (e.g. population equivalents, treated amount of effluent, use of

[6] Treatment costs per cubic metre of treated effluent (SEK/m^3) are calculated by dividing the total Annual investment costs and operation costs by the total annual effluent treated by the WWTP. The dimensioning flow used for all facilities is 150 m^3/ (p.e. / year).
[7] Granular activated carbon
[8] Powdered activated carbon
[9] Biologically active filtration

already existing processes, cost structures, etc.), key findings from the report indicate that the calculated costs are similar across the three countries (Table 4 and Table 5).

Table 4: Cost comparison – Netherlands and Germany for micropollutant removal (m^3/per WWTP effluent)[10]

Equivalent		Netherlands	Germany
Capacity p.e. – NL (150g TOD)[11]	Capacity p.e. – DE (60g BOD)[12]		
20 000	14 000	0.22 – 0.26 € ± 0.05 €	0.21 € ± 0.08 €
100 000	70 000	0.18 – 0.20 € ± 0.05 €	0.19 € ± 0.08 €
300 000	210 000	0.16 – 0.18 € ± 0.05 €	0.14 € ± 0.08 €

Table 5: Cost comparison – Netherlands and Switzerland for micropollutant removal[13]

Treated capacity: > 80%	**Total costs**	**Costs per Swiss p.e.** (120g COD)[14]	**Costs per Dutch p.e** (150g TOD)[11]
4 500 000 p.e. CH	66.5 M€	14.30 €	12.40 €
13 500 000 p.e. NL	150 -190 M€	12.80 – 16.20 €	11.10 – 14.10 €

Other cost figures identified through the literature review that can provide additional insights on the overall cost implications of advanced water treatment technologies indicate the following figures:

- Traditional wastewater treatment = 0.17 €/m^3, with 47% of residues left after treatment
- Reverse osmosis = 0.48 €/m^3, with 4 % of residues left after treatment
- Powered activated carbon = 0.65 €/m^3, with 3% of residues left after treatment
- Ultraviolet (UV) irradiation = 0.35 €/m^3, with 13% of residues left after treatment
- Ozone: 0.23 €/m^3, with 2% of residues left after treatment[15]

The above figures should however be considered with caution and could be misleading, due to potentially vested interests of the source for these figures. The data listed above is provided by Primozone, a Norwegian based company specialised in ozone technology.

[10]Mulder (2015). The cost calculations in the Mulder (2015) study are based on the study: UBA (2015). Measures to reduce micropollutants entering aquatic environment [Masnahmen zurVerminderung des Eintrages von Mikroschadstoffen in die Gewasser, Umweltbundesamt Dessau-Roslau, and Januari 2015].
[11] TOD= total oxygen demand / 1 p.e in the Netherlands = 150g TOD
[12] BOD= biochemical oxygen demand / 1 p.e. in Germany = 60g BOD
[13] Mulder (2015). Estimations provided: removal per m^3 incoming wastewater, based on removal of indicator substances of the BAFU, 2012 study (Diclofenac, Carbamazepine, Sulfamethoxazole, Benzotriazole, Mecoprop). Cost calculations based on the study: BG Ingenieure und Berater AG (BAFU), 2012. Planning and Financing for the elimination of micropollutants in waste water.
[14] COD= chemical oxygen demand/ 1 p.e. in Switzerland = 120g COD
[15] Micropollutants "Cost of treating water micropollutants". Accessible at: http://micropollutants.com/Portals/0/Downloads/Cost-of-treatment-water-micropollutants.pdfs

4.2.1 Costs for drinking water treatment

The presence of micropollutants and microplastics in the aquatic environment not only affects the costs for wastewater treatment, but also those of drinking water operations. Drinking water can be produced from both groundwater and surface water sources depending on the geographic context. Similar to wastewater treatment technologies, conventional drinking water treatment processes (e.g. sand filtration, flocculation etc.), which were primarily developed for the removal of pathogens and nutrients, have proven inefficient in the removal of many micropollutants. Advanced treatment processes such as nanofiltration and reverse osmosis membrane can more efficiently decrease the levels of micropollutants in raw water sources, however complete removal is not always achieved and the effectiveness of treatments generally decreases with usage and time (Tröger 2018). Their practical use in full-scale drinking water treatment plants (DWTP) can be problematic in the case of high micropollutant concentrations in the retentate, which can eventually lead to human exposure and bioaccumulation of hazardous compounds, particularly in the case of perfluoroalkyl substances (PFASs).

Furthermore, much of the drinking water produced from groundwater or spring water only require minimal treatment making it a natural product containing many valuable minerals. Drinking water produced through reverse osmosis would require re-mineralisation turning it into an artificial product. In addition, advanced drinking water treatment processes may require additional costs in terms of investments for upgrades to DWTP, operations and training. Figures on drinking water costs associated with micropollutants resulting from the agriculture sector are summarised below (EurEau, 2016):

- **Austria:** In Austria, a relatively small portion of the country's water resources (approximately 7%) is treated because of the generally high quality of drinking water resources (ground water, spring water). In cases where drinking water sources must be treated due to, for example, elevated nitrate levels caused by agricultural activities, cost estimates from a regional water supplier (supplying 6% of the Austrian population) indicate investment costs of almost 14 million € (over a 16 year period from 1998 – 2014) for establishing treatment plants (membrane filters in combination with activated carbon). Operating costs were estimated at approximately 0.40 €/m³. Costs for the construction of new wells, regional drinking water pipes and mobile membrane filters were not included in these figures.
- **Denmark:** In Denmark, drinking water treatment costs associated with the presence of micropollutants in water sources are difficult to estimate because of national and regional specificities. There are only a small amount of the Danish drinking water suppliers that have extended water treatment. The number is rising though, due to increasing problems with emerging substances, primarily metabolites from pesticides and biocides. Water prices are set to reflect a variety of parameters such as infiltration rates to aquifers and the percentage of the catchment areas which are subject to certain measures. Further, some costs are covered through public and government funds e.g. taxes for planning costs. Nonetheless, significant efforts are made by the national government to regulate groundwater sources (and therefore the use of fertilisers and pesticides) due to the fact that about 2/3 of the area in Denmark is farmland. Measures to reduce nitrate leaching to groundwater can vary from a few thousand Euro to 20 000 € per hectare (lump sum); and costs for protecting groundwater against pesticide pollution can range from 2 000 € to 10 000 € (lump sum) depending on the crop system and proximity to abstraction areas. Other important costs include rising drinking production costs, protection of groundwater sources, administrative expenses required

for planning, monitoring and enforcement activities and public awareness raising campaigns on groundwater protection issues.

- **Germany:** In Germany, costs related to nitrate elimination when treating raw water for drinking water purposes vary between 0.10 €/m³ and 0.50 €/m³.

4.2.2 Reduced sludge quality and circular economy options

Sludge refers to the residual, semi-solid material that is produced as a by-product during treatment of industrial or municipal wastewater. EU policy has placed priority on the use of sludge on land – for agricultural for example – to utilise the resource value of organic matter and nutrients, and to avoid the use of incineration if possible, which would promote the transition to a circular economy. However, the use of sludge on land must abide by **strict quality standards**, due to the possible presence of heavy metals and pathogens, which is highly dependent on factors such as the nature of the catchment of sewage treatment works (i.e. presence of industries, hospitals, abattoirs, combined drainage etc.) and the type of advanced treatment technique applied. The content of different pharmaceutical residues and other hazardous substances in the sludge resulting from advanced treatment impacts the quality of the sludge that is produced (SEPA, 2017). Other considerations for sludge use includes potential problems of odour, litter (screenings) and bulk (high water content).

Despite the considerable advances in control and treatment technologies, albeit with increased costs, sludge quality remains one of the principal constraints on sludge use particularly as quality standards continue to be tightened.[16] Sludge managers are therefore faced with the challenge of finding cost-effective and innovative solutions whilst responding to ever-growing environmental, regulatory and public pressures. Sludge production will continue to increase as new sewage treatment works are built and effluent and environmental quality standards are tightened to reduce nutrient emissions. In the case that future quality standards for sludge and its application are made too stringent, the agricultural outlet may no longer be a viable option for the water utility sector, resulting in sludge being disposed of by other means that offer the utilities greater operational and financial security, but which may be less sustainable in the long-term[17].

4.2.3 External costs & benefits of avoiding the release of pollutants in the environment

Chemicals undoubtedly play an important role in today's society, to support human health, agricultural production, manufacturing, construction, and many other industrial sectors. Nevertheless, the expanding use of chemicals poses risks to the environment and human health. As such, the costs of additional treatment should be weighed against the benefit of removing micropollutants and microplastics from wastewater or drinking water resources. In order to evaluate the trade-offs between the benefits brought by the production and application of chemicals and the costs associated with the negative impacts that result from their unsustainable use and presence in the environment, robust information would

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[16] European Commission, DG ENV (n.d.). Workshop on sludge papers, Session 3: Technology and Innovative options related to sludge management. Accessible at: http://ec.europa.eu/environment/archives/waste/sludge/pdf/workshoppart4.pdf

[17] European Commission, DG ENV (n.d.). Workshop on sludge papers, Session 3: Technology and Innovative options related to sludge management. Accessible at: http://ec.europa.eu/environment/archives/waste/sludge/pdf/workshoppart4.pdf

be needed on the price involved in the production and use of chemicals, of current levels and effects of chemicals once they are placed on the market, society's willingness to accept the risks and a clear knowledge of the major entry routes of micropollutants and microplastics to water bodies. Further, micropollutants often occur in the environment not as single compounds, but in mixtures with many other chemicals. Whereas individual substances may be present in concentrations too low to cause effects, additive or synergistic effects due to the presence of other substances can cause detrimental impacts on organisms (Institute of Water Policy 2011). The relatively limited number of studies and information on these aspects hinder a more robust evaluation of the benefits associated with the reduction of these substances in drinking water or wastewater through updating treatment plants with new and often costly advanced treatment technology (Baltic Sea Centre, 2018).

The costs of advanced water treatment as discussed in the previous section have been evaluated by several studies, however, less information is available regarding the benefits of removing known and unknown substances from our water sources. This is a key challenge of environmental policy in terms of being able to evaluate the monetary quantification of its nonmarket values (costs and benefits). Nonmarket values have been estimated in some studies by measuring **peoples' willingness to pay** for the protection of for instance water resources or the estimated socioeconomic value of these resources. The only study identified by the research team that attempts to quantify the potential benefits is the study carried by Logar et al., 2015 and study published by DG Environment on the Economic Value of Water (Ecorys 2018). Although, these surveys indicate that economic benefits exceed the costs of additional treatment, the actual value of this precaution is very difficult to estimate (Baltic Sea Centre, 2018).

As one of the few countries that have implemented a nation-wide policy on reducing micropollutants in waste water treatment plants, experience from the Switzerland case can provide some insights on the costs and benefits. A recent study published by the Swiss Federal Institute of Aquatic Science and Technology, estimated the benefits of reducing micropollutants loads from wastewater. The results of the study show that despite high uncertainty surrounding the impacts of micropollutants, Swiss households are willing to pay a substantial amount of money on top of their current water bill for their reduction (Logar 2015). Findings of the study indicate that the estimated annual cost for upgrading 123 sewage treatment plants (STPs)[18] is CHF 133 million (€ 117 million) or CHF 86 (€ 76) per household. The average willingness to pay per household for reducing the potential environmental risk of micropollutants is CHF 100 (€ 73) annually, which generates a total annual economic value of CHF 155 million (€ 137 million). Based on the figures of the report's cost-benefit analysis, the benefits (€ 137 million), calculated based on willingness to pay, outweigh the costs (€ 117 million), thereby justifying the investment decision from an economic point of view and supports the implementation of the national policy in ongoing political discussions (Logar, 2015).

The DG Environment study estimated the indirect use value of water, which the study defines as the benefits of water to people's wellbeing that are not included in market prices. Under a hypothetical scenario of reduced access to water, the use of alternative strategies

[18] These costs comprise investment and operating costs, including the increased energy consumption required by the implementation of new technologies.

or technologies would increase the costs of water by 15 to 55% (Ecorys, 2018).The above findings should however be considered carefully as the methods used to measure the potential benefits via people's willingness to pay, is based on stated preference surveys. A major criticism of stated preference methods is their **hypothetical nature and potential overestimation** of stated preference values compared to real market payments (Logar, 2015). The Avoided Cost methodology used in the DG Environment study to calculate indirect use value is subject to high uncertainties due to significant data gaps, scope constraints and the definition of the alternative situation (Ecorys, 2018). In addition, it is important to highlight the significance of national and local specificities and associated public perspective. In Switzerland, for example, many of the receiving waters are also drinking water sources (SEPA, 2017), which is a factor that could affect general public perception of water quality. Further, the cost estimates in the study are based on several assumptions and scenarios and not on real cost data. Certain elements of the report could be utilised as a basis for future assessments and calculation models, however careful attention must be made in terms of extrapolating the findings in the context of other countries due to national specificities such as different development stages and awareness levels.

Other indications that could provide some insight on the potential price of inaction include cases of drinking water reservoir contamination, increasing water scarcity and increased policy priority on protecting water resources and their safe reuse. Further, there are many examples of the substantial costs (financial, but also health and environmental) and the technical difficulties of the remedial actions needed to clean-up polluted areas.

Finally, another factor that merits consideration is the potential impact on other economic sectors such as product manufacturers and the advanced water treatment solution sector. For example, measures to reduce or prevent the release of certain substances into the aquatic environment could drive certain manufacturers to use alternative substances (see section 6.2.1) or adopt different production practices. In cases where producers are faced with higher costs for the use of alternative (and less toxic) substances and materials, these additional costs could be potentially passed on to the consumer in the final purchase price of the product. Concerning the water treatment solutions sector, potential impacts could include new market and research opportunities for more cost-effective treatment technologies. As such, the potential impacts on other sectors is another aspect that needs to be further investigated in order to obtain further information on the potential external costs and benefits of avoiding the release of pollutants in the environment.

4.3 Key stakeholders

Table 6 summarises the key stakeholders concerned in regards to their relevance to EPR and products that release micropollutants / microplastics into the aquatic environment during their life-cycle. Please refer to the study Module 3 report for in-depth overview of the main feedback received during the dedicated stakeholder consultation.

Table 6: Roles and responsibilities of key stakeholders

Stakeholder group	Role and potential impacts
Manufacturers (including suppliers and distributors or retailers)	- Key emission sources/ manufacturers of products from which micropollutants / microplastics are released into the aquatic environment

Stakeholder group	Role and potential impacts
	- Compliance with existing national and European legislations related to limits of use of certain substances, disposal requirements, etc. - Responsible for placing products put on the market
European Institutions: • EMA • EC • ECHA • Etc.	- Approval for products placed on the market - Regulations on substance concentrations and use in different applications, monitoring and reporting obligations - Scientific and technical assessments
National/ local MS authorities: • National environmental, public health, transport and urban planning agencies	- Responsible for implementation of relevant MS and EU level legislation - Surveillance of national waterbodies to ensure water quality standards
Consumers or end-users: • Hospitals, pharmacists, patients • Households (habitants) • Businesses • Agriculture	- Entry pathways of micropollutants into water bodies (product disposal) - Purchase and consumption of products (use-phase) that emit micropollutants into the aquatic environment - Use and release of substances through agricultural activities (farming, breeding, application of pesticides)
Waste management and drinking water sector: • Drinking water producers • Wastewater treatment operators • Municipal waste management sector	- Compliance with existing national and European legislations related to water quality standards - Responsible for collection, treatment and proper discharge of different waste streams (microplastics from single use plastic products, unused pharmaceuticals, unused potentially hazardous substances)

5. Emission sources and pathways

A detailed overview of the different **emission sources** and **entry pathways** of micropollutants and microplastics found in the aquatic environment is particularly important when considering extended producer responsibility principles, as it can trace back dangerous substances to the associated product that was placed on the market.

5.1 Overview of emission sources & entry pathways

Emission sources refers to the product (final and/ or intermediate) that is placed on the market (by manufacturers, importers, retailers or distributors), which ultimately releases micropollutants and microplastics to the aquatic environment during one or more life cycle stages. In general, micropollutants and microplastics are released into the aquatic environment from two types of sources: point sources or diffuse sources. Point source pollution comes from a specific source, such as wastewater discharged from industrial sites (effluents). Point source pollution is usually easy to identify. This study focuses specifically on micropollutants and microplastics that enter the waterways through **nonpoint or diffuse sources**, meaning that the substances come from many different sources (e.g. a wide range of products placed on the European market), released (entry pathways) from different entry points and locations e.g. via households, businesses and industry, etc. and consequently transported throughout the water cycle e.g. through wastewater, run-off, melting snow and rainwater. Nonpoint source pollution is difficult to pinpoint, and therefore control and monitor because of the difficulty of tracing it back to the original source of pollution.

Although the concentration of pollutants from diffuse sources may be lower than the concentration from a point source, the total amount of a pollutant delivered from nonpoint sources may be higher because the pollutants come from many places. It also varies over time in terms of the flow and the types of pollutants. The water catchment area where the micropollutant is most frequently detected presents the highest risk in terms of contamination and the possible adverse health and environmental impacts.

"Approximately 10 to 33 % of prescribed medicines are **not consumed**. Due to a lack of safe and secure disposal options, 30% of consumers dispose of unused medicines through the household trash or toilet."
- Bicket, 2017

Entry pathways describe how substances are released (e.g. during use phase, processing phase, etc.) and where it finds itself in the aquatic environment (e.g. surface waters, groundwater, etc.). The entry pathways of micropollutants and microplastics found in waterbodies vary greatly and depend on factors such as how the substance is used or where they are produced or applied. Table 7 summarises the different entry pathways for the micropollutants and microplastics released by the product categories assessed. The following section provides specific details of the most significant entry pathways as identified in existing literature.

Table 7: Main entry pathways for micropollutants

Entry pathways	Description
Urban wastewater treatment plants	Urban waste water generally constitutes domestic waste water from households, and wastewater from offices and public facilities including hospitals and retirement homes. Therefore, urban wastewater treatment plants receive a cocktail of substances stemming from pharmaceuticals, personal care products, household chemicals and microfibers from textiles. It can also treat run-off rain water in the case of combined sewer systems (explained below). As these plants are not designed to treat micropollutants and microplastics, they represent a major entry pathway of these substances in the aquatic environment. Further details on substance removal efficiencies are provided in section 6.2.1
Industrial wastewater plants	This entry pathway refers to plants' effluent containing substances that are mainly emitted in industrial effluents from manufacturing processes. These industrial processes emit micropollutants both during the manufacturing of substances and/ or the substance's use as a component for the manufacturing of the final product.
Combined sewer overflows	Combined sewer systems which collect rainwater runoff and domestic sewage in the same pipe, can receive higher than normal flows during heavy rain or snow storms. Thus, these sewers are designed to overflow occasionally and discharge excess wastewater directly to waterbodies. These overflows, also known as combined sewer overflows (CSO), contain numerous untreated substances including micropollutants and microplastics emitted from the wear and tear of tyres from road run-offs.
Agriculture	Agricultural areas constitute another important diffuse source for potentially harmful substances emitted from the use of and/or disposal of veterinary pharmaceuticals and pesticides. Such substances are emitted into the water cycle via run-off through the application of pesticides and in some cases via the absorption of pesticide products by plants. Other entry pathways from agriculture include the spreading of manure or contaminated sludge on agricultural fields causing leaching to surface waters and groundwater.
Waste (landfill)	Waste from landfill areas can potentially leach out and emit micropollutants directly into the water cycle (particularly groundwater sources). These may include in particular chemical wastes from the manufacturing processes, expired or unused pharmaceutical products and products containing PFAS.

5.2 In-depth overview of emission sources and pathways of selected product categories

Pharmaceuticals

The study focuses specifically on herbicides and insecticides (in particular neonicotinoid insecticides), several of which are included in the current EU watch List of substances to be monitored in surface waters. Herbicides are generally more frequently detected and found in larger concentrations than fungicides and insecticides, reflecting differences Pharmaceuticals are the source of many major chemicals that are emitted into waterbodies. The impact of the presence of active pharmaceutical ingredients has been underestimated for many years – that is until the discovery of synthetic estrogens in sewage effluents as a cause of the feminisation of fish in the late 1990s. Studies have also uncovered high concentration of analgesics, antibiotics, and psychiatric drugs in the environment at levels, which research indicates is dangerous for wildlife, in particular the aquatic environment. Antibiotics and growth hormones used in medicines initially destined for human consumption are also used as veterinary medicines, increasing the emission sources of these substances in the environment. Moreover, wastewater treatment plants, representing a main pathway for their release into waterbodies, are not equipped to treat these substances.

In terms of pharmaceutical sales, the EU is second only to the United States, accounting for 25% of the world pharmaceutical sales for human purposes, and 31% for veterinary purposes. The sector represent approximately 3000 different ingredients in the EU, including antibiotics and macrolide antibiotics, hormones/ synthetic estrogens, analgesics (NSAIDs), antidepressants and many more, for human consumptions (therapeutic or diagnostic purposes) (Ternes, 2006).

Due to their adverse effects on aquatic organisms, the EU is focusing the watch list on substances linked to pharmaceuticals through the Water Framework Directive (2000/60). In particular, the updated watch list[19] includes the sex hormones 17-beta-estradiol (E2) and estrone (E1), the contraceptive hormone 17-alpha-ethinylestradiol (EE2), and macrolide antibiotics (erythromycin, clarithromycin and azithromycin) and other antibiotics (amoxicillin and ciprofloxacin). The Directive also requires the European Commission (hereafter the "Commission") to quickly come forward, with proposals for a strategy for dealing with pharmaceuticals. Control-at-source measures must have priority and covers actions such as the phasing out of particularly harmful substances for which alternatives exist, eco-design, ban of over-the-counter sales etc.). As this may not be sufficient, other measures down the supply chain (doctors, hospitals, pharmacies, WWTP) may need to be considered. For those cases, EPR could be an effective way to limit the release of these products in the aquatic environment.

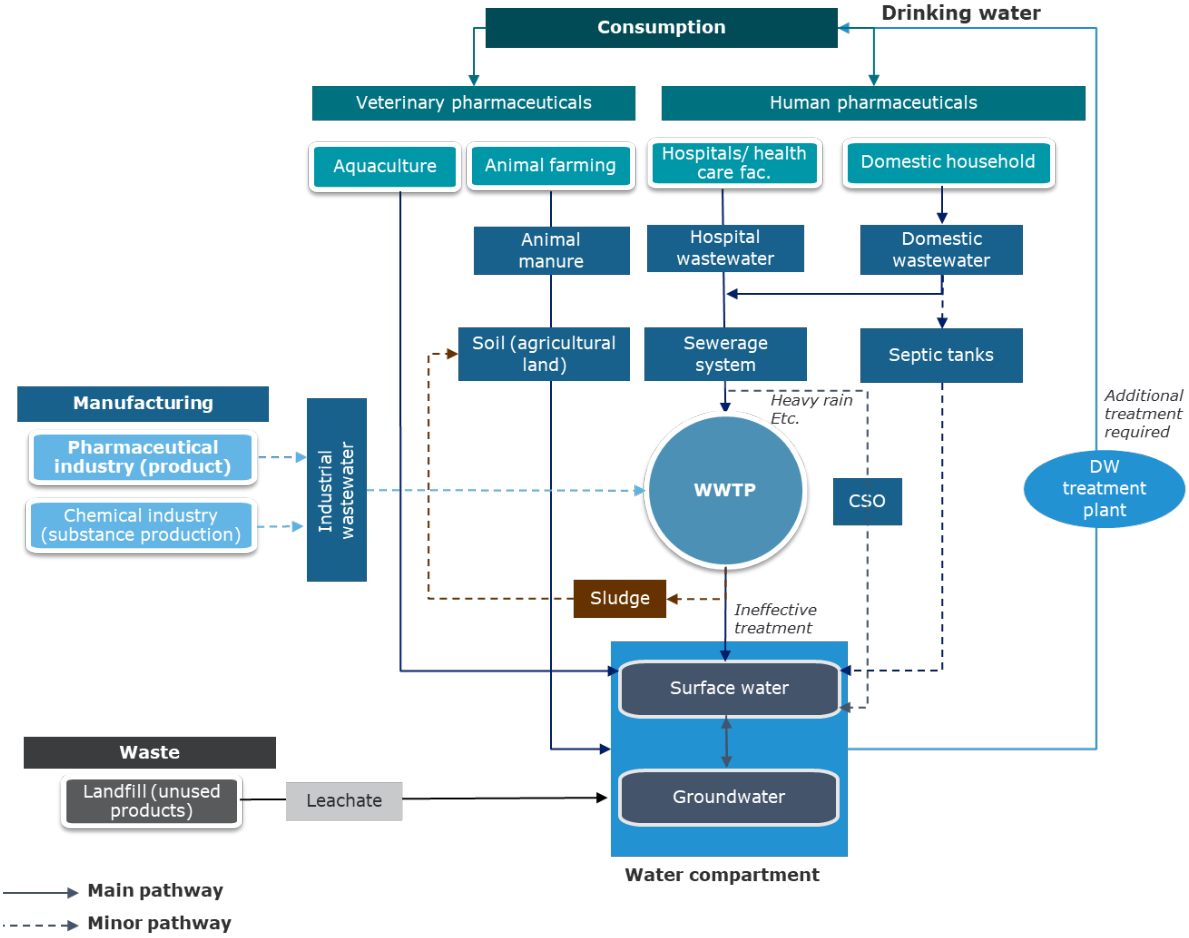
In Europe and the United States, the consumption phase of pharmaceuticals is considered to be the most significant contributor to the emissions of medicinal products into the environment, notably through excretions (between 30% and 90% of an orally administered

[19] An updated surface water Watch List was adopted by the Commission in July 2018

dose is generally excreted as an active substance in the urine of animals and humans) and incorrect disposal of unused medicines e.g. via sewer systems through sinks and toilets (EC, 2016b). The main entry pathways include (see Figure 2):

- **Domestic households** are the main entry pathway of harmful substances from pharmaceuticals in the aquatic environment, through excretion and incorrect disposal of the expired medicines and their leftovers. These substances are emitted in the sewerage system and, depending on the substance, ineffectively treated by urban WWTPs.
- **Hospitals** are also considered as one of the main emission source of pharmaceuticals related-substances into the water cycle. Most hospitals are, in fact, not specifically equipped with waste water treatment infrastructure to immediately treat their effluent after discharge. As such, a large amount of chemicals resulted from healthcare services (hospitals, long-term care facilities and other medical facilities) are discharged directly into the urban wastewater system.
- **Combined sewer systems**, which are generally designed to overflow in case of heavy rain for example, is also an entry pathway of numerous untreated pollutants into waterbodies including pharmaceuticals. The significance of CSO as a pathway for micropollutants will vary from one location to another depending on wet weather conditions.
- **Unused or expired medicinal products**, if disposed in landfilling areas, could lead to the release of substances in waterbodies. In fact, once discarded in municipal solid waste, pharmaceuticals within a landfill may undergo degradation, adsorption, or enter the leachate and eventually exit the landfill (Metzger, 2004). In case of no collection of the effluent, this may be a source for contamination of surface water or groundwater (Kalyva, 2017).
- **Veterinary use of pharmaceuticals,** e.g. for animal farming (in particular, large intensive animal farms) and aquaculture, is also a major emission source of pharmaceuticals in the aquatic environment. In such case, significant amounts of micropollutants can be emitted through excreted animal faeces; up to 75% in animal faeces according to some studies (BIO 2013). Harmful substances stemming from veterinary pharmaceuticals are released into the water cycle depending on their application. For example, when applied in animal husbandry (agricultural activities involving the breeding and raising of livestock animals on land), they are released into the soil environment, where over time, residues from these veterinary drugs accumulate in the soil or drain into groundwater or surface water (UBA 2014) or through the spreading of contaminated manure on land. Veterinary pharmaceuticals used in aquaculture (cultivation of freshwater and saltwater populations- fish, crustaceans, algae, etc. - under controlled conditions) directly enter surface waters.
- **Industrial chemical residues** from medicines manufacturing processes could also enter the water cycle through direct discharge (in industrial wastewater) or indirect discharge (in case of leakage). In Europe, this entry pathway is minor compared to the others.

Figure 2: Entry pathways for pharmaceuticals (human and veterinary medicines)



Pesticides

The study focuses specifically on herbicides and insecticides (in particular neonicotinoid insecticides), several of which are included in the current EU watch List of substances to be monitored in surface waters. Herbicides are generally more frequently detected and found in larger concentrations than fungicides and insecticides, reflecting differences in mobility in the environment (Sandin, 2017). In the case of neonicotinoids, their use has been prohibited in the EU on May 2018. However two of these substances, including thiacloprid (candidate for substitution) and Acetaprimid, can be used with some restriction.

Generally speaking, pesticides refer to any chemicals that is intended to kill or control pests. This includes herbicides (weeds), insecticides (insects), fungicides (fungi), and nematocides (nematodes), rodenticides (vertebrate poisons) amongst others. Pesticide products are mainly used for agricultural purposes – as a plant protection product (PPP), one of the few activities where chemicals are intentionally released into the environment. Other uses for pesticides (non-professional uses for home gardening purposes, for instance) have also been identified and can be a major source of emission depending on the product.

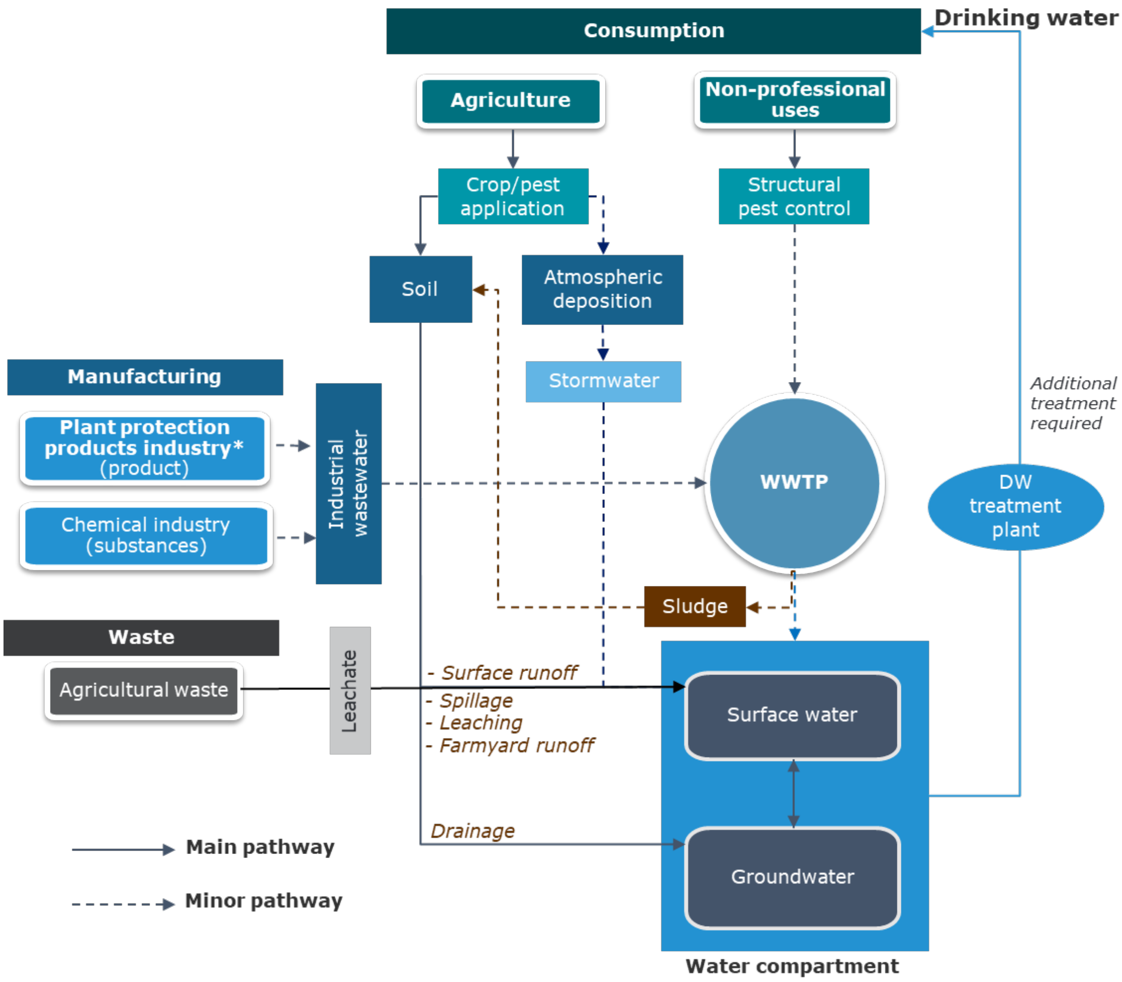
In terms of use, pesticide use in the EU has not decreased despite much of the recent debate on the sustainability of agricultural activities. In 2016, almost 400 000 tonnes of pesticides were sold in Europe, with the vast majority used in the agricultural sector (Eurostat, 2018).

Regarding the impacts, although terrestrial impacts by pesticides do occur, the principal pathway that causes harmful ecological impacts is that of water contaminated by pesticide runoff. The impact on water quality is associated with different factors including the chemical, microbial or photochemical degradation of the active ingredient in pesticide formulation. The Netherlands National Institute of Public Health and Environmental Protection (RIVM, 1992) concluded that *"groundwater is threatened by pesticides in all European states. It has been calculated that on 65% of all agricultural land the EU standard for the sum of pesticides (0.5 mg/l) will be exceeded..."* Pesticides are also degraded into toxic metabolites biologically active, which can be detected in water sources and wastewater effluents at higher concentrations (Gavrilescu, 2015). These products are thus a serious issue to drinking water services, as they are directly released in water in general.

Pesticides can reach waterbodies along several pathways, originating mainly from point sources such as farmyard runoff or wastewater treatment plants, and also from surface runoff and leaching to field drains or to groundwater, or as diffuse losses due to spray drift and atmospheric deposition. Generally the largest concentrations of these substances occur during rainfall-induced high-flow conditions (Neumann, 2002; Petersen, 2012).

- Pesticides could be mainly emitted to the natural environment from farmyards runoff due to improper waste disposal or accidental spills, and also wastewater treatment plants. Some studies have showed that these point sources account for 20-80% of total pesticide loads to surface waters (Holvoet, 2007). It has been assumed in most cases that wastewater treatment plants are minor entry pathways of pesticides into the water cycle. Those reaching wastewater treatment plants originate from industrial discharges (manufacturing processes), and urban activities using these substances e.g. in households gardens. Munz (2017) however found elevated concentrations downstream of WWTPs.
- These substances can also be transported with wind during spreading on crop and deposited, depending on meteorological conditions, on surface water through rainwater. However, the contribution from atmospheric deposition to pollution loads in surface waters is generally small compared with other entry routes (Sandin, 2017).
- Regarding surface runoff which is another main entry pathway of pesticides in waters, it occurs in case of infiltration-excess. In fact pesticides could be transported, dissolved in the aqueous phase, or adsorbed to eroded soil particles entrained in the flow. Infiltration-excess runoff then occurs when the rainfall intensity exceeds the local infiltration capacity and depression storage capacity of the soil. This can increase leaching of pesticides to groundwater (Sandin, 2017).
- Lastly, pesticides could be transported through drainage from fields to surface and groundwater. Drainage generally depends on soil clay content and can also occur in lighter-textured loamy soils (Sandin, 2017). Other transport sources include gardeners, imported plants and greenhouses.

Figure 3: Entry pathways for pesticides



PFASs (perfluoroalkylated substances)

Perfluoroalkylated substances (PFASs) are a family of more than 3 000 manmade fluorinated organic chemicals that have been widely used in various industrial and consumer applications since the 1950s, from chromium metal plating to various fire-fighting foams and for surface treatment of textiles, carpets and papers (OECD, 2015). The release of PFASs in the environment can occur during the manufacturing, the use and disposal of products containing these substances. Certain PFASs are persistent, bioaccumulative and toxic (CDC, 2018). Due to this risk to human health and the environment, PFOS are regulated as a persistent organic pollutant under Regulation 850/2004 (POP Regulation), and PFOA, its salts and PFOA-related substances were added to the list of restricted substances in Annex XVII to the REACH Regulation on June 2017. Perfluorohexane-1-sulphonic acid and its salts (PFHxS) was also added to the REACH candidate list of substances of very high concern as a 'very persistent and very bioaccumulative substance'.

In terms of market sales, the production of PFOA and its salts has been declining for the last three years. However, in 2016, PFOS and its derivatives were still being produced in

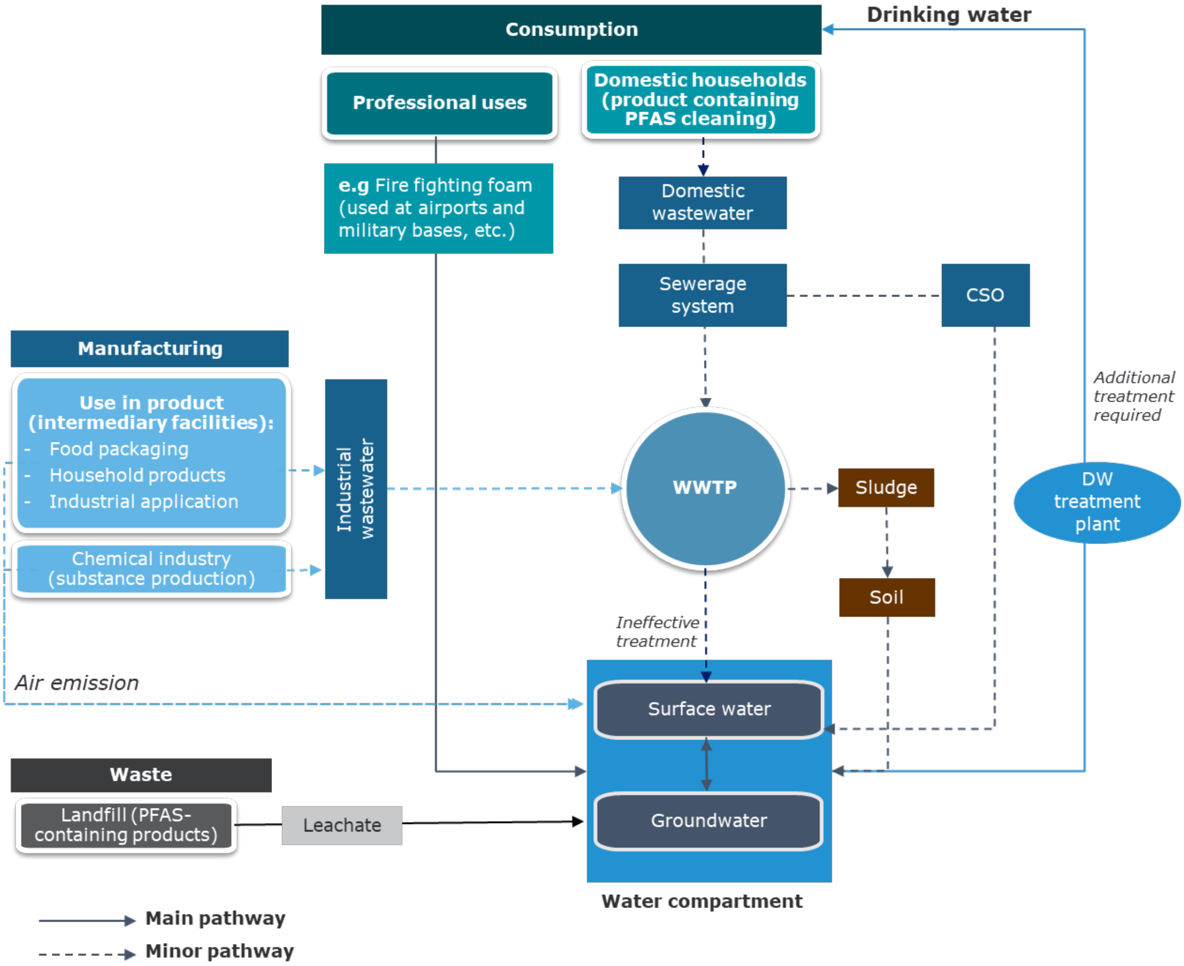
Germany, Italy, and China[20] (ITRC, 2017). The inclusion of these substances to the annexes of the REACH regulation has notably led to the decrease of their use in Europe. However, they are being replaced by short-chain PFAS, which are assumed to be less bioaccumulative but are more mobile comparing to long-chain PFAS and difficult to remove by wastewater treatment and drinking water treatment plants (Brendel, 2018).

PFAS are found in groundwater primarily as a consequence of contamination of soil by fire-fighting foams. However, they can also result from industrial point pollution, and stem from domestic household products during washing/clearing and end up in drinking water supplies (ITRC, 2017).

- Firefighting foams containing a mixture of PFAS, and used as fire suppression at military installations and civilian airports, as well as at petroleum refineries and chemical manufacturing plants, are a major entry pathway of PFAS into the aquatic environment. They enter in the water compartment through atmospheric deposition, surface runoff (and thus surface waters) and infiltrate to groundwater (Liu, 2016).
- PFAS can also be released from manufacturing facilities through air emission and dispersion, spills, and disposal of manufacturing wastes and wastewater. Several manufacturing sectors were identified to potentially release these substances including, textiles & leather, paper products, metal plating and etching, wire manufacturing, etc. (Liu, 2016).
- PFAS, in particular PFOA and PFOS, can be found in WWTP effluents, originating from consumers and industrial discharges (through the use of PFAS-containing materials), and also CSO depending on weather conditions. Conventional sewage treatment methods do not efficiently remove PFAS (Gallen, 2018).
- Disposal of waste generated during primary PFAS manufacturing (substance production) and secondary manufacturing using PFAS (use in product) can be sources of PFAS environmental contamination. Leachate from municipal solid waste landfills, has been shown to be another source of PFAS release (Benskin, 2012).

[20] In accordance to the Stockholm Convention on POPs, a grant from Global Environment Facility (GEF) was approved in 2017 to support the reduction of PFOS in China as well (ITRC, 2017).

Figure 4: Entry pathways for PFASs



Biocides

According to the Biocidal Products Regulation (BPR) *"a 'biocidal product' is defined as any substance or mixture, in the form in which it is supplied to the user, consisting of, containing or generating one or more active substances – or – generated from substances or mixtures which do not themselves fall under the first indent, to be used with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on, any harmful organism by any means other than mere physical or mechanical action. A treated article that has a primary biocidal function shall be considered a biocidal product"*. Biocides are classified into 22 biocidal product-types, grouped in four main areas:

- Disinfectants composed of five product-types including those intended to be incorporated in textiles such as silver;
- Preservatives used to prevent microbial and algal development and divided into 8 product-types such as wood preservatives; and
- Pest control products (7 product-types) and other biocidal products (two product-types).

As mentioned above, three relevant product categories and associated substances will be analysed to characterize the impacts of biocidal products used for non-agricultural purposes:

- **Silver** used as an antibacterial to "reduce odours" in sportswear
- **Triclosan** used as a preservative in cosmetics
- **Tolylfluanid** used as a wood preservation agent

The use of biocidal products has been growing in recent years, this is reflected in the increasing sales of antimicrobial hand-wash, cleaning products and even in sports sock textiles. However, at least 30% of biocides are endocrine disruptive, persistent, or carcinogenic, according to the Pesticide Action Network (PAN). They can also pose a risk for the environment (toxic to water organisms) (Balmer, 2004).

Biocides enter water systems via various routes, for example as preservative residues washed off building facades with rainwater, from consumer products during cleaning, or as disinfectants residues from clothes treatment and washing.

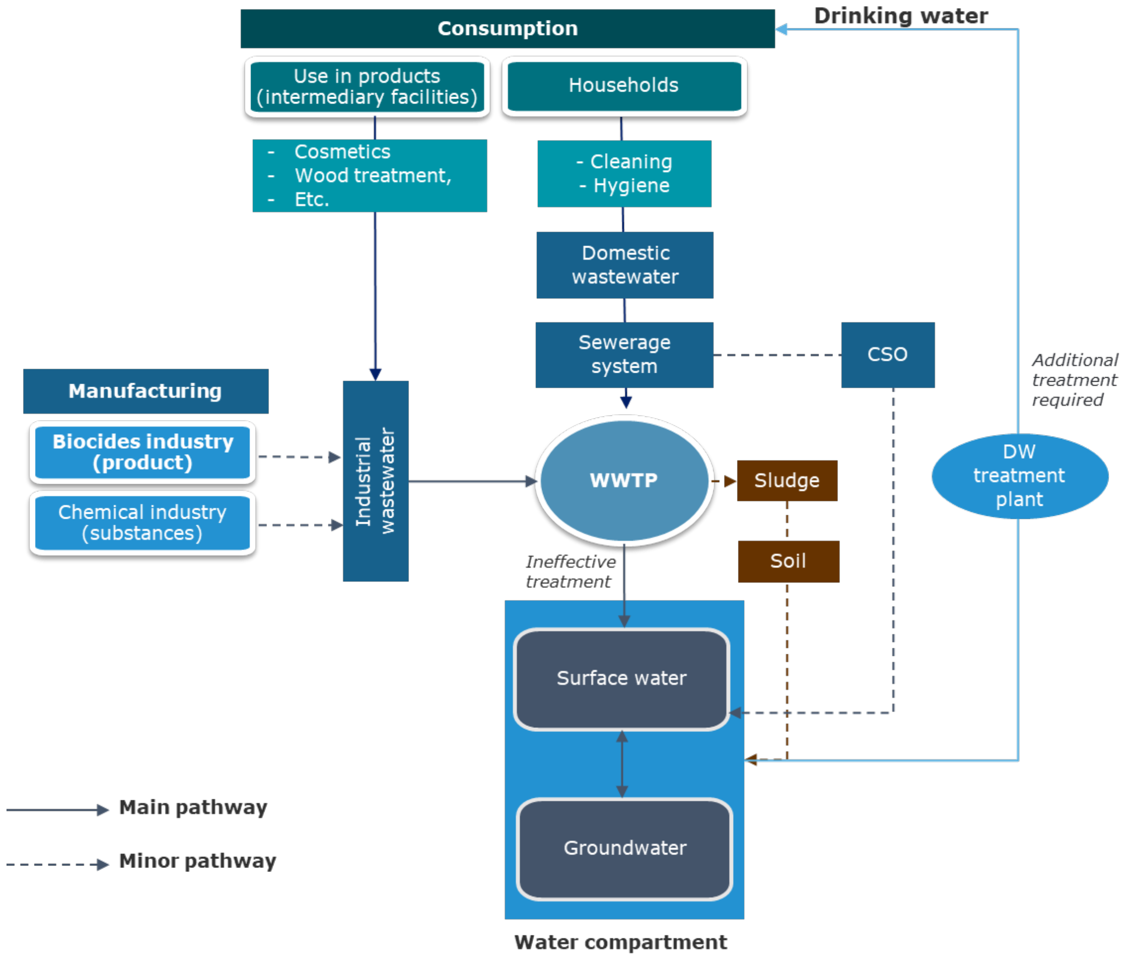
Biocides as disinfectants : silver

For many years silver has been known to be effective against a broad range of microorganisms. Today, silver ions are used to control bacterial growth in a variety of medical applications, and nonmedical purposes, such as anti-odour in sportswear. But some studies showed the emission of this metal in the water cycle and its adverse effects on the aquatic organisms due to its biocidal action. In fact, when washing sportswear a certain amount of silver leaches out, a significant part also stems from industrial activities (manufacturing and use in product). According to the Swedish Water & Wastewater Association (Svenskt Vatten), about 31–90 % of silver leach from the silver-treated clothing after ten washes, 10% is emitted in the receiving waterbodies and 90% of the silver is successfully separated by the treatment plants but contaminates sewage sludge which is generally used for agricultural purposes (Svenskt Vatten, 2018).

Silver has been shown to be highly toxic to the aquatic environment. At the laboratory level, silver ions have shown a low biodegradability (depending on physicochemical conditions) and were extremely toxic to aquatic plants and animals (WHO, 2002). Besides, the spread of silver in the environment may be contributing to the rise in antimicrobial resistance.

There are several different entry pathways for disinfectants to the environment because of its wide-range of use and presence in many different types of products. As such, Figure 5 mapping out the entry pathways for silver illustrates only one example of how disinfectants enter the environment.

Figure 5: Main entry pathway for silver as disinfectant (biocide)



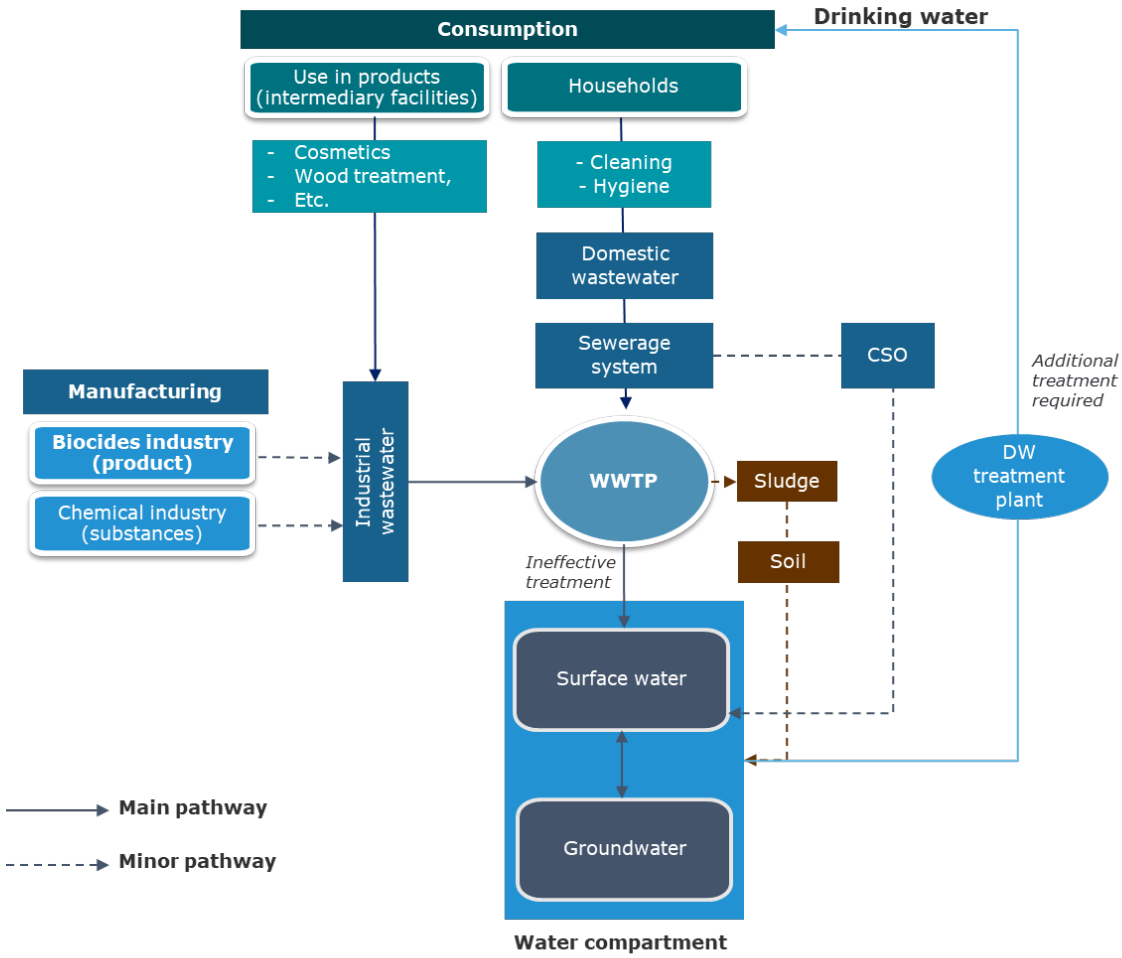
Biocides as preservatives : tolylfluanid (wood preservative) and triclosan (cosmetics preservative)

Tolylfluanid (TF) is a member of the phenylsulfamide family of fungicides. It was banned from use as an active agent in pesticides, but still approved for use as a wood preservative. Although tolyfluanid has been defined as non-bioaccumulative (ECHA, 2016), it is highly hydrophobic, strongly suggesting the capacity to concentrate in lipid-rich tissues. Besides some studies have shown that exposure to TF may promote the development of metabolic disease in humans (Endocrine Society, 2014).
Tolylfluanid is of concern from the view of drinking water production due to a transformation product (N, N-dimethylsulfamide) that can be converted to carcinogenic N-nitrosodimethylamine (NDMA) during ozonation of raw water for drinking water production. Moreover, the high mobility and persistency of N, N-dimethylsulfamide in water makes it a potential precursor of NDMA for a very long time (Committee on Biocidal Products 2009). TF can be emitted in waterways though manufacturing discharge, during product application and also from the use phase in particular treated-wood cleaning.

Triclosan (TCS) is a broad range antimicrobial agent used in many personal care products such as soaps, deodorants, toothpastes, etc. This substance has been reported in various environmental compartments including surface water and sewage water in many European countries such as Germany, and Switzerland. Once in the sewer system, they are transported to wastewater treatment facilities. Triclosan has been shown to undergo complete biodegradation in an activated-sludge treatment system (Ciba Specialty Chemicals, 2001). However, TCS may be biotransformed to a more slowly degradable methoxy-triclosan (TCS-OMe; 5-chloro-2- [2, 4-dichloro-phenoxy]-anisole) intermediate in wastewater treatment systems (Ciba Specialty Chemicals, 2001). TCS and its biotransformation by-products have been reported to have a low removal in the aquatic environment.

Regarding the entry pathways, this substance is mainly emitted in the sewage system from consumer uses (from cosmetics). A minor quantity is also expected to stem from the manufacturing process (producers) and intermediary facilities using the substance in their products.

Figure 6: Main entry pathway for preservatives (biocides)



Secondary microplastics emissions from textiles and tyres

Plastic use has increased exponentially since synthetic organic polymers were developed in the mid-20th century. Over 300 million tons are currently produced yearly to manufacture objects in plastic: 29 % in China, 19 % in Europe, 18% in North America, and 34 % in the rest of the world. The long-term average annual growth rate has been roughly 4% (PlasticsEurope, 2018). In addition to that, there are the plastics for other uses that are not accounted in these statistics such as synthetic fibres for textiles (37.2 million tons produced worldwide) or synthetic rubber for tyres (6.4 million tons produced worldwide) (IUCN 2017). A large number of these plastics ends up in the aquatic environment through different pathways. For example, Jambeck (2015) reported that between 4.8 and 12.7 Mtons of plastic are released globally into the oceans every year because of mismanaged waste, which can lead to microplastics (Eriksen, 2014); (Sebille, 2015).

There are two types of microplastics: primary and secondary microplastics. The distinction is based on whether the particles were originally manufactured to be that size or whether they have resulted from the breakdown of larger items. According to the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP, 2016):

- **The primary sources** of microplastics are manufactured microplastics that are designed for particular applications. These primary particles may be released from point sources such as plastic processing plants (production pellets or powders for injection moulding) or from more diffuse and regular source points such as populated places along rivers and coastlines (microbeads, industrial abrasives). As these microplastics are currently undergoing a regulatory review (REACH restriction proposed), the study focusses on secondary sources of microplastics, as described below.
- **The secondary sources** are microplastics created by fragmentation and degradation of macroplastics. For example, they can originate from the erosion of tyres when driving or stem from the abrasion of synthetic textiles during washing. There are also pre-production pellets, which are the second source of microplastics in Europe. Their release (estimated to 16 888 – 167 431 tonnes per year according to Eunomia), is not intended during normal operation but can occur in case of spills (e.g. when loading material from trucks) or during storage (Eunomia, 2018). Biobeads, which are used by WWTP to filter chemical and organic contaminants have been identified as another source of microplastics. Rough estimates based on UK data indicates that approximately 1 200—5 000 tonnes/ year is released into the environment (not including one-off spills).

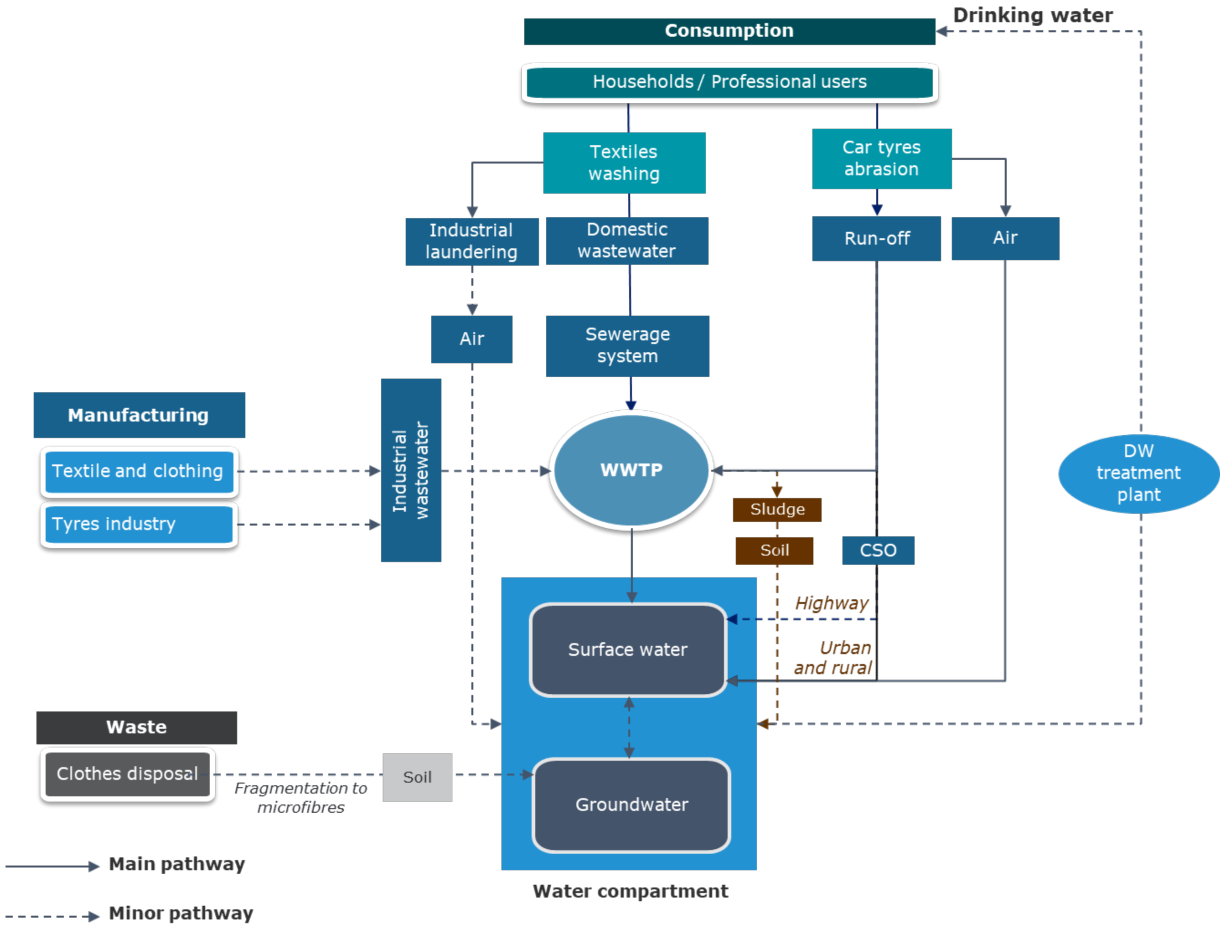
Regarding the impacts, the concern is focused not only on the effect of microplastics as such but also on additives and chemical contaminants absorbed by microplastics that may be released and affect negatively environmental health. Even though it has been assumed that microplastics have almost infiltrated all of the marine habitats and many species of wildlife, much of the impact evidence has been demonstrated in laboratory studies typically at high concentrations and there are only limited studies from nature (Rainieri, 2018). Hence, there is a clear need for further research regarding the impacts related to microplastic debris. Furthermore, a few studies also highlight the importance of microplastics as a potential transport route for other contaminants in the aquatic environment. For example, in the case where microplastics take up or absorb other substances in areas of high concentration, and then release (desorb) them as they move throughout the water cycle.

Several studies have suggested that wear and tear from car tyres and synthetic fibres from clothes are an important source of microplastics in the environment. An IUCN report showed that between 15 and 31% of the estimated 9.5 m tonnes of plastic released into the oceans each year could be microplastics, almost two-thirds of which come from the washing of synthetic textiles and the abrasion of tyres while driving (IUCN, 2017). Another study from Eunomia showed that automotive tyres and washing of clothing are the largest source of microplastics entering the aquatic environment (Eunomia, 2018). In fact, 503 586 tonnes of microplastics are generated from the wear of automotive tyres in Europe every year, and microfibres released from the washing of synthetic clothing in Europe have been estimated between 18 000 to 47 000 tonnes per year. These two sectors are therefore key sources of microplastic emissions into the aquatic environment. While wastewater treatment plants are not specifically equipped for microplastics treatment, a modern treatment plant with secondary treatment removes the large majority of them.

Eunomia's study also showed that the main entry pathways of car tyres are urban and rural roads drains, representing 80% of tyre wear emissions in Europe (highways account for 20%). Another major entry pathway of microplastics stemming from car tyres, is rubber particle dust (mainly <80 µm) which can end in surface waters (GESAM, 2016). In fact, a significant part of the dust is transported into the air as particulate matter, the rest lands directly on the road or adjoining land and from there a proportion enter surface waters or drains. For example, annual emission estimates of tyre rubber dust for Norway, Sweden and Germany are 4 500, 10 000 and 110 000 tonnes respectively (NEA, 2014). WWTPs are concerned by microplastics stemming from car tyres, as these pollutants may enter the sewer system through urban run-off. There is no evidence of drinking water pollution (from groundwater) by microplastics.

Regarding microfibers from synthetic clothing, the main entry pathway is domestic wash. Commercial laundering which is a minor entry pathway of microfibers accounts for 14% of the total washed domestically. It has been assumed that about 0, 9 g of fibres is released per wash in Europe. Browne (2011) also found that an estimated 1 900 synthetic microfibres were rinsed out of a single piece of clothing. Industrial laundering facilities have also been reported to likely expel microfibers to the atmosphere in unknown quantities, which can end up into surfaces water. They can originate from disposal, where clothes can undergo fragmentation processes and migrate from soil to the aquatic environment.

Figure 7: Main entry pathways for microplastics (tyres and textiles)



Part III. Relevance & applicability of extended producer responsibility

6. Existing measures to reduce micropollutants & microplastics emissions

Several policy measures and technical solutions are employed at EU, MS and international levels to reduce and/or avoid the release of harmful substances and microplastics to the aquatic environment, which are, however, not always sufficient.

6.1 Regulatory measures – control-at-source & quality standards

The two main policy approaches used at EU level to control and address the release of harmful substances into the aquatic environment include control and source measures and quality standards.

Control-at-source: Control-at-source measures consist of actions taken as far upstream as possible by implementing measures to reduce or even phase out substances and products that emit these micropollutants. Referring back to the EU Treaty, this approach must be the guiding principle when controlling the release of pollutants to the (aquatic) environment. The most sustainable and preferred solution is therefore to prevent pollutants – including microplastics - from entering the water cycle. Control at source approach involves the implementation of two types of actions including, legislative measures that regulate the placing on the market and the use of certain hazardous substances, and voluntary industrial initiatives (best practices) reducing micropollutant emissions.

Generally, regulatory measures are the starting point to promote control-at-source measures. It defines a framework and guides the chemical users to implement a pollutants release prevention strategy. The EU has implemented a stringent authorisation of chemicals through a number of product and substance-related regulations. These policies include environmental criteria in the authorisation procedures and a more controlled use of potentially harmful products. Source control also includes implementing best environmental practices (at industrial level) and disposal requirements, which also contribute to avoiding and reducing pollutants loads in the natural environment. Those practices are generally implemented to be compliant to the regulatory measures but can also be voluntary initiatives.

Quality standards: Quality standards refer to standards that set requirements, specifications, guidelines, or characteristics that must be complied with to achieve or maintain specific environmental quality objectives in the long term. For example, environmental quality standards that lay down the maximum allowable concentration of a substance in air, soil or water. At EU level, environmental quality standards in the context of water pollution are established under the Environmental Quality Standards Directive (EQSD), which covers a list of 45 priority substances. These priority substances have defined Environmental Quality Standards (EQS), i.e. concentration thresholds that should not be exceeded in the aquatic environment. The main provisions and requirements of the EQSD are described in the next section.

Limitations of control at source measures & quality standards

> "There has been a **dichotomy** in the pollution control approach at European level. **Each approach has potential flaws**. Source controls alone can allow a cumulative concentration of pollution sources, which is severely detrimental to the environment. Quality standards can underestimate the effect of a particular substance on the ecosystem due to the limitations in scientific knowledge on dose-response relationships and the mechanics of transport within the environment."

Despite existing regulatory measures and source control initiatives to reduce micropollutants and microplastics emissions into the waterbodies, the release and presence of these substances continue to be an issue at EU level.

In the EU, good chemical status for surface waters (rivers, lakes and transitional and coastal waters) is defined by limits set by environmental quality standards (EQS) on the concentration of certain pollutants, known as priority substances. In a recent report, the European Environment Agency (EEA) concluded that only 38% of European surface waters are in good chemical status, while 46 % have not achieved good chemical status and for 16 % with their status unknown (EEA 2018). In most Member States, a few priority substances account for poor chemical status, the most common being mercury. If mercury and other ubiquitous priority substances were omitted, only 3 % of surface water bodies would fail to achieve good chemical status. Improvements for individual substances show that Member States are making progress in tackling the sources of contamination.

Generally speaking, the introduction of control mechanisms takes several years and is not adequate or feasible in all situations: for example, in the case of requirements on the safe and sound disposal of pharmaceuticals from households, it is very difficult to implement realistic control mechanisms. Controlling every household and its respective pharmaceutical disposal habits on a regular basis would not be economically feasible for governments. Information campaigns on optimal usage, storage and disposal of chemicals may lead to behavioural changes. However, product-related regulations alone, or even coupled with changes in consumer behaviour, are unlikely to be sufficient to lower the release of the many thousands of chemicals that are used in different ways and can enter the water cycle over a variety of pathways.

There are also inconsistencies across certain policies, whereby potentially hazardous substances are not adequately addressed. For example, the sustainable use of pesticides directive aims at reducing the risks and impacts of pesticide use and promoting the use of Integrated Pest Management through the use of alternative approaches to pesticides. The directive actively contributes to the reduction of substances stemming from agricultural pesticides, however, does not cover biocide-based products, many of which are composed of similar active ingredients and properties.

Another limitation in current EU policies is the need to fully integrate a complete life cycle approach for products. Even though some stringent procedures, including binding tests on the ecotoxicological impacts, are being applied in the context of products/substances approval, in most cases regulation does not require producers to perform a full life cycle assessment (LCA) of such products, which prevents the possibility of a full assessment of the potential impacts of the substance or product in question. In the case of human medicinal products for example an Environmental risk Assessment (ERA) is required under the Directive on medicinal products for human use (Directive 2001/83) in order to obtain marketing authorisation. The ERA is based on the use of the product and the physio-chemical, ecotoxicological, and fate properties of its active substance. However, the results of the ERA does not constitute a criterion for refusal of a marketing authorisation (EMA, 2018). Instead, based on the outcome of the ERA, specific arrangements to limit the impact of the pharmaceutical on the environment should be considered e.g. product labelling, instructions for safe disposal and storage in patient leaflets, etc. This is not the case for veterinary pharmaceuticals, where a risk to the environment does lead to refusal of a marketing authorisation.

Further, other factors such as the high costs and time needed to monitor micropollutants, the insufficient enforcement and control of hazardous substances contained in imported products, along with global treaties that complicate compliance further exacerbate the problem of "free-riders".

Finally, a particularity of chemicals regulation is the issue of time. Regulation of chemicals is usually implemented on a case by case basis and takes several years. In many cases, regulation is enacted as a reactive measure, once there are demonstrated adverse impacts in the environment. In other words, the potential risks due to combination effects and effects of unknown degradation products are not currently considered in existing legislation at EU level.

The main limitation concerning quality standards is the general lack of data on concentrations of contaminants and the knowledge gap at European level of their ecotoxicological effects to demonstrate the significant risk to or via the aquatic environment, either individually or in combination with other substances. In addition, information on the sources and emissions of many pollutants remains incomplete and uncertain, limiting the scope for identifying and targeting appropriate measures. Other elements such as eutrophication, overfishing and climate related changes, combined with the lack of data mentioned previously make it difficult to assess for example the real-life status of different water bodies[21]. In the example of the EQSD, the number of priority substances (45) may not be sufficient to accurately evaluate the chemical status of different water bodies. The majority of assessments are based on only a few indicator substances, however more than a thousand chemicals have been identified in European waters, and are rarely monitored, despite their known or suspected adverse ecological effects.[22] Finally, it should be noted that apart from source control and quality standards, end-of-pipe requirements have been set. For example, the DWD sets parametric values for pesticide concentrations in DW.

6.1.1 EU policy context

This section provides a brief description of some the relevant legislation for the product categories assessed (Table 9). A more in-depth assessment of the applicability of these legislations in the context of a potential EPR scheme is provided in Module 2.

The increasing demand of citizens to have a better water quality in Europe has highly contributed to the establishment of measures in order to prevent and reduce water pollution and incite states and industries to integrate water resources management in the

[21] Baltic Eye, Advanced wastewater treatment, 10/19/2018. Accessible at: https://balticeye.org/en/pollutants/policy-brief-advanced-wastewater-treatment/ 5/6
[22] Baltic Eye, Advanced wastewater treatment, 10/19/2018. Accessible at: https://balticeye.org/en/pollutants/policy-brief-advanced-wastewater-treatment/ 5/6

national and business strategies. This is achieved by a combination of precautionary measures at the source and during product use that include stringent regulatory measures and best practices at industrial level, the establishment of environmental quality objectives and the implementation of the best available technologies for reducing downstream emissions.

At EU level, the **EU Water Framework Directive (WFD)** serves as the legislative basis for water management in Europe, establishing water quality standards through **environmental quality standards (EQS)** for **priority substances** to ensure minimum water quality throughout Europe. This is laid out under the **European Quality Standards Directive** (EQSD). The WFD is currently under-going a "fitness check", with the aim of assessing whether the current regulatory framework is "fit for purpose" in regards to its effectiveness, efficiency, coherence, relevance and EU added value in meeting current and future challenges. Aspects such as the potential for regulatory simplification and burden reduction, assessment of costs and benefits, impacts on business and elements of the legislation or implementation that could be improved will be covered.[23] The review phase is expected to be complete by the end of 2019.

Two major water-related directives set end-of-pipe requirements. The **Urban Waste Water Treatment Directive** (UWWTD) aims to protect the environment from the adverse effects of urban waste water discharges from households and sets requirements on the collection, treatment (see also section 4.2.1 and the Module 2 report). The UWWTD is currently under-going a review and evaluation. The **Drinking Water Directive** (Directive 98/83) addresses the quality of water intended for human consumption and the protection of human health. The Directive establishes the essential quality standards at EU level, covering a total of 48 microbiological, chemical and indicator parameters that must be monitored and tested regularly. On 1 February 2018, the Commission adopted a proposal for a revised drinking water directive to improve the quality of drinking water and provide greater access and information to citizens. Some of the key elements of the proposal include:

- Updates to existing safety standards in line with latest recommendations of the World Health Organisation (WHO) to ensure safe drinking water is safe in the long-term;
- Better assist authorities in addressing water supply risks and engage with polluters;
- Additional requirements regarding materials in contact with drinking water;
- Providing consumers with more transparent information on the efficiency and effectiveness of water suppliers; and
- Contributing to the transition to a circular economy by considering drinking water in a resource-efficient and sustainable manner, reduce energy use and unnecessary water loss.[24]

EU chemicals legislation, particularly Regulation 1907/2006 concerning the **Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)** is a core piece of legislation to address the protection of human health and the environment from the risks that can be posed by chemicals. REACH places the burden of proof on

[23] EC website on Fitness Check of the Water Framework Directive, accessible at: http://ec.europa.eu/environment/water/fitness_check_of_the_eu_water_legislation/index_en.htm
[24] EC website on the "Review of the drinking water directive". Accessible at: http://ec.europa.eu/environment/water/water-drink/review_en.html

companies by requiring that companies identify and manage the risks linked to the substances they manufacture and market in the EU. Proof that the substance can be safely used and that risk management measures are communicated to the users are important elements of the regulation. REACH also restricts the use of certain substances based on risk assessment findings and promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals.

Other European legislation that are applicable when considering water pollution targets and water quality concern specific areas such as industrial activity, for example in the context of agriculture (i.e. the Nitrates Directive regulating the use of fertilisers and serving to reduce nutrient loads from agriculture) or specific products/ substances (e.g. Ecodesign Directive, Biocide Products regulation, Sustainable Use of Pesticides Regulation, etc.).

Finally, EU waste legislation, notably, the **Waste Framework Directive** (Directive 2008/98) and the accompanying **EU Circular Economy package** also cover important principles such as **polluter pays and extended producer responsibility**, notably rules to harmonise EPR systems to ensure consistent implementation across the EU. The EU Circular Economy package proposes to strengthen measures introduced under the EU's eco-design working plan to improve the recyclability, reparability, durability, and reuse potential of end-of-life products. In particular, Article 8 of the new Directive on the reduction of the impact of certain plastic products on the environment[25] (or the Directive on Single-Use Plastics) specifically calls for the application of EPR schemes for single-use plastic products. EPR schemes should be established to ensure that costs for the collection, transport, treatment, including litter clean up and awareness raising measures are covered by producers. Further analysis of the applicability of the provisions of the Directive is carried out in Module 2.

6.2 Non-regulatory measures

Given the number of micropollutants and microplastics, as well as the diversity of their use and pathways, effectively reducing their discharge to the aquatic environment requires a combination of complementary measures. Therefore, in addition to the control at source regulatory measures as described previously, there are several measures applied at industrial level and end-of-pipe solutions downstream to ensure the compliance to the quality standards.

Existing technical solutions that aim to avoid or reduce the release of micropollutants and microplastics into the aquatic environment include the use of alternative, less toxic substances and materials and end-of-pipe solutions (i.e. requirement of advanced water treatment, quality of effluent, etc.). These options have varying levels of effectiveness, depending on the sector or product concerned, or the type of substance targeted and technology used in the case of end-of-pipe solutions.

6.2.1 Use of alternative substances

The use of substitutes that are less harmful for human health and the environment can be a sustainable option in terms of reducing or avoiding the release of their more toxic

[25] Link to text of the Directive: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52018PC0340

counterparts. It can also have a significant positive impact on the implementation of a circular economy and drive research and innovation. Different substitution options include for example switching to a less hazardous chemical, using an alternative technique or creating a different product design. According to ECHA and several stakeholders interviewed in the context of this study, companies in the EU are increasingly substituting hazardous chemicals and manufacturing processes with safer chemicals and greener technologies[26]. However, the use of alternative substances and other substitution options are not always straightforward.

Box 1: Best practice – reducing microplastic emissions from textiles

An example of best practice to reduce or avoid the release of microfibres from textiles is based on a combination of ecodesign principles, consumer information and end-of-pipe treatment. This practice, which is seeing increased uptake across the textile industry, incorporates the use of more **natural textiles** such as wool and cotton, which can shed little to no microplastic particles (depending on the overall textile composition of the garment) during wash compared to synthetic based or low-quality textiles. Natural fibres are biodegradable and do not accumulate in the environment compared to synthetic materials, in particular nylon and polyester. Moreover, wool is easy-to-recycle and easier to maintain, as it requires less frequent washings, less detergents or conditioners and at lower temperatures.

Despite the benefits of natural fibres, it is important to note that certain chemicals used to dye and treat cotton or wool can increase the eco-toxicity of natural fibres. Other solutions that are being considered include the development of **improved filters** in washing machines to reduce the amount the microfibers entering laundry effluent and **educating consumers** (households and businesses) about how to change their consumption patterns to extend the life of garment and reduce washing frequency.

Substitutes should not only respond to client demands or legal requirements but also maintain technical performance, improve the environmental footprint of products or manufacturing processes and reduce the overall risks to human health and the environment. As such, finding suitable alternatives and testing them can be a lengthy and expensive process. For example, methods that work in one sector or company may not work for all, implying that several alternative solutions may need to be tested before the best option is identified. Wider effects such as energy and resource use, waste, recycling or social impact should also be considered. Another important element to consider in substitution is the impact on the final price of the product – producers may find suitable substitution options that reduce the potential risks caused by the substances used, but at a higher price. Such costs have so far been unquantifiable and most likely vary from one substance to another. Nonetheless, there are cases where substitution has improved production efficiency, increased competitive advantage and saved overall costs[26].

6.2.1 End-of-pipe solutions

In the context of water services, end-of-pipe solutions refers to water treatment processes that aim to improve the quality of water through the removal or reduction of contaminants in order to be used for its desired end-use. End uses can include drinking, industrial water

[26] ECHA website on « Substitution to safer chemicals ». Accessible at: https://echa.europa.eu/substitution-to-safer-chemicals

supply, irrigation, water recreation, river flow maintenance, including being safely returned to the environment. End-of-pipe solutions are therefore opposite to control-at-source measures and usually constitute the last step (and oftentimes additional treatment steps) for drinking and waste water plants to achieve relevant quality standards e.g. Drinking Water Directive, Urban Waste Water Directive.

In the case of drinking water, treatment involves the removal of contaminants from raw water sources to produce water that is pure enough for human consumption without any short term or long term risk of any adverse health effect. Substances that are removed during the process of drinking water treatment include suspended solids, bacteria, algae, viruses, fungi, and minerals such as iron and manganese. The processes involved in removing substances include physical processes e.g. settling and filtration, chemical processes e.g. disinfection and coagulation and biological processes e.g. slow sand filtration. For wastewater, treatment refers to the processes that remove contaminants from wastewater or sewage, producing both liquid effluent suitable for disposal to the natural environment and sludge.

As described previously in section 4.2, conventional drinking and wastewater treatment plants are not specifically designed to treat new and persistent substances. The **additional treatment steps** required to tackle micropollutants and microplastics in drinking water production and wastewater often entail the use of **advanced treatments**. Advanced treatment can be loosely categorised under four different methods: physical, oxidative, biological and adsorptive (Figure 8). However, the use and operation of advanced treatment technologies entail high costs and can result in increased energy and chemical consumption, representing significant investments for drinking and waste water treatment plants. In addition to high costs of advanced water treatment technologies, there are also important **technical limitations** that merit consideration:

- **Increased energy demand and costs:** According to the Swedish Environment Protection Agency, the advanced treatment technologies and technology combinations assessed in their study will result in increased energy use and therefore emissions during energy production. This is particularly the case for ozonation and ultrafiltration (UF) technologies (SEPA, 2017). The additional electricity consumption for operating these technologies is estimated to be between 0.01 and 0.55 kWh/m^3 depending on the technology. In the example of Switzerland presented above, additional treatment processes will result in increased energy consumption of between 5 and 30 %, which will increase total national consumption of electricity is by 0.1 % (Eggen, 2014).
- **Use of harmful chemicals**: Some treatment technologies such as oxidative treatments require chemicals that can cause negative environmental impact during production and use and a risk of forming new potentially toxic contaminants (SEPA, 2017).
- **Need for increased training and skills**: additional competence requirements (and associated labour costs) may be needed in order to operate and monitor certain advanced treatment technologies, particularly for smaller treatment plants.
- **Generation of by-products/ transformation products with potentially adverse effects**: Some advanced water treatment processes can generate by-products such as bromate, from parent compounds (transformation products) of often-unknown chemical structure, fate and toxicity. For example, several studies have shown that wastewater treatment by ozone in particular may result in a selection of antibiotic resistance genes (ARGs) in effluent (Klaus, 2019, Lüddeke, 2015; Moreira, 2016; Alexandera, 2016; Czekalski, 2016). This makes it extremely challenging to use such

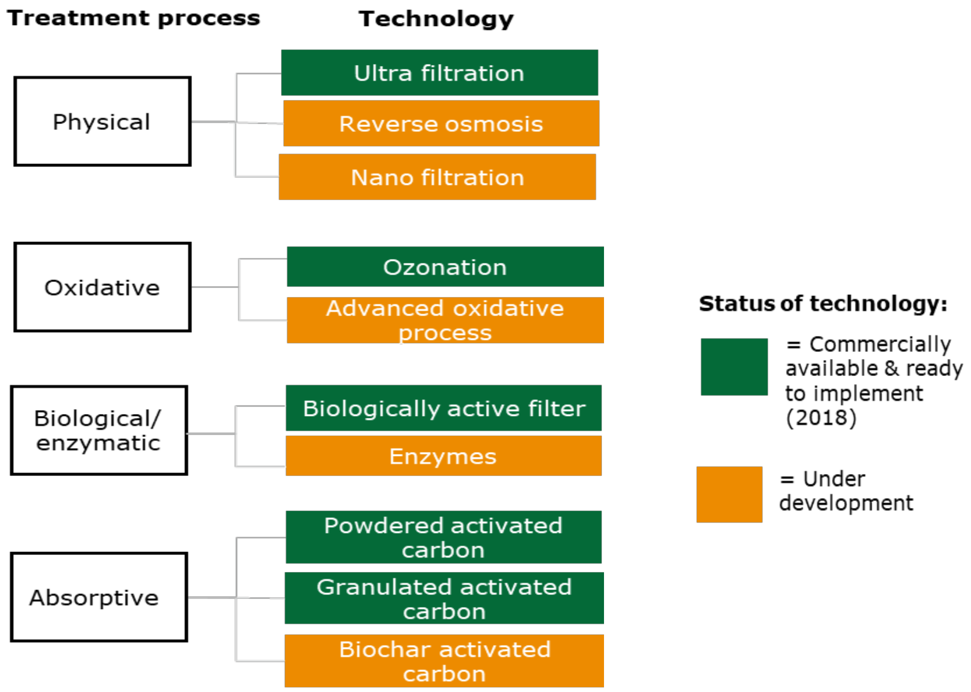
treated effluents for drinking water purposes or for (waste) water reuse e.g. irrigation of agricultural land as such compounds can reach groundwater and contaminate clean water resources. To be noted that ozonation and powdered activated carbon treatment are systematically used for drinking water treatment.

- **Higher space requirements and sludge production** for treatment technologies such as powder activated carbon (Poyroy, 2016), which usually require multiple tanks and pumping systems.
- **Reduced sludge quality and circular economy options** (see section 4.2.2)
- **CSO:** Combined sewer overflows contain untreated or partially treated human and industrial waste, toxic materials, and debris as well as storm water and can represent an importance source of micropollutant emissions in wastewater (see chapter 5). During periods of particularly heavy rainfall or snowmelt (referred to as wet weather conditions), CSO can further effect the efficiency of WWTPs as the wastewater volume in a combined sewer system can exceed the capacity of WWTPs. Increased flows at wastewater treatment facilities create operational challenges, potentially affecting treatment efficiency, reliability, and control of treatment units at these facilities.[27]
- **Varying removal efficiencies:** the efficiency rates of different advanced water treatment technologies vary greatly depending on the technology, the way in which the technique is implemented and the substance targeted. For example, according to Mulder (2015), depending on the substance and treatment technology used, the rate of removal can vary anywhere between 30-50% to more than 80%. The SEPA (2017) study found that none of the advanced treatment technologies studied (Figure 9) applied individually can achieve a complete removal (>90%) of certain pharmaceutical residues and contaminants. The study concludes that only a combination of different technologies that use various treatment mechanisms can ensure an almost complete removal of pharmaceutical substances from wastewater. Regarding microplastics in particular, some studies show that removal by conventional primary and secondary wastewater treatment technologies are relatively effective – up to 99% removal rate (IVL, 2014), however due to the large volumes of wastewater processed daily, a large WWTP could still release approximately 900 000 to 3 600 million microplastics per day to aquatic environments (Horton, 2017).

Figure 8 provides an overview of existing advanced water treatment technologies and Box 2 summarises removal efficiency rates identified through various literature sources. It should be noted the varying removal efficiencies from published literature reflect the wide variety of definitions, calculation/ modelling methodologies, assumptions and approximations that different authors adopt and make, highlighting the importance of referring to original sources to avoid misinterpretations.

[27] US EPA website on CSO: www.epa.gov/npdes/combined-sewer-overflows-csos

Figure 8: Overview of advanced treatment technologies[28]



Box 2: Examples of removal efficiencies by technology and substance

During **powdered activated carbon** (PAC) treatment processes, powdered activated carbon is added to an anaerobic or aerobic treatment system, which adsorbs recalcitrant compounds that are not readily biodegradable, thereby reducing the chemical oxygen demand of the wastewater and removing toxins. According to Besnault (2014), PAC had the following elimination efficiency rates:

- > 85% for urea-based pesticides and triazine
- Partial removal efficiency that decreases with time for polycyclic aromatic hydrocarbons (PAHs)
- 30 to 70% for alkyphenol (a compound used in the manufacturing of a variety of products from detergents and fuel additives to fire retardants and pesticides.
- > 99% for beta blockers
- > 73% for antibiotics

Ozonation (O_3) is an oxidative treatment in which different substances are oxidized with ozone. The ozonation process eliminates a range of organic and inorganic matter, bacteria and substances. The elimination efficiency rates are (Besnault 2014):

- > 55% for urea-based pesticides and triazine
- > 67% for aminomethylphosphonic acid (main metabolite of glyphosate)
- > 90% for polycyclic aromatic hydrocarbons
- 70 to 90% for alkyphenol (a compound used in)
- > 98% for beta blockers
- > 72% for antibiotics

[28] Figure adapted from the SEPA, 2017 study

In the city of Cracow, Poland, a project was launched to assess the effectiveness of existing waste water treatment technology relating to new contaminants. Some substances have been measured: Salicylic acid, aspirin, ibuprofen, caffeine, bisphenol A, diclofenac, carbamazepine, naproxen, ketoprofen, paracetamol, triclosan, bezafibrate, trifluoroacetic acid, propranolol, metoprolol. The range of concentration of these substances in waste water is [0.25 – 12.8] μg/ L while the range of concentration in treated waste water is [0.31 – 2.9] μg/ L. The highest concentration is for carbamazepine and diclofenac. In this case, removal of these substances from waste water is the most problematic.

Despite the considerable technological advances observed in water treatment solutions, which are more effective at treating newer or more persistent water pollutants compared to conventional treatment, they also come with important limitations that must be taken into account when considering potential reduction and mitigation measures. Stand-alone advanced treatment techniques are not able to completely remove substances found in effluents. Further, the diversity of already existing chemicals, the usage of old and new chemicals, the potential effects when certain substances are mixed together, as well as their anticipated increase presents a significant challenge as technologies may not be developed as quickly as needed to address them (Kümmerer, 2019).

End of pipe solutions by way of advanced water treatment technologies do not constitute a viable long-term solution to addressing increasing demographic and environmental pressures that can jeopardise access to sufficient quantity and adequate quality of water resources. The key challenges to consider therefore include not only ensuring that regulations are in place, but also that they are able to keep up with technological evolutions that result in the use of new substances and consequently new pollutants. In addition to regulatory factors, it is also essential that all actors, but in particular manufacturers, bear responsibility to ensure effective end-of-life management of products that release pollutants into the aquatic environment.

6.3 National level and industry-led initiatives

Examples of national, international and sector specific initiatives can provide additional insights on how the micropollutants and microplastics challenge is being addressed and whether there are lessons learned and best practices that can be considered in the application of a potential EPR scheme at EU level.

6.3.1 National legislation

Several EU Member States have initiated policies at national level to further address the release and presence of micropollutants and microplastics.

Germany: As part of the on-going work to establish the Trace Substance Strategy of the Federal Government, a multi-stakeholder dialogue was held including industry, environmental non-governmental organisations, drinking water suppliers, operators of waste water treatment plants, public authorities and Federal State representatives, etc. The purpose of the strategy is to prevent and reduce inputs of trace substances to the aquatic environment from biocides, human and veterinary pharmaceuticals, plant protection products, industrial chemicals, detergents and personal care products. A key result of the multi-stakeholder dialogue was the elaboration of 14 source-related, user-related and end-of-pipe related recommendations covering issues such as producer responsibility, communication of potential hazards, sector-specific agreements on imported products and closing knowledge gaps. The proposed recommendations are to be further concretised in a follow-on phase (UBA, 2017).

France: France aims to reduce at source, the transfer of micropollutants to aquatic environments through the government launched the "National plan against micropollutants 2016-2021" (Ministère de la Transition écologique et solidaire, 2016). The strategy consists of a comprehensive program to protect and preserve water quality and biodiversity through the achievement of 3 main objectives: (1) reduce as of now micropollutants emissions that end up in aquatic environments, whose relevance is known, (2) consolidate knowledge to adapt the fight against water pollution and preserve biodiversity, (3) Identify the priority pollutants where reduction actions are most needed. Furthermore, approximately 13 pilot projects have been launched over a four-year period (2014 - 2018) covering topics such as the emissions of hazardous substances from pharmaceutical residues and cosmetics, hospital waste discharges, integrated micropollutant management in communal sanitation networks, and storm water management solutions.

The Netherlands: In early 2016, a small team led by the Ministry of Infrastructure and Water Management as well as representatives from regional water authorities, drinking water companies, the Ministry of Health and the Ministry of Agriculture, started work on a "pharmaceutical chain approach". The pharmaceutical chain approach is a multi-stakeholder programme based on the following objectives:

1. Form a small project team with each stakeholder represented;
2. Detailed mapping of the entire pharmaceutical chain and the stakeholders concerned;
3. Agree on the 'rules of the game' (prerequisites for action);
4. Explore possible actions; and
5. Choose promising measures for the establishment of an implementation plan.[29]

By the end of 2016, a set of 17 possible measures to reduce or mitigate the impacts of pharmaceutical residues in water had been identified for further investigation. Each of the measures evaluated and proposed target one of three intervention steps of the pharmaceutical chain. These steps for intervention are clustered as 'development and authorisation', 'prescription and use', and 'waste and sewage treatment'. Table 8 below lists some of the relevant measures that were developed.

A key challenge that was highlighted from this exercise is the capacity to take measures to the next level of implementation as well as retain the attention, energy and enthusiasm that all stakeholders have expressed so far. Currently, the measures are being further developed, notably through an assessment of the overall costs and benefits and effectiveness of individual measures.

Table 8: Examples of measures developed under the Netherlands' pharmaceutical chain approach[29]

Intervention point	Possible measure	Sector responsible
Environmental impacts	Identify pharmaceuticals that have negative environmental effects	Water authorities, drinking water sector

[29]Based on an excerpt from a case study for a paper prepared for the OECD workshop on Contaminants of Emerging Concern in 2018. Accessible at: https://zoek.officielebekendmakingen.nl/blg-834486.pdf

Intervention point	Possible measure	Sector responsible
Development/ authorisation	• Development of 'green medicines' that have less environmental impact • Access to (environmental) data on active ingredients	Pharmaceutical companies, research institutions, authorising agencies, international authorities
Waste & sewage treatment	• Development of improved treatment of sewage at STP's, including overview of existing innovative treatment and overview of costs • Identify STP's with highest impact on aquatic ecology and drinking water sources	Water authorities, research institutions
Cross cutting issues	• Learn from the best practices abroad • Put issue on international agenda (e.g. river basin commissions of Rhine and Meuse, European Commission, etc.)	Ministry of Water Management

Switzerland: In 2016, following the precautionary principle, the Swiss government was one of the first to impose national legal requirements for reducing micropollutants in effluents from WWTPs, through an amendment of the Waters Protection Act to establish the new Water Protection Ordinance (WPO). The WPO requires certain municipal sewage treatment plants to take the necessary steps (upgrades) to eliminate at a minimum 80% of selected trace substances. WWTPs targeted for the upgrades include those that serve:

- ≥ 80 000 connected residents (for load reduction)
- ≥ 24 000 connected residents in the catchment area of lakes (for drinking water protection)
- ≥ 8 000 connected residents that discharge into a watercourse containing more than 10 % waste water
- ≥ 8 000 connected residents, if the removal is required due to special hydrogeological conditions

Approximately 100 out of 650 WWTPs are concerned by the new legislation in Switzerland. Upgrades to WWTPs are funded through a waste water charge, which is based on the following (see also section 4.2.1):

- 75% of the investment provided through the national budget:
    - Municipalities pay 9 CHF (7.9 €)/person/year into the fund
    - Municipalities with upgraded WWTPs are exempted
    - Only direct costs for upgrading for micropollutant removal covered (nutrient removal not covered)
    - Financing starts in 2016 and ends in 2040
- 25% of the investment + operation costs covered by the municipalities[30]

6.3.2 Research & funding initiatives

In addition to national measures at MS level, there are several examples of research

[30]Joss, Adriano (Eawag), Keynote presentation on "Micropollutants: the Swiss strategy". Accessible at: www.water2020.eu/sites/default/files/keynote_adriano_joss_eawag_switzerland.pdf

projects (e.g. EU level research projects: COHIBA[31], RiSKWa[32], OgRe[33]) and funds dedicated to micropollution of waters and the necessity of reduction measures:

- **Sweden:** The Agency for Marine and Water Management received 32 million kronor (3 million €) in funding over a 4-year period (2014–2018), which was awarded to eight projects that promote advanced wastewater treatment with the aim to reduce discharges of pharmaceutical residues and other micropollutants that cannot be removed in the treatment plants' current processes (SEPA, 2017)
- **Denmark:** Denmark funds the Bonus CleanWater research project, which focuses on reducing the input of micropollutants and microplastic into the Baltic Sea by exploring, developing and comparing new eco-technological approaches[34].
- **German:** The German Environment Agency (Umweltbundesamt, UBA) has commissioned a number of research projects at the national level. A number of German federal states such as North Rhine Westphalia and Baden-Württemberg, are also working on solutions, through for example the establishment of competence centres (UBA, 2018).

6.3.3 Industry-led initiatives

To achieve corporate social responsibility objectives and anticipate environmental, demographic, regulatory and economic pressures, many companies have launched and/ or participate in industry-based voluntary initiatives that cover topics such as the sustainable use of substances, circular economy principles including cleaner production practices, etc. to reduce the environmental impacts of their activities. Among the numerous voluntary industry initiatives that exist, a few non-exhaustive examples include:

- **The Raw Water Database on Plant Protection Products (RWD PPP)**: is a joint initiative established in 2012 by the German Technical and Scientific Association for Gas and Water (DVGW), Industrieverband Agrar (IVA), the German Association of Energy and Water Industries (BDEW) and the German Association of Drinking Water Utilities (VKU). Several major pesticides producers including Bayer, BASF, and Monsanto are participants of the programme. The objectives of the collaboration are:
    - To promote the preventive protection of water in the further development and use of plant protection products for sustainable agricultural practices.
    - To encourage the mutual exchange of information and discussion of the problems faced by both sides and develop options for joint actions oriented towards water protection for the use of plant protection products.

  The RWD PPP is the first ever national systematic compilation and analysis of PPP raw water data. Data on pesticides (active substances, metabolites) is systematically collected and monitored to identify potential 'hot spots' of contaminated drinking water resources. In the case of contaminated sites, possible solutions are discussed amongst

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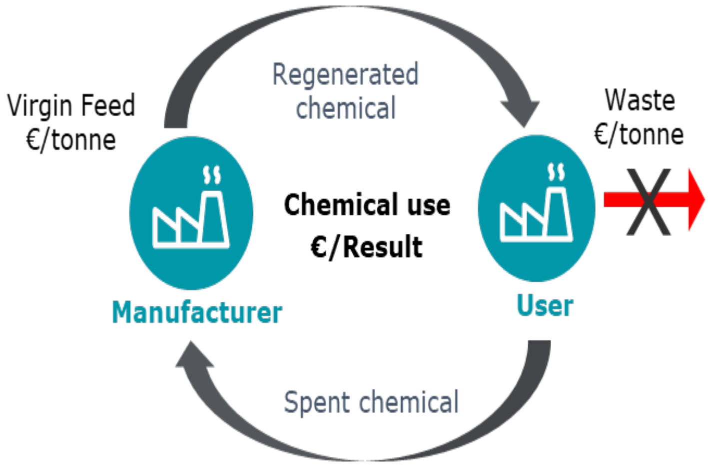
[31] www.helcom.fi/helcom-at-work/projects/completed-projects/cohiba
[32]www.researchgate.net/publication/257885065_SchussenAktivplus_Reduction_of_micropollutants_and_of_potentially_pathogenic_bacteria_for_further_water_quality_improvement_of_the_river_Schussen_a_tributary_of_Lake_Constance_Germany
[33] www.kompetenz-wasser.de/en/project/ogre-relevanz-organischer-spurenstoffe-im-regenwasserabfluss-berlins
[34] http://envs.au.dk/en/current/news/artikel/bonus-cleanwater-innovative-research-on-water-technology-to-remove-micropollutants-and-microplastic/

all stakeholders (including the respective pesticides producer, water utility, farmers and water authorities) to ensure that the water resource can be used again for drinking water production purposes. The involvement of the pesticides industry ranges from financing, monitoring of specific water catchment areas, feasibility studies and recommendations for the use of alternative pesticides to farmers. Despite the active participation of the different stakeholder groups involved, certain limitations of the initiative include the time and resource consuming process of collecting, monitoring and assessing data and the need for the involvement of all actors concerned in order to resolve individual contamination cases.

- **Take Back Chemicals:** is a business model based on circular economy principles that was launched by the chemicals industry. The Take Back Chemicals business model aims at closing material cycles for chemical related industries by increasing the value and therefore efficiency of specific chemical substances. To do this, the model is based on a « chemicals leasing » system where the supplier of a particular material or substance is paid for the service delivered rather than the amount of substance used, and the type of payment changes from a traditional volume-driven pricing (€/tonne chemical supplied) to a results-driven, measurable metric pricing system (e.g. €/tonne treated product) (Figure 9). The supplier retains ownership of the material it supplies, and takes it back after use. The ultimate result is that the material is 'leased' to the customer. The model aims to incentivise both suppliers and users (manufacturers) to continuously increase the efficiency of chemical substances use. A study was carried out on the feasibility and applicability of the Take Back Chemicals model in the Netherlands and Belgium in several sectors including textiles, salts, plastics and pharmaceuticals[35].

Figure 9 : "Take Back Chemicals" economic model[35]



- **Global Organic Textile Standard (GOTS)[36]:** GOTS is an international textile processing standard for organic fibres established in 2006. The objective of the standard is to establish globally-recognised requirements that ensure the organic status

[35] Adapted from the report: Take Back Chemicals, 2017, Business Incentives of Chemical leasing, Case-based learnings for the Netherlands, White Paper, and 1 March 2017.
[36] www.global-standard.org

of textiles, covering the processing, manufacturing, packaging, labelling, trading and distribution of all textiles made from at least 70% certified organic natural fibres.

- **Zero discharge of hazardous chemicals (ZDHC) Programme[37]:** The ZDHC Programme was launched in 2011 by six textile brands to promote best practices in the discharge of hazardous chemicals across the textile and footwear product life cycle. The fundamental principles of the programme include: transparency, fact-based decision making and integrated approaches to chemicals management. Currently, the programme involves the collaboration of 27 signatory brands, 77 value chain affiliates, and 18 associates that are working together on the following areas: Manufacturing Restricted Substances List (MRSL) & Conformity Guidance, Wastewater Quality, Audit Protocol, Research, Data and Disclosure, and Training. In particular, the MRSL includes a list of chemical substances (e.g. alkylphenol, chlorobenzenes and chlorotoluenes, , dyes, flame retardants, halogenated solvents, organotin compounds, polycyclic aromatic hydrocarbons, perfluorinated and polyfluorinated chemicals, phthalates, etc.) banned from intentional use in facilities that process textile materials in apparel and footwear. The ZDHC MRSL establishes acceptable concentration limits for substances in chemical formulations used within manufacturing facilities that are designed to eliminate the possibility of intentional use of listed substances[38]
- **The Tire Industry Project (TIP)**: The Tire Industry Project was established in 2005 under the umbrella of the World Business Council for Sustainable Development (WBCSD). It represents the primary global forum for the tire industry on sustainability issues. This voluntary initiative is currently comprised of 11 major tyre manufacturing companies, accounting for approximately 65% of the world's tire manufacturing capacity.[39] TIP aims to proactively identify and address the potential human health and environmental impacts associated with the life cycle impacts of tires in order to proactively contribute to a more sustainable future. The European Tyre & Rubber Manufacturers' Association (ETRMA) is currently carrying out a study on the fate and possible effects of tire and road wear particles generated during tire use. The research project is based on the work produced by the TIP, which according to ERTM is "supported by an independent scientific advisory board, which has validated its approach and protocol".[40] ETRMA intends to use the results of the study as part of a larger European Commission investigation into options for reducing releases in the aquatic environment of microplastics.

Despite the many voluntary initiatives launched by industry, the **voluntary nature** of these collaborations may not be sufficient to tackle the still very present problem of micropollutants and microplastics in the aquatic environment, particularly in terms of engaging the participation of major industries (and polluters) and addressing the problem of free-riders. Further, according to a recent OECD report, due to public budget constraints and a lack of environmental regulations on diffuse pollution, other measures such as subsidy-based programmes can have limited impact (OECD, 2017).

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[37] www.roadmaptozero.com
[38] ZDHC, 2015. Joint Roadmap Update. Available at: www.roadmaptozero.com/fileadmin/layout/media/downloads/en/JointRoadmapUpdate_FINAL.pdf
[39] WBCSD website on the Tire Industry Project, Accessible at: www.wbcsd.org/Sector-Projects/Tire-Industry-Project
[40] www.rubbernews.com/article/20170410/NEWS/170419993/etrma-to-study-environmental-impact-of-tire-particles

7. Potential of extended producer responsibility

Extended producer responsibility presents significant opportunities to address the serious challenges of micropollutants and microplastics emitted into the aquatic environment.

Increasing demand and the acceleration of the renewal of post-consumer products is resulting in a significant increase in post-consumer waste, posing serious risks and concerns regarding their end-of-life. The burden and risk that remain at the end of a product's life suggest a need for policy measures to help align the experiences of different actors throughout a product's lifecycle with the social and environmental costs that they incur.

Among the possible policy approaches, extended producer responsibility (EPR) gained momentum in the 1990s and has since been applied in various sectors throughout the world. The Organisation for Economic Co-operation and Development (OECD) defines extended producer responsibility as a 'policy approach under which producers are given a significant responsibility – financial and/or physical – for the treatment or disposal of post-consumer products. Assigning such responsibility could in principle provide incentives to prevent wastes at the source, promote product design for the environment and support the achievement of public recycling and materials management goals.'[41]

EPR is therefore an approach that recognises the producers' distinct responsibility for the products they place on the market, which extends beyond the production and consumption stage to its end-of-life stage. For example, through EPR policies, the producer takes on the costs of ensuring safe end-of-life waste disposal. In this way, EPR can be expected to help relieve the public of some of the costs of waste disposal, and supports the consideration of social and environmental impacts that a product may incur.

The principles of EPR can be widely interpreted depending on the value chain of the product and the type of waste generated (especially when it is not imposed by existing legislation e.g. the End of life vehicles Directive, Batteries Directive, Waste Electrical and Electronic Equipment Directive, Packaging and Packaging waste Directive). In general, EPR is when producers are given a significant responsibility – financial and/or physical, organisational – for the treatment or disposal of post-consumer products (e.g. waste). An important aspect of EPR is to **provide incentives for producers** to take into account environmental considerations along the products' life-cycle by improving product design, using alternative substances, etc. In other words, internalising costs to drive and incentivise greener design. Figure 11 summarises some of the principle policy instruments used to implement EPR.

There are numerous EPR schemes implemented in the EU and globally covering a wide range of products from end-of-life vehicles, used oils, used tyres, graphic paper and textile, medicines, fluorinated refrigerant fluids to agricultural films, mobile homes and furniture, etc.

[41] OECD website on EPR: www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm

According to the most recent EPR guidance published by the OECD in 2016 (updating the 2001 EPR Guidance report), small consumer electronic equipment accounts for more than one-third of EPR systems, followed by packaging and tyres (each 17%), end-of life vehicles, lead-acid batteries and a range of other products (Figure 10).

"About 400 EPR systems currently in operation. Nearly three-quarters were established since 2001. Legislation has been a major driver, and most EPRs appear to be mandatory rather than voluntary."

- OECD, 2016

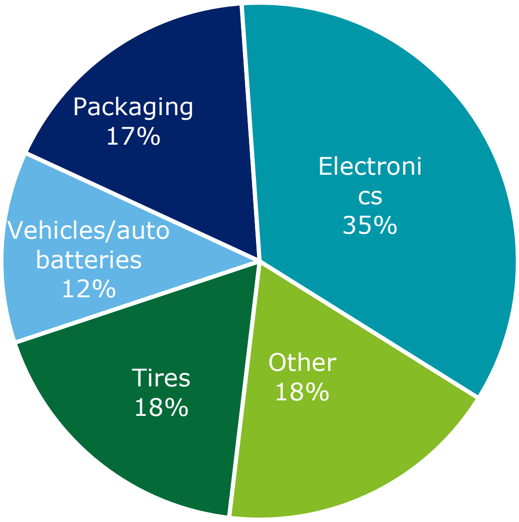

Figure 10: EPR schemes–product type, 2016[42]

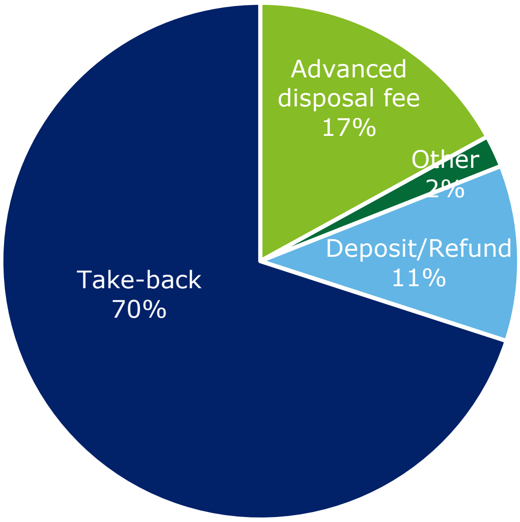

Figure 11: EPR by policy[42]

The recently adopted Directive on Single Use Plastics covers a range of products under Part E, Article 8 on extended producer responsibility[43]:

- **Food containers** i.e. receptacles such as boxes, with or without a cover, used to contain food that is intended for immediate consumption from the receptacle either on-the-spot or take-away without any further preparation, such as food containers used for fast food, except beverage containers, plates and packets and wrappers containing food
- **Packets and wrappers** made from flexible material containing food that is intended for immediate consumption from the packet or wrapper without any further preparation
- **Beverage containers** i.e. receptacles used to contain liquid such as beverage bottles including their caps and lids
- **Cups for beverages,** including their caps and lids
- **Tobacco products with filters** and filters marketed for use in combination with tobacco products
- **Wet wipes** i.e. pre-wetted personal care, domestic and industrial wipes
- **Balloons,** except balloons for industrial or other professional uses and applications, that are not distributed to consumers

[42] OECD, 2016, Improving EPR programs worldwide: the new OECD guidelines.
[43] https://eur-lex.europa.eu/resource.html?uri=cellar:fc5c74e0-6255-11e8-ab9c-01aa75ed71a1.0002.02/DOC_1&format=PDF

- **Lightweight plastic carrier bags** as defined in Article 3(1c) of Directive 94/62

In addition to the wide variety of products that are covered by existing EPR schemes, EPR can also be applied using different approaches and policy instruments. They can be voluntary or mandatory, with the possibility of individual or collective organisation schemes. Regarding financial instruments in particular, different types of financial mechanisms can be used for cost recovery, including for example advance disposal fees (ADF), take-back requirements, product taxes and charges, etc. (Figure 11).

7.1 The potential of EPR to address the challenges posed by micropollutants and microplastics

As demonstrated in the previous chapter, there are many limitations and loopholes in the existing regulatory and voluntary measures to reduce or avoid the emission of micropollutants and microplastics into the aquatic environment. Products containing potentially hazardous substances continue to be placed on the marketed and humans and other living organisms will continue to be exposed to their potentially harmful effects. Further action is therefore needed to ensure that all key players are actively involved towards a common goal; as such the principles of EPR can serve as the basis for a potential solution to the problem.

7.1.1 Contributions to meeting EU environmental and human health objectives

A particularity of the current situation in Europe of micropollutants and microplastics is the **cross-sectoral** scope and the **transboundary nature of substances** and water bodies. Chemicals cross national borders via the import and export of products, as well as transported throughout the environment through moving air and water masses. As such, **application of EPR at the EU-level** would be more effective compared to the national-level in terms of being able to fully address the scale of the micropollution problem. This reflects the principles of subsidiarity and proportionality as enshrined in Article 5(3) of the Treaty on European Union (TEU) and Protocol (No 2), which seeks to safeguard the ability of the Member States to take decisions and action and authorises intervention by the Union **when the objectives of an action cannot be sufficiently achieved by the Member States, but can be better achieved at Union level**, 'by reason of the scale and effects of the proposed action'. The Commission for example, demonstrates the subsidiarity principle to justify EU action for each of its legislative proposals through impact assessments. Some of the principle questions used in the Commission's impact assessment guidelines to assess subsidiarity (and proportionality) include:

- Why can the objective not be sufficiently achieved by Member States?
- Why would EU-level action better achieve the objective?
- Does the issue being addressed have transnational aspects which cannot be dealt with satisfactorily by action by Member States?
- Would action at Community level produce clear benefits compared with action at the level of Member States by reason of its scale and by reason of its effectiveness?

Based on the responses to the questions above, it appears clear that the environmental, economic and human health implications of the micropollution and microplastics problem in Europe would clearly call for action at EU level. In existing legislations such as the UWWTD, for example, this aspect is clearly reflected in the text of the directive, "*Whereas pollution due to insufficient treatment of waste water in one Member State often influences* *other Member States' waters; whereas in accordance with Article 130r, action at Community level is necessary*."

In addition, application of EPR at EU level would also contribute to addressing the issue of **free riders** – a challenge that existing voluntary and national measures face in terms of ensuring that all relevant actors are involved and collectively responsible for the efforts needed to address the micropollution problem. As it stands, certain industries have no incentive to improve product design or find alternative substances and users are not necessarily aware of the environmental impact their behaviours have ("licence to pollute").

Due to the cross-sectoral and transnational nature of micropollutant emissions, there are limits to the extent that voluntary initiatives or even national legislations can address the geographic and economic scale of the situation. Further, an EPR scheme at EU level would enable increased transparency, harmonisation and coherence of practices across Europe, which could ultimately contribute to creating a fairer and even playing field within the Single Market.

7.1.2 EPR as a financial mechanism to incentivise best practices

A key component of EPR is ensuring the financial responsibility of product manufacturers for the remedial actions along the supply chain, which could addresses pollutants stemming from different phases of the product's life cycle. EPR provides incentives to producers to implement more efficient and sustainable product-design and manufacturing practices that have less environmental and human health impacts. This is a fundamental element of closed-loop economies and the transition towards a circular economy, which EPR encourages through the use of more environmentally-friendly materials and products that can be recovered and re-introduced in the economy.

"**Plastic waste prevention should be the first priority**. We must start by limiting the use of plastic products and by setting compulsory eco-product design criteria. We need less and better plastics. We must remove existing subsidies on fossil fuels and barriers to a single market for secondary raw materials. Both make virgin plastics cheaper than recycled or bio-based plastics and obstruct the development of a circular economy for plastics."

- André Van de Nadort
Mayor of Weststellingwerf, Netherlands

An important element of the EU's Water Framework Directive is Article 9(1), which introduces the principle of **cost recovery** for water services in accordance with the **polluter pays principle (PPP)**. Article 9 of the WFD establishes that:

- Water prices must allow for the (adequate) cost recovery of water services, including environmental and resource costs;
- The main water uses (households, industry and agriculture) must adequately contribute to the recovery of costs of water services, proportionally to their contributions to the pressures imposed on aquatic ecosystems in line with the PPP;
- Water pricing policies must 'provide adequate incentives for users to use water resources efficiently and thereby contribute to environmental objectives.

However, the application of the above principles into real water pricing policies applied in EU Member States remains unclear and the WFD does not stipulate the use of a particular approach for assessing financial, environmental and resource costs (EEA, 2013). The approaches and calculation methods for internalising external (environmental and resource) costs, including the lifetime of investments, discount rates and costing methods, which have a direct impact on the assessment of financial cost recovery rate into water pricing remain a subject of debate (Entec, 2010).

It is therefore necessary to determine how current pricing and other financial mechanisms are applied in EU MS in relation to the meeting of environmental objectives and the requirements of the WFD regarding cost recovery, the PPP and incentives. In particular, how such costs are calculated and recovered and whether they reflect the real costs related to the investments, maintenance, infrastructure and upgrades needed to ensure a minimum level of water quality. In some cases, consumers and the water services sector are currently bearing the increased water treatment costs associated with the presence of micropollutants and microplastics in the aquatic environment – rather than industry or agriculture. In this context, EPR could provide the basis for setting an appropriate financing mechanism for water pricing in accordance with the polluter pays principle by ensuring that producers are also held financially accountable and responsible – to promote more efficient and fair water resource management.

Measures within an ERP scheme can cover a wide range of costs; for example, the costs for additional treatment of drinking or waste water, awareness raising measures, product labelling, remedial and restoration of contaminated water resources, monitoring of water resources, etc. Most importantly, extended producer responsibility schemes should take into account the full cost coverage of the end of life of products, which would hold producers accountable for costs such as separate collection, sorting and treatment operations, waste disposal, litter cleaning and transport of waste. A targeted and effective use of financing instruments within an EPR approach could provide incentives that could have both short-term effects (such as substitution of micropollutants or relevant products with already available alternatives) and medium to long-term effects (such as research and development of new environmentally friendly approaches or substitutes). For example, an EPR approach that incorporates an incentive system that applies a flat wastewater charge for discharging micropollutants but which offers the possibility of exemption and/ or reduction if certain efficiencies or targets are reached or which offers the opportunity to offset potential investment costs. By holding producers responsible for the full costs caused by their products, companies will be incentivised to design products that can be more easily recycled or prepared for reuse or less costly to treat at its end-of-life.

As such, an EPR scheme can contribute towards the reduction and shift of financial and physical responsibility for treating difficult-to-treat drinking or waste water from local authorities and public utility services (and citizens' in regards to their water bills) to producers. With this in mind, however, one of the most important aspects to consider when evaluating the re-distribution of financial burden, is on the one hand, the **polluter-pays principle** and, on the other hand, **a fair and just distribution of costs between producers, the water sector and citizens**. This is because the decision of who shall bear the costs not only determines who has to contribute to a measure and how much, but also has significant effects that could lead directly and indirectly to further reduction of pollution. In all cases, cost recovery as stipulated by Article 9(1) of the WFD – whether it is established within an EPR scheme or not – should not result in a situation where industry is not held financially responsible and only citizens, public authorities and the water sector bear the costs.

7.2 Applicability of EPR approach on products releasing micropollutants and microplastics

Notwithstanding the significant opportunities that EPR could offer, several aspects should be considered to ensure its **effective and feasible application**. In addition to the need for a **clear legislative framework** at EU level (see Module 2 report), it is important to emphasise that the overall feasibility and effectiveness of an EPR scheme can greatly differ depending on its scope, level of implementation (voluntary versus mandatory) and governance (including financial and operating mechanisms). Some of the major challenges to overcome for an effective EPR approach on products that release micropollutants and microplastics are described in the following paragraphs.

7.2.1 Lack of a sufficient knowledge base

Extended producer responsibility is an important tool in waste legislation because it focuses on the end-of-use treatment of consumer products, with the aim of increasing the amount and degree of product recovery and to minimize the environmental impact of waste materials. This is an essential component in any EPR scheme in terms of the scope and coverage of the products (and waste streams) targeted. It is necessary to be able to link the generated waste directly to the product produced or consumed in order to establish an appropriate cost recovery and operating system. However, this is not always straight-forward as:

- The amount of waste delivered is sufficiently linked to the amount of product supplied, i.e. there are few leaks/additions from upstream to downstream; and
- A given product can be linked to a given (homogeneous) waste stream, i.e. amounts can be tracked from upstream to downstream.

For the purposes of this study, under a potential EPR scheme, we assume that the waste streams targeted are the micropollutants and microplastics released in the aquatic environment through different pathways including the sewer network and that the products responsible for their release are those evaluated (pharmaceuticals, pesticides, antibacterial products containing biocides, flame resistant products containing PFASs, textiles and tyres). One of the key obstacles, which has been reflected in literature, existing legislation as well as in stakeholder feedback, is the general lack of knowledge and data on where, why and in which products chemicals are used and on which pathways they are released to the aquatic cycle. This issue prevents an accurate **traceability** of certain hazardous substances back to a specific sector; and going further to a specific producer. Several factors make it difficult to ensure a more robust traceability of such substances:

Although we have a generally good understanding of the main products groups responsible for the presence of micropollutants and microplastics in inland waters, their effects on complex aquatic ecosystems is currently poorly understood. They usually occur in low concentrations, in changing mixtures and are a part of multiple other stressors (e.g. changes in UV or light intensities, temperature, pH, predators, etc.) present in the aquatic environment that can effect organisms in natural ecosystems. This makes it difficult to pinpoint all the potentially hazardous substances (of which there are potentially thousands to consider) present in the aquatic environment that should be targeted.

Furthermore, the diffuse nature of how micropollutants and microplastics end up in the aquatic environment means there are multiple emission sources and entry pathways through which they are discharged and released. Likewise, the level of concentration and characteristics of micropollutants and microplastics vary across different water bodies in

EU due to factors such as location of the WWTPs, proximity of urban areas and industrial and agricultural sites, etc. Finally, at EU level, a harmonised and comprehensive list on the production numbers, use, emissions, toxicological properties, and environmental effects of micropollutants and microplastics is lacking.

Due to the absence of sufficient understanding and consensus on which substances should be regulated and at what concentrations, many potentially harmful substances found in wastewater effluents are not regulated by current legislation. The above points are often used as arguments, brought forth by certain stakeholder groups to oppose changes in regulations that would establish stricter control and monitoring measures. In this context, the EPR principles can be used as a driver for further research and monitoring activities that are needed in order to establish a consensual knowledge base concerning the traceability of waste streams and products. In this case, major industrial sectors could contribute for example to a collective dedicated fund that could be used to pay for EU wide data collection, monitoring and assessment related to targeted substances and the actors involved. An example of this is seen in the current initiative carried out in Germany on the RWD PPP mentioned in the previous chapter.

7.2.2 Stakeholder acceptance and willingness

Ensuring an adequate level of stakeholder support and willingness is essential in any functional EPR scheme, particularly for the establishment of an effective financing mechanism, which would require the collaboration/ financial contributions from producers. The lack of a general consensus means that many producers are either not aware, do not recognise their role and responsibility and consequently unlikely to accept a mandatory EPR scheme. Therefore, a key obstacle to overcome is raising the awareness of producers so that they are informed and clearly understand the importance of their engagement. One way to do this is to focus stakeholder discussions and information exchanges on concrete impacts and data highlighted in this report and in an increasing number of studies and initiatives on how the presence of micropollutants effect drinking water and wastewater treatment requirements and costs as well as potential effects on human health and the environment.

7.2.3 Governance and operations

In order to enforce a level playing field, environmental standards and targets and maximum transparency, governance mechanisms (planning, decision making, monitoring and reviewing) involving relevant stakeholders (manufacturers, retailers, recyclers, experts etc.) as well as strong government involvement are key factors for a well-functioning EPR scheme. As such, it is important that operational aspects such as the composition and functions of the governing body, the waste collection and treatment system, reporting and monitoring, the cost recovery scheme and a clear legislative framework in the case of a mandatory EU level scheme are defined. Finally, Member State (national markets, employment, existing initiatives, etc.) and sector specificities (potential impacts on competition for certain industries, import of products into the EU, compliance with international trade, etc. are also important factors to consider. Recent developments such as the revision of the Waste Framework Directive and the Directive on Single-Use Plastics explicitly call for the application of extended producer responsibility, providing important insights and direction for its extension to the product categories assessed in this study.

Annex. Supporting information

8. Overview of applicable EU Legislation

Table 9: List of potential EU legislations to be assessed

Product category	Overview of relevant requirements
ALL PRODUCT CATEGORIES	
EU Treaty Art. 191.2	Art. 191.2: Environmental policies shall be based on the precautionary principle and on the principles that preventive action should be taken…environmental damage should as a priority be rectified at source and that the polluter should pay.
Groundwater Directive (GWD) 2006/118	Specifications for good groundwater chemical status; reversal of significant and sustained upward trends in concentrations of pollutants; environmental quality standards (EQS) for pesticides and parameters for threshold values. Measures for achieving/maintaining good water status and for preventing or limiting the input of pollutants
Regulation 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	For all substances > 10 tons/produced/year, REACH requires a chemical safety assessment (CSA) wherein producers have to provide toxicological and ecotoxicological data (Annex VII to X). The suppliers have to identify all the final uses of the substances (along the substance's life cycle), exposure scenarios and characterise the risks: • No urban water cycle risk assessment included in this assessment. • Some restriction only for SVHCs • No fees for these substances treatment in wastewater • Polymers are not covered by the REACH regulation
Directive 2000/60 (Water Framework Directive)	Recovery of costs for water services: Article 9.1 establishes water pricing based on the contribution of different water uses and taking into account the polluter pays principle. This could serve as a potential driver to integrate the cost recovery for all activities emitting micropollutants in water bodies. Priority substances: Article 16 on strategies against pollution of water established a list of priority substances, which was later replaced by the Directive on Environmental Quality Standard (EQSD) also known as the Priority Substances Directive. The EQSD, however, which set environmental quality standards (EQS) for the substances in surface waters does not cover the scope of all micropollutants (e.g. stemming from certain medicinal products and microplastics
Waste legislation: • EU Circular Economy package • Waste Framework Directive 2008/98	EU Circular Economy package includes numerous measures addressing product recycling and reuse, including rules to harmonize EPR systems to ensure consistent implementation between EU MS, consolidating and building upon experience gained over the last two decades. This package proposes to strengthen measures introduced under the EU's eco-design working plan covering reparability, durability, and recyclability and review of the EU Waste Framework Directive to address implementation of EPR as well as waste collection and recycling targets
PHARMACEUTICALS	
Directive 2001/83 on medicinal products for human use Regulation 726/2004 on authorisation and supervision of medicinal products	The authorisation of human medicinal products requires testing for potential impacts on the environment. If a risk to the environment is identified, denial of authorisation is not possible; authorisation can be subjected to conditions for the protection of the environment.

Product category	Overview of relevant requirements
PESTICIDES	
Directive 2009/128 on the sustainable use of pesticides	Aims to achieve a sustainable use of pesticides in the EU by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management (IPM) and of alternative approaches or techniques, such as non-chemical alternatives to pesticides. EU countries have drawn up National Action Plans to implement the range of actions set out in the Directive.
Regulation 1107/2009 concerning the placing of plant protection products (PPP) on the market	PPPs contain at least one approved active substance; these may include micro-organisms, pheromones and botanical extracts. Before any PPP can be placed on the market or used, it must be authorised in the EU country concerned. Regulation 1107/2009 lays down the rules and procedures for authorisation of PPPs.
BIOCIDES	
Regulation 528/2012 on biocidal products	Regulation concerning the making available on the market and use of biocidal products. The Annex II of this regulation contains some requirements for active substances and a list of experimentations which have to be performed before use in a biocidal products. These test include a biodegradation test in freshwater and toxicity to aquatic organisms.
TEXTILES	
REACH: substances used in articles produced in textile industry	For textiles produced in Europe, substances incorporated in the textiles, need to be registered. For imported (outside of the EU) textiles, importers need to notify ECHA if the textiles they import contain SVHC (substances of very high concern) in concentration above 0,1% (w/w) if the total annual volume in all products imported is greater than 1 tonne. Consumers also have the possibility to ask retailers if products contain SVHC in a concentration above 0,1%
EU Eco-label, (Commission Decision 2009/567)	Criteria have been developed for textiles: bed mattresses, textile floor coverings and footwear
Waste Framework Directive 2008/98	The Waste Framework Directive specifically refers to textiles. Besides defining the waste hierarchy i.e. prevention, preparation for reuse, recycling, energy recovery and disposal, the directive also calls for end of waste specific criteria for textiles to be developed.
Regulation 1007/2011 on textile fibre names and related marking of the fibre composition of textiles	Development of a label for fibre release from washing of clothing to be included under the Regulation for labelling and marking of the fibre composition of textile products.
TYRES	
Regulation 1222/2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters (the Tyre Labelling Regulation - TLR),	Proposals for updating and improving the EU regulation for the labelling of tyres were published by the Commission in May 2018 within the broader package of measures on Low Carbon Mobility. Aimed at giving consumers more information on fuel efficiency, safety and noise when they buy tyres, the changes aim to ensure that labels provide accurate, relevant and comparable information on those aspects. • Inclusion of tyre tread abrasion rates • Development of a standard measure of tyre tread abrasion

Product category	Overview of relevant requirements
Regulation 661/2009 concerning type-approval requirements for the general safety of motor vehicles	Amendment of the regulation to restrict the worst performing tyres (in respect of tyre tread abrasion) from the market (once a standard measure of tyre tread abrasion has been developed)

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