



Proposal for a simplified method for the quantification of emissions to water



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2 **Executive summary**

3 As part of the Water Framework Directive (WFD) (EC, 2000), Member States are required to
4 report an inventory of emissions, discharges and losses of priority substances. This can give
5 information on the success of measures to reduce emissions and indicate whether further
6 efforts may be needed to achieve a good chemical status of the surface waters. Experience from
7 the reporting of the second River Basin Management Plans showed that while there is a
8 Technical Guidance on the preparation of the inventory (EC, 2012), further information is
9 needed to help Member States report in a consistent and comparable way. A simplified method
10 for the quantification of emissions to water is presented, which has been used as a basis for the
11 WFD Working Group Chemicals sub-group on reporting of emissions to water. The report
12 describes quantification methods for the 13 most relevant pathways of emissions to surface
13 water as mentioned in the Technical Guidance (EU, 2012).

14 This activity started under the WFD's Common Implementation Strategy (CIS) work program
15 (2019-2021), as a collaborative activity under the Working Group Chemicals - Subgroup on
16 reporting of the inventory of priority substances. The participation of Member States and
17 stakeholder experts was essential in the development of this report. To finalise and make the
18 work more available, the European Topic Centre for Inland, Coastal and Marine Waters
19 (ETC/ICM) and the European Environment Agency (EEA) has worked with the Eionet.

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1 Introduction

1.1 Background

Several projects related to emissions to water, carried out in recent years for the European Commission (EC) (Roovaart et al., 2013) and the EEA (Roovaart et al., 2016; ETC/ICM, 2017; EEA, 2018a, 2018b), show serious problems regarding consistency, completeness and quality of the EU reported emission data. More specific, these reports have shown:

- very little reporting on diffuse sources
- limited (incomplete) reporting on urban wastewater treatment plant (UWWTP) effluents (not all UWWTPs, not all relevant pollutants)
- unclear quality of emission data of industrial sources (not all facilities, not all relevant pollutants)
- inconsistent reporting in time and space (no comparable and consistent time ranges and not all river basin districts reported)
- little flexibility in updating of reporting obligations (slow embracement of emerging sources and pollutants)
- some double reporting or reporting gaps between the most important EU emission reporting requirements: WFD, E-PRTR (EC, 2006), Water Information System Europe – State of the Environment (WISE-SoE, 2022) and the Urban Waste Water Treatment Directive (UWWTD) (EC, 2022).

As a consequence of this, according to the EU reported emission data, there is:

- no EU wide overview of relevant emission sources/pollutants
- no consistent time series, so no idea of trends
- limited insight in the effects of emission reduction measures carried out in the past
- no clear relation between emissions and water quality
- no insight which measures are needed to meet the water quality targets
- extra effort for EEA and others in evaluation reports and comparison of different datasets

These problems are not limited to the EU, and are recognized also on a global scale, see OECD (2017) and World Bank (Damania et al., 2019) publications.

1.2 Aim of this report

The aim of this work is to support Eionet members reporting emissions to water for the River Basin Management Plans (RBMPs) and in other data collections, e.g. WISE-1 emissions ⁽¹⁾. Technical Guidance Document (TGD) no.28 was developed for the WFD inventory (EC, 2012). However, reporting of 2nd RBMPs showed only a few MS succeeded in reporting on diffuse sources and for more than a few pollutants (EEA, 2018b).

⁽¹⁾ <http://dd.eionet.europa.eu/datasets/latest/Emissions>



This report is drafted as supplementary advice to help support emissions reporting by countries and is not intended to replace the existing TGD. The proposal may also contribute to the harmonization of the methods used for the quantification of emissions to water and in that way improve the comparability of reported emission data. The proposed methods have been deliberately designed to be as simple as possible. It is not intended that these simple methods override more detailed approaches already being used by countries and the use of the proposed methods is not mandatory. The proposal is rather targeted towards those countries which currently lack data and/or methods.

We see use of this document at two levels:

1. For countries with limited data or capacity to develop quantification methods for diffuse emissions: information, data and methods already used by others is provided.
2. For countries already reporting diffuse emissions: possibility to benchmark emission factors and quantification methods.

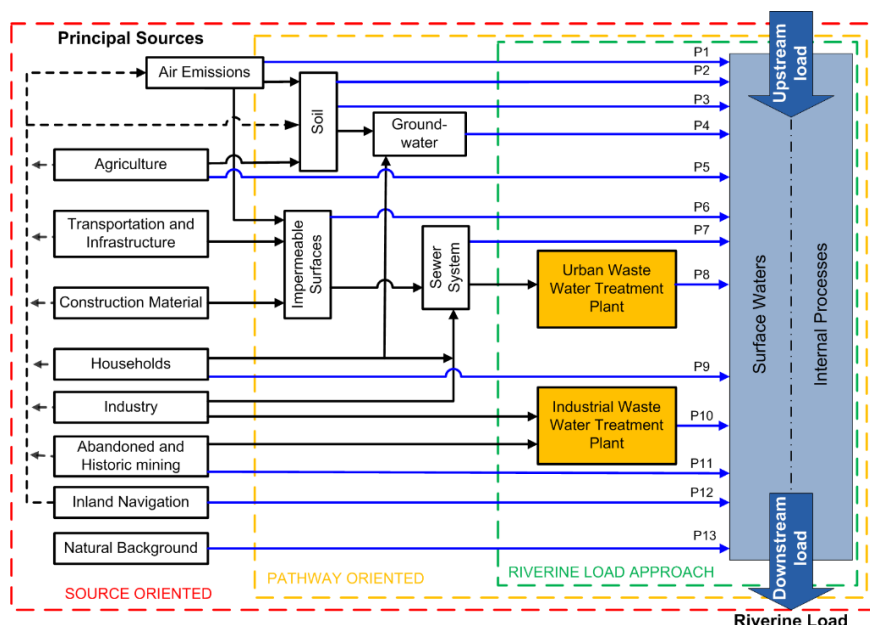


2 Simplified method for the quantification of emissions to surface water

2.1 Sources and pathways of emissions

A general scheme in which the main principal sources, pathways and intermediates of emissions to water are represented was developed under the WFD Common Implementation Strategy (EC, 2012) (Figure 2. 1). On the left side of this scheme, the principal sources of pollutants are shown, representing groups of sources which can be related to economic sectors or activities. The natural background is also represented as a separate source. In fact, this is a rather complicated source because natural background concentrations can also be a part of the other pathways and double counting must be avoided. Emissions, discharges or loads can follow different pathways, either directly to surface water, or to other compartments of the environment (air, soil, groundwater). A specific place is given to urban areas with the impermeable surfaces, the sewer system and the wastewater treatment plants, both urban (UWWTPs) and industrial (IWWTPs).

Figure 2. 1 Relationship between the different surface water compartments and pathways (P1-P13).



P1 Atmospheric Deposition directly to surface water	P8 Urban Waste Water treated
P2 Erosion	P9 Individual - treated and untreated- household discharges
P3 Surface runoff from unsealed areas	P10 Industrial Waste Water treated
P4 Interflow, Tile Drainage and Groundwater	P11 Direct Discharges from Mining
P5 Direct discharges and drifting	P12 Direct Discharges from Navigation
P6 Surface Runoff from sealed Areas	P13 Natural Background
P7 Storm Water Outlets and Combined Sewer overflows + unconnected sewers	

Source: EC (2012)

While different approaches are shown in the scheme (riverine load approach, source-oriented approach and pathway-oriented approach), the quantification of the different pathways (P1-P13) is the core of a complete emission inventory. Most of the existing emission reporting requirements can be related to one or more of these defined pathways.

Even though the riverine load approach is less accurate than the pathway approach, it is better than no inventory at all. Further, it is known that several countries use this method. Nevertheless, it is not the preferred method here, mainly because it lacks to give insight into the different sources behind the pathways. As a result, it would not be easy to make a connection with possible mitigation measures. Still, the riverine load approach stays available as a separate method and the calculation of river loads can play an important role in the quality assurance of the pathway approach, but this proposal will focus on the quantification of the pathways P1-P13.

It is interesting to have information on the primary sources (e.g. use of products, processes) within households and small and medium enterprises (SME's) which end up in the sewer and the UWWTP's. As this is a rather complicated exercise, it is likely to be more appropriate in more advanced stages of emission inventories.

2.2 Simplified emission factor

It is proposed to use a simplified emission factor method as developed in the International Commission for the Protection of the Rhine (ICPR), using a limited number of emission factors and statistical data. This method has been described by Mohaupt et al. (2001) and has been applied for seven metals in the Rhine catchment. The estimated loads agreed rather good with the loads of the river Rhine, as measured at the Dutch-German border. This method has been applied in various emission inventories in the Rhine catchment (Besozzi et al., 2003), including nutrients (ICBR, 2016) and PAHs (ICBR, 2021).

This emission factor method was also used in the EC project: 'Diffuse water emissions in E-PRTR' (Roovaart et al., 2013). In this project, diffuse emissions to water have been quantified for a selection of 40 key sources – key substance combinations, covering the EU Member States and the EFTA countries on a River Basin District sub-unit scale (Roovaart et al., 2013).

A good explanation of emission factors used in emission inventories can be found in a publication of TNO: 'The Art of Emission Inventorying' (Pulles and Heslinga, 2007). Although this publication is related to air emission, a lot of the problems and solutions are also recognized in emissions to water inventories.

Emissions of a pollutant for an activity are calculated by multiplying an activity rate (AR_a) for a specific activity (or pathway) by an emission factor for this activity and a certain pollutant ($EF_{p,a}$), expressed in emission per AR unit. An example for an activity is the production of urban waste water. The AR will then be the number of inhabitants producing waste water. The EF for a pollutant, e.g. total Nitrogen, will then be the yearly load of total Nitrogen in urban waste water per inhabitant. The calculation method is shown in the formula below:

$$E_{p,a} = AR_a \times EF_{p,a}$$

Where:

- $E_{p,a}$ = Emission of a pollutant for an activity
- AR_a = Activity Rate for an activity
- $EF_{p,a}$ = Emission factor of a pollutant for an activity

The emission calculated in this way is referred to as the total emission. For an activity, where all emissions are released directly into surface waters (e.g. P12 Inland Navigation), the total emission equals the net emission to surface waters. When only a part of the calculated emissions ends up in the surface water, and the other part for example in soil, an extra factor needs to be introduced to describe the percentage of the emissions going to surface water.

Not all the pathways can be covered with the simplified emission factor method. Some pathways are too complex to be described with only an AR and an EF. For those pathways (e.g. P1 and P3) models are often used. Some models used by European countries for the quantification of emissions to water are e.g. MONERIS ⁽³⁾, MoRE (Fuchs et al., 2017), and Pegase (Deliège et al., 2009). Different models may use different definitions of pathways, combine pathways or split up pathways in relevant sub pathways. All these models make use of emission factors. When EU-wide models are known for specific pathways and quantified emissions are available, these models can be used and are mentioned in this paper.

2.2.1 Activity Rates (AR)

It is proposed for the AR's to make use of freely available statistical data, which are updated on a regular basis (e.g. the Eurostat Database ⁽⁷⁾). This will facilitate the regular updating of the emission inventory and limit the overall burden of emission reporting. Examples of an activity rate are, for instance, inhabitants, population equivalent (p.e.) or the amount of km driven by cars. The chosen AR should be relevant for the specific activity or process (e.g. km driven by cars). In the following chapters in which the different pathways are described, more specific references are added.

In some cases, appropriate data for the ideal AR are not available. In other cases, the available data sets might contain gaps for specific areas or time periods. In such cases, application of a so-called "proxy variable" can help to derive at least a rough estimate of the AR. A proxy variable is a variable that is not directly related to the data that are needed but might have a good correlation with such data. Such proxy data could be the population size or gross domestic product or other high-level indicators of the size and the economic activities in a country. When using a proxy, one has to assume or derive a relationship between the value of the data searched for and the value of the proxy in countries or years where data are available. The estimates for the gaps then follow from the application of this relationship (adapted text from Pullis and Heslinga, 2007).

⁽³⁾ <https://www.igb-berlin.de/en/moneris>

⁽⁷⁾ <https://ec.europa.eu/eurostat/data/database>

2.2.2 Emission Factors (EF)

Emission factors are related to a specific AR (and pathway) and are pollutant specific. An EF may vary in time and space, mainly as a result of the implementations of new technologies and mitigation measures (like banning or limiting specific products or uses) and differences in national or regional use of products or appliance of processes. One of the big challenges for a simple emission inventory is to find an optimum between using general EF's where possible, but with the ability to differentiate if necessary.

A simple example is given for the quantification of emissions from UWWTPs (pathway 8, see Chapter 7) for the substance lead:

$$E = AR \times EF$$

Where:

E (Emission) = emission of lead by UWWTPs in a RBD (kg/year)

AR (Activity Rate) = annual (mean) effluent flow for all UWWTPs in a RBD (m³/year)

EF (Emission Factor) = concentration of lead in effluent (µg/l)

With an EF for lead of 0.73 µg/L (see Table 7.4) and a hypothetical AR of 10⁶ m³/year, we can calculate an emission of lead to surface water of 0.73 * 10⁻⁹ (µg to kg) * 10⁶ * 10³ (m³ to l) = 0.73 kg/year.

2.2.3 Spatial scale

The easiest way of using the simplified emission factor method is to apply it at a country level, as a lot of statistical data are available at this scope and for some countries this would be a good place to start for the emission inventory. However, it should be noted that pollutants that are not relevant to the river basin do not need to be quantified and reported (EC, 2012). As a first approximation, it is suggested that the emission quantification is made at a country level. More detailed calculations to the level of River Basin Districts (RBD) may be made once capacity and expertise improve. When data is presented on a country level in this report, the intention is to cover the full list of Eionet members (32 countries: EU 27 and Iceland, Lichtenstein, Norway, Switzerland and Turkey) and the 6 Eionet cooperating countries (Albania, Bosnia and Herzegovina, Kosovo ⁽⁸⁾, Montenegro, North Macedonia and Serbia) so 38 countries in total. When data is not available for specific countries, this is mentioned in a footnote.

2.2.4 Temporal scale

The objective of most emission inventories is to estimate the total mass of one or more emitted pollutants within one specified year. Therefore, the quantified emissions will be expressed in mass units per year, corresponding to a specific year.

2.2.5 Pollutants

The WFD inventory applies to the list of priority substances and other pollutants (EQS Directive Article 5, EC (2008)), which means that the inventory should address all inputs of those substances into the environment that are likely to reach surface waters. An overview of reported emission data by EEA (2018b) shows the 17 pollutants most frequently causing failure to achieve good chemical status for the WFD (Table 2. 1). This Table also shows the limited

⁽⁸⁾ Under UN Security Council Resolution 1244/99



number of MS reporting diffuse sources, with only about one third of MS reporting diffuse sources of metals. For other pollutants, even fewer MS manage to report.

It was not possible to achieve a complete overview of all relevant pollutants within this report. We focused on the pollutants mentioned in the WFD (EQS Directive Article 5, EC (2008)), but could only include pollutants for which data were available. Relevant data on pollutants not mentioned in the WFD was found when carrying out a literature check for different pathways. Monitoring data were found for many pollutants, particularly for the pathways P6, P7, P8 and P9. Pollutants most often described in the factsheets are metals and PAHs. For a small number of pesticides some data is included in the pathways P2-P5. The focus of this activity has been on the WFD priority substances, not nutrients. The ecological parameters total Nitrogen and total Phosphorus were therefore not included in the fact sheets.

Table 2. 1 EEA Report No 18/2018 Chemicals in European Waters (EC, 2018)

Table 3.2 Number of Member States in which data are available for emissions of the 15 priority substances most frequently causing failure to achieve good chemical status

Pollutant	Source or pathway		
	Industry	UWWTP	Diffuse sources
Cadmium	24	22	8
Lead	26	22	9
Mercury	22	23	8
Nickel	26	26	9
Anthracene	9	9	7
Benzo(a)pyrene	7	4	5
Benzo(b)fluoranthene	5	2	3
Benzo(k)fluoranthene	5	2	3
Indeno(1,2,3-cd)-pyrene	5	2	3
Benzo(g,h,i)perylene	9	7	2
Fluoranthene	14	11	6
4-Nonylphenol	11	16	5
DEHP	14	17	5
pBDEs	3	3	4
Tributyltin-cation	5	3	2
Isoproturon	7	3	5
HCH	6	4	3

■ 14 or more Member States reporting
 ■ Between 7 and 14 Member States reporting
 ■ Fewer than 7 Member States reporting

Source: EEA, 2015, 2017b, 2018b.

3 ATMOSPHERIC DEPOSITION DIRECTLY TO SURFACE WATER (P1)

3.1 Introduction

Atmospheric deposition of substances on water and soil can be described as “the load to surface water or soil via the atmosphere”. Once emissions from sources (e.g. traffic, shipping, industries) have entered the atmosphere, the substances are distributed through the atmosphere and end up in the surface water and on the soil as a result of deposition in wet (precipitation) and dry form.

Emissions to water from atmospheric deposition result from direct emissions to surface water and indirect emissions due to emissions from the sewer system (e.g. collecting run-off water from paved areas), overflows from combined sewer systems and effluents from wastewater treatment plants. For this factsheet, the calculated emissions are only the direct loads to surface water. The loads to the sewer system and the sewer overflows are not considered in this factsheet but are included in the pathways P7 and P8. The loads to unsealed areas and the resulting loads from soil to surface water are included in the pathways P2-P5.

This factsheet sets out a method for calculating the atmospheric load to surface water (not to soil) for metals (Cd, Hg and Pb), PAH, HCB, PCDD/F and PCB13.

Significant amounts of metals are emitted to the atmosphere from anthropogenic sources, natural sources and volcanism. Currently the main anthropogenic emission sources in the EMEP region ⁽⁹⁾ are combustion and industrial processes. In addition to the anthropogenic sources, a considerable amount of particle-bound metals (e.g. Pb, Cd) enters the atmosphere through wind re-suspension of dust, containing metals. Metals released to the atmosphere are partly of natural origin and partly come from (previously) accumulated anthropogenic deposition (MSC-E, 2022).

Most of the persistent organic pollutants (POPs) are emitted into the environment by anthropogenic emission sources. Anthropogenic emissions of POPs can be divided into industrial and agricultural emissions. In addition, a contribution for PAH can be expected from the natural sources like, for example, forest fires and volcanic activities.

For the emissions per country or River Basin District (RBD), the model studies of EMEP can be used. EMEP (Co-operative programme for monitoring and evaluation of long-range transmission of air pollutants in Europe) has carried out model studies for the total deposition for different pollutants, including metals such as cadmium, mercury and lead, benzo(a)pyrene, HCB, PCB153 and PCDD/F from 2015-2019. All data are recalculated by EMEP every year.

3.2 Calculation methods

EMEP distinguishes two types of modelling:

⁽⁹⁾ <https://www.en.msceast.org/index.php/j-stuff/content/list-layout>

1. Modelling of ecosystem dependent deposition including land cover. The deposition flux on water bodies and wetlands is calculated in kg/km²/year for cadmium, lead, and mercury (see par. 3.2.1). Land cover data in EMEP developed by the MODIS (Strahler et al, 1999) is used in the model, for water bodies and wetlands the following definition is used:
 - wetlands: Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in either salt, brackish, or fresh water
 - water bodies: Oceans, seas, lakes, reservoirs, and rivers. Can be either fresh or salt-water bodies
2. Modelling of the total deposition flux expressed in g/km²/year for the other substances (see par. 3.2.2 and 3.2.3).

The EMEP modelling results are based on the EMEP 0.1° x 0.1° longitude-latitude grid. Shapefiles ⁽¹⁰⁾ per country are available.

3.2.1 Ecosystem dependent deposition (metals)

For cadmium, lead and mercury, the modelled deposition flux is available per type of land use in g/km²/year, the 'Ecosystem dependent deposition'. Water bodies and wetlands are part of these various types of land use. For each EMEP grid, a flux for waterbodies and a flux for wetlands is available ⁽¹¹⁾ in the Ecosystem-specific information datasets. The area (km²) of the grids ⁽⁹⁾ differ per country. At the border with other countries or the ocean, the grid will be smaller. To calculate the atmospheric deposition loads, the fraction of water bodies and wetland per EMEP grid must also be known. This information (GIS shapefile) is not reported on the EMEP website but can be requested from EMEP by [e-mail](#).

Calculation:

1. Deposition on surface water per EMEP-grid:
Deposition to water = Flux to water * Area_km² * Water Fraction
Deposition to wetland = Flux to wetland * Area_km² * Wetland Fraction
2. Deposition on surface water per MS = sum of deposition on surface water of all EMEP-grids:

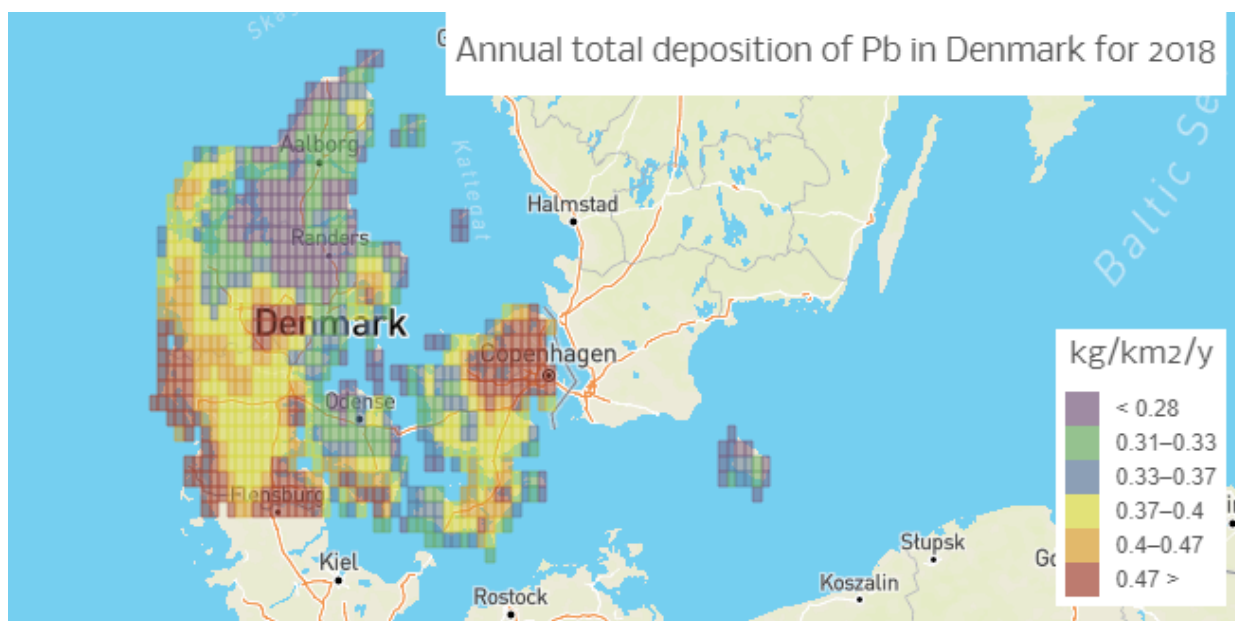
The flux and area per EMEP-grid is reported in the EMEP downloads. The percentage water fraction per EMEP-grid should be requested from EMEP. In EMEP, country specific deposition figures ⁽¹⁰⁾ are available as well, Figure 3. 1 gives an example for Denmark.

⁽¹⁰⁾ <https://www.ceip.at/the-emep-grid/grid-definiton>

⁽¹¹⁾ <https://www.en.msceast.org/index.php/pollution-assessment/emep-countries-menu>



1 **Figure 3. 1 Lead flux atmospheric deposition(kg/km²/year) in Denmark for 2018 (EMEP).**



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4 **3.2.2 Total deposition flux (other substances than metals)**

5 EMEP model fluxes for the total deposition (¹⁴) are reported per EMEP-grid for benzo(a)pyrene,
6 HCB, PCB153 and PCDD/F. The EMEP website shows also maps and data per country for the
7 deposition from and to a country for the year 2018 (¹⁵).

8

9 For these substances no distinction has been made per landcover by EMEP. To calculate the
10 deposition per country to surface water, the percentage of surface water per total country area
11 should be known. For that purpose, the surface water fraction per grid cell can be calculated
12 from the file with the water and wetland fractions requested from EMEP (see par. 3.2.1).

13

14 Calculation:

15 - Deposition on surface water by the total flux per EMEP-grid:

16 Total deposition = Total flux * Area_km² * (Water + Wetland fraction)

17 - Deposition on surface water per MS = sum of deposition on surface water of all EMEP-
18 grids

19 The flux and area per EMEP-grid is reported in the EMEP downloads. The percentage of surface
20 water per country can be calculated with the water and wetland fraction per EMEP grid.

(¹⁴) <https://www.en.msceast.org/index.php/pollution-assessment/emep-domain-menu/data-hm-pop-menu>

(¹⁵) <https://www.en.msceast.org/index.php/pollution-assessment/emep-countries-menu>

3.2.3 PAH (16 EPA) compared to Benzo(a)Pyrene

Because EMEP models only benzo(a)pyrene (BaP), the ratio of the other PAHs to BaP is determined using the deposition measurements in precipitation which are available on the EMEP website ⁽¹⁶⁾.

For all monitoring stations, the average per year is calculated for 2015-2019 (Aas, 2020). For each monitoring station, this average per PAH is divided by the average of BaP for the specific year. Then, the median, 10 and 90 percentile and the number of the deposition measurements are determined for all monitoring stations. Table 3. 1 shows the ratio for the 16 EPA PAH fluxes compared to the BaP flux in precipitation.

Table 3. 1 Calculated ratios of 16 EPA PAHs compared to benzo(a)pyrene for 2015-2019 for measurements in precipitation (EMEP). Benzo(a)pyrene is scaled as 1.

Substance	Precipitation			
	Median	P10	P90	Count
Benzo(a)pyrene	1	1	1	127
Acenaphthene	0.96	0.26	4.42	41
Acenaphthylene	0.52	0.00	2.00	41
Anthracene	0.24	0.12	1.00	86
Benzo(a)anthracene	0.90	0.54	1.29	127
Benzo(b)fluoranthene	1.97	1.03	2.41	74
Benzo(gg,h,i)perylene	1.23	0.65	1.77	91
Benzo(k)fluoranthene	0.77	0.52	1.00	87
Chrysene	1.84	0.50	4.86	50
Dibenzo(aa,h)anthracene	0.28	0.07	0.63	109
Fluoranthene	4.18	1.06	7.79	85
Fluorene	1.02	0.29	22.72	46
Inden(11,2,3-cd)pyrene	1.39	0.82	1.81	127
Naphthalene	2.11	0.21	23.88	46
Phenanthrene	5.06	1.58	16.13	81
Pyrene	2.93	1.06	5.90	86

3.3 Conclusions

Atmospheric deposition to surface waters can be quantified by using available EMEP data for the pollutants: cadmium, mercury and lead, PAH (16 EPA), HCB, PCB153 and PCDD/F. Where a country does have monitoring data of (wet and dry) deposition measurements in precipitation from national monitoring or project results, pollutants loads to the surface water can be quantified more accurately.

The EMEP website mentions the following remarks to the emission data modelled by EMEP:

⁽¹⁶⁾ <http://ebas.nilu.no/>



1 “Emission data is one of the most important types of model input information greatly
2 determining the results of modelling of pollutants long-range transport. Reliable values of
3 emission at the model input are vital for estimating realistic levels of pollution using the models.
4 Since wind re-suspension is dependent on a large number of local-scale environmental
5 parameters, model estimates of re-suspension in the EMEP region are subject to high
6 uncertainty. In addition to this, natural emission and re-emission of elemental mercury is also
7 considered in calculations.”
8



4 EROSION (P2), SURFACE RUNOFF FROM UNSEALED AREA (P3), INTERFLOW/TILE DRAINAGE/GROUNDWATER (P4), DIRECT DISCHARGES AND DRIFTING (P5)

4.1 Introduction

This fact sheet describes the pathways P2, P3, P4 and P5. Metals and pesticides from agricultural land will reach the surface water by one or more of these pathways and their loads are related. Agricultural practices are responsible for a large part of diffuse anthropogenic emissions to surface waters. Depending on the soil management and type of crop, a certain percentage of agricultural inputs will then leach, run-off, erode or reach surface waters in some other way. The different pathways are described in this introduction. It has to be stated that not all existing primary sources are covered in this chapter. The focus is on the agricultural sources with a large contribution to the loads to surface water. Other, minor sources like surface runoff from natural areas (e.g. forests) are not included.

4.1.1 Erosion (P2)

Erosion describes the transport process of land surface materials, especially rocks, sediments, and soils by the action of water, wind, or a glacier. The displacement of the upper soil layer is mainly caused by the runoff through heavy rainfall events or by strong winds. Although erosion is a natural process, it was greatly accelerated by human activities over the past decades. For instance, intensive agriculture and deforestation foster erosion processes due to related long periods where soils are left without a vegetation cover that serves as a protection against weathering. Furthermore, anthropogenic climate change enhances erosive processes caused by regionally or locally increasing numbers of heavy rainfall events and longer dry periods as plant covers can be destroyed and leave the soil surface unprotected. In general, surface runoff is the dominant erosive process in the EU. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil, also.

Erosion causes both "on-site" and "off-site" problems. The eroded material is transported downhill and deposited again or transported to surface waters, where it may cause siltation with negative effects for ecosystems and stream hydraulics. On-site, erosion leads to soil loss and soil degradation at the hillside, e.g. decline in organic matter and nutrient content, the breakdown of soil structure, and a reduction of the available soil water holding capacity. Off-site erosion describes the transport of eroded material downhill and its deposition or further transport into surface waters. Eroded soil material from agricultural fields may contain a number of pollutants, which are sorbed to soil particles, like clay (e.g., phosphate, metals, some pesticides).

4.1.2 Surface runoff from Unsealed Areas (P3)

Runoff occurs when there is more water than the land surface can infiltrate or hold. The excess liquid flows across the surface of the land and into nearby creeks, streams, or ponds. The most



familiar types of natural runoff are caused by rain or melted snow water. But, runoff may originate from irrigation, too.

Runoff from agricultural fields may contain several pollutants, e.g. nutrients (phosphate, nitrate), pesticides, pathogenic bacteria and veterinary antibiotics (from organic fertilizers), as well as metals (from inorganic fertilizers or natural background). Depending on pollutant properties, different portions of the output from fields may be transported either in the dissolved or the sediment phase (erosion) of runoff water.

The extent of erosion during runoff events depends on the speed and turbulence of surface runoff and is mostly associated with linear runoff in landscapes. Thus, surface runoff and erosion are often highly related processes.

4.1.3 Interflow, Tile Drainage and Groundwater (P4)

This pathway covers the transport of substances after leaching into the soil, whereas pathway P3 describes the runoff at the soil cover. We distinguish three types of leaching:

- *Interflow*

The subsurface runoff is a relatively rapid flow toward the stream channel that occurs near to the surface of the soil. Interflow typically flows more slowly than surface runoff. But it occurs more rapidly than baseflow, which does not result from direct runoff, but is the portion of stream discharge derived from groundwater (Figure 4. 1).

- *Tile drainage*

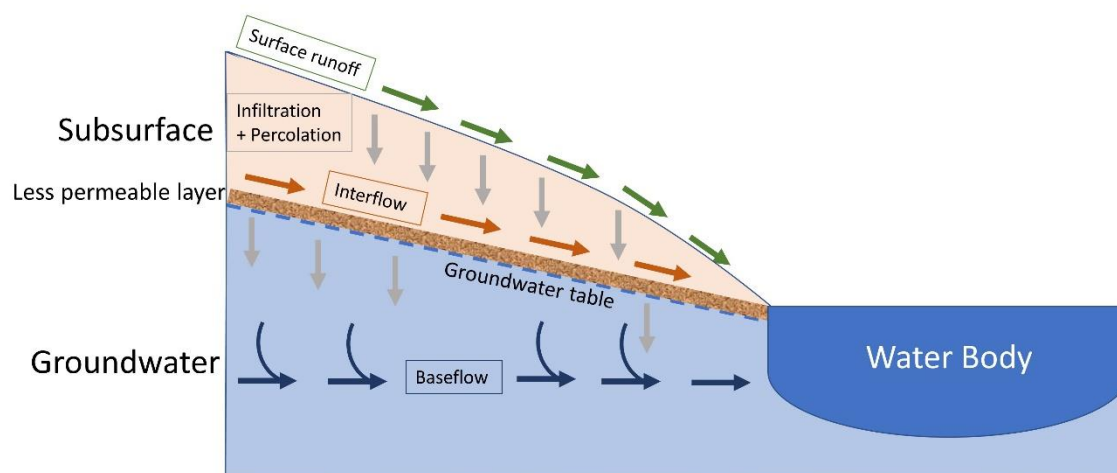
An artificial drainage system removes excess water from soil below its surface. All parts except the outlet are located below the surface of the ground. It provides better drainage because it removes water from the soil to the depth of the drain.

- *Groundwater*

The leaching of pollutants from the soil particles into water as it moves towards groundwater.



1 **Figure 4. 1 Schematic overview of surface runoff, interflow and baseflow in a catchment.**



2

3 **4.1.4 Direct Discharges and Drifting (P5)**

4 Pathway 5 covers the direct discharges and drifting of pollutants:

5 - *Direct discharges*

6 When fertilisers, manure or pesticides are handled on farms, a part of it may cause
7 unintended pollution of ditches/streams via spillages on hard surfaces or direct input from
8 application machinery (e.g. overspray).

9 - *Drifting*

10 Drift or spray drift can occur during the application of fertilizers or Plant Protection Products
11 (PPP) in the field. It is the airborne movement of fertilizers or pesticides from a treated area
12 to any unintended site. Drift can happen during application, when droplets are transported
13 away from the target site, or after the application, when some chemicals become vapours
14 that can move off-site. This so called 'vapour drift,' and an important factor for the
15 quantification of vapour drift can be calculated with the pesticide's vapour pressure. Spray
16 drift can be important under specific conditions and also affects soil and surface water.
17 Examples are where one field is sprayed with herbicides and the drift affects the growth of a
18 crop in a neighbouring field. Spray drift is more important for pesticides, than fertilizers. In
19 section 4.3 (calculation methods - pesticides) we only consider spray drift directly reaching
20 surface water.

21

22 **4.1.5 Modelling the pathways P2 - P5**

23 Without detailed models, it is not possible to distinguish between pathways P2 to P5. Therefore,
24 we have chosen to discuss these pathways together in this factsheet. It was decided to follow
25 the approach of trying to estimate the land-based sources and then combining these with an
26 (average) loss to surface water.

This factsheet distinguishes between metals and pesticides. Regarding the metals it is restricted to the WFD priority substance ⁽¹⁷⁾ metals cadmium (Cd), lead (Pb) and nickel (Ni). They will be described in 4.2. The pesticides are described in 4.3. It deals with three WFD priority substances: acetonifin, bifenoxy and cypermethrin ⁽¹⁸⁾, and a number of pesticides identified as River Basin Specific Pollutants (RBSPs).

4.2 Calculation methods - metals

Concerning metals, this fact sheet describes the two pathways of soil erosion and leaching to surface waters and further, the calculation of the resulting loads of metal emissions to surface waters through these pathways.

Data availability on pollutant concentrations in soils is often limited. For some pollutants, such as metals and PAH's, there is a natural background component to the total amount present (see also fact sheet P13).

4.2.1 Soil erosion

In Comber (2021), the background concentrations of metals from natural soils are used to estimate the loads to surface waters from natural erosion processes. The Foregs database ⁽¹⁹⁾ provides natural background concentrations across numerous countries (Table 4. 1). The soil losses are available from an extensive database on soil loss across the EU in Eurostat (2021c) ⁽²⁰⁾. Eurostat (2021d) also provides the amount of agricultural area per country ⁽²¹⁾. Metal losses to water can therefore be calculated by multiplying the soil loss by the metal concentration in the soil (Table 4. 2).

Equation 4.1 Load of soil erosion to surface water (ton/year).

$$L_{so} = \frac{ConcSoil * SoilLoss * AgrArea}{1000000} * \%SW$$

Where:

L_{so}	= Total load of soil erosion to surface water (t/year)
ConcSoil	= Background concentration for the individual metals per country, Table 4. 1 (mg/kg)
SoilLoss	= Total annual soil loss per country, (t/ha/year)
AgrArea	= Agricultural land per country,
%sw	= % surface water, part of the annual soil loss by erosion that ends up in surface water per country

Note: in this calculation it is assumed all the soil loss will end up in the surface water (see yellow text). There are indications from DE and NL that only a percentage of the soil loss especially the

⁽¹⁷⁾ EQS-Directive, Annex I, Part A

⁽¹⁸⁾ EQS-Directive, Annex I, Part A

⁽¹⁹⁾ <http://weppi.gtk.fi/publ/foregsatlas/ForegsData.php>

⁽²⁰⁾ https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_soiler&lang=en

⁽²¹⁾ [Statistics | Eurostat \(europa.eu\)](https://statistics.eurostat.eu)



smallest particles will reach the surface water (DE: 6%). This discussion is still running. We hope to clarify this as part of the Eionet consultation process.

Table 4. 1 Background Cd, Ni and Pb concentrations in European soils (Comber, 2021).

Country*	Mean soil concentration (mg kg ⁻¹)***		
	Ni	Pb	Cd
Albania	52.5	13.5	0.36
Austria	25.2	27.1	0.37
Belgium	29.8	32.8	0.87
Bosnia and Herzegovina	-	-	-
Bulgaria	-	-	-
Croatia	35.5	19.7	0.33
Cyprus	-	-	-
Czechia	17.5	28.1	0.26
Denmark	3.4	4.3	0.04
Estonia	9.1	11.6	0.14
Finland	9.3	5.5	0.07
France	23.7	36.3	0.41
Germany	16.8	25.9	0.34
Greece	171	39.2	0.83
Hungary	18.2	13.8	0.17
Iceland	-	-	-
Ireland	22	19.5	0.51
Italy	83.4	35.6	0.37
Kosovo**	-	-	-
Latvia	8.1	8.2	0.09
Liechtenstein	-	-	-
Lithuania	7.5	8.7	0.11
Luxembourg	-	-	-
Malta	-	-	-
Montenegro	-	-	-
Netherlands	9.3	26.9	0.29
North Macedonia	-	-	-
Norway	12.4	8.1	0.09
Poland	7.4	10.7	0.17
Portugal	13.2	18.2	0.08
Romania	-	-	-
Serbia	-	-	-
Slovakia	22.9	34.5	0.31
Slovenia	39.8	29.2	0.59
Spain	25.6	26.9	0.26
Sweden	6.5	10	0.09
Switzerland	55.3	36.2	0.54
Turkey	-	-	-
Mean	51.7	21.9	0.31

* Eionet Members and cooperating countries. No data available for a number of countries.

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*** <http://weppi.gtk.fi/publ/foregsatlas/ForegsData.php>

1 Table 4. 2 Cd, Ni and Pb average loss from European soils (Comber, 2021).

Country*	Agricultural areas and natural grassland total annual soil loss ^b (t/ha/year)	Agricultural area ^c (*10 ⁶ ha)	Load ^a (kg/day)		
			Cadmium	Nickel	Lead
Albania	3.2**	11.74	4	536	140
Austria	7	26.54	19	1283	1376
Belgium	1.6	13.56	5	177	195
Bosnia and Herzegovina	3.2**	17.80	5	813	344
Bulgaria	3.3	50.30	14	2349	995
Croatia	3.5	14.86	5	505	280
Cyprus	3.5	1.32	0	65	28
Czechia	2.6	35.23	6	439	705
Denmark	0.5	26.33	0	12	15
Estonia	0.5	10.04	0	12	16
Finland	0.4	22.72	0	23	14
France	2.3	290.20	74	4334	6637
Germany	1.75	166.45	27	1339	2069
Greece	4.9	52.88	59	12131	2784
Hungary	2.1	53.44	5	560	422
Iceland	3.2**	15.55	4	710	301
Ireland	0.9	45.16	6	245	216
Italy	11	128.43	143	32263	13773
Kosovo***	3.2**	4.20	1	192	81
Latvia	0.7	19.38	0	30	30
Lithuania	0.8	29.47	1	48	56
Luxembourg	3.4	1.32	0	63	27
Malta	4.7	0.12	0	8	3
Netherlands	0.3	18.22	0	14	40
North Macedonia	3.2**	12.64	3	577	244
Norway	3.2**	9.83	1	108	70
Poland	1.5	145.40	10	444	637
Portugal	3.1	35.91	3	401	555
Romania	4.2	134.14	47	7972	3376
Serbia	3.2**	34.87	9	1592	674
Slovakia	3.8	19.20	6	458	690
Slovenia	14.8	4.78	12	771	565
Spain	4.6	242.02	78	7802	8212
Sweden	1	30.00	1	53	82
Switzerland	3.2**	15.15	7	740	484
Turkey	3.2**	382.39	103	17461	7393

2 * Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro.

3 ** Mean value of 3.2 t/ha/year is used for calculations.

4 *** Under UN Security Council Resolution 1244/99.

5 ^a Load to water from soil background is still being reviewed by the metal's associations.

6 ^b https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_soiler&lang=en

7 ^c [Statistics | Eurostat \(europa.eu\)](https://statistics.eurostat.eu)

4.2.2 Leaching from agricultural soils

In a European wide study, Eurometaux (Comber, 2021) mentioned pollutant loads to agricultural soils for selected metals (lead, cadmium and nickel) on a country level which can be used if more detailed national information is not available (Table 4. 3). These (total) loads can be used as activity rates for pathways 2, 3, 4 and 5 in the different Member States.

The loads to agricultural soils are the sum of loads of different sources to agricultural land:

- Natural background concentrations in soils; (see Comber (2021), Table 6 and fact sheet P13 'Natural background'),
- Fertilizer used
 - o Sewage sludge (biosolids)
calculation of loads to arable land based on the amount of sludge to land (ton/year/dry matter) used as fertilizer on the country level and mean metal concentrations in sludge (mg/kg/dry matter); see Comber, 2021 (Table 1),
 - o Inorganic P-fertilizer
calculation of loads to arable land based on the amount of fertilizer used (kg P/day) and mean metal concentrations (mg/kg) in inorganic fertilizers; see Comber, 2021 (Table 2) and
 - o Farmyard manure (FYM), organic fertilizer
calculation of loads to arable land based on mean concentrations in the manure (mg/kg) and animal numbers on the country level for different animals, see Comber, 2021 (Table 5). It has been assumed that all animal manure produced in a country is returned to the soil in the same country. Other types of organic fertilizers like compost and digestate from biowaste that are not mentioned here, were not taken into account because these are minor loads compared to the manure and because data is not easy available and comparable between countries.
- Atmospheric deposition
calculation of loads to arable land based on annual rainfall (mm), agricultural used area (km²) and metal concentrations in rainfall (ug/l), see Comber, 2021 (Table 8). This data only refer to wet deposition.

The total load to agricultural land of the individual sources estimated by Comber is reported in kg/day in Table 4. 4. The loads of the different sources can be found in Comber (2021, paragraph 2.1 – 2.6.) and in Annex P2-P5. These total loads can be used as activity rates for pathways 2, 3, 4 and 5 in the different Member States.

Equation 4.2 Load of leaching from agricultural soils to surface water (t/year)

$$L_{las} = \frac{PC * L_{agr}}{1000} * 365 * \%sw$$

Where:

- L_{las} = Total load of leaching to surface water (t/year)
- PC = partition coefficient, Table 4. 3

- 1 L_{agr} = Loads to agricultural land (kg/day), Table 4. 4
2 %sw = % surface water, part of the leaching that ends up in surface water

Note: in this calculation it is assumed all the soil loss will end up in the surface water (see yellow text). There are indications from DE and NL that only a percentage of the soil loss will reach the surface water (DE: 6%). This discussion is still running. We hope to clarify this as part of the Eionet consultation process.

There is a scarcity of data to quantify the metals leaching from soil. Comber (2021) estimated the ratio of loss from soil using soil/water ratio partitioning coefficients (Table 4. 3). These loss values could then be applied to the total loads applied to generate a loss of metals to water via leaching.

Table 4. 3 Derived soil partition coefficients for cadmium, nickel and lead (Comber, 2021).

	Cadmium	Nickel	Lead
Ratio of loss from soil to water	0.090	0.090	0.078

In Table 4. 4 the total loads to agricultural land (Comber, 2021) are reported. The individual sources per metal per country can be found in Annex P2-P5(Annex P2-P5 Table A P2-5. 1). The total load of leaching from agricultural soils to surface water is reported in Table 4. 5.

Table 4. 4 Total cadmium, nickel and lead loads to agricultural land from leaching (Comber, 2021, chapter 2.7, Tables 9 – 11).

Country*	Load (kg/day)		
	Cadmium	Nickel	Lead
Albania	1.4	13.8	23.5
Austria	4.1	43.2	51.3
Belgium	5.8	55.3	60.6
Bosnia and Herzegovina	1.9	23.6	34.1
Bulgaria	4.2	41.2	61.6
Croatia	2.2	22.2	30.8
Cyprus	0.4	3.4	2.8
Czechia	3.8	42.2	54.3
Denmark	4.2	44.5	62.8
Estonia	1.3	15.9	12.8
Finland	2.4	24.4	22.9
France	45	551.4	655
Germany	27.2	303.8	342
Greece	4.9	42.5	59.6



Country*	Load (kg/day)		
	Cadmium	Nickel	Lead
Hungary	8.9	81.7	89
Iceland	0.7	15.9	14.9
Ireland	6	49.5	72
Italy	26.4	305.2	387
Kosovo**	0.6	6.5	7.5
Latvia	1.5	16.3	24.1
Lithuania	3.1	31.5	41.8
Luxembourg	0.2	2.6	3.1
Malta	0	0.4	0.4
Netherlands	6.3	60.5	67
North Macedonia	0.8	10.4	19.4
Norway	0.8	9.3	18
Poland	38.5	335	307
Portugal	6.2	61.9	72.8
Romania	13.1	128.1	180
Serbia	4.2	34.4	81.7
Slovakia	1.7	20	43.2
Slovenia	0.9	8.4	7.7
Spain	49.5	620.9	711
Sweden	3.3	25.5	29.8
Switzerland	3.1	38.2	53.6
Turkey	88.9	1045.7	1808

1 *Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro.

2 ** Under UN Security Council Resolution 1244/99.

3 **4.2.3 Total sum of emissions to surface water**

4 There are two pathways for the loss of metals from agricultural land (Table 4. 5):

5 1. Erosion, Soil loss

6 A reported loss of soil multiplied by a concentration of metals (broadly speaking assumed to be
7 particulate), which depends on the agricultural practices and should not be confused with the
8 natural background concentrations.

9 2. Leaching, total loss based on source inputs.

10 A calculated summed load applied per year from fertilisers and atmospheric deposition,
11 multiplied by a proportion that is leached rather than taken up into crops or adsorbed to the
12 soil matrix (assumed to be mostly dissolved in nature). As can be seen in the table below, loss
13 of metal associated with the soil is far higher than that leached from inputs, although the
14 leached metal may be more bioavailable since it is assumed to be more in dissolved form.

1 **Table 4. 5 Total cadmium, nickel and lead loads to agricultural land in t/year, erosion and**
2 **leaching (Comber, 2021).**

Country*	Erosion calculated based on soil loss (t/year)			Leaching total loss based on source inputs (t/year)		
	Cadmium	Nickel	Lead	Cadmium	Nickel	Lead
Albania	1.38	195.64	51.10	0.05	0.46	0.68
Austria	6.81	468.30	502.24	0.14	1.43	1.47
Belgium	1.88	64.61	71.18	0.19	1.83	1.74
Bosnia and Herzegovina	1.76	296.75	125.56	0.06	0.78	0.98
Bulgaria	5.08	857.39	363.18	0.14	1.36	1.77
Croatia	1.72	184.33	102.20	0.07	0.73	0.88
Cyprus	0.14	23.73	10.22	0.01	0.11	0.08
Czechia	2.34	160.24	257.33	0.13	1.39	1.56
Denmark	0.05	4.38	5.48	0.14	1.47	1.80
Estonia	0.07	4.38	5.84	0.04	0.52	0.37
Finland	0.06	8.40	5.11	0.08	0.81	0.66
France	27.16	1581.91	2422.51	1.49	18.21	18.80
Germany	9.78	488.74	755.19	0.90	10.04	9.82
Greece	21.38	4427.82	1016.16	0.16	1.40	1.71
Hungary	1.95	204.40	154.03	0.29	2.69	2.55
Iceland	1.54	259.15	109.87	0.02	0.53	0.43
Ireland	2.08	89.43	78.84	0.20	1.63	2.07
Italy	52.04	11776.00	5027.15	0.87	10.07	11.10
Kosovo**	0.41	70.08	29.57	0.02	0.22	0.22
Latvia	0.12	10.95	10.95	0.05	0.54	0.69
Lithuania	0.26	17.52	20.44	0.10	1.04	1.20
Luxembourg	0.14	23.00	9.86	0.01	0.08	0.09
Malta	0.02	2.92	1.10	0.00	0.01	0.01
Netherlands	0.16	5.11	14.60	0.21	2.00	1.92
North Macedonia	1.25	210.61	89.06	0.03	0.34	0.55
Norway	0.28	39.42	25.55	0.03	0.31	0.51
Poland	3.75	162.06	232.51	1.27	11.06	8.80
Portugal	0.93	146.37	202.58	0.20	2.04	2.09
Romania	17.24	2909.78	1232.24	0.43	4.23	5.18
Serbia	3.44	581.08	246.01	0.14	1.14	2.34
Slovakia	2.28	167.17	251.85	0.06	0.66	1.24
Slovenia	4.20	281.42	206.23	0.03	0.28	0.22
Spain	28.40	2847.73	2997.38	1.63	20.49	20.40
Sweden	0.26	19.35	29.93	0.11	0.84	0.85
Switzerland	2.64	270.10	176.66	0.10	1.26	1.54
Turkey	37.76	6373.27	2698.45	2.93	34.51	51.83

3 *Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro.

4 ** Under UN Security Council Resolution 1244/99.

5

4.3 Calculations methods - pesticides

Pesticides include both active substances from plant protection products and biocides. Thus, pesticides can enter surface waters through point sources (e.g. WWTP) but are mostly introduced through diffuse sources from mainly agricultural practices, but also from forestry, municipal use (e.g. on roadsides), grasslands (e.g. golf courses) and domestic gardens. Apart from their diffuse input, a challenge of pesticides assessment is that concentration peaks can be only observed with event-based monitoring (directly after spraying/application or extreme weather events).

It is also uncertain, what the effects of mixtures of pesticides are and which combined impact they have on aquatic ecosystems, as this is difficult to measure. Consequently, there is limited data on actual risks of pesticides to European waters (EEA, 2018b). For pesticides, an indicator was developed to show the status of pesticide concentration in Europe. This was based on data reported by European countries (Mohaupt et al., 2020; ETC/ICM, 2021).

The WFD includes a scheme for water management of hazardous substances on a river basin level and distinguishes between EU-wide relevant Priority Substances (PS) and regional at country level relevant River Basin Specific Pollutants (RBSP). Numerous pesticides are identified in both relevance groups. RBSP are regulated on a national level as their use is mainly dependent on local conditions such as the type of crops planted, seasons, weather and available equipment (Mohaupt et al., 2020). The number of monitoring stations and pesticides reported to the EEA shows high differences between the MS, as well as the quality of this data. Also, the Ecological Quality Standards (EQS) values for certain pesticides listed as RBSP vary between the countries, which complicates an EU-wide comparison. In addition to that, data on sales and uses of Plant Protection Products (PPP) and biocides in Europe is limited, which makes it difficult to draw conclusions on local hotspots or assessments of the environmental impact (Mohaupt et al., 2020). In a study by Silva et al. (2019), high concentrations of pesticides were found in agricultural topsoil, which could be used to estimate the potential risk to surface waters. An important information for this is the percentage of land bordering to surface waters, where pesticides are applied. Still, it is not possible to extrapolate these concentrations to a wider spatial scale, as the links to pathways (e.g. erosion, leaching) and environmental conditions (e.g. geomorphology, adsorption processes) need to be investigated locally (Mohaupt et al., 2020). It is recommended to assess the emissions by pesticides to surface waters with the knowledge of the local regulations and conditions.

If more detailed (local) data is available, models can be used for the assessment of pesticides output to surface waters and groundwater. The models under the FOCUS group are EU-wide harmonized e-fate models that calculate the concentrations of pesticides in water bodies. For this, the SWASH model can be used as a user-friendly shell that connects different models relevant to the pathways P2-P5. It is connecting the Spray Drift Calculator (P5), the MACRO model for the contribution of drainage (P4), the PRZM model for surface runoff (including erosion) (P2/P3) and the TOXSWA model for the estimation of pesticide concentrations and fate in surface waters and sediment (Linders et al., 2003). An overview of pesticide models used in the EU can be found on: <https://www.pesticidemodels.eu/>.

For a simplified calculation of pesticide emissions to surface waters, two methods are described: method 1 is based on the national sold volume of pesticides, method 2 is based on the

application rate per treatment per pesticide on treated area level. Both methods must be seen as a first step in the quantification of loads of pesticides into surface water and will only give a rough indication of these loads.

4.3.1 Method 1

One way to calculate emissions is to use the national volume sold per individual pesticide combined with the percentage of the substance reaching the surface water (Kruijne et al, 2012). The national volume could be distributed to different catchments to estimate the loads per e.g. River Basin District via the area of cropland related to the pesticide application.

Equation 4.3 Loads to surface water

$$L_{sw} = \text{Activity Rate 1} * \%sw$$

Where:

L_{sw} = load to surface water
Activity Rate 1 = national volume sold per pesticide
 $\%sw$ = estimation of the percentage of pesticides reaching surface water

The EUROSTAT database provides information about the volume of pesticides ⁽²²⁾ sold in the EU. In 2019, 333 million kilograms were sold, the amount per country is shown in Table 4. 6. There are big differences in pesticide sales between Member States in Europe. The pesticide sales and use are largely dependent of the amount of arable land per country. Four countries (France, Spain, Italy and Germany) accounted for over two thirds of the pesticides sales in the EU.

Since the total volume of sold pesticides is known per MS, the sale of individual pesticides might be known as well per MS but is in most cases considered as confidential information.

Table 4. 6 Sales of pesticides, by country 2019 in tonnes (EUROSTAT).

Member State	Fungicides and bactericides	Herbicides, haulm destructors and moss killers	Insecticides and acaricides	Molluscicides	Plant growth regulators	Other plant protection products	Total
Austria	2068	1151	1613	5	63	55	4954
Belgium	2449	2328	359	11	297	682	6126
Bulgaria	1579	4340	727	(c)	10	4	6660
Croatia	656	700	122	2	80	4	1564
Cyprus	867	168	135	2	0	58	1231
Czechia	1651	2399	307	3	435	258	5053
Denmark	436	2026	57	2	131	9	2661

⁽²²⁾http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_fm_salpest09&lang=en



Estonia	105	531	33	(c)	76	(c)	745
Finland	2832	1107	23	0	56	16	4034
France	24484	22484	4367	279	1786	905	54304
Germany	10217	13941	18665	59	2089	204	45176
Greece	1756	1830	965	2	134	181	4867
Hungary	2796	3906	690	1	179	243	7815
Iceland	0.209	0.749	0.011	0	0.001	0	0.979
Ireland	922	1845	23	8	157	17	2972
Italy	24286	8524	1683	41	455	13417	48405
Latvia	295	972	39	5	321	18	1651
Lithuania	575	1199	76	(c)	468	(c)	2318
Luxembourg	(c)	54	(c)	0	8	(c)	63
Malta	70	2	3	1	0	(c)	76
Netherlands	3897	2739	1959	14	557	96	9261
Norway	77	479	8	2	37	9	611
Poland	6867	11705	2724	24	2353	579	24253
Portugal	5767	2222	812	14	5	1045	9866
Romania	4021	4013	809	4	68	132	9047
Slovakia	653	1160	149	(c)	322	70	2352
Slovenia	752	172	36	2	7	4	973
Spain	34073	17023	7636	88	145	16225	75190
Sweden	164	1544	45	0	34	13	1801
Switzerland	954	509	293	264	33	110	1921
Turkey	19333	7159	12086	21	956	11393	51190

*Eionet Members, no data for Liechtenstein and cooperating countries.

Note: (c) = confidential value

4.3.2 Method 2

In this method, an application rate per pollutant per treatment is combined with the area where the pollutant has been applied and the percentage of the substance reaching the surface water.

Equation 4.4 Loads to surface water

$$L_{sw} = \text{Emission factor} * \text{Activity Rate 2} * \%sw$$

Where:

L_{sw} = load to surface water per pollutant

Emission factor = application rate per pollutant treatment is the maximal use of the pesticide per treatment (in kg active substance per hectare)

Activity Rate 2 = area where the pesticide has been applied in hectare

$\%sw$ = estimation of the percentage of pesticides reaching surface water



Per treated area, an advised (maximum) application rate per pollutant per treatment is available for aclonifen and bifenox on the CIRCABC website ⁽²³⁾ and for isoproturon on the EFSA website ⁽²⁴⁾. If the surface of the area is known where the pesticides are used, an estimation of the loads used can be calculated. Information about the crop production in hectare is available on Eurostat ⁽²⁵⁾. The last update is from 2020. In Table 4. 7 for most substances one maximum application rate is given for a number of different crops. In common practice, the application rate may be crop specific.

Table 4. 7 Maximum application rate per pesticide allowed in the EU (kg as/ha).

Substance	Crop	Number of applications a year	Kg active substance/ha
aclonifen ⁽²⁶⁾	sunflower	1	2.4
isoproturon ⁽²⁷⁾	grass weeds, broadleaved weeds	1	1.5
bifenox ⁽²⁸⁾	broadleaved weeds	1	0.750
quinoxifen ⁽²⁹⁾	wheat and barley	1	0.3
dicofol ⁽³⁰⁾	fruit, vegetables, ornamental crops and field cultures and as a biocide	1	no info in Circabc
cypermethrin	fruit, vegetables, ornamental crops and field cultures and as a biocide	1	no info in Circabc
alachlor ⁽³¹⁾	weed control on corn, soybeans, sorghum, peanuts, and beans		1.8 (USA)
atrazine	no information		

4.3.3 Percentage loads to surface water

In both methods, an estimation has to be made of the percentage of the used pesticides reaching the surface water. This percentage will be determined by a lot of factors like the chemical properties of the pollutant, soil condition, crop type, application procedure, meteorological circumstances and the presence of surface water near the application site. Since all these factors are very local specific and differ in time and space, it is almost impossible to give an average percentage in this report. If no surface water is available, the pesticides will stay

⁽²³⁾ Communication and. Information Resource Centre for Administrations, Businesses and Citizens, provides a web-based. application that is used to create collaborative. workspaces

⁽²⁴⁾ European Food Safety Authority

⁽²⁵⁾ https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1/default/table?lang=en

⁽²⁶⁾ <https://circabc.europa.eu/sd/a/b55c02ff-83b1-4a39-9a66-6d36988ffd86/Aclonifen%20EQS%20dossier%202011.pdf>

⁽²⁷⁾ <https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2015.4206>

⁽²⁸⁾ <https://circabc.europa.eu/sd/a/9badfa79-645d-414b-a77f-03c7d6868ccf/Bifenox%20EQS%20dossier%202011.pdf>

⁽²⁹⁾ <https://circabc.europa.eu/sd/a/960dfe08-a463-44ba-ae9-d7675681e60f/Quinoxifen%20EQS%20dossier%202011.pdf>

⁽³⁰⁾ <https://circabc.europa.eu/sd/a/668ff210-4c7e-44bc-8c0f-20be8424e5d7/Dicofol%20EQS%20dossier%202011.pdf>

⁽³¹⁾ https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/fs_PC-090501_1-Dec-98.pdf

in the soil and degrade with time, reach the atmosphere or leach into groundwater. In case the soil is drained, also a part of the applied amount may go through the drains ultimately reaching surface waters. A number of examples with estimations of percentages loss to surface water from different studies are given below.

It is difficult to find percentages of the amount of used substances lost through drift and run-off to surface water. In the Netherlands, the NMI model is used (Kruijne et al, 2012). In NMI different formulas are used to calculate the drift and run-off. For this, a lot of information is necessary, like the crop-free buffer zone, distance between top of ditch bank and centre of first plant row, distance between last nozzle position and last crop row, etc. Pesticide information is available about the percentage of the application that goes to air and surface water (drift, run-off). Three WFD substances are calculated in the model (Kruijne et al, 2021): aclonifen, bifenox and isoproturon. For the other WFD substances, a 95th percentile of 1.65% of the pesticide loads to surface water was derived from the NMI-model (Table 4. 8). The 95th percentile has been used to simulate a “worst case” scenario because the pesticide loads to surface water often occur as peak flows in wet circumstances.

Table 4. 8 Percentage of total amount of pesticide sold reaching the surface water (derived from Kruijne et al, 2021).

Pollutant	Average percentage of amount of pesticide sold reaching the surface water		
	Drift	Drain/Run-off	Total
Aclonifen	0.002%	0.004%	0.006%
Isoproturon	0.01%	0.02%	0.03%
Bifenox	0.04%	3.70%	3.74%
Other substances	0.05% (95 th percentile)	1.60% (95 th percentile)	1.65% (95 th percentile)

In an American study (Kellogg et al, 2000), model runs give the 95th percentile loss as a percentage of the amount applied.. The results for the 95th percentile are: 0.5% for leaching, 3.1% for dissolved runoff and 1.5% for adsorbed runoff. The reported total percentage of pesticides reaching the surface water is 5.1%.

Tiktak et al. (2002) distinguish four types of fluxes of pesticides to four surface waters in the Netherlands: rapid drainage at the soil surface, drainage system, saturated part of the soil and leaching into groundwater. The 95th percentile for the sum of the four fluxes is 3.95%.

A Finnish report (Siimes, 2021) describes a way to estimate agricultural pesticide losses from soil to surface water in Finland. Based on this method, Finland was able to include reporting of pesticide diffuse loading into the second Finnish WFD RBPM inventory of losses. The loads of pesticides to surface water are based on the used amount of substance in the upper catchment area and the proportion of applied pesticide lost into surface water (as in method 1 described above). It was concluded that real loss fraction (via spray drift, surface runoff, erosion and drainage flow) varies in space and time. Values of loss fraction to surface water from smaller than 0.1% up to 2% are reported for Northern European areas (e.g. Kreuger 1998, Laitinen et al. 2000, Siimes et al. 2005, Kreuger & Adielsson 2008). An estimation of the substance use in the upper basin area was based on national pesticide usage statistics for almost 20 crops from about 5000 farms. For MCPA (2-Methyl-4-ChlorPhenoxyAcetic) a loss fraction of 0.16% has been used,

as mean value of a range from 0 to 0.48%. Calculated loads were compared with river loads based on measured concentrations and river flows and appeared within the same range. It was seen as a problem that, as in other countries, pesticide sale statistics are confidential at substance level, if less than three companies are producing product including the substance. It was concluded that the lack of necessary input data may hamper the applicability of pesticide quantification methods at EU Member States.

From the different literature, a global worst case range (using the 95th percentile) for the percentage of pesticides used ending up in the surface water of 0% (in case no surface water is present) to 5% can be given, as a maximum (in areas with abundant surface water like some areas in the Netherlands).

4.4 Conclusions

Metals and pesticides from agricultural land can reach the surface water by one or more of the pathways P2 to P5. Many factors influence the transport to surface waters both for metals and pesticides, such as timing and intensity of precipitation, hydrology, area ratios, and the general presence of surface water bodies. The loads to surface waters from these pathways are related to each other. Without detailed models, it is not possible to distinguish between pathways P2 to P5. Therefore, we have chosen to discuss these pathways together. It was decided to follow the approach of trying to estimate the land-based sources and combining these with the (average) loss to surface water.

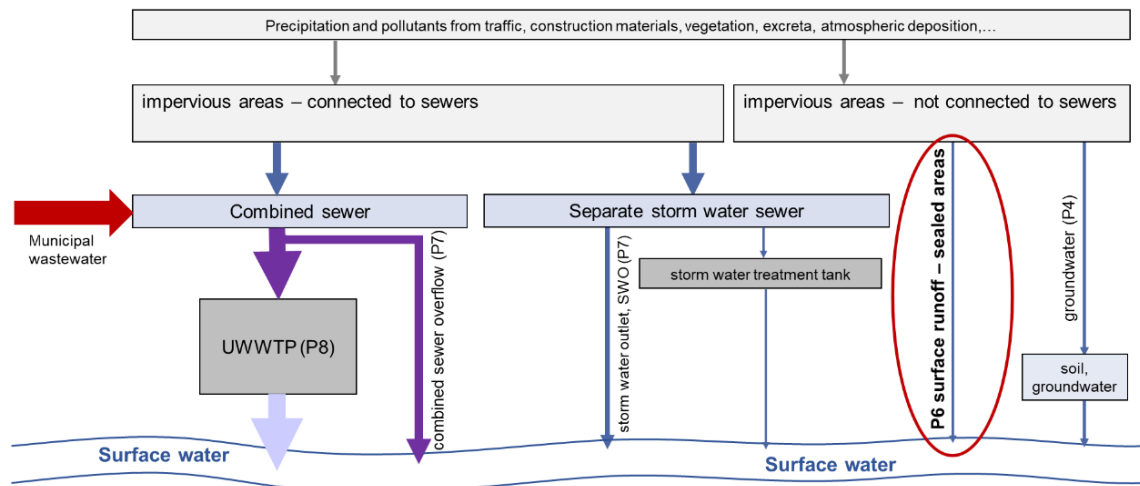


5 SURFACE RUN-OFF FROM SEALED AREAS (P6)

5.1 Introduction

In urban areas, not all impervious surfaces are connected to the sewer system (separate or combined) (Figure 5. 1). Consequently, deposited pollutants on impervious surfaces are washed off and transported to not impervious areas with vegetation or bare soils, where water possibly infiltrates or discharges with the overflow directly into surface waters. P6 only considers the emissions transported with the surface run-off (overflow) from impervious (sealed) areas directly to surface waters. This pathway includes run-off from off-site roads like highways and intra-urban impervious surfaces.

Figure 5. 1 Schematic overview of emissions to surface waters via surface run-off from sealed areas not connected to sewer systems.



In case of run-off from surfaces not connected to the sewer system, it is hard to differentiate if run-off reaches the surface water network or infiltrates in neighbouring unsealed surfaces (see P3, section 4.1.2). Even if impervious areas are connected to the sewer system (see P7, section 6), the situation might be different in other countries and landscapes (e.g. mountain areas).

For bigger cities, it might be assumed that most impervious areas are connected to sewers and if not, that water evaporates or the run-off infiltrates and pollutants are emitted to soils, retained there or washed out into groundwater. Consequently, this pollution load is included in P4 (groundwater). It can be assumed that most of the surface run-off infiltrates into soils and does not reach surface waters directly except locally during heavy rain fall events. It needs to be mentioned that in most areas this pathway for loads transported to surface waters is usually not significant in comparison to those e.g. via erosion or groundwater discharge. In the light of

climate change with expected increase of intense rainfall, this aspect might probably needs to be reviewed in the future.

Methodically, this fact sheet is strongly connected to fact sheet P7 (storm water outlets/combined sewer overflows/unconnected sewers), especially to calculations of loads in surface waters via storm water outlets.

As described for P7, pollutant sources are traffic (e.g. combustion processes, tyre wear particles, brake abrasion), atmospheric deposition (caused by anthropogenic sources or natural sources like wildfire or volcanoes), construction materials (e.g. for roofs or gutters, facade coatings (wall paint)) etc.

Main pollutants washed-up from sealed surfaces are:

- Metals
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Perfluorocarbons (PFC)
- Biocides

5.2 Calculation method

The calculation method is similar to the method described in P7 for storm water outlets. Information needed includes that about substance concentrations in rain water, deposition on urban impervious surfaces and substance concentrations that are washed out of materials like roofs and facades. The main difference to P7 is that only impervious surface areas that are not connected to sewers are considered.

To calculate emissions from surface run-off from impervious areas, the applied approaches mainly depend on the availability of information and data. One possibility is to use locally available monitoring or mean concentration values from storm water outlets. That data can be used because that information is often available and represents the surface runoff from sealed areas. The only difference is that in case of storm water outlets the water (runoff) is collected in separate sewers while here the unsealed area is not connected to a sewer.

To calculate loads information of annual stormwater run-off volume is necessary. In most countries this information (volume of stormwater) is not known on the river basin or even on the national level. To estimate loads on the local level a simplified method can be applied.

On the local level specific loads in surface waters via storm water run-off from impervious surfaces not connected to sewers can be estimated based on substance concentrations in storm water outlet using Equation 5.1.

Equation 5.1 Annual load in storm water sewer.

$$L_{sw_nc} = \frac{Q_{sw_nc} * C_{sw_o}}{1,000}$$

Where:

- | | |
|--------------|---|
| L_{sw_nc} | = annual pollutant load emitted to sewer in kg/a |
| Q_{sw_nc} | = annual stormwater run-off from impervious urban area not connected to sewers in m ³ /a |

- 1 C_{sw} = substance concentration in stormwater run-off in g/m³
2 1,000 = conversion factor (g in kg)

3

4 The volume of annual stormwater run-off from impervious urban areas not connected to
5 separate storm water outlets (Q_{sw_nc}) can be calculated according to Equation 5.2:

6

7 **Equation 5.2 Annual stormwater run-off from impervious urban area connected to separate**
8 **storm water sewers.**

$$Q_{sw_nc} = A_{c,sw_nc} * P_a * 10 * R_{coeff}$$

10

11 Where:

12 Q_{sw_nc} = annual stormwater run-off from impervious urban area not connected
13 to sewers in m³/a

14 A_{c,sw_nc} = contributing drainage area not connected to sewer in ha

15 P_a = annual precipitation in mm

16 10 = conversion factor (mm in m³/ha/a)

17 R_{coeff} = run-off coefficient for urban areas (dimensionless)

18

19 Averaged values of run-off coefficient for urban impervious areas typically range between 0.4 to
20 0.9 (U.S. Department of Transportation, 2001). For a first estimate, a run-off coefficient of 0.6
21 seems to be suitable.

22 The contributing drainage area, which is not connected to the storm water sewer, can be
23 calculated using Equation 5.3.

24

25 **Equation 5.3 Contributing drainage area not connected to the storm water sewer.**

$$A_{c,sw_nc} = A_{urb} * \frac{R_{imp}}{100} * \frac{R_{con_sw_nc}}{100}$$

27 Where:

28 A_{c,sw_nc} = contributing drainage area connected to sewer in ha

29 A_{urb} = impervious urban area in ha

30 R_{imp} = rate of imperviousness in %

31 $R_{con_sw_nc}$ = connection rate to sewer (not connected) in %

32 R_{imp} is introduced to determine the run-off producing areas, whereas R_{coeff} considers the run-off
33 generation of different materials.

34

35 Substance concentration in stormwater run-off (storm water outlets) (C_{sw}):

36 The results of different monitoring programs on substance concentrations in storm water
37 outlets and combined sewer overflows are given in Table A P6. 1 and Table A P6. 2 in the Annex
38 P6.

39 Furthermore, Comber et al. (2021) derived mean values for metal concentration in urban run-off
40 on national and European level (Table 5.1). The derived concentrations comprise sources such as
41 atmospheric deposition (wet and dry), rainwater concentrations, road run-off (traffic) including

tire, brake abrasion, exhaust emissions and oil loss. These values can be used to estimate the emissions to surface waters via storm water outlets.

Table 5. 1 Derived mean metal concentrations in urban run-off (rain water from urban impervious areas) in Europe (Comber et al. 2021).

Substance	Concentration in run-off, total (µg/L)	Concentration in run-off, dissolved (µg/L)
Nickel	6.6	3.0
Cadmium	0.35	0.15
Copper	36.1	14.4
Zinc	185	68.3
Aluminium	1,102	339
Silver	0.34	< LoD*

* LoD – Limit of detection

Annual precipitation (P_a):

Most countries should have national climate information to be used for that calculation. Alternatively, the total daily amount of rainfall on the European scale is available (E-OBS data set; daily gridded meteorological data for Europe. The data set can be downloaded from the side of the European Centre for Medium-Range Weather Forecasts (ECMRW) or the European Climate Assessment & Dataset (ECA&D). The E-OBS data are often used on the national level e.g. for modeling activities.

The run-off coefficient (R_{coeff}):

The run-off coefficient determines the share of precipitation on impervious areas that creates surface run-off. The remaining precipitation is temporarily stored in surface depressions and transferred to the atmosphere because of transpiration processes.

Averaged values of run-off coefficients for urban impervious areas typically range between 0.4 to 0.9 (U.S. Department of Transportation, 2009). The mean run-off coefficient for urban areas can be assumed to be 0.6 as a first approximation. If more detailed national or catchment specific information is available that value should be used.

Impervious urban area (A_{urb}) and rate of imperviousness (R_{imp}):

If no national land use data set is available CORINE land cover could be used to identify urban (impervious) land use classes (Corine 2018: <https://land.copernicus.eu/pan-european/corine-land-cover/clc2018>). To account for urban impervious land surfaces the European-wide data set (imperviousness) provided by the EEA (European Environment Agency) can be used: <https://www.eea.europa.eu/data-and-maps/dashboards/imperviousness-in-europe>. Both GIS-datasets (land use and imperviousness) need to be merged using a GIS-programm.

As an example, the intersection was carried out for three countries (Germany, Portugal and Romania). Results in terms of mean impervious values for the different Corine urban land use classes are listed in Table 5. 2.

1 **Table 5. 2 Statistical values for imperviousness of different urban Corine (CLC) land use classes**
2 **on country level.**

CLC land use class	Germany		Portugal continental		Romania	
	imperviousness in %		imperviousness in %		imperviousness in %	
	Mean	Median	Mean	Median	Mean	Median
111 continuous urban fabric	79	98	80	94	58	59
112 discontinuous urban fabric	56	53	65	67	39	37
121 industrial or commercial units	77	99	80	99	59	58
122 roads and rail networks and associated land	74	91	67	70	52	51
123 port areas	91	100	89	100	67	73
124 airports	77	98	77	93	68	73
141 green urban area	44	33	60	60	43	39
142 sport and leisure facilities	46	37	62	64	49	47

- 3
- 4 Connection rate to sewer ($R_{con_sw_nc}$):
- 5 The share of impervious area connected to sewer systems can locally and nationally differ. If
- 6 regionalized information is not available, a national default value (estimated value) should be
- 7 used.
- 8 If no information as described above is available Comber et al. (2021) derived mean loads on a
- 9 country level (Annex P7 Table A P7. 3) using the source-oriented approach.

10 **5.3 Conclusions**

11 This fact sheet describes simple methods for the calculation of substance loads washed off from

12 sealed areas that are not connected to surface waters. Several European data sets are available

13 and mean concentration values for metals are provided as well. It needs to be mentioned that

14 this pathway for loads transported to surface waters is usually not significant in comparison to

15 those via erosion or groundwater discharge.

16

6 STORMWATER OUTLETS/COMBINED SEWER OVERFLOWS/UNCONNECTED SEWERS (P7)

6.1 Introduction

The urban wastewater system collects domestic ⁽³²⁾ and commercial wastewater as well as storm water from impervious surfaces connected to the sewer system. Thereby, a variety of pollutants reach the sewers coming from many different sources in urban areas such as households (e.g. domestic chemicals, pharmaceuticals), traffic (e.g. combustion processes, tire wear particles, brake abrasion), construction materials (e.g. for roofs or gutters), facade coatings (wall paint), atmospheric deposition etc.

In principle two different sewer systems can be distinguished:

- Separate sewer systems (see Figure 6. 1) with
 - o separate storm water sewer and
 - o separate urban waste water sewer
- Combined sewer systems (see Figure 6. 2) collecting both storm water and urban waste water in one channel

Storm water run-off from impervious areas flushes all particulate substances deposited on top of the impervious area as well as dissolved substances detached from construction materials (e.g. for roof tiling and façade coating) into sewers. In a separate sewer system, the resulting pollutant load is usually directly released into the next water body. Only if high pollution is assumed in recent planning (e.g. in commercial areas), stormwater is treated in sedimentation tanks.

For combined sewer systems, an additional pollutant load from untreated urban waste water is emitted into surface waters during combined sewer overflows. The overflowing water is therefore a mix of substances from domestic and industrial/commercial wastewater and deposits from impervious surfaces.

As a result, high pollutant concentrations may temporarily occur specially in small receiving waters, affecting sensitive organisms and possibly being responsible for failing good ecological and chemical status under Water Framework Directive (WFD).

Main pollutants in storm water outlets and combined sewer overflows are:

- Metals
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Perfluorocarbons (PFC)

⁽³²⁾ Domestic wastewater under Urban Waste Water Treatment Directive (UWWTD) is defined as: "... waste water from residential settlements and services which originates predominantly from the human metabolism and from household activities"



- 1 - Biocides
- 2 - Pharmaceuticals
- 3 - And others e.g. DEHP, TBT or Nonylphenol.

Due to unconnected sewers in both sewer systems a certain share of inhabitants is not connected to Urban Waste Water Treatment Plants (UWWTP) and are emitting mainly the dissolved share of the urban wastewater into surface waters.

Figure 6. 1 Schematic overview of emissions to surface waters via separate sewer systems (separate storm water sewers and separate municipal wastewater sewers) including storm water outlets and unconnected separate urban wastewater sewer.

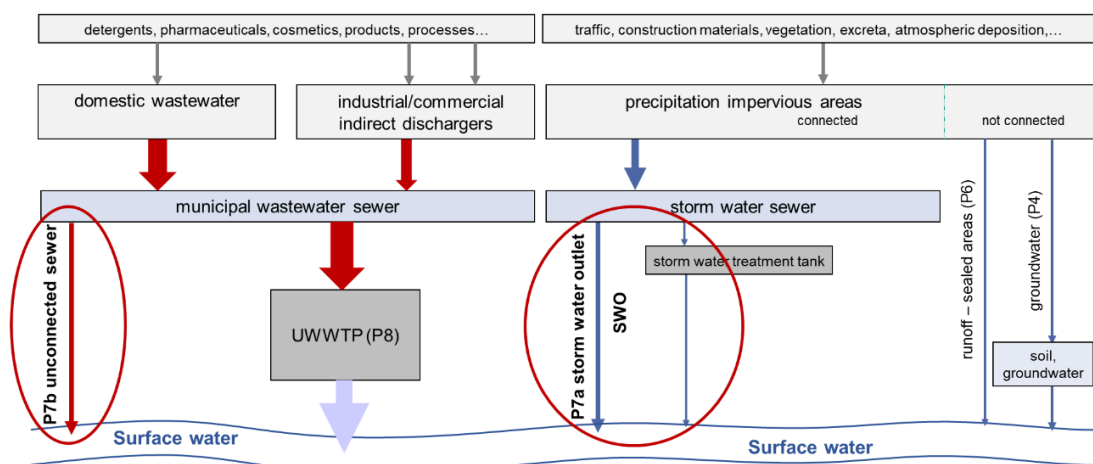
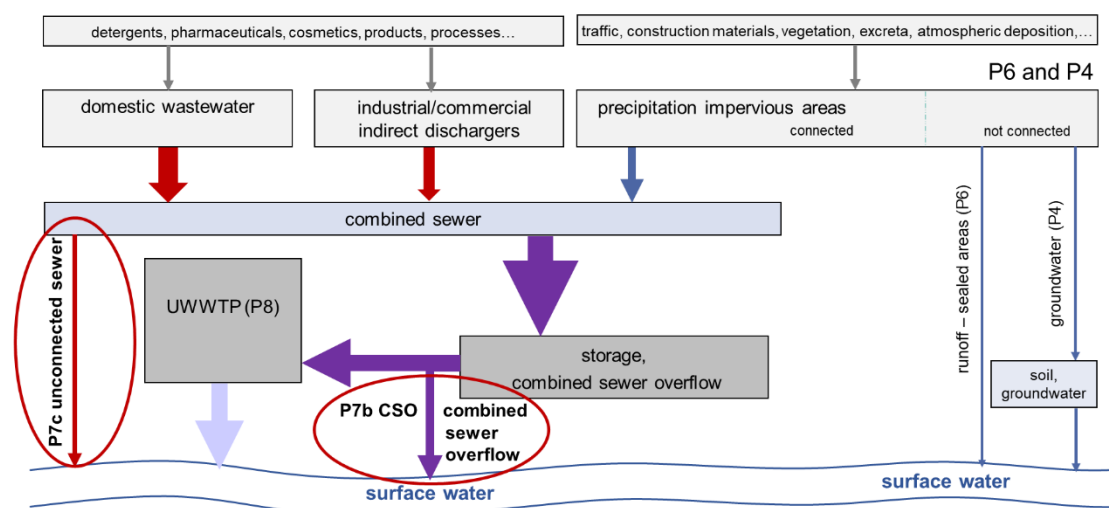


Figure 6. 2 Schematic overview of emissions to surface waters via combined sewer systems including combined sewer overflows (CSO) and unconnected combined wastewater sewer.



As described above, P7 includes three sub-pathways of wastewater collected in sewer systems but not treated in UWWTPs (see Figure 6. 1 and Figure 6. 2):

- P7a: storm water outlets, SWO (separate storm water sewers),
- P7b: combined sewer overflows, CSO (combined sewers), when rainfall exceeds the capacity of the combined sewer system and the UWWTP and untreated waste water discharges directly to surface waters and
- P7c: unconnected sewers (separate urban wastewater sewers and combined sewers not connected to UWWTPs)

The main objective of this fact sheet is to provide information on substance emissions from urban sewers (storm water outlets, combined sewer overflows and unconnected sewers).

Surface run-off from impervious areas, which are not connected to neither a combined nor a separate sewer system (related to P6 (see Figure 6. 1 and Figure 6. 2)), is very likely to infiltrate and not reach the surface water. Considering the purification capacity of soil and the distance/connection to receiving surface waters, this pathway is not seen as an important source of direct surface water pollution.

6.2 Calculation methods

The total loads considered in P7 are the sum of the loads emitted via the sub-pathways storm water outlets (P7a), combined sewer overflows (P7b) and unconnected sewers (P7c) (see Equation 6.1):

Equation 6.1 Total load emitted to surface waters via sewage systems (storm water outlets, combined sewer overflows and unconnected sewers).

$$L_{P7} = L_{SWO} + L_{CSO} + L_{nc}$$

Where:

- L_{P7} = total load from sewer systems (storm water outlets, combined sewer overflows and unconnected sewers)
- L_{SWO} = annual pollutant load emitted via storm water outlets SWO (kg/a); P7a
- L_{CSO} = annual pollutant load emitted via combined sewer overflows CSO (kg/a); P7b
- L_{nc} = annual pollutant load emitted via unconnected sewers (kg/a); P7c

To calculate emissions from urban sewers, different calculation methods can be used, depending on the availability of information and data. It is assumed that in most countries the data availability to calculate loads on the river basin or even on the national level is very limited. Therefore, simplified approaches to estimate the annual loads from storm water outlets L_{SWO} (par. 6.2.1), combined sewer overflows L_{CSO} (par. 6.2.2 and unconnected sewers L_{nc} (par. 6.2.3) are introduced below.

6.2.1 Loads from storm water outlets (P7a)

To calculate loads in storm water outlets, the annual stormwater run-off from impervious areas connected to the storm water sewers and substance concentrations need to be known (see Equations 6.2 – 6.4).

Equation 6.2 Annual load in storm water outlets (kg/a).

$$L_{swo} = \frac{Q_{swo} * C_{swo}}{1,000}$$

Where:

- L_{swo} = annual pollutant load emitted via storm water outlets (kg/a); P7a
- Q_{swo} = annual stormwater run-off from impervious urban area connected to separate storm water sewers in m³/a
- C_{swo} = substance concentration in stormwater run-off (storm water outlets) in g/m³
- 1,000 = conversion factor (g in kg)

The volume of annual stormwater run-off from impervious urban areas connected to separate storm water outlets (Q_{swo}) can be calculated according to Equation 6.3:

Equation 6.3 Annual stormwater run-off from impervious urban area connected to separate storm water sewers.

$$Q_{swo} = A_{c,swo} * P_a * 10 * R_{coeff}$$

Where:

- Q_{swo} = annual stormwater run-off from impervious urban area connected to separate storm water sewers in m³/a
- $A_{c,swo}$ = contributing drainage area connected to the SWO in ha
- P_a = annual precipitation in mm
- 10 = conversion factor (mm in m³/ha/a)
- R_{coeff} = run-off coefficient for urban areas (dimensionless)

Averaged values of run-off coefficients for urban impervious areas typically range between 0.4 to 0.9 (U.S. Department of Transportation, 2009). For a first estimate, a run-off coefficient of 0.6 seems to be suitable.

The contributing drainage area connected to the storm water outlet can be calculated using Equation 6.4.

Equation 6.4 Contributing drainage area connected to the storm water outlets (storm water sewer).

$$A_{c,swo} = A_{urb} * \frac{R_{con_swo}}{100} * \frac{R_{imp}}{100}$$

Where:

- $A_{c,swo}$ = contributing drainage area connected to the SWO in ha
- A_{urb} = impervious urban area in ha

R_{con_swo} = connection rate to storm water sewer in %

R_{imp} = rate of imperviousness in %

Note: R_{imp} is introduced to determine the run-off producing areas, whereas R_{coeff} considers the run-off generation of different materials.

Substance concentration in stormwater run-off (storm water outlets) (C_{swo}):

The results of different monitoring programs on substance concentrations in storm water outlets and combined sewer overflows are given in Table A P7. 1 and Table A P7. 2 in Annex P7. and Table A P7. 2 in Annex P7.

Furthermore, Comber et al. (2021) derived mean values for metal concentration in urban run-off on national and European level (Table 6. 1). The derived concentrations comprise sources such as atmospheric deposition (wet and dry), rainwater concentrations, road run-off (traffic) including tire, brake abrasion, exhaust emissions and oil loss. These values can be used to estimate the emissions to surface waters via storm water outlets.

Table 6. 1 Derived mean metal concentrations in urban run-off (rain water from urban impervious areas) in Europe (Comber et al. 2021).

Substance	Concentration in run-off, total ($\mu\text{g/L}$)	Concentration in run-off, dissolved ($\mu\text{g/L}$)
Nickel	6.6	3.0
Cadmium	0.35	0.15
Copper	36.1	14.4
Zinc	185	68.3
Aluminium	1,102	339
Silver	0.34	< LoD*

* LoD – Limit of detection

Annual precipitation (P_a):

Most countries should have national climate information to be used for that calculation. Alternatively, the total daily amount of rainfall on the European scale is available (E-OBS data set; daily gridded meteorological data for Europe:

<https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-gridded-observations-europe?tab=overview>). The E-OBS data are often used on the national level (e.g. for modeling activities).

Connection rate to storm water sewer (R_{con_swo}):

The share of impervious area connected to the different sewer systems can locally and nationally differ. Regionalized statistical information might be available on the national level. If regionalized information is not available in a country, Table 6. 2 provides an overview (an approximation) on the national level given by Milieu Ltd. (2016), based on sewer length. In the report is mentioned that for many countries it seems to be a general rule that older systems or those used for smaller populations are combined, while newer systems are separate. That is why



old city centers often have higher percentages of combined sewers than newer suburbs (Milieu Ltd., 2016).

Table 6. 2 Percentage of types of sewage pipes in terms of length (Milieu Ltd. (2016)) on country level.

Country*	Percentage of separate sewers	Percentage of combined sewers
Austria	71.5	28.5
Belgium (mean)	10	90
Bulgaria	n/a	majority
Croatia	41	50
Cypris	100	0
Czechia	34-25 (new structures)	66-75
Denmark	50	50
Estonia	New structures	
Finland	95	5 (Helsinki 30)
France	68	32
Germany	57	43
Greece	65-97	35-3
Hungary	97 (excluding Budapest 38)	3 (excluding Budapest 62)
Ireland	76,3	15,8
Italy		majority
Latvia	n/a	20
Lithuania	50	50
Luxembourg	10	90
Malta	100	0
Netherlands	27,3	68,2
Poland	8	73-90
Portugal	66	33
Romania	0	100
Slovakia	90-95	5-10
Slovenia	41	59
Spain	87	< 13
Sweden	88	12

* only EU 27 countries presented

If no information as described above is available, Comber et al. (2021) derived mean loads on a country level (Annex P7Table A P7. 3) using the source-oriented approach which can be used.

The run-off coefficient (R_{coeff}):

The run-off coefficient determines the share of precipitation on impervious areas that creates surface run-off. The remaining precipitation is temporarily stored in surface depressions and transferred to the atmosphere because of evaporation processes.

The mean run-off coefficient for urban areas can be assumed to be 0.6 as a first approximation. If more detailed national or catchment specific information is available that value should be used.

Impervious urban area (A_{urb}) and rate of imperviousness (R_{imp}):

If no national land use data set is available CORINE land cover could be used to identify urban (impervious) land use classes (Corine 2018: <https://land.copernicus.eu/pan-european/corine-land-cover/clc2018>). To account for urban impervious land surfaces the European-wide data set (imperviousness) provided by the EEA can be used: <https://www.eea.europa.eu/data-and-maps/dashboards/imperviousness-in-europe>. Both datasets (land use and imperviousness) need to be intersected.

Exemplarily the intersection was carried out for three countries (Germany, Portugal and Romania). Results in terms of mean impervious values for the different Corine urban land use classes are listed in Table 6. 3.

Table 6. 3 Statistical values for imperviousness of different urban Corine (CLC) land use classes on country level.

CLC land use class	Germany		Portugal continental		Romania	
	Mean	Median	Mean	Median	Mean	Median
<i>111 continuous urban fabric</i>	79	98	80	94	58	59
<i>112 discontinuous urban fabric</i>	56	53	65	67	39	37
<i>121 industrial or commercial units</i>	77	99	80	99	59	58
<i>122 roads and rail networks and associated land</i>	74	91	67	70	52	51
<i>123 port areas</i>	91	100	89	100	67	73
<i>124 airports</i>	77	98	77	93	68	73
<i>141 green urban area</i>	44	33	60	60	43	39
<i>142 sport and leisure facilities</i>	46	37	62	64	49	47

6.2.2 Loads in combined sewer overflows (P7b)

The calculation of loads in combined sewer overflows (CSO) is similar to the method described in chapter 6.2.1 (see Equations 6.5 – 6.7). In a combined system, the additional load from the share of wastewater discharged need to be considered (different substance concentration) and the information to describe the overflow situation is needed.

Equation 6.5 Annual load in combined sewer overflows (kg/a).

$$L_{CSO} = \frac{Q_{CSO} * C_{CSO}}{1,000}$$

Where:

- L_{CSO} = annual pollutant load emitted via combined sewer overflows CSO (kg/a); P7b
- Q_{CSO} = annual amount of wastewater in CSO in m³/a
- C_{CSO} = substance concentration in combined sewage in g/m³
- 1,000 = conversion factor (g in kg)

The annual volume released at combined sewer overflows (Q_{CSO}) is calculated according to Equation 6.6.

Equation 6.6 Volume of annual discharges via combined overflows.

$$Q_{CSO} = (P_a * 10 * A_{C,CSO} * R_{coeff} + Q_{DW} * D_{over}) * R_{over}$$

Where:

- Q_{CSO} = annual amount of wastewater in CSO in m³/a
- P_a = annual precipitation in mm
- 10 = conversion factor mm in m³/(ha*a)
- $A_{C,CSO}$ = contributing drainage area connected to the CSO in ha
- R_{coeff} = run-off coefficient for urban areas (dimensionless)
- Q_{DW} = averages dry weather flow in the combined system in m³/a
- D_{over} = annual duration of CSO in h
- R_{over} = average annual overflow rate (dimensionless)

The discharge relevant for an impervious urban area connected to combined sewers is calculated using Equation 6.7.

Equation 6.7 Discharge relevant impervious urban area connected to combined sewer connected to UWWTP.

$$A_{C,CSO} = A_{urb} * \frac{R_{imp}}{100} * \frac{R_{con_CSO}}{100}$$

Where:

- $A_{C,CSO}$ = contributing drainage area connected to the CSO in ha
- A_{urb} = impervious urban area in ha
- R_{imp} = rate of imperviousness in %
- R_{con_CSO} = connection rate to combined sewers in %

The average dry weather flow in the combined system is calculated using Equation 6.8.

Substance concentration in combined sewer overflows (C_{CSO}):

The substance concentration in measured combined sewer overflows always comprise the wash off from impervious areas during storm events and a certain amount of waste water. Therefore, the reported values in Annex P7 can be used directly for the load calculation according to Equation 6.6.

To calculate loads to surface water via combined sewer overflows, Comber et al. (2021) also derived (as a first approximation) mean concentrations and loads in combined sewer systems including domestic wastewater, run-off, industrial discharges (discharges to communal sewer system) and services (light industry estates, car washes, and town center activities from offices, laundries, bars, restaurants etc.). Concentrations are given in Table 6. 4. It needs to be mentioned that more specific data/information is needed to improve the given values.

Table 6. 4 Derived mean metal concentrations in urban wastewater entering UWWTP in Europe (Comber et al. 2021).

Substance	Concentration in domestic wastewater ($\mu\text{g/L}$)		Concentration from trade* wastewater ($\mu\text{g/L}$)		Concentration from light industrial wastewater ($\mu\text{g/L}$)		Concentration from services ($\mu\text{g/L}$)	
	total ($\mu\text{g/L}$)	dissolved ($\mu\text{g/L}$)	total ($\mu\text{g/L}$)	dissolved ($\mu\text{g/L}$)	total ($\mu\text{g/L}$)	dissolved ($\mu\text{g/L}$)	total ($\mu\text{g/L}$)	dissolved ($\mu\text{g/L}$)
Nickel	4.8	3.1	32	14	23.6	13.9	5.1	3.5
Cadmium	0.19	0.1	1.03	0.37	0.53	0.18	0.25	0.11
Copper	59.4	25.4	560	223	73.2	25.1	61.4	23.2
Zinc	156	38.9	808	474	536	153	132	38.7
Aluminium	822	89	1,256	183	725	50	787	47
Silver	0.49	0.19	2.13	0.80	0.48	0.13	0.63	0.11

* trade - consented industry releasing metals of interest under permit conditions

Annual precipitation (P_a):

See chapter 6.2.1

The run-off coefficient (R_{coeff}):

See chapter 6.2.1

Impervious urban area (A_{urb}) and rate of imperviousness (R_{imp}):

See chapter 6.2.1

Connection rate to combined sewer (R_{con_CSO}):

See chapter 6.2.1 (Table 6. 2)

The impervious area connected to combined sewers which are connected to UWWTPs might be available from national statistics. If that information is not available, data from the EU-UWWTD referring to unconnected sewers could be used at least to estimate the proportion (connected sewers/unconnected sewers), even if data don't allow the differentiation between unconnected combined sewers and separate domestic wastewater sewers (see fact sheet P9). Under UWWTD Member states report the rate (%) of generated load (person equivalent (p.e.)) in agglomerations⁽³³⁾ > 2,000 p.e. which is connected to sewer system but not connected to UWWTD (<https://www.eea.europa.eu/data-and-maps/data/waterbase-uwatd-urban-waste-water-treatment-directive-8>).

Averages dry weather flow in the combined system (Q_{DW}):

The average dry weather flow describes the average urban waste water flow in the sewer without storm water flow. If national information is not available, the following data/information could be used to give a first approximation:

- Annual wastewater flows should be available at least for UWWTPs larger than 2,000 p.e. available from UWWTD-reporting at least for the year 2020 (<https://uwatd.eu/>; <https://www.eea.europa.eu/data-and-maps/data/waterbase-uwatd-urban-waste-water-treatment-directive-8>). It needs to be mentioned that UWWTD-data include both treated urban wastewater and storm water. Furthermore, the information is only available for UWWTP serving agglomerations > 2,000 p.e.
- Annual dry weather flow could also be estimated on the basis of the average drinking water consumption per person (<https://www.eureau.org/resources/publications/1460-eureau-data-report-2017-1/file>). In a first approach it can be assumed that 80 % of the average consumption creates waste water. and that the infiltration water is in the same order of magnitude.

In addition, a certain amount of infiltration water occurs in sewers. Infiltration water comprises all unwanted flows in the respective sewer (e.g. groundwater) in combined sewers. Using this simplified method, infiltration waters is not considered.

Annual duration of CSO (D_{over}):

The annual duration of CSO depends mainly to the storage volume available in the sewer system and the hydraulic capacity of the UWWTP. In Germany, the wastewater treatment plant can accept 3 to 6 times the dry weather flow and in the combined system a storage volume of around 20 m³/ha connected area is provided. This result in an average overflow duration of 120 hours per year. The (average) situation in Germany is being used here as an example and might be used by countries which have no country specific data available.

Average annual overflow rate (R_{over}):

⁽³³⁾ Agglomeration under UWWTD means: "...an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point".

In Germany, during the duration period of one year, approximately 50 % of surface run-off from impervious surfaces discharge to surface waters ($R_{\text{over}} = 0.5$). These overflow events release between 1 – 2 % of additional annual municipal wastewater flow.

To calculate loads in surface water via combined sewer overflows, Comber et al. (2021) also derived as a first approximation loads on country level (Annex P7Table A P7. 4). It needs to be mentioned that more specific data/information is needed to improve the given values.

6.2.3 Loads from unconnected sewers (P7c)

In general, the total loads from unconnected sewers is the sum of loads from combined and separate domestic wastewater sewers not connected to UWWTPs (see Figure 6. 1 and Figure 6. 2 and Equation 6.8).

Equation 6.8 Load in storm water outlets/combined sewer overflows/unconnected sewers.

$$L_{nc} = L_{nc_combined} + L_{nc_seperate}$$

Where:

L_{nc} = annual pollutant load emitted via unconnected sewers in kg/a; P7c
 $L_{nc_combined}$ = annual pollutant load in unconnected combined sewers in kg/a
 $L_{nc_seperate}$ = annual pollutant load in unconnected separate urban wastewater sewers in kg/a

Load in unconnected separate urban wastewater sewers

To calculate loads from unconnected sewers, different approaches can be applied based on the data availability. Generally, it can be assumed that information/data to differentiate between the different sewer systems is barely possible. Therefore, a simplified method is presented.

As a first step, annual pollutant loads, generated by inhabitants connected to sewers but not connected to UWWTPs, needs to be calculated according to Equation 6.9 (see also fact sheet P9).

Equation 6.9 Annual pollutant load generated by individual households not treated (not connected).

$$L_{nc_seperate} = \frac{N_{inh_cnt} * E_{inh} * 365}{1,000}$$

Where:

$L_{nc_seperate}$ = annual pollutant load generated by inhabitants connected to sewer not treated in UWWTP in kg/a
 N_{inh_cnt} = number of inhabitants connected to sewer but not to UWWTP
 E_{inh} = pollutant emission per capita in g/day
365 = conversion factor (d in a)
1,000 = conversion factor (g in kg)

Pollutant emission per capita (E_{inh}):

See also fact sheet P9.

If national information on substance concentration/load generated per capita is not available, examples of derived values by different studies or countries (e.g. national modelling activities) are given in Table 1 (par. 3.). Examples for emission factors per capita on the country level derived by Comber (2021) using the source-oriented approach are given in Table 2 (par. 3.).

Number of inhabitants connected to sewer but not connected to UWWTP (N_{inh_st}):

The number of inhabitants connected to sewer not connected to UWWTP can locally and nationally differ. Regionalized statistical information might be available on the national level. For this, the information on rates of inhabitants connected might be available from at least European statistics (EUROSTAT, 2021a):

<https://ec.europa.eu/eurostat/databrowser/view/ten00020/default/table?lang=en>.

If information on the entire number of inhabitants is not available, EU-UWWTD (Urban waste Water Directive) data referring to person equivalent (p.e.)⁽³⁴⁾, could be used. Under UWWTD Member States report the rate (%) of generated load (p.e.) in agglomerations⁽³⁵⁾ > 2,000 p.e. which is connected to sewer and the rate (%) of generated load which is treated in UWWTPs. Using this information for each agglomeration the number of p.e. (based on the generated load of an agglomeration) not treated can be calculated according to Equation 6.10 assuming that:

$$N_{inh_cnt} = N_{pe_cnt}$$

Equation 6.10 Wastewater load (p.e.) connected to sewer but not treated (based on EU-UWWTD data).

$$N_{pe_cnt} = \left(\frac{L_{WW_AG}}{R_{con_sewer}} * 100 \right) - \left(\frac{L_{WW_AG}}{R_{con_uwwtp}} * 100 \right)$$

Where:

N_{pe_cnt}	= number of p.e. collected (sewer) but not treated
L_{WW_AG}	= generated nominal load of the agglomeration in p.e. (UWWTD-attribute: <i>aggGenerated</i>)
R_{con_sewer}	= rate of generated nominal load of the agglomeration connected to sewer in % (UWWTD-attribute: <i>aggC1</i>)
R_{con_uwwtp}	= rate of generated nominal load of the agglomeration not connected (treated) in % (UWWTD-attribute: <i>aucPercEnteringUWWTP</i>)

Load in unconnected combined sewers

To calculate loads from unconnected combined sewers, the above proposed equations for loads from combined sewer overflows (see par. 6.2.2) and input data have also validity. The Equations

⁽³⁴⁾ p.e. under UWWTD means: "...the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day"

⁽³⁵⁾ Agglomeration under UWWTD means: "...an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point".

6.6 to 6.7 determine the total annual flow in the combined system, and it has just to regarded whether the sewer end at a UWWTP or a receiving water body (Equation 6.9).

Equation 6.9 Load in combined sewer not connected to UWWTP.

$$L_{nc_combined} = \frac{Q_{nc_combined} * C_{cso}}{1,000}$$

Where:

$L_{nc_combined}$ = annual pollutant load in unconnected combined sewers in kg/a
 $Q_{nc_combined}$ = volume of annual stormwater run-off from impervious urban area connected to combined sewers not connected to UWWTPs in m^3/a
 C_{cso} = substance concentration in combined sewer (combined sewer overflow) in g/m^3
 1,000 = conversion factor (g in kg)

The volume of annual stormwater run-off from impervious urban area connected to combined sewer ($Q_{nc_combined}$) not connected to UWWTP is calculated using Equation 6.10.

Equation 6.10 Volume of annual stormwater run-off from impervious urban area connected to combined sewers not connected to UWWTP.

$$Q_{nc_combined} = P_a * A_{c,nc_combined} * R_{coeff}$$

Where:

$A_{c,nc_combined}$ = discharge relevant impervious urban area connected to combined sewers not connected to UWWTP in ha
 P_a = annual precipitation in mm
 R_{coeff} = run-off coefficient for urban areas (dimensionless)

The discharge relevant impervious urban area not connected to combined sewer is calculated using Equation 6.11.

Equation 6.11 Discharge relevant impervious urban area connected to combined sewer not connected to UWWTP.

$$A_{c,nc_combined} = A_{urb} * \frac{R_{imp}}{100} * \frac{(R_{con_sewer} - R_{con_uwwtp})}{100}$$

Where:

A_{urb} = impervious urban area in ha
 R_{imp} = rate of imperviousness in %
 R_{con_sewer} = rate of generated nominal load of the agglomeration connected to sewer in % (UWWTD-attribute: aggC1)

R_{con_uwwtp} = rate of generated nominal load of the agglomeration not connected (treated) in % (UWWTD-attribute: *aucPercEnteringUWWTP*)

Connection rate to combined sewer (R_{con_nc}):

See chapter 6.2.1.

The impervious area connected to combined sewers which are connected to UWWTPs might be available from national statistics. If that information is not available, EU-UWWTD data referring to unconnected sewers could be used at least to estimate the proportion (connected sewers/unconnected sewers) even if data don't allow the differentiation between unconnected combined sewers and separate domestic wastewater sewers (see fact sheet P9). Under UWWTD Member states report the rate (%) of generated load (person equivalent (p.e.)) in agglomerations > 2,000 p.e. which is connected to sewer system but not connected to UWWTD (<https://www.eea.europa.eu/data-and-maps/data/waterbase-uwwtd-urban-waste-water-treatment-directive-8>).

6.2.4 Emission factors

The emission factor refers to the pollutant emission per inhabitant and is expressed in g per inhabitant/capita per day. Examples of derived values in different studies or countries (e.g. national modelling activities) are given in Table 6. 5 Emission generated per capita per year/day (domestic wastewater); entering IAS e.g. package plant.. These values can be used to calculate the load entering an IAS.

Table 6. 5 Emission generated per capita per year/day (domestic wastewater); entering IAS e.g. package plant.

Substance	Netherlands National Water Board 2011		Germany (national modelling activity)		EU 27	
	Emission (mg/capita/day)	Source	Emission (mg/capita/day)	Source	Emission (mg/capita/day)	Source
Cadmium	0.137	mean value based on international studies	0.097	Fuchs et al., 2010, Wander, 2005; mean values based on several German studies	0.085 (sd: 0.036)	wca, 2021; mean values and standard deviation (sd) of EU27 countries based on literature and predicted data
Copper	17.9		16.3		21.3 (sd: 11.3)	
Mercury	0.049		0.0792			
Lead	2.16		1.83			
			1.36			
Nickel	1.37				0.55 (sd: 0.20)	
Zinc	28.2		43.3		21.5 (sd: 7.7)	
Anthracene	0.0019		-			
Fluoranthene	0.068		-			
Chrome	-		0.53			
PAH ₁₆	-		0			

sd = standard deviation



Information on emission factors given by the Netherlands National Water Board (2011) is taken from international studies about emissions from dwellings. In Germany, the model MoRE (Modelling of Regionalized Emissions) ⁽³⁶⁾ is used to calculate emissions to surface waters on a national level using the regionalized pathway-oriented approach (see also Technical Guidance Document No. 28 (EC, 2012)). Values of inhabitant specific emissions were derived based on a source-oriented approach (Wander 2005), similar to the method used by Comber (2021), to derive the metal load (cadmium, nickel, lead) entering septic tanks on a per capita basis on the country level (Table 6. 6).

Table 6. 6 Metal load (Cadmium, Nickel, Lead) entering septic tanks on a per capita basis on the country level (Comber 2021).

Country*	Cadmium concentration (mg/capita/day)		Nickel concentration (mg/capita/day)		Lead concentration (mg/capita/day)
	Based on calculated loads	Based on measured loads	Based on calculated loads	Based on measured loads	Based on measured loads
Albania	0.172	0.162	1.02	1.37	3.26
Austria	0.092	0.072	0.63	0.61	1.44
Belgium	0.078	0.055	0.53	0.47	1.11
Bosnia and Herzegovina	0.073	0.050	0.49	0.42	1.00
Bulgaria	0.081	0.060	0.56	0.51	1.20
Croatia	0.091	0.071	0.61	0.60	1.42
Cyprus	0.177	0.171	1.00	1.45	3.44
Czechia	0.074	0.051	0.56	0.43	1.02
Denmark	0.097	0.079	0.63	0.67	1.26
Estonia	0.076	0.054	0.51	0.46	1.09
Finland	0.127	0.069	0.76	0.59	1.39
France	0.108	0.086	0.67	0.73	1.73
Germany	0.083	0.073	0.58	0.62	1.47
Greece	0.227	0.225	1.30	1.91	4.53
Hungary	0.080	0.057	0.55	0.49	1.15
Iceland	0.135	0.120	0.83	1.02	2.42
Ireland	0.086	0.065	0.58	0.55	1.31
Italy	0.122	0.136	0.78	1.15	2.72
Kosovo**	0.069	0.045	0.49	0.39	0.91
Latvia	0.097	0.078	0.64	0.66	1.56
Lithuania	0.065	0.041	0.47	0.35	0.82
Luxembourg	0.137	0.123	0.81	1.05	2.48
Malta	0.091	0.070	0.60	0.60	1.41
Netherlands	0.088	0.078	0.57	0.66	1.57

⁽³⁶⁾ <https://iswww.iwg.kit.edu/MoRE.php>



North Macedonia	0.200	0.195	1.10	1.65	1.35
Norway	0.152	0.106	0.92	0.90	2.14
Poland	0.077	0.053	0.54	0.45	1.07
Portugal	0.114	0.097	0.71	0.82	1.94
Romania	0.067	0.043	0.48	0.37	0.87
Serbia	0.094	0.074	0.61	0.63	1.49
Slovakia	0.092	0.063	0.57	0.53	0.98
Slovenia	0.068	0.043	0.46	0.37	1.27
Spain	0.106	0.088	0.72	0.75	1.77
Sweden	0.124	0.083	0.83	0.70	1.66
Switzerland	0.089	0.102	0.59	0.87	1.96
Turkey	0.086	0.064	0.58	0.55	1.30

* Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro.

** Under UN Security Council Resolution 1244/99.

Comber (2021) used data taken from influent sewage treatment works concentrations (Comber et al. 2021). Values are based on estimations considering mean concentrations in main domestic wastewater components multiplied with daily amount of drinking water used. The methodology used, namely the source-oriented approach, is described in Comber et al. (2021).

For substances where information on emissions generated per capita is not available the emission factors presented in fact sheet P8 Table 6 (urban waste water treated) could be used to get a first approximation on the emissions directly to surface waters or to groundwater. Because the values already refer to treated wastewater, further retention (see Equation 3) should not be considered.

6.3 Conclusions

There are possibilities to estimate emissions in surface waters via storm water outlets, combined sewer overflows and unconnected sewers, even if on the national level data is barely available. A quite simple calculation method is described. Several European data sets are available and mean concentration values for metals are provided as well as examples from several studies. All this information can be used to calculate emissions for this pathway even if it might be just a first approximation.

7 URBAN WASTE WATER TREATED (P8)

7.1 Introduction

Point sources such as urban waste water treatment plants (UWWTPs) can be important sources for emissions to water. In particular, the urban waste water system collects a variety of pollutants coming from many different sources in urban areas such as households or industrial facilities (e.g. domestic chemicals, pharmaceuticals), traffic (e.g. combustion processes), facade coatings (e.g. wall paint), etc. For quantifying feasible input loads, reliable monitoring data are needed. Even if some pollutants are frequently monitored and well-reported for UWWTPs, there still is a lack of data and information for a lot of pollutants. Main reasons are:

- most pollutants are not included in routine national monitoring programs,
- often very low environmental concentrations and low concentrations in waste water, (effluent)
- the need for sensitive analytical methods, for instance low limits of detection (LoD) and quantification (LoQ), while at the same time the waste water matrix is more difficult to analysis.

The main objective of this document is to provide recent information on substance emissions from UWWTPs. This document focuses in a first step on substances under the EQS-Directive. The aim is to support countries with monitoring information for quantifying at least effluent emissions from ideally all UWWTPs at country or River Basin District (RBD) level for selected relevant substances. Such information can generally be difficult to obtain. The information should be appropriate to give a more reliable and complete picture of emissions from all UWWTPs.

In earlier studies, gap-filling focused on more frequently monitored pollutants (e.g. nutrients, metals and DEHP; (Roovaart and Duijnhoven, 2018)). These calculations were based on information reported under the E-PRTR – and even these pollutants (metals and DEHP) seemed to be underreported in the E-PRTR and only information from UWWTP > 100.000 p.e. (person equivalent) was considered. There is a capacity threshold for UWWTP (100.000 p.e.) and plants below that capacity are not in the scope of the EPRTR. For pollutants, there are also pollutant thresholds (Annex II of the EPRTR Regulation) below which they do not have to report the releases either. Note that this is the actual situation but both the E-PRTR and the UWWT Directive are in revision. Most of the less frequently monitored pollutants are nevertheless important as they can cause water quality problems (like PAHs, PFCs or different pesticides).

7.2 Calculation methods

Depending on the availability of information for calculating UWWTP effluent loads, two different approaches can be applied:

1. Using UWWTP effluent concentrations and effluent flows or
2. Using emission factors (EF) and a proxy variable to which the EF refers to (e.g. treated p.e., connected inhabitants etc.).

Information on UWWTP effluent concentrations or emission factors can be related to:

- The mean situation in a country or an RBD,
- Different treatment types (primary, secondary, tertiary or more stringent treatment),
- Different sizes of UWWTP etc.

For each of the two approaches mentioned above, examples are given in par. 7.2.1 and par. 7.2.2.

7.2.1 Example effluent concentrations

Assuming that the applied mean pollutant concentration represents the mean situation in a country or a River Basin District (RBD) and information about annual treated waste water flows⁽³⁷⁾ are available, the following equation (Equation 7.1) can be used:

Equation 7.1 Annual UWWTP load calculation using mean effluent concentrations.

$$L_{UWWTP(X)} = C_{pollutant(Y)} \times F_{effluent-UWWTP(X)}$$

Where:

$L_{UWWTP(X)}$ = annual load of individual UWWTP(X) for all UWWTPs in a RBD/country (kg/year)
 $C_{pollutant(Y)}$ = average/mean pollutant concentration of pollutant Y (µg/L)
 $F_{effluent-UWWTP(X)}$ = annual (mean) effluent flow of UWWTP(x) for all UWWTPs in a RBD/country (m³/year)

Example UWWTP(X):

$F_{effluent-UWWTP(X)}$ = 37,896,680 m³/year

$C_{pollutant(Y)}$ = 0.0016 µg/L

$L_{UWWTP(X),pollutant(Y)}$ = 0.061 kg/year

7.2.2 Example emission factor

Assuming that the applied EF represents the mean situation in a country or an RBD and information about the referring proxy variable is available e.g. information about amount/number of treated p.e.⁽³⁸⁾ the following equation (Equation 7.2) can be used to calculate annual UWWTP effluent loads both at country level or RBD level.

⁽³⁷⁾ Under UWWTD the mean annual volume of waste water treated should be reported at least for all UWWTPs with a design capacity more than 100,000 p.e. (potentially reportable in E-PRTR).

⁽³⁸⁾ Under the Urban Waste Water Directive^{a)} Member States have a biennial obligation to report amongst others on UWWTPs. Information about all UWWTPs serving 'agglomerations'^{b)} > 2,000 p.e.^{c)} generated load needs to be reported. Required information is, for instance, UWWTP capacity, treated nominal load in p.e. for each UWWTP and UWWTP location.

^{a)} [Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment as amended by Commission Directive 98/15/EC and Regulations 1882/2003/EC and 1137/2008/EC](#) (UWWTD)

Equation 7.2 Annual UWWTP load calculation using emission factors.

$$L_{UWWTP(X)} = EF_{pollutant(Y)} \times TW_{UWWTP(X)}$$

Where:

$L_{UWWTP(X)}$ = annual load of individual UWWTP for all UWWTPs in an RBD/country (kg/year)
 $EF_{pollutant(Y)}$ = mean emission factor for pollutant Y (mg/p.e./year)
 $TW_{UWWTP(X)}$ = annually treated amount of wastewater per UWWTP/in the RBD/country (p.e./year)

Example UWWTP(X):

$TW_{UWWTP(X)}$ = 100,000 p.e./year
 $EF_{pollutant(Y)}$ = 1.6 mg/p.e./year
 $L_{UWWTP(X),pollutant(Y)}$ = 0.16 kg/year

7.2.3 Different groups of pollutants

Based on a literature check, recommendations on mean UWWTP effluent concentrations and available emission factors are given in the following.

Related to the WFD priority substances ⁽³⁹⁾, several monitoring campaigns for different countries with varying number of UWWTPs were found. Results of the literature check on monitoring information identified three different groups of pollutants (A, B and C).

A) Several substances were measured in a number of monitoring programs/studies. Most studies found this group of substances in a large number of samples with varying mean/median concentrations (Table 7. 1 and Annex P8).

For some substances monitoring results vary significantly between different studies and Member States. In a few studies, some substances can be found quite often in UWWTP effluents while in other studies they cannot be found with values > LoQ. Reasons might be:

- emissions are caused by regional or even local conditions/emission situations,
- special selection of UWWTPs,
- differing monitoring strategies related to sampling procedures, for instance, frequency, timeframe (short-term or long-term samples) and preparation of samples, and

^{b)} Pursuant Article 2 (4) of UWWTD 'agglomeration' means an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point.

^{c)} Pursuant Article 2 (5) of UWWTD 'p.e. (population equivalent)' means the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day.

⁽³⁹⁾ EQS-Directive, Annex I, Part A

- differing analytical methods applied, for instance, regarding sensitivity (LoD/LoQ) or analyzing of dissolved or total concentration.

Unfortunately, not all the above-mentioned information is available for all studies. The group A) substances will be tested here to see if reliable mean concentrations can be derived.

Table 7. 1 A set of pollutants for which a large number of monitoring data is available. For 11 of the 19 pollutants mean UWWTP effluent concentrations have been derived.

Number ⁴⁰	CAS-number	Parameter	Number	CAS-number	Parameter
(20)	7439-92-1	Lead	(19)	34123-59-6	Isoproturon
(6)	7440-43-9	Cadmium	(45)	886-50-0	Terbutryn
(23)	7440-02-0	Nickel	(25)	140-66-9	4-tert.-Octylphenol
(21)	439-97-6	Mercury	(28)	50-32-8	Benzo[a]pyrene
(24)	-	4-iso Nonylphenols		205-99-2	Benzo[b]fluoranthene
(12)	117-81-7	DEHP		191-24-2	Benzo[g,h,i]perylene
(35)	1763-23-1	PFOS		193-39-5	Indeno[1,2,3-cd]-pyrene
(15)	206-44-0	Fluoranthene	(22)	91-20-3	Naphthalene
(13)	330-54-1	Diuron			

Four countries (NL, FR, IT and DE) derived mean emission factors for several substances (see Annex P8). For German UWWTPs, emission factors were calculated only if more than 50 % of measured values were above LoQ. For the Netherlands, a method is used in which the number of observations lower than the LoQ is expressed as a percentage of the total number of observations. The larger this percentage, the lower the LoQ value is valued. For Italy, the emissions factors were derived for three UWWTP. The emission factors for FR are average emission factors of all the UWWTPs (more than 400).

B) Some substances, especially new substances of the EQS-Directive, were measured in different monitoring programs/studies but could not (or at least only with a few values) be found with concentrations > LoQ in UWWTP effluents in all studies (Table 2, and Annex P8). For these substances, UWWTP effluent does not seem to be a relevant pathway for emissions to surface waters. Therefore, no mean concentrations or emission factors have been derived for these substances.

⁽⁴⁰⁾ Substance number – EQS-Directive (Annex I, Part A)

For some of these substances (shown in **bold** in Table 7. 2), analytical methods might still not be sensitive enough to assess the relevance of UWWTP effluent as pathway for emissions to surface waters. Analytical LoQs are larger than EQS values (Annex P8).

Table 7. 2 A set of pollutants for which the majority of UWWTP effluent concentrations are below LoQ and for which no mean UWWTP effluent concentrations have been derived.

Number ⁴¹	CAS-number	Parameter	Number	CAS-number	Parameter
(28)	207-08-9	Benzo[k]fluoranthene	(34)	115-32-2	Dicofol
(2)	120-12-7	Anthracene	(41)	52315-07-8	Cypermethrin
(3)	1912-24-9	Atrazine	(44)	1024-57-3	cis-Heptachlorepoxyde and trans-Heptachlorepoxyde
(43)	-	HBCDD	(38)	74070-46-5	Aclonifen
(40)	28159-98-0	Cybutryne	(39)	42576-02-3	Bifenox
(44)	76-44-8	Heptachlor	(36)	124495-18-7	Quinoxifen
(42)	62-73-7	Dichlorvos			

C) For some substances only very few monitoring information were found (Table 7. 3 and Annex P8). Reasons might be the following:

- In different countries some substances were identified as not relevant or even to be of minor relevance at RBD level. Reasons might be the ban on production and application. In this case (according to the recommendations of the guidance) detailed analyses are not required.
- For some substances UWWTP effluent is not a relevant pathway because of their specific use and application (e.g. pesticides like DDT, which was mainly used in agricultural sector). For these substances, mean concentrations have not been derived.

Table 7. 3 A set of pollutants for which scarce data is collected of UWWTP effluent concentrations and for which no mean UWWTP effluent concentrations have been derived.

Number ⁴²	CAS-number	Parameter	Number	CAS-number	Parameter
(1)	15972-60-8	Alachlor	(16)	118-74-1	Hexachlorobenzene
(4)	71-43-2	Benzene	(17)	87-68-3	Hexachlorobutadiene

⁴¹ Substance number – EQS-Directive (Annex I, Part A)

⁴² Substance number – EQS-Directive (Annex I, Part A)

Number ⁴²	CAS-number	Parameter	Number	CAS-number	Parameter
(5)	32534-81-9	BDE	(18)	608-73-1	Hexachlorocyclohexane
(6a)	56-23-5	Carbo-tetrachloride	(26)	608-93-5	Pentachlorobenzene
(7)	85535-84-8	C10-C13 Chloralkanes	(27)	87-86-5	Pentachlorophenol
(8)	470-90-6	Chlorfenvinphos	(29)	122-34-9	Simazine
(9)	2921-88-2	Chlorpyrifos	(29a)	127-18-4	Tetrachloroethylene
(9a)	309-00-2, 60-57-1, 72-20-8, 465-73-6	Cyclodiene pesticides	(29b)	79-01-6	Trichloroethylene
(9b)	-	DDT total	(30)	36643-28-4	Tributyltin compounds
	50-29-3	para-para-DDT	(31)	12002-48-1	Trichlorobenzenes
(10)	107-06-2	1,2-Dichloroethane	(32)	67-66-3	Trichloromethane
(11)	75-09-2	Dichloromethane	(33)	1582-09-8	Trifluraline
(14)	115-29-7	Endosulfan			

1 **7.2.4 Mean effluent concentrations and emission factors**

2 In this section it is explained how mean effluent concentrations and emission factors were
3 derived.

4 **Mean effluent concentrations**

5 In some cases, mean concentrations highly differ between different monitoring studies (see
6 Annex P8). Reasons might be:

- 7 - a specific national or local emission situation;
- 8 - differences in applied sampling strategies;
- 9 - differences in applied analytical methods, especially concerning sensitivity (LoQ) etc.

10
11 First, it needs to be considered that statistical values derived from monitoring studies refer to
12 the whole group of investigated UWWTPs in each study. Further information about UWWTPs
13 (meta-data like size or treatment type) were not available for all studies. Therefore, further
14 differentiation, for instance, for treatment types was not possible based on the available
15 information.

16
17 Bearing this in mind, calculated UWWTP effluent loads using the average concentrations derived
18 from all these different studies (based on median concentration values of the different studies)
19 should only be seen as a first approximation. Regional peculiarities or even special situations for
20 single UWWTPs (regarding e.g. treatment type, sewage composition) cannot be considered.

Nevertheless, in case no other data is available, the loads calculated using the derived mean concentrations should provide an indication of the relevance of UWWTPs as emission pathway to surface waters.

To derive average concentrations supporting countries, the following predefinitions were applied:

- Assuming that the distribution of monitored effluent values is right skewed (low concentration values (Median < Mean)), the median concentration values from the studies instead of mean concentration values were used.
- More than two median values (which means two median values from two different studies) needed to be available.
- Only studies not older than 2010 were considered because both substance application and (average) UWWTP treatment efficiency changes over time.
- If measured median concentration is < LoQ, the value ½ LoQ was used.

An example how to proceed deriving a mean concentration is given in the following Table 7. 4.

Table 7. 4 Example on deriving an average UWWTP effluent concentration for Lead using median concentration values from different monitoring studies in Europe (see data listed in Annex P8).

Parameter	Median (µg/L) concentration	Reference	Comment
Lead, and its compounds	0.14	Toshovski et al. 2020; 49 UWWTP, n=1,000, 2017-2019, total concentration, DE	
	1.0	French Database "RSDE-STEU" (2020) (still unpublished); LoQ 2.0 µg/L, 477 UWWTP, n=2,639, 2018-2020, total concentration, FR	½ LoQ
	0.25	Miljøstyrelsen (2021); LoD 0.5 µg/L, 34 UWWTP, n=122, 2011-2019, total concentration, DK	½ LoD
	1.1	Miljøstyrelsen (2021); LoD 0.5 µg/L, 19 UWWTP, n=101, 2011-2019, total concentration, DK	
	0.9	ICPDR cooperation with SOLUTION project (Danube); LoQ 0.13 µg/L, 12 UWWTP, n=12, 2017, total concentration, RO, RS, HR, SK, SI, HU, CZ, AT, DE	
	0.27	Joint Danube Survey 4 (JDS4); LoQ 0.13 µg/L, 11 UWWTP, n=11, 2019, total concentration, RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	
	0.24	Vieno (2014); LoQ 0.05 µg/L, 54 UWWTP, 2013-2014, total concentration, FI	

Parameter	Median (µg/L) concentration	Reference	Comment
	0.25	Clara et al. (2017); 8 UWWTP, (LoQ 0.5 µg/L); not detected in 10 out of 32 samples, 22 out of 32 values < LoQ, median < LoQ, total concentration, AT	½ LoQ
	0.64	Data base NL; 25 UWWTP, 2015-2018, total concentration, NL	
	2.5	VMM, Wastewater Monitoring Network; 331 UWWTP (Flanders), 6.3 % of values > LoD (LoQ: 5 µg/L), 2010-2019, total concentration, BE	½ LoQ
	0.649	UK data base (chemical-investigations-programme (CIP2)); 600 UWWTP, n=605, 2015-2020, total concentration, UK	
	0.86	Gardner et al. (2014); 162 UWWTP, 2010-2013, total concentration, UK	
Resulting average median concentration (arithmetic mean) lead (µg/L)	0.73		Range ¹⁾ : 0.14 – 2.5 µg/L; 12 different studies, 17 MS

¹⁾ Range of median values of different single studies

Using the described criteria average UWWTP effluent concentrations have been derived for the following substances:

- Lead, Cadmium, Nickel, Mercury, Nonylphenols, DEHP, PFOS, Fluoranthene, Diuron, Isoproturon and Terbutryn (Table 7. 5).

Table 7. 5 Derived average (median) UWWTP effluent concentrations (total concentration) based on median concentration values from different monitoring studies in Europe (see data listed in Annex P8).

Parameter	Average median concentration (µg/L)	Comment
Lead	0.73	Range ¹⁾ : 0.14 – 2.5 µg/L; 12 different studies, 18 countries
Cadmium	0.13	Range ¹⁾ : 0.006 – 0.5 µg/L; 12 different studies, 16 countries

Parameter	Average median concentration (µg/L)	Comment
Nickel	3.95	Range ¹⁾ : 1.25 – 8.6 µg/L; 11 different studies, 15 countries
Mercury	0.018	Range ¹⁾ : 0.0007 – 0.1 µg/L; 11 different studies, 15 countries
4-iso-Nonylphenols	0.082	Range ¹⁾ : 0.005 – 0.25 µg/L; 10 different studies, 8 countries
DEHP	0.923	Range ¹⁾ : 0.001 – 6.3 µg/L; 12 different studies, 18 countries
PFOS	0.011	Range ¹⁾ : 0.0005 – 0.05 µg/L; 12 different studies (1 European wide + 18 countries)
Fluoranthene	0.00513	Range ¹⁾ : 0.001 – 0.0125 µg/L; 10 different studies, 7 countries
Diuron	0.0203	Range ¹⁾ : 0.025 – 0.059 µg/L; 10 different studies (1 European wide + 16 countries)
Isoproturone	0.017	Range ¹⁾ : 0.0004 – 0.056 µg/L, 8 different studies (1 European wide + 15 countries)
Terbutryne	0.0205	Range ¹⁾ : 0.005 – 0.05 µg/L, 8 different studies, 14 countries

¹⁾ Range of median values of different single studies

Emission factors

The available emission factors are listed in Table 7. 6. These factors refer to UWWTPs with secondary and tertiary levels of treatment. Both UWWTPs equipped with primary level treatment only and those with more advanced levels of treatment (e.g. targeted micropollutant elimination such as activated-carbon filter or ozonisation) are not represented in the listed studies. In most EU countries, the number of UWWTPs with treatment levels beyond tertiary is limited. On the other hand, urban waste water treatment has improved in all parts of Europe over the last 30-40 years (EEA 2020). In 2017, most European countries collected and treated sewage to tertiary level from most of their population. In EU-27 countries, 69 % of the population were connected to tertiary level treatment and 13 % to only secondary level treatment (EEA 2020). Nevertheless, in Roovaart and Duijnhoven (2018) emission factors for UWWTPs with only primary level treatment had been derived even if it was based on a very limited number of plants. That is why the results of Roovaart and Duijnhoven (2018) are less reliable. The available emission factors also may differ quite a lot (

Table 7. 6 and Annex P8). Reasons might be:

- differences in used data base,

- differences in used method to derive the emission factor etc.

This is why a recommendation which value should be used is not given in the document. As described for the mean concentrations, calculated loads using mean emission factors can only be seen as a first approximation. Regional peculiarities or even special situations of single UWWTPs cannot be considered.

Table 7. 6 Emission factors for UWWTP effluents (results from a literature study)⁽⁴³⁾.

Parameter	Emission factor (µg per capita per day)	Emission factor (g per p.e. per year)				
		Italy (TT, ST) ⁽⁴⁴⁾ , Castiglioni et al. 2015	France (TT, ST) ⁽⁴⁵⁾ national data base 2020	Germany (TT, ST) ⁽⁴⁶⁾ , Toshovski et al 2020	Netherlands (TT, ST); national data base	PRTR (EU) ⁽⁴⁷⁾ (differentiated by treatment type)
						TT ST
Lead	-		0.0432	0.0116	0.018	0.29
Cadmium	-		0.0213	0.0005	0.000521	0.07
Nickel	-		0.119	0.365	0.284	0.47
Mercury	-		0.0029	0.0002	0.000255	0.01
4-iso-Nonylphenols	-		0.0105	0.0036	-	-
DEHP	-		0.0251	0.141	-	0.04 0.36
PFOS	1 – 8		0.0012	0.0002	-	-

⁽⁴³⁾ For mean effluent concentrations in UWWTP with only mechanical treatment see Kjølholt et al. (2021).

⁽⁴⁴⁾ The concentrations measured in three UWWTPs were multiplied by the daily flowrate to obtain a mass balance between influents and effluents and were then normalized to per capita loads considering the population equivalents of each plant (Castiglioni et al. 2015).

⁽⁴⁵⁾ For each UWWTP, and for each substance an average daily emission was calculated, based on 4 to 6 measures of flow rate and concentration at the outlet. Knowing the capacity (in p.e.) of the UWWTP, the average emission factor was calculated. The emission factors for FR are, for each substance, the median of the average emission factors of all the UWWTP.

⁽⁴⁶⁾ The emission factor is based on i) monitored median effluent concentrations (long term samples; ca. 1,000 values per substance) of 49 UWWTPs of different size (2,000 p.e. - > 100,000 p.e.) and ii) the total mean value of number of treated p.e. in Germany (for all UWWTPs > 50 p.e.). A substance-specific emission factor has only been derived if more than 50 % of monitoring values were > LoQ. Therefore, the German emission factors refer to the number of treated p.e. in Germany.

⁽⁴⁷⁾ Based on PRTR data 2011-2015, differentiated by treatment type (Roovaart and Duijnhoven 2018).

Parameter	Emission factor (µg per capita per day)	Emission factor (g per p.e. per year)				
	Italy (TT, ST) ⁽⁴⁴⁾ , Castiglioni et al. 2015	France (TT, ST) ⁽⁴⁵⁾ national data base 2020	Germany (TT, ST) ⁽⁴⁶⁾ , Toshovski et al 2020	Netherlands (TT, ST); national data base	PRTR (EU) ⁽⁴⁷⁾ (differentiated by treatment type)	
					TT	ST
Fluoranthene	-	0.0002	0.0002	-	-	
Diuron	-	0.0016	0.0013	0.0012	-	
Isoproturon	-	0.0011	0.0016	0.0016	-	
Terbutryn	-	0.0021	0.0029	0.000389	-	

Note: TT – tertiary treatment; ST – secondary treatment

Depending on data availability and the specific situation the derived mean UWWTP effluent concentrations or the presented emission factors can be used to calculate UWWTP effluent pollutant loads emitted to surface waters as a first approximation on a national or a River Basin District level. Based on the results of the literature check for a small number of “priority substances”, recommendations for average UWWTP effluent concentrations to calculate UWWTP effluent loads can be given.

For the remaining priority substances, mean concentrations have not been provided due to the lack of sufficient information for some priority substances, while for others UWWTPs do not seem to be a relevant pathway to surface waters. For a small number of priority substances, examples for MS specific emission factors can be given.

7.3 Conclusions

Urban waste water treatment plants can be seen as a relevant source of emissions to water for a large number of pollutants. In this fact sheet, two methods are given for the quantification of the loads to surface water based on literature references. Mean effluent concentrations have been derived for 11 priority substances from 12 monitoring studies in Europe covering 18 Member States. Combined with annual treated waste water flows per RBD or country, a total annual load of these pollutants can be calculated. As an alternative method, mean emission factors (mg/p.e./year) were derived from a limited number of literature studies for 11 pollutants, which can be combined with the annually treated amount of wastewater per UWWTP/in the RBD or country (p.e./year) to calculate the total loads to surface water. In the Annex P8, detailed information is given, both about the pollutants with enough data to derive mean effluent concentration or emission factors, and about less frequently monitored pollutants.

8 INDIVIDUAL – TREATED AND UNTREATED – HOUSEHOLD DISCHARGES (P9)

8.1 Introduction

Grebot et al. (2019) mentioned that ‘In 2017, approximately 11 % of the EU population was not connected to waste water collection (Eurostat, 2019)’ (p. 7). Individual household discharges have already been considered in order to fulfill requirements of different European Directives and international Commissions where appropriate including reporting processes. But naming and definitions thresholds may differ:

- ‘non-connected dwellings’⁽⁴⁸⁾ under WFD (Water Framework Directive; 2000/60/EC),
- ‘individual appropriate systems (IAS)’⁽⁴⁹⁾ under UWWTD (Urban Waste Water Treatment Directive; 91/271/EEC) and
- ‘scattered dwellings’⁽⁵⁰⁾ under the HELCOM (Helsinki Commission) reporting for the Baltic Sea.

The main similarity between these definitions is to look at generated and (hopefully) treated waste water, which is not collected in centralized systems. This factsheet also considers the direct discharges of mainly domestic⁽⁵¹⁾ waste water from residential settlements/individual households neither connected to a sewer system or an urban waste water treatment plant (UWWTP) (see Figure 8. 1). These emissions do not include non-domestic emissions from (small-scale) industries.

In cases where a collecting system is not in place e.g. it is not justified, either because it would produce no environmental benefit or because it would involve excessive cost, individual private and appropriate treatment systems, e.g. package plants or contained systems (e.g. waste water storage tanks (impervious without outlet)), should be established (Figure 8. 1 paths I2 and I4). These individual systems should be appropriate and achieve the same level of environmental protection as urban waste water discharges (e.g. under UWWTD) (Grebot et al. 2019).

Contained systems like waste water storage tanks (impervious without outlet) are periodically pumped down and domestic waste water is completely taken to an UWWTP and treated. These

⁽⁴⁸⁾ non-connected dwellings: “...dwellings not connected to a central waste water collection system. In many cases, these dwellings apply on-site waste water treatment systems known as individual or other appropriate systems (IAS). Alternatively, they apply no treatment at all.” (Grebot et al. 2019, p. 9)

⁽⁴⁹⁾ appropriate treatment under UWWTD means: “...treatment of urban waste water by any process and/or disposal system which after discharge allows the receiving waters to meet the relevant quality objectives and the relevant provisions of this and other Community Directives”

⁽⁵⁰⁾ scattered dwellings: “...on-site waste water systems which receive domestic or similar waste water from single family homes, small businesses or settlements outside urban waste water collection systems...” (HELCOM RECOMMENDATION 28E/6)

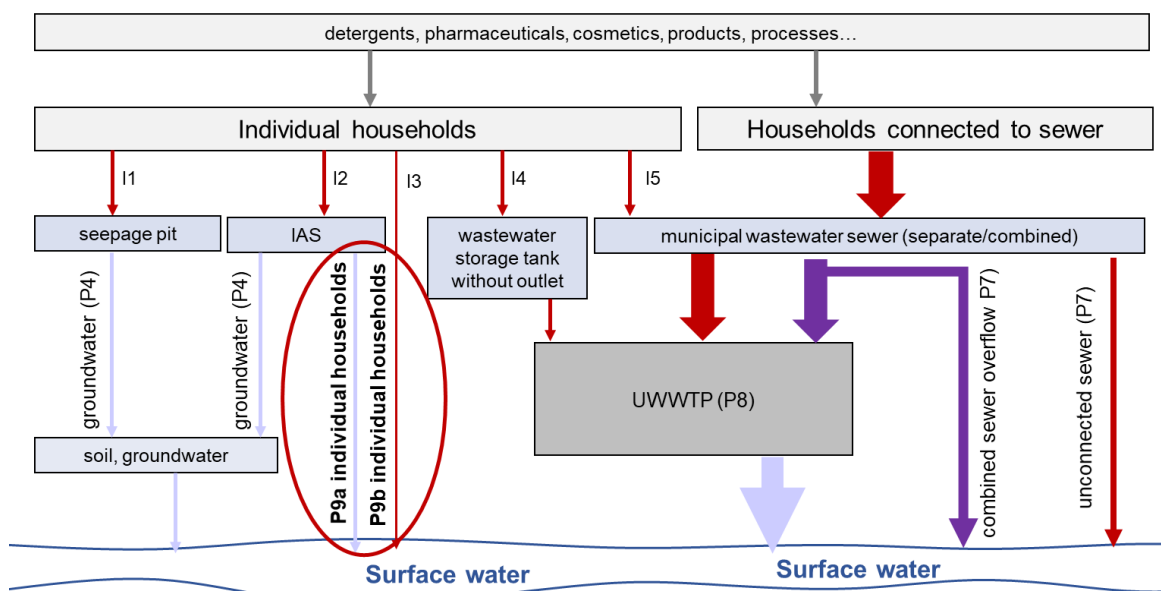
⁽⁵¹⁾ Domestic waste water under UWWTD is defined as: “... waste water from residential settlements and services which originates predominantly from the human metabolism and from household activities”

individual systems don't need to be further considered for P9, as these pollutant loads are included in P8 (urban waste water treated).

IAS like package plants (Figure 8. 1, path I2) should receive raw sewage undiluted by runoff, which then separates into solids and liquids (Comber 2021, Grebot et al. 2019). Solids settle on the bottom of the tank or in a separate vault and are periodically removed as sludge and taken to an UWWTP. Liquids flow out of the system and drain, e.g. directly into the soil in which case they don't have to be considered for P9. If liquids discharge directly to a surface water body, they need to be considered for P9.

However, a certain portion of the individual households has no appropriate systems, which means that the untreated domestic waste water and its pollutant loads are directly discharged to surface waters or probably in most cases infiltrate into soil (see Figure 1, paths I1 and I3). An example is seepage pit, which drain directly to the soil without any further treatment (Figure 1; path I1). Seepage pits are still quite common in some parts of Europe or in prospective EU-Member States (MS). But since there is no direct connection to the surface water, seepage pits should not be considered for P9. The waste water (liquids) leaches and pollutants may reach the groundwater (diffuse pollution). Therefore, it is related to the groundwater pathway (P4). If the untreated waste water discharges directly to surface waters it need to be considered for P9 (see Figure 1, path I3). A short description of common IAS technologies is given in Grebot et al. 2019. It is also seen that individual households are connected to the sewer system, but the sewer system is not connected to an UWWTP (Figure 8. 1; path I5). Unconnected sewers are not considered for P9 but are included in P7.

Figure 8. 1 Scheme of individual household discharges (treated and untreated) to surface waters.



Domestic waste water originates from dwellings, offices and shops etc. The water primarily comprises tap water used for toilet flushing, cleaning, cooking, dish and clothes washing etc.

Main pollutant sources are human excretion (faeces, urine), emissions due to corrosion of the pipe system, food remains, dishwasher detergent, cleaning agents and emissions from diverse household and personal products. Therefore, domestic waste water contains a mixture of different potential WFD pollutants such as:

- Metals
- PAHs
- Perfluorocarbons (PFC)
- Biocides
- Pharmaceuticals
- And others e.g. DEHP, TBT or Nonylphenol.

8.2 Calculation methods

It is an established approach to calculate individual household discharges based on substance concentrations/loads generated per capita and connected inhabitants. Therefore, using the pathway-oriented approach, the main information needed is:

- substance concentration/load generated per capita and
- the number of inhabitants per catchment area which are:
 - o **P9a**: connected to IAS/e.g. package plants (Figure 8.1) or
 - o **P9b**: discharge directly without any treatment (not connected).

8.2.1 Loads from individual households connected to IAS (P9a)

The first step is to calculate annual pollutant loads generated by inhabitants connected to individual appropriate treatment system (IAS) (Figure 8. 1, pathway 9a) according to Equation 8.1.

Equation 8.1 Annual pollutant load generated by individual households connected to individual appropriate systems.

$$L_{inh_IAS} = \frac{N_{inh_IAS} * E_{inh} * 365}{1,000}$$

Where:

- | | |
|----------------|---|
| L_{inh_IAS} | = annual pollutant load generated by inhabitants connected to IAS in kg/a |
| N_{inh_IAS} | = number of inhabitants connected to IAS |
| E_{inh} | = pollutant emission per capita in g/day |
| 365 | = conversion factor (d in a) |
| 1,000 | = conversion factor (g in kg) |

Pollutant emission per capita (E_{inh}):

If national information on substance concentrations/load generated per capita are not available, examples of derived values by different studies or countries (e.g. national modelling activities) are given in Table 8. 1 (par. 3). Examples for emission factors per capita on the country level derived by Comber (2021) using the source-oriented approach are given in Table 8. 2 (par. 3.).

Number of inhabitants connected to IAS (N_{inh_st}):

The number of inhabitants connected to individual waste water treatment systems (e.g. package plants) can locally and nationally differ. Regionalized statistical information about rates of inhabitants connected to IAS/e.g. package plants might be available from at least European statistics (EUROSTAT, 2021a): <https://ec.europa.eu/eurostat/databrowser/view/ten00020/default/table?lang=en>. For example, Comber (2021) used percentage of people connected to a sewers system reported in Eurostat to calculate the share of people connected to IAS as the difference to the total population.

If information on the entire number of inhabitants is not available, EU-UWWTD (Urban Waste Water Directive) data, referring to person equivalent (p.e.)⁽⁵²⁾, could be used. Assuming that in IAS mainly domestic waste water is collected and treated, using this information based on p.e. seems to be appropriate. Under UWWTD, Member States report the rate (%) of generated load (p.e.) in agglomerations⁽⁵³⁾ > 2,000 p.e. which is:

- addressed via IAS (<https://www.eea.europa.eu/data-and-maps/data/waterbase-uwwtd-urban-waste-water-treatment-directive-8>). If a certain threshold is exceeded, MS must report if the waste water in IAS is receiving:
 - o primary treatment,
 - o secondary treatment and/or
 - o more stringent treatment.

IAS under UWWTD comprise septic tanks or package plants where waste water is treated or waste water tanks without outlet where the waste water is completely stored and periodically transported to UWWTPs (Grebott et al. 2019). For separation, MS report the rate of generated load of an agglomeration, which is transported to UWWTP, by tracks. Therefore, for each agglomeration the number of p.e. (based on the generated load of an agglomeration) treated in package plants and the number of p.e. not treated can be calculated according to Equation 8.2, assuming that:

$$N_{inh_IAS} = N_{pe_IAS}$$

Equation 8.2 Waste water load (p.e.) treated in IAS (based on EU-UWWTD data).

$$N_{pe_IAS} = \left(\frac{L_{WW_AG}}{R_{IAS}} * 100 \right) - \left(\frac{L_{WW_AG}}{R_{truck}} * 100 \right)$$

Where:

N_{pe_IAS} = number of p.e. treated in IAS

⁽⁵²⁾ p.e. under UWWTD means: "...the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day"

⁽⁵³⁾ Agglomeration under UWWTD means: "...an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point".

- 1 L_{WW_AG} = generated nominal load of the agglomeration in p.e. (*UWWTD-attribute: aggGenerated*)
- 2
- 3 R_{IAS} = rate of generated nominal load of the agglomeration addressed via IAS
- 4 in % (*UWWTD-attribute: aggC2*)
- 5 R_{truck} = rate of generated nominal load of the agglomeration transported to
- 6 UWWTP by truck in % (*UWWTD-attribute: aucPercC2T*)
- 7

8 However, experience shows that the number of individual household discharges via IAS in

9 smaller agglomerations can be higher and loads for a certain area (Member State/River

10 Basin/Subunit) could be underestimated using this data. But to give a first approximation this

11 information is helpful. Individual household discharges can generate high pressure to water- and

12 groundwater bodies (Grebot et al. 2019). Nevertheless, these pressures are mainly caused by

13 diffuse pollution (leaching) via groundwater pathways. In comparison, direct discharges to

14 surface waters are of minor relevance even if it can generate high pressure locally.

15

16 Based on the calculated load generated by individual households connected to IAS, the next step

17 is to estimate the load released to surface water. Therefore, pollutant retention in the IAS,

18 means separated in the sludge, need to be considered. To calculate the retention Equation 8.3

19 can be applied.

20

21 **Equation 8.3 Pollutant loads in IAS effluents.**

22
$$L_{IAS_eff} = L_{inh_IAS} * \frac{R_{st}}{100}$$

23 Where:

- 24 L_{IAS_eff} = annual pollutant load in IAS effluent in kg/a
- 25 L_{inh_IAS} = annual pollutant load generated by inhabitants connected to IAS in
- 26 kg/a
- 27 R_{st} = pollutant load retention/removing in e.g. package plants
- 28

29 For substances, which tend to adsorb to particles such as metals, a high removal/retention rate

30 (stored in sewage sludge) can be expected. For substances which are mainly transported in

31 dissolved form, retention might be very low. If no further information regarding retention in

32 sludge is available, reduction efficiencies for urban waste water treatment plants might be used

33 as a first approximation. Examples are given in Annex P9. Depending on the substance

34 reduction, efficiencies highly vary. Based on the given examples in Annex P9(monitors results)

35 it can be assumed that the treatment efficiency is at least comparable to a secondary treatment

36 phase:

- 37 - For metals listed in the EQS-Directive (Cd, Hg, Ni, Pb) the removal efficiency increases as
- 38 follows $Ni < Hg < Cd \leq Pb$
- 39 ○ for cadmium and lead removal efficiency is around 90 % and higher,
- 40 ○ for mercury removal efficiency is between 80 and 90 %,
- 41 ○ for nickel removal efficiency is lower than 50 % (25 – 44 %).
- 42 - For pesticides Diuron, Isoproturon and Terbutryn the reduction efficiency is expected to be
- 43 < 50 % and ranges between zero (no reduction) and approximately 50 %.

- For PFOS reduction efficiency ranges between around 40 % and 70 %.
- For Nonylphenol and DEHP reduction efficiency ranges between 60 % and > 90 %.

The last step is to differentiate between IAS effluents infiltrating in soils and discharging directly to surface waters. That information has poor availability, either at national or catchment level. If it is assumed that most IAS effluents infiltrate into soil and not discharge to surface water, the emitted load will be minor.

8.2.2 Loads from individual households not connected (waste water not treated (P9b))

As described in paragraph 8.2.1, the first step is to calculate annual pollutant loads generated by inhabitants not connected according to Equation 8.4.

Equation 8.4 Annual pollutant load generated by individual households not treated (not connected).

$$L_{inh_nc} = \frac{N_{inh_nc} * E_{inh} * 365}{1,000}$$

Where:

L_{inh_nc}	= annual pollutant load generated by inhabitants not connected to sewer and IAS in kg/a
N_{inh_nc}	= number of inhabitants not connected to sewer, UWWTP and IAS
E_{inh}	= pollutant emission per capita in g/day
365	= conversion factor (d in a)
1,000	= conversion factor (g in kg)

Pollutant emission per capita (E_{inh}):

see chapter 8.2.1.

Number of inhabitants not connected to sewer, UWWTP and IAS (N_{inh_nc}):

see chapter 8.2.1

Under UWWTD, Member States report the rate (%) of generated load (p.e.) in agglomerations > 2,000 p.e. which is not collected in sewers and not treated in IAS.

Therefore, for each agglomeration the number of p.e. (based on the generated load of an agglomeration) not treated can be calculated according to Equation 8.5 assuming that:

$$N_{inh_nc} = N_{pe_nc}$$

Equation 8.5 Waste water load (p.e.) not connected and not treated (based on EU-UWWTD data).

$$N_{pe_nc} = \frac{L_{WW_AG}}{R_{nc}} * 100$$

Where:

N_{pe_nc} = number of p.e. not treated

L_{WW_AG} = generated nominal load of the agglomeration in p.e. (UWWTD-attribute: aggGenerated)

R_{nc} = rate of generated nominal load of the agglomeration not connected (treated) in % (UWWTD-attribute: aggPercWithoutTreatment)

Because the individual household are not connected, the total amount of waste water generated can be assumed to reach surface waters.

As described above regarding individual households connected to IAS (par. 8.2.1), it can be assumed that also the number of individual households not connected (waste water not treated) in smaller agglomerations can be higher and loads for a certain area (Member State/River Basin/Subunit) could be underestimated using this data. However, this information is helpful to give a first approximation. Otherwise, referring to total emissions of priority substances for a certain area compared to other pathways in most areas individual household discharges are of minor relevance, even if it can generate high pressure locally.

Emission factor

The emission factor refers to the pollutant emission per inhabitant and is expressed in g per inhabitant/capita per day. Examples of derived values by different studies or countries (e.g. national modelling activities) are given in Table 8. 1. These values can be used to calculate the load entering an IAS.

Table 8. 1 Emission generated per capita per year/day (domestic waste water); entering IAS e.g. package plants.

Substance	Netherlands National Water Board 2011		Germany (national modelling activity)		EU 27	
	Emission (mg/capita/day)	Source	Emission (mg/capita/day)	Source	Emission (mg/capita/day)	Source
Cadmium	0.137	mean value based on international studies	0.097	Fuchs et al. (2010), Wander (2005); mean values based on several German studies	0.085 (sd: 0.036)	WCA (2021); mean values and standard deviation (sd) of EU27 countries based on literature and predicted data
Copper	17.9		16.3		21.3 (sd: 11.3)	
Mercury	0.049		0.0792			
Lead	2.16		1.83			
Nickel	1.37		1.36		0.55 (sd: 0.20)	
Zinc	28.2		43.3		21.5 (sd: 7.7)	
Anthracene	0.0019		-			
Fluoranthene	0.068		-			
Chrome	-		0.53			
PAH ₁₆	-		0			

sd = standard deviation

Information on emission factors given by the Netherlands National Water Board (2011) is taken from international studies about emissions from dwellings. In Germany on the national level the model MoRE (Modeling of Regionalized Emissions)⁽⁵⁴⁾ is used to calculate emissions to surface waters using the regionalized pathway-oriented approach (see also Technical Guidance Document No. 28). Values of inhabitant specific emissions were derived based on a source-oriented approach (Wander 2005) similar to the method used by Comber (2021) to derive metal load (cadmium, nickel, lead) entering septic tanks on a per capita basis on the country level (Table 8. 2).

Table 8. 2 Metal load (Cadmium, Nickel, Lead) entering septic tanks on a per capita basis on the country level (Comber 2021).

Country*	Cadmium concentration (mg/capita/day)		Nickel concentration (mg/capita/day)		Lead concentration (mg/capita/day)
	Based on calculated loads	Based on measured loads	Based on calculated loads	Based on measured loads	Based on measured loads
Albania	0.172	0.162	1.02	1.37	3.26
Austria	0.092	0.072	0.63	0.61	1.44
Belgium	0.078	0.055	0.53	0.47	1.11
Bosnia and Herzegovina	0.073	0.050	0.49	0.42	1.00
Bulgaria	0.081	0.060	0.56	0.51	1.20
Croatia	0.091	0.071	0.61	0.60	1.42
Cyprus	0.177	0.171	1.00	1.45	3.44
Czechia	0.074	0.051	0.56	0.43	1.02
Denmark	0.097	0.079	0.63	0.67	1.26
Estonia	0.076	0.054	0.51	0.46	1.09
Finland	0.127	0.069	0.76	0.59	1.39
France	0.108	0.086	0.67	0.73	1.73
Germany	0.083	0.073	0.58	0.62	1.47
Greece	0.227	0.225	1.30	1.91	4.53
Hungary	0.080	0.057	0.55	0.49	1.15
Iceland	0.135	0.120	0.83	1.02	2.42
Ireland	0.086	0.065	0.58	0.55	1.31
Italy	0.122	0.136	0.78	1.15	2.72
Kosovo**	0.069	0.045	0.49	0.39	0.91
Latvia	0.097	0.078	0.64	0.66	1.56
Lithuania	0.065	0.041	0.47	0.35	0.82
Luxembourg	0.137	0.123	0.81	1.05	2.48
Malta	0.091	0.070	0.60	0.60	1.41
Netherlands	0.088	0.078	0.57	0.66	1.57

⁽⁵⁴⁾ <https://iswww.iwg.kit.edu/MoRE.php>

North Macedonia	0.200	0.195	1.10	1.65	1.35
Norway	0.152	0.106	0.92	0.90	2.14
Poland	0.077	0.053	0.54	0.45	1.07
Portugal	0.114	0.097	0.71	0.82	1.94
Romania	0.067	0.043	0.48	0.37	0.87
Serbia	0.094	0.074	0.61	0.63	1.49
Slovakia	0.092	0.063	0.57	0.53	0.98
Slovenia	0.068	0.043	0.46	0.37	1.27
Spain	0.106	0.088	0.72	0.75	1.77
Sweden	0.124	0.083	0.83	0.70	1.66
Switzerland	0.089	0.102	0.59	0.87	1.96
Turkey	0.086	0.064	0.58	0.55	1.30

* Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro.

** Under UN Security Council Resolution 1244/99.

Comber et al. (2021) used data from influent sewage treatment works concentrations. Values are based on estimations considering mean concentrations in main domestic waste water components multiplied with daily amount of drinking water used. The methodology used, namely the source-oriented approach, is described in Comber et al. (2021).

For substances where information on emission generated per capita is not available, the emission factors presented in fact sheet P8 (chapter 7).

Table 7. 6 (Urban waste water treated)) could be used to get a first approximation on the emissions directly to surface waters or to groundwater. As the values already refer to treated waste water, further retention (as shown in Equation 8.3) should not be considered.

8.3 Conclusions

This fact sheet describes a simplified method to estimate emissions to surface waters originating from individual households that are not connected to waste water treatment plants. For certain substances, examples for emission per capita per in generated domestic waste water are given. Information on necessary statistical data and examples for data availability on the European scale are given in case national data are not available.

9 INDUSTRIAL WASTE WATER TREATED (P10)

9.1 Introduction

Pathway 10 (P10) is the pathway for all industrial waste water loads directly to surface water. The reporting in the European Union (EU) of this pathway is already covered by:

- The European Pollutant Release and Transfer Register ⁽⁵⁵⁾ (E-PRTR), data can be explored in the Emissions portal ⁽⁵⁶⁾ or fully downloaded from the E-PRTR database ⁽⁵⁷⁾
- The Water Information System for Europe for the State of the Environment on Emissions ⁽⁵⁸⁾, WISE SoE – Emissions (WISE-1).

These two databases are publicly available and can be used in an emission inventory as basis for the industrial emissions to water.

9.2 Calculation methods

9.2.1 E-PRTR

The E-PRTR contains data from large sources, either industry or UWWTPs serving over 100,000 people. In theory, all emissions to water are reported on a yearly basis by the Member States under three conditions:

1. They fall under the activities selected for reporting in the E-PRTR,
2. They are released from activities with capacities above the capacity thresholds mentioned in the E-PRTR and
3. The loads are above the pollutant thresholds mentioned in the E-PRTR.

E-PRTR aims to cover 90% of emissions to water. If no additional information is available from the remaining 10% per MS, only data from E-PRTR can be used. Data have been reported under this EU obligation since 2007.

In E-PRTR, both the loads directly to surface water and the indirect loads (to a wastewater treatment plant) need to be reported. The indirect loads are covered under P8. Only the loads directly to surface water are included in P10.

⁽⁵⁵⁾ https://ec.europa.eu/environment/industry/stationary/e-prtr/pdf/en_prtr.pdf

⁽⁵⁶⁾ <https://industry.eea.europa.eu/>

⁽⁵⁷⁾ https://www.eea.europa.eu/ds_resolveuid/DAT-238-en

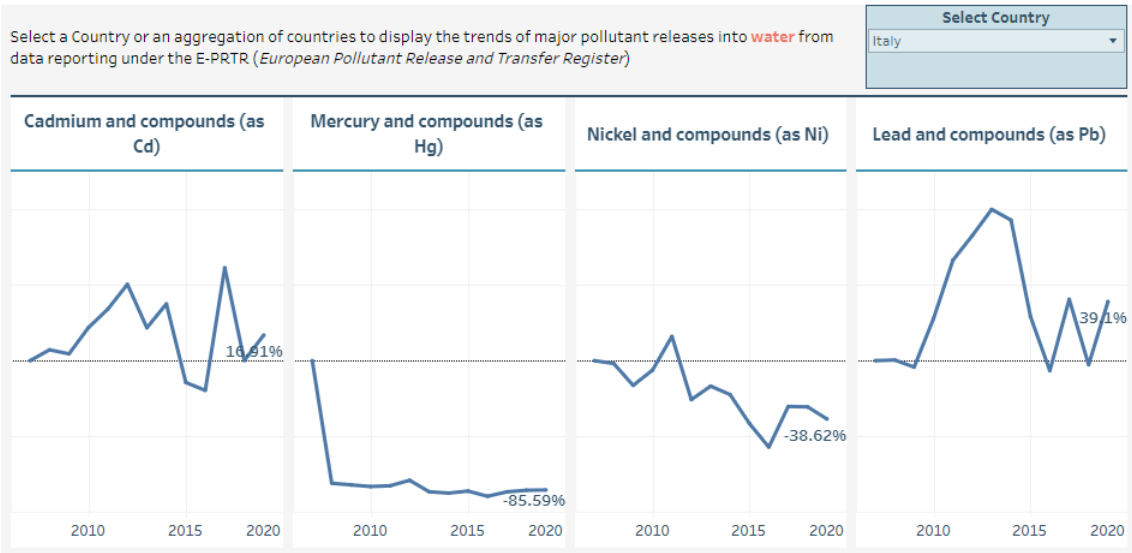
⁽⁵⁸⁾ <https://www.eea.europa.eu/data-and-maps/data/waterbase-emissions-10>

⁽⁶⁰⁾ <https://industry.eea.europa.eu/analyse/pollutant>

In Annex P10a summary of the E-PRTR calculation method for loads to surface water is described . For reporting, the measured, calculated or estimated value of a release is relevant. The pollutant only has to be reported, if the amount of the pollutant released is equal to or above the threshold value. The total and eventually accidental releases are reported in kg/year on facility level.

The European industrial emissions portal ⁽⁶⁰⁾ presents information on the largest industrial complexes in Europe. In its analysis viewer ⁽⁶¹⁾, it shows different views on pollutants per country and sector. Figure 9. 1 shows an example of the releases to water in Italy from 2007-2019 for the metal's cadmium, mercury, nickel and lead.

Figure 9. 1 Example from the E-PRTR industrial emissions portal, trends (%) of releases into water for 4 metals in Italy between 2007-2020.



9.2.2 WISE-1

This dataset contains time series of emissions of nutrients and hazardous substances to surface water, voluntary reported by EEA member countries and cooperating countries. The data have been reported by Eionet countries, compiled and processed by ETC/ICM and EEA.

The scope for reporting is on River Basin District (RBD) or national level for the total load of industrial loads to surface water. No restrictions are made for activities of the industry, capacity or pollutant threshold values. Diffuse sources and UWWTPs from WISE are not included in P10 but are related to other pathways.

⁽⁶⁰⁾ <https://industry.eea.europa.eu/analyse/pollutant>

⁽⁶¹⁾ <https://industry.eea.europa.eu/analyse/pollutant>

1 For WISE ⁽⁶²⁾ the releases to surface water are added up to a RBD per pollutant per year. Point
2 sources for industrial wastewater are divided in treated and untreated wastewater.
3 The WISE emissions dataset is available from the EEA website ⁽⁶³⁾). The dataset contains time
4 series of emissions of nutrients and hazardous substances to water, reported by EEA member
5 countries and cooperating countries.

6 **9.3 Conclusions**

7 Although the existing E-PRTR gives a good overview of the existing data of loads to surface
8 water from the industrial activities under E-PRTR, it might be useful for MS to check if additional
9 data is available from the industry itself, from enforcing authorities or from project datasets.
10 When relevant, data could be added to this pathway about:

- 11 - loads of pollutants not covered by the E-PRTR
- 12 - loads of pollutants from activities not covered by the E-PRTR
- 13 - loads from activities below the E-PRTR capacity thresholds
- 14 - loads from pollutants below the E-PRTR pollutant thresholds

15
16 This extra information could be added to WISE-1. At this moment, WISE-1 is mostly filled with
17 industrial loads to surface water reported to E-PRTR. Adding this extra information will result in
18 a more complete report of industrial loads to surface water in Europe.
19
20

⁽⁶²⁾ <http://dd.eionet.europa.eu/datasets/3351>

⁽⁶³⁾ <https://www.eea.europa.eu/data-and-maps/data/waterbase-emissions-10>

10 DIRECT DISCHARGES FROM MINING (P11)

10.1 Introduction

Direct discharges from mining considered in this factsheet are only from former mines. Typically, such sources are in the form of abandoned non-coal mine levels and adits (horizontal passages into the side of a mountain or ridge), and occasionally mine shafts. The direct discharges from mining include measurable (volume and concentrations) discharges only, other diffuse discharges are not accounted for. Discharges or losses of pollutants as a result of operational mining activities should be reported under the E-PRTR Regulation as Annex I Activities: 3 (a) Underground mining and related operations or 3 (b) Opencast mining and quarrying. They are not included here.

For this factsheet we only consider metals defined as priority substances under the WFD: cadmium (Cd), lead (Pb), nickel (Ni) and mercury (Hg).

Direct discharge is the emission directly into the surface water bodies. In this pathway also loads as a result of natural background of metals are included, because significant metal fluxes are from areas with ore deposits and these deposits were (or are) also extracted. However, metal flux from ore deposits without mining are lower than from abandoned mines. Another important factor is acidification, because acid water dissolves metals from rocks. The contribution of diffuse (indirect) mine water pollution, particularly during high flow conditions, are not included here, but they can be significant.

10.2 Calculation methods

The calculation approach used was from Environment Agency UK documents (Prioritization) and it was adapted for this general document (Environment Agency UK, 2012). It is not possible to use any European emission factor due to specific conditions in Member States. In case of too many abandoned mines, it is not necessary to calculate metal fluxes from all of them, but we need to identify the catchments with potential significant metal discharges from mining.

We can use monitored metal data in surface water and/or information about abandoned non-coal mines – the combination of both is the best option. As a first step, we should select the catchments with relevant metals, with confirmed former non-coal mines, in poor chemical status. The second step is the prioritisation of water bodies affected by non-coal mines, where the impact on surface water quality, groundwater quality, water resources and ecology should be assessed, if information are available. The next step should be to calculate metal flux from the mines, so if too many catchments were selected, we could use another prioritization – e.g. catchments with existed negative impact to biological quality elements and/or human health. The final step is the formulation of priority lists with technical summaries of mine sites that are prone to risks of mine water outbreaks and mine sites with surface waste issues that are connected to the Mining Waste Directive (Environment Agency UK, 2012).

The metal flux from the abandoned mines should be calculated from concentration data and flowrate. The water flow can be measured or estimated on the basis of the amount of

precipitation. The monitoring should be under varying hydrological conditions, but preliminary sampling and analysis campaign is recommended during baseflow conditions (if feasible). More detailed information is on <https://www.gov.uk/government/publications/prioritisation-of-abandoned-non-coal-mine-impacts-on-the-environment>.

Data about the content of metals in subsoils and water are available in the Statistical data from Geochemical Atlas of Europe - a geochemical baseline across Europe (FOREGS) and can be used as a rough information about how much of metals could be leached from former mines. Because mines are situated in the areas with higher content of metals in rock, the 90th percentile seems to be better than median or mean. However, if countries did not include these specific areas into the FOREGS data, the value can be underestimated for historical mines.

10.3 Conclusions

The simple estimation of emissions from former mining in surface waters is very difficult due to specific conditions in Member States. In this pathway, loads as a result of natural background of metals are included, because significant metal fluxes are from areas with ore deposits and these deposits were also extracted. However, metal fluxes from abandoned mines are likely to be higher than fluxes from ore deposits where there has been no mining. Flux calculations from former mining areas should preferably be informed by monitoring of flow rates and metals concentrations. If the data is missing, the European and national data sets of metal content in subsoils and water are available. This information can be used to estimate emissions from historical mining, but without monitored data it will be a rough approximation only.

11 INLAND NAVIGATION (P12)

11.1 Introduction

In this factsheet a method for the calculation of diffuse emissions resulting from inland navigation is described. Inland navigation comprises shipping activities for goods transport that are categorised in national as well as international navigation. Here, inland navigation is defined as *all* shipping (both national and international) activity on inland waters per country. This factsheet does not include recreational vessels and seagoing vessels.

Professional inland vessels cause losses of PAHs to surface water as a result of the following sources:

- Coatings (paint products applied to vessels). Ships' outer hulls are fitted with coatings to protect them against organisms growing on the hull. PAH-components and metals in the paint products leach out into the surrounding surface water, leading to diffuse emissions into surface waters.
- Bilge water. Ships unintentionally collect bilge water (the bilge is the lowest compartment on a ship) while traveling. Bilge water is often contaminated with oil containing PAHs. Although boat masters are required to collect and deliver the bilge water, it is assumed that a certain amount is still discharged illegally, leading to diffuse emissions of PAHs into surface waters.
- Oil spills of cargo and fuels. Oil spills are the result of accidental and intentional discharges of liquid waste. Spills are caused by a series of incidents and events, in some cases intentionally. The nature of the spilled material varies from mineral oils such as fuels and greases to watery oil emulsions.

11.2 Calculation methods

The emissions are calculated for inland vessels. Emissions are calculated by multiplying an activity rate (AR), in the case of inland navigation the number of ton-kilometres (tkm) traversed by all professional vessels on inland waters within a country/River basin, by an emission factor (EF), expressed in emission per AR unit. The calculation method is shown in the formula below:

$$E_s = AR * EF$$

Where:

E_s	=	Emission of substance (pollutant) to surface waters
AR	=	Activity rate, in this case the traffic performance (distance covered on the EU surface waters in 10 ⁶ tkm)
EF	=	Emission factor (kg/10 ⁶ tkm)

The emission calculated in this way is referred to as the total emission. Because all emissions are released directly into surface waters, the total emission equals the net emission to surface waters.

11.2.1 Activity rates

As activity rate is chosen the number of ton-kilometres traversed in inland navigation because it is a well-known unit of measurement within transport. It represents activities of vessels on inland waters and because it is assumed that the numbers are available for most EU member states. There is no distinction between different types of inland vessels. Emissions are calculated for the inland navigation sector as a whole. Therefore, the total amount of ton-kilometres per EU member state is required.

Activity rates are monitored per country. Table 11. 1 shows the national number of ton-kilometres traversed by inland vessels in the years 2018, 2019 and 2020 (most recent year on Eurostat ⁽⁶⁷⁾ (Eurostat, 2021b) For a quantification on a River Basin District scale, more detailed information is needed.

Table 11. 1 Number of ton-kilometres per country (Eurostat, 2021b).

Country*	Amount of 10 ⁶ ton-kilometres performed by all vessel's inland navigation		
	2018	2019	2020
Austria	7202	8512	8247
Belgium	151972	155695	156131
Bulgaria	15462	18735	18924
Croatia	5182	6491	7077
Czechia	390	779	397
Finland	-	527	512
France	59582	64207	55979
Germany	197904	205066	188022
Hungary	6926	8592	8803
Luxembourg	5741	6433	5755
Netherlands	357279	357069	349006
Poland	3126	2870	2517
Romania	29714	33261	30518
Slovakia	5567	6430	6004

* EIONET Members and cooperating countries. No data available or no inland navigation for a number of countries.

11.2.2 Emission factors

In this section it is explained how the EU inland navigation emission factors are obtained. The general applied method consists of dividing the Dutch 2019 emissions by the Dutch 2019 number of ton-kilometres traversed (ER, 2021). In this way, an implied emission factor for inland navigation is derived. Emissions and ton-kilometres were obtained from the Dutch factsheets 'Coatings, inland navigation', 'Oil spills by inland navigation' and 'Discharges of bilge water by inland navigation' (Netherlands National Water Board – Water Unit, 2016a, 2016b, 2016c).

⁽⁶⁷⁾ <https://ec.europa.eu/eurostat/databrowser/view/ttr00007/default/table?lang=en> (Accessed 28.06.2022)

These factsheets contain emissions that were calculated with data obtained from (inter)national literature sources. Therefore, it is assumed that the derived implied emission factors are suitable for the calculation of diffuse emissions in the EU.

The methodology for the three sources is described in detail in the factsheets of the Netherlands National Water Board (2016a, 2016b, 2016c). The following is a brief description of how the emissions were calculated:

- Coatings. Emissions for leaching from coatings are calculated by a simple method which involves multiplying an activity rate (AR), in this case the "wet surface area x route covered" of inland vessels on country specific routes, by an emission factor (EF) per substance, expressed in emission per unit of AR. The occurrence of PAH-based coatings plays also an important role in this respect.
- Bilge water. The emissions are calculated by multiplying the quantity of bilge water produced (minus the collected amount of bilge water) by the average content of mineral oil in the bilge water. The average oil content in the bilge water is the emission factor (EF), expressed in emission per unit of AR (mg/kg). The PAH emission is then derived from the assumed PAH content in used mineral oil.
- Oil spills. The emissions are calculated based on the recorded quantity of spills annually. In this derivation, the activity rate (AR) is the annually registered spilled quantity of mineral oil (kg). The emission factors (EF) for the assumed PAH content (fresh oil) is expressed in g/kg of the AR.

To obtain emission factors per pollutant, emissions for all sources, calculated in the mentioned Dutch factsheets, were added up and divided by the number of ton-kilometres on Dutch inland waters so that emission factors representative for the sum of all three sources are compiled. The results are emission factors for each pollutant in $\text{g}/10^6 \text{ t-km}$. In Table 11. 2 the calculated emission factors are shown.

Table 11. 2 Implied emission factors per substance per source for inland navigation in $\text{g}/10^6$ ton-kilometres.

Emission to surface water ($\text{g}/10^6$ tonkm)	Leaching from coatings	Discharges of bilge water	Oil spills of cargo and fuels	EF
Anthracene	0.68	0.061	0.88	1.6
Benz[a]anthracene	0.7	0.0081	0.12	0.83
Benzo[a]pyrene	0.72	0.004	0.059	0.79
Benzo[b]fluoranthene	0.89	0.004	0.0008	0.89
Benzo[g,h,i]perylene	0.77	0.0001	0.002	0.77
Benzo[k]fluoranthene	0.38	0.004	0.0008	0.38
Chrysene	0.77	0.004	0.059	0.83
Fluoranthene	1.4	0.041	0.58	2.02
Indeno[1,2,3-c,d]pyrene	0.72	0.004	0.0003	0.73
Naphtalene	13.5	0.44	6.3	20.2
Phenantrene	1.4	0.3	4.4	6.1

1

2 **11.2.3 Emissions to water**

3 Emissions from coatings result from contact of ships with surface water. Accordingly, these
4 emissions are directly (100%) released into surface waters. Emissions of bilge water are assumed
5 to be partly collected and partly released into surface waters. Collected bilge water is usually
6 treated; the pollutants therein are not released into the environment. The discharged part (EF
7 for bilge water, Table 11. 2) however, is assumed to be directly released into surface waters, as
8 well as oil spills. Therefore, the emissions from inland navigation are 100% released into surface
9 waters.

10 **11.3 Conclusions**

11 The emission factors described are derived from international literature, used for the
12 Netherlands and have also been applied in the Rhine catchment. The emission factors can also
13 be applied to RBDs in other countries. In case there should be more (country specific)
14 information available on the use of PAH coatings, the collection of bilge water or the occurrence
15 (amount and size) of oil spills, these can be adjusted.

16

17

12 NATURAL BACKGROUND (P13)

12.1 Introduction

The inventory of emissions, discharges and losses of priority and priority hazardous substances focuses on the identification and quantification of anthropogenic sources, although some substances also have a significant naturally occurring source at least in some areas (EU, 2012). Metals and Polycyclic Aromatic Hydrocarbons (PAHs) can be released from natural sources or processes (e.g. geogenic background, soil genesis, volcanicity, storm, wildfire) (Wiłkomirski et al. 2018). Therefore, natural background is considered as a separate relevant pathway, representing the loads which would occur under pristine ⁽⁶⁸⁾ conditions. But it needs to be considered that anthropogenic sources are usually much more significant. This work focuses on priority and priority hazardous substances, so it includes only specific metals (cadmium, nickel, lead and mercury) and PAHs e.g. as sum of the 16 EPA ⁽⁶⁹⁾ PAHs or benzo(a)pyrene (BaP).

Information about natural background can be important in the context of planning measures. Natural background loads could be seen as the load which can't be reduced by implementing measures. If the same substances are pollutants in a water body, it is necessary for river basin management planning to quantify the proportions of natural background and anthropogenic emissions.

Natural background is in fact a rather complicated source because it is part of different diffuse pathways and double counting must be avoided. Metals are naturally parts of different rocks which might be rock aquifers as well as the base material for soils. The natural metal content depends on the rock constituents and affects the background concentration in soils and groundwater. Furthermore, because of volcanicity, fires and storm events, metals and PAHs can naturally end up in the atmosphere, are air-transported and finally deposited, both on land and directly on surface water.

In that context e.g., natural metal and PAHs background concentrations can be directly part of the total diffuse load for the following diffuse pathways:

- P1 - Atmospheric deposition directly to surface water;
- P2 - Erosion (natural soil content and natural deposition);
- P3 - Surface runoff from unsealed areas (mainly based on dry and wet atmospheric deposition);
- P4 - Groundwater and interflow (based on natural rock and soil content);
- P6 - Surface runoff from sealed areas (mainly based on dry and wet atmospheric deposition);
- P11 - Direct Discharges from Mining (only relevant for metals).

⁽⁶⁸⁾ Related to a period without any anthropogenic activity.

⁽⁶⁹⁾ US Environmental Protection Agency

12.2 Calculation methods

Calculation of natural background concentrations for metals or PAHs is complicated because of the need to separate the contributions from anthropogenic and natural sources. To get reliable information, monitoring data are needed, and assumptions have to be made to estimate natural background loads. Three different ways are described to get an impression of the natural background loads.

12.2.1 Approach using in-river processes, river loads, anthropogenic loads and point source loads

An example for an approximate substance specific estimation on RBD/Subunit level, based on the riverine load approach for substances, where in-river processes like biodegradation, retention or sedimentation and natural background is relevant, is given in the Guidance Document No 28 (EU 2012). The method is based on a river load approach established by OSPAR (2004) (Equation 12.1):

Equation 12.1: River load approach to calculate natural background loads (LB).

$$L_{Diff} = L_y - D_p + LB + NP$$

That means:

$$LB = L_y - D_p - L_{Diff} + NP$$

Where:

L_y	= is total annual riverine load,
L_{Diff}	= is anthropogenic diffuse load,
D_p	= is total point source discharge,
LB	= is natural background load and
NP	= is net outcome of in-river processes upstream of the monitoring point.

Requirement to apply the described river load approach is that information on total anthropogenic diffuse loads and total point sources loads is known. The main problem here is to calculate diffuse loads differentiated into anthropogenic and natural diffuse loads.

Mohaupt et al. (2001) used this method to calculate natural background loads in the river discharge at RBD level (River Rhine). Known anthropogenic loads were e.g. sum of industrial and communal discharges and storm water overflows.

12.2.2 Surface water data approach

Another possibility to calculate natural background loads is to use monitored natural background concentration values in surface waters (surface data approach).

Knowing natural background concentrations might be also important for Member States when assessing the monitoring results against the relevant Environmental Quality Standard (EQS), especially when such concentrations prevent compliance with the relevant EQS (CIS Technical Guidance on Implementing Environmental Quality Standards (EQS) for Metals; Final Draft Nov.

2019, unpublished⁽⁷⁰⁾). According to the recommendations of this CIS document LB in surface waters could be estimated using the surface water data approach. It is based on appropriate monitoring data sets from sites preferably under undisturbed pristine conditions (in any case without known anthropogenic point sources) or with low levels of distortion and/or slight deviations resulting from human activities. “*The data set should be of sufficient quality i.e. acquired with adequate sampling protocols and analytical methods with sensitivity limiting the number of measures below the limit of quantification (LOQ), so to ensure that the NBCs⁷¹ can be confidently estimated for trace metals.*” (see Final Draft page 63). But it needs to be mentioned that according to the Guidance natural background concentrations only need to be considered if EQS values are exceeded.

As a data source to estimate background concentrations if national information is not available, the guidance refers to the European Geological Survey’s (FOREGS) Geochemical Atlas of Europe because it is focused on sites with low anthropogenic input. To estimate natural background concentrations on the regional scale, further information is needed.

It should be kept in mind that even in undisturbed catchments, there is atmospheric deposition to surface waters.

Using monitored concentrations and discharge data, natural background loads could be estimated/calculated on the catchment or sub-catchment scale (Equation 12.2).

Equation 12.2: Natural background load (LB) calculation.

$$LB = C_{nb} * Q$$

Where:

C_{nb} = is mean monitored natural background concentration (catchment/sub-catchment scale),

Q = is mean river discharge (catchment/sub-catchment scale).

12.2.3 Calculating pathway specific natural background loads

For calculating pathway specific background loads, models can be used defining pristine scenarios. For the definition of such scenarios, many assumptions might be required, e.g. a value for a pristine atmospheric deposition. But it will have to be kept in mind that most processes like hydrology, erosion and surface runoff are anthropogenically affected itself. Naturally – without any human activity – hydrological conditions, erosion and surface runoff would be completely different (no agriculture, natural vegetation etc.). The most important related pathways are described below.

12.2.4 Erosion

To calculate natural background loads in surface waters by water erosion, complex input data (soil type and soil characteristics, climate, slope, management, etc.) and calculation methods are needed.

⁽⁷⁰⁾ https://circabc.europa.eu/sd/a/2f0dbde9-9161-4c8d-8503-d221ab93d718/WD2019-2-3_Implementing%20Metals%20EQS%20DRAFT%20guidance%20WD%20meeting%2026%20Nov%202019.pdf

⁽⁷¹⁾ NBCs – natural background concentrations

1 Firstly, information on soil loss caused by water (surface runoff) is required to calculate
2 emissions. Based on soil loss information, sediment transport to surface waters can be
3 estimated. Depending on landscape characteristics like slope steepness, slope length, distance
4 to surface waters and barriers (e.g. streets, land use pattern like tree rows or hedges) only a
5 certain proportion of soil loss reaches surface waters. Most of the material is again deposited on
6 land. The ratio between soil loss and sediment inputs to surface water is so called Sediment
7 Delivery Ratio (SDR).

9 If sediment transfer to surface waters is known, the concentrations of natural background
10 concentration in the top soil are used to calculate substance emission to surface waters. It
11 needs to be considered that the fine fraction (silt and clay) of the soil carries the highest
12 substance loading and that the overland transport results in a grain size classification. That
13 means heavily laden fine particles reach the surface water. The ratio between topsoil
14 concentrations and the concentrations in the sediments entering the surface water is the
15 Enrichment Ratio (ER). A description of methods and data availability is given in fact sheet P2-
16 P5.

18 Natural metal background concentrations in soils were considered by Comber (2021) in a
19 European wide study to assess diffuse sources for the metals cadmium (Cd), nickel (Ni) and lead
20 (Pb) to calculate emissions to water from natural erosion processes. He used the FOREGS⁽⁷²⁾
21 database to provide mean (natural) soil concentrations for several countries (see). The FOREGS
22 database is focused on sites with low anthropogenic input e.g. to target unamended soil and
23 therefore reflects the natural geology of the different regions. To calculate the background loads
24 from erosion processes, soil losses and sediment inputs to surface waters are needed (see also
25 fact sheet P2 Erosion). Ideally, information referring to pristine conditions (e.g. forested areas
26 without any agricultural use) are used.

28 Similar information for PAHs could not be identified, but Wiłkomirski et al. (2018) referred to
29 different scientific studies. Monitored PAHs background concentrations in different studies
30 ranges from 22 µg/kg up to around 3,700 µg/kg especially in peat with very high humus
31 contents.

33 To give two national examples:

34 For Austria, national top soil concentrations for metals were derived based on monitoring data
35 (Freudenschuß et al. 2007). The values are land use specific (forest, pasture and arable land).
36 Monitoring data were analyzed considering e.g. pH values, clay content, geology formation. The
37 values are land use specific and regionalization of top soil concentration was carried out based
38 on geological formations (bedrock for soil genesis).

(72) FOREGS – EuroGeoSurveys Geochemical Baseline Database <http://weppi.gtk.fi/publ/foregsatlas/ForegsData.php>
(part of the electronic publication version of the Geochemical Atlas of Europe; Salminen et al. 2005)

In Germany, the national working group LABO (Bund/Länder Arbeitsgemeinschaft Bodenschutz) for soil protection (LABO 2017) provide background concentrations including ubiquitous pollutant distribution for inorganic and organic substances like metals (e.g. Arsenic, Cadmium, Nickel, Lead, Mercury), B(a)P, PAH16, HCB, γ -HCH, Σ -HCH, PCB6, Σ -dl-PCB and Σ -PCDD/F (see also: <https://geoviewer.bgr.de/mapapps4/resources/apps/geoviewer/index.html?lang=de>). The values for metals are land use specific and regionalization of top soil concentration was carried out based on geological formations (bedrock for soil genesis). The values for PAHs are land use specific (field, pasture and forest) and differentiated by humus content classes. In general, it can be concluded - the higher the humus content, the higher the PAH concentration (see Table A P13. 1, Annex P13).

12.2.5 Atmospheric deposition

Because pollutants emitted to the atmosphere can be transported worldwide it is very difficult to identify the amount/concentration caused by natural sources and processes. EMEP provide atmospheric deposition data for metals (e.g. cadmium, lead and mercury) and the PAH benzo(a)pyrene (Chapter 3, ATMOSPHERIC DEPOSITION DIRECTLY TO SURFACE WATER (P1)) But in need to be kept in mind that EMEP modelling results contains natural background as well as anthropogenic emissions. Based on available information it is not possible to provide information/data on natural atmospheric background deposition.

12.2.6 Groundwater, interflow and surface runoff from unsealed areas

Natural background concentrations in groundwater are highly affected by the contents of the underlying geology. Concentrations in interflow and surface runoff from unsealed areas are affected by soil contents and atmospheric deposition (wet and dry). Data to calculate natural background loads of these pathways is scarce. Nevertheless, if monitoring data are available it could be used to derive loads from groundwater.

Surface runoff from unsealed areas under pristine conditions should be highly affected by substance concentrations in rainwater.

12.3 Conclusions

Different methods can be used to calculate natural background loads such as the simple river load approach or more complex modelling scenarios can be applied. Even if the simplest methods are of high uncertainty and data availability might be difficult, they can be used to give a first approximation if the information is needed.

Obviously, data availability to calculate natural background loads considering the pathway-oriented approach (EU 2012) is scarce. Furthermore, depending on applied modelling approach it needs to be mentioned, that natural background is mainly included in calculated pollutant loads of different pathways.

1 List of abbreviations

Abbreviation	Name
AR	Activity Rate
CSO	Combined Sewer Outflow
DEHP	Diethylhexyl phthalate
EC	European Commission
EEA	European Environment Agency
EF	Emission Factor
Eionet	European Environment Information and Observation Network
EMEP	European Monitoring and Evaluation Program
E-PRTR	European Pollutant Release and Transfer Register
EQS	Environmental Quality Standards
ETC/ICM	European Topic Centre for Inland, Coastal and Marine Waters
EU	European Union
UWWTD	Urban Waste Water Treatment Directive
HCB	Hexachlorobenzene
IAS	Individual Appropriate Treatment System
ICPR	International Commission for the Protection of the Rhine
IWWTP	Industrial Waste Water Treatment Plant
LoD	Limit of Detection
LoQ	Limit of Quantification
MS	Member States
PAHs	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated biphenyls
PCDD/F	Polychlorinated dibenzo-para-dioxins/dibenzofurans
PFC	Perfluorocarbons
PFOS	Perfluorooctanesulfonate
POP	Persistent Organic Pollutants
RBD	River Basin District
RBMP	River Basin Management Plan
SWO	Storm Water Outlet
TGD	Technical Guidance Document
UWWTP	Urban Waste Water Treatment Plant
WFD	Water Framework Directive

WISE(-SoE)	Water Information System for Europe (-State of the Environment)
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Annex P1

Example for the calculation of atmospheric deposition to surface water for Poland

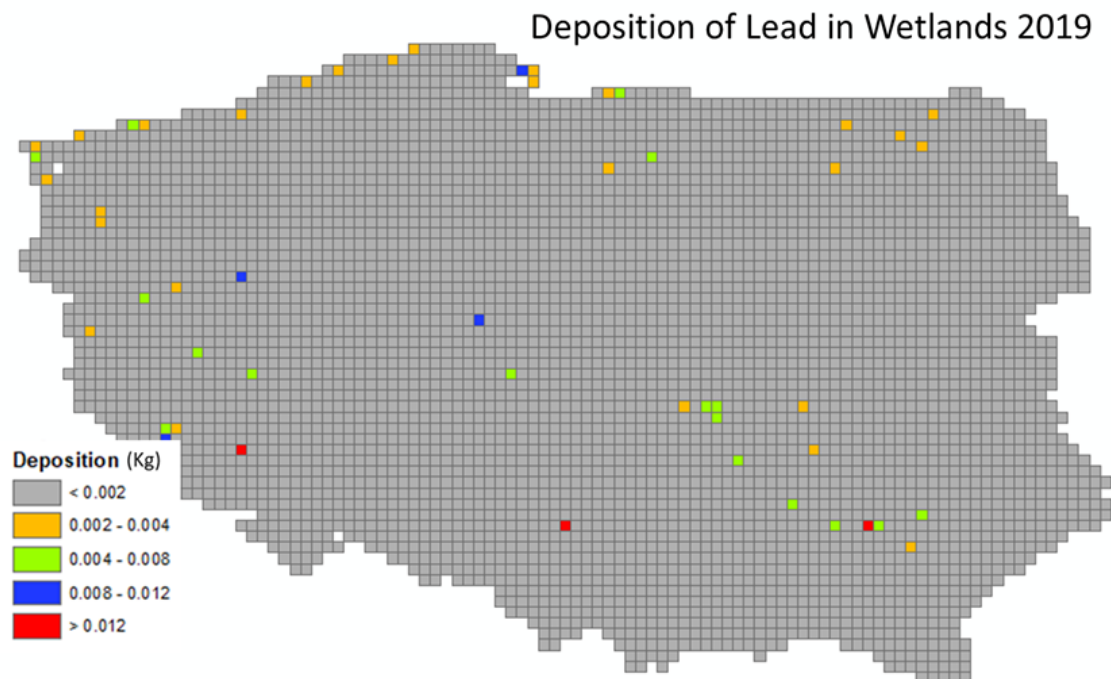
Ecosystem dependent deposition (metals), example for lead:

- Lead deposition flux data are available for [wetlands](#) and [water bodies](#). Per grid the fluxes in kg/km²/year in fresh surface waters are available.
- For the area per grid in the specific country and the fraction of wetlands and water bodies, data were received from EMEP.
- Calculation per EMEP-grid, according calculation 1.
 - Deposition to water = Flux to water * Area_km² * Water Fraction
 - Deposition to wetland = Flux to wetland* Area_km²* Wetland Fraction
- The calculated total deposition on fresh surface water for Lead in Poland is 19.6 kg in 2019.

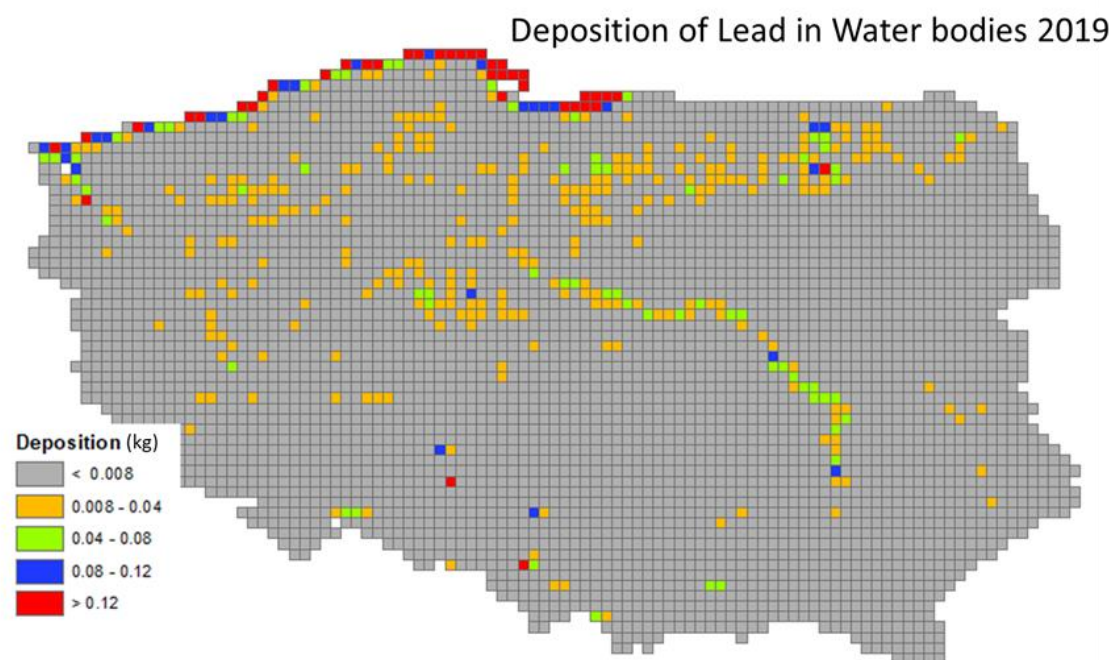
Atmospheric deposition lead	Wetlands (kg)	Water bodies (kg)	Total (kg)
Poland	0.28	19.3	19.6

- In Figure A P1.1 and A P1.2 the results for Poland are shown for wetlands and water bodies.

1 Figure A P1. 1 Annual deposition load per grid for lead in Poland 2019 in wetlands



2
3 Figure A P1. 2 Annual deposition load per grid for lead in Poland 2019 in water bodies.



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5

Total deposition flux PAHs (other than BaP):

- The [BaP fluxes](#) per grid data in g/km²/year are available in g/km²/year. There is no distinction in ecosystem dependent deposition.
- Calculate the fraction of surface water per grid with data requested at EMEP. The area (km²) per grid is also reported in the requested file.
- Calculate the flux per grid for Poland according calculation 3
 - Deposition to water = Total flux * Area_km² * (Water + Wetland fraction)
- The calculated total deposition on fresh surface water for BaP in Poland is 384 kg in 2019.
- With the derived ratio factors for the 16 EPA PAHs compared to BaP the deposition for the other PAHs are calculated for Poland.

Table A P1. 1 Ratio factors for the 16 EPA PAH compared to BaP and the calculated atmospheric deposition load to surface water in Poland.

Country	Substance	Fraction	Deposition (kg)
Poland	Benzo(a)pyrene	1	384
	Acenaphthene	0.96	369
	Acenaphthylene	0.52	200
	Anthracene	0.24	92
	Benz(a)anthracene	0.9	346
	Benzo(b)fluoranthene	1.97	756
	Benzo(ghi)perylene	1.23	472
	Benzo(k)fluoranthene	0.77	296
	Chrysene	1.84	707
	Dibenzo(ah)anthracene	0.28	108
	Fluoranthene	4.18	1605
	Fluorene	1.02	392
	Inden(123cd)pyrene	1.39	534
	Naphthalene	2.11	810
	Phenanthrene	5.06	1943
	Pyrene	2.93	1125

1 Annex P2-P5

2 Table A P2-5. 1 Total Cadmium loads to agricultural land in kg/day; (nd = no data (Comber,
3 2021)).

	Agricultural land	Total FYM	Biosolids	P fertiliser	Atmospheric deposition	Biocides	Total
Country	Km ²	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹
Albania	11740	0.20	0.05	0.36	0.77	0.0	1.4
Austria	26538	2.46	0.25	0.34	1.05	0.0	4.1
Belgium	13561	4.91	0.10	0.13	0.71	0.0	5.8
Bosnia	17796	0.76	0.00	n/d	1.17	0.0	1.9
Bulgaria	50303	1.29	0.10	0.85	1.95	0.0	4.2
Croatia	14857	0.79	0.01	0.40	0.99	0.0	2.2
Cyprus	1319	0.29	0.03	0.06	0.03	0.0	0.4
Czech Republic	35232	1.90	0.42	0.58	0.94	0.0	3.8
Denmark	26325	2.09	0.39	0.53	1.21	0.0	4.2
Estonia	10042	0.39	0.00	0.10	0.78	0.0	1.3
Finland	22719	1.53	0.01	0.28	0.53	0.0	2.4
France	290202	20.10	1.06	4.27	19.54	0.0	45.0
Germany	166451	18.14	1.16	2.33	5.53	0.0	27.2
Greece	52881	2.80	0.11	0.66	1.28	0.0	4.9
Hungary	53438	5.52	0.11	1.31	1.96	0.0	8.9
Iceland	15551	0.09	0.00	0.05	0.54	0.0	0.7
Ireland	45160	2.83	0.25	1.19	1.72	0.0	6.0
Italy	128433	14.29	1.12	3.03	7.91	0.0	26.4
Kosovo	4195	0.44	n/d	n/d	0.19	0.0	0.6
Latvia	19379	0.41	0.03	0.29	0.80	0.0	1.5
Lithuania	29472	1.12	0.07	0.58	1.31	0.0	3.1
Luxembourg	1316	0.13	0.01	0.01	0.08	0.0	0.2
Malta	116	0.04	0.00	0.00	0.00	0.0	0.0
Netherlands	18224	5.00	0.00	0.15	1.12	0.0	6.3
N Macedonia	12641	0.13	0.00	n/d	0.68	0.0	0.8
Norway	9825	0.00	0.35	0.22	0.24	0.0	0.8
Poland	145396	26.78	0.57	3.79	7.37	0.0	38.5
Portugal	35914	3.88	0.01	0.53	1.76	0.0	6.2
Romania	134137	5.62	0.18	2.11	5.21	0.0	13.1
Serbia	34869	2.61	0.00	n/d	1.59	0.0	4.2
Slovakia	19195	0.80	0.00	0.29	0.64	0.0	1.7
Slovenia	4779	0.77	0.00	0.11	0.05	0.0	0.9
Spain	242019	19.54	4.34	4.77	20.85	0.0	49.5
Sweden	30004	1.88	0.17	0.37	0.90	0.0	3.3
Switzerland	15147	1.26	0.00	0.10	1.78	0.0	3.1
Turkey	382390	24.22	48.87	5.83	9.98	0.0	88.9
UK	173570	22.25	4.46	2.10	3.37	0.0	32.2
EU27		168	15.0	31.2	89.6	0.0	303

4

1 Table A P2-5. 2 Total Nickel loads to agricultural land in kg/day; (nd = no data (Comber, 2021)).

	Agricultural land	Total FYM	Biosolids	P fertiliser	Atmospheric deposition	Biocides	Total
Country	Km ²	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹
Albania	11740	1.7	0.7	0.7	10.7	0.0	13.8
Austria	26538	24.5	3.5	0.6	14.7	0.0	43.2
Belgium	13561	47.9	1.5	0.2	5.6	0.0	55.3
Bosnia	17796	7.2	0.0	n/d	16.3	0.0	23.6
Bulgaria	50303	11.7	0.8	1.6	27.2	0.0	41.2
Croatia	14857	7.6	0.1	0.7	13.8	0.0	22.2
Cyprus	1319	2.8	0.1	0.1	0.4	0.0	3.4
Czech Republic	35232	18.7	8.2	1.1	14.2	0.0	42.2
Denmark	26325	24.9	5.3	1.0	13.3	0.0	44.5
Estonia	10042	3.9	0.0	0.2	11.8	0.0	15.9
Finland	22719	14.8	0.3	0.5	8.8	0.0	24.4
France	290202	198.5	17.2	7.8	327.9	0.0	551.4
Germany	166451	182.0	29.0	4.3	88.6	0.0	303.8
Greece	52881	21.9	1.6	1.2	17.8	0.0	42.5
Hungary	53438	49.9	2.0	2.4	27.4	0.0	81.7
Iceland	15551	0.8	0.0	0.1	14.9	0.0	15.9
Ireland	45160	31.3	3.4	2.2	12.7	0.0	49.5
Italy	128433	132.3	57.0	5.5	110.3	0.0	305.2
Kosovo	4195	3.8	n/d	n/d	2.7	0.0	6.5
Latvia	19379	4.1	0.4	0.5	11.2	0.0	16.3
Lithuania	29472	10.7	1.4	1.1	18.3	0.0	31.5
Luxembourg	1316	1.4	0.1	0.0	1.0	0.0	2.6
Malta	116	0.3	0.0	0.0	0.1	0.0	0.4
Netherlands	18224	52.4	0.0	0.3	7.8	0.0	60.5
N Macedonia	12641	0.9	0.0	n/d	9.5	0.0	10.4
Norway	9825	0.0	4.8	0.4	4.2	0.0	9.3
Poland	145396	245.2	7.8	6.9	75.1	0.0	335.0
Portugal	35914	35.7	0.6	1.0	24.6	0.0	61.9
Romania	134137	49.1	2.5	3.9	72.6	0.0	128.1
Serbia	34869	12.2	0.0	n/d	22.2	0.0	34.4
Slovakia	19195	7.5	0.0	0.5	12.0	0.0	20.0
Slovenia	4779	7.4	0.0	0.2	0.8	0.0	8.4
Spain	242019	183.1	62.0	8.7	367.1	0.0	620.9
Sweden	30004	18.3	2.9	0.7	3.7	0.0	25.5
Switzerland	15147	13.3	0.0	0.2	24.8	0.0	38.2
Turkey	382390	228.2	667.7	10.7	139.1	0.0	1045.7
UK	173570	198.3	60.9	3.8	34.4	0.0	297.4
EU27		1586	269	57	1323	0	3235

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4

1 Table A P2-5. 3 Total Lead loads to agricultural land in kg/day; (nd = no data (Comber, 2021)).

	Agricultural land	Total FYM	Biosolids	P fertiliser	Atmospheric deposition	Biocides	Total
Country	Km ²	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹	Kg d ⁻¹
Albania	11740	2.9	1.5	0.2	19	0	23.5
Austria	26538	18.0	7.3	0.1	26	0	51.3
Belgium	13561	34.4	7.2	0.1	19	0	60.6
Bosnia	17796	5.2	0.0	n/d	29	0	34.1
Bulgaria	50303	9.8	3.4	0.4	48	0	61.6
Croatia	14857	6.1	0.2	0.2	24	0	30.8
Cyprus	1319	2.0	0.1	0.0	1	0	2.8
Czech Republic	35232	13.5	11.3	0.3	29	0	54.3
Denmark	26325	17.0	11.1	0.2	34	0	62.8
Estonia	10042	2.8	0.0	0.0	10	0	12.8
Finland	22719	10.7	0.1	0.1	12	0	22.9
France	290202	150.4	40.9	1.9	462	0	655
Germany	166451	131.8	42.9	1.0	167	0	342
Greece	52881	24.5	3.2	0.3	32	0	59.6
Hungary	53438	37.3	2.8	0.6	48	0	89.0
Iceland	15551	0.6	0.0	0.0	14	0	14.9
Ireland	45160	26.5	7.0	0.5	38	0	72.0
Italy	128433	103.0	87.3	1.3	195	0	387
Kosovo	4195	2.8	n/d	n/d	5	0	7.5
Latvia	19379	3.1	1.0	0.1	20	0	24.1
Lithuania	29472	8.0	1.2	0.3	32	0	41.8
Luxembourg	1316	1.0	0.2	0.0	2	0	3.1
Malta	116	0.3	0.0	0.0	0	0	0.4
Netherlands	18224	38.1	0.0	0.1	29	0	67.0
N Macedonia	12641	2.5	0.0	n/d	17	0	19.4
Norway	9825	0.0	9.9	0.1	8	0	18.0
Poland	145396	177.9	16.3	1.7	111	0	307
Portugal	35914	28.1	1.0	0.2	43	0	72.8
Romania	134137	45.5	5.3	0.9	128	0	180
Serbia	34869	42.4	0.0	n/d	39	0	81.7
Slovakia	19195	5.8	0.0	0.1	37	0	43.2
Slovenia	4779	5.4	0.0	0.0	2	0	7.7
Spain	242019	146.9	140.5	2.1	422	0	711
Sweden	30004	13.8	4.6	0.2	11	0	29.8
Switzerland	15147	9.7	0.0	0.0	44	0	53.6
Turkey	382390	167.6	1391.9	2.6	246	0	1808
UK	173570	167.6	126.9	0.9	80	0	375
EU27		1229	522	14	2062	0	3826

2

3

1 Annex P6

2 Table A P6. 1 Statistical values – Literature check – measured pollutant concentration values in
3 urban storm waters

Parameter	Artihmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Lead	6.5	5.9	1.2 – 16	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	12.3			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.3 – 7.4	storm water, 8 samples, October - November 2008, total concentration	DK	Birch et al. (2011)
			<5 – 6.4	storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
			67.5 – 780	storm water sewer, 119 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
			3.11 – 19	storm water sewer, 28 samples, May 2014 - June	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				2015, volume proportional, dissolved concentration		
Cadmium	0.088	0.079	0.33 – 0.31	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.49			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.0045 – 0.63	storm water, 8 samples, October - November 2008	DK	Birch et al. (2011)
			<0.05 – 0.14	storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.61		n.n. – 4	storm water, 69 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.15		n.n. – 0.72 (dissolved)	storm water, 28 samples, May 2014 - June 2015, volume proportional,	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				dissolved concentration		
	<0.2 0.28			storm water, 1 sample, October 2009 - June 2010, grab sample, total concentration	SE	Kaj et al. (2011)
			<0.05 – 0.13	urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
	0.16 (storm water) 0.05 (meltwater)			storm water, 1 sample, March - May 2010, grab sample, total concentration	EE	Kõrgmaa et al. (2011)
	<0.10 0.06			storm water, 1 sample, November 2009 - April 2010, grab sample, total concentration	FI	Huhtala et al. (2011)
	0.9			storm water, 1 sample, September 2010, grab sample, total concentration	LV	Strāķe et al. (2011)
	<0.05			storm water, 1 sample, November 2009 - June 2010, grab sample, total concentration	LT	Manusadžianas et al. (2011)
	18.05 0.20			storm water, composite sample out of 5 samples, December 2009 - October 2010,	PL	Fochtman et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				grab sample, total concentration		
Nickel	4.7	4.5	2 – 7.1	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	9.6			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.91 – 40.5	storm water, 8 samples, October - November 2008, total concentration	DK	Birch et al. (2011)
			<2 – 4	storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	7.81		n.n. – 37	storm water, 37 samples, May 2014 - June 2015, volume proportional, total concentration	De	Wicke et al. (2016)
	2.07		n.n. – 8.2 (dissolved)	storm water, 28 samples, May 2014 - June 2015, volume proportional, dissolved concentration	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	2.8 8.8 4.1			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Mercury	0.0144	0.0125	0.004 – 0.032	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			0.0043 – 0.046	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
4-iso-Nonylphenol	0.0822	0.0585	<0.04 – 0.46	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			0.17 – 0.43	storm water, 3 sites, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	>0.02			storm water sewer, single value, June + October 2006, discharge proportional, total concentration	SE	Björklund et al. (2009)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
		0.47		storm water sewer, 11 events, January 2008 - April 2009, discharge proportional, total concentration	FR	Bressy et al. (2012)
	0.4	0.398	0.27 – 0.53	storm water sewer, 4 events, July - October 2011, time proportional, total concentration	FR	Cladière et al. (2013)
	0.76 – 0.77			storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.359			storm water, 21 events, July 2011- May 2013, discharge proportional, event mean concentration, total concentration	FR	Gasperi et al. (2012)
	1.1 0.27			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	2.17		n.n. – 15	storm water, 72 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.19			urban storm water, 3 samples, September 2009 - June 2010,	DK	Nielsen et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				discharge proportional, total concentration		
4-tert.-Oktylphenole	0.1135	0.0615	<0.02 – 0.3	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.42 (dissolved)			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, dissolved concentration	FR	Becouze-Lareure et al. (2019)
		0.036		storm water sewer, 11 events, January 2008 - April 2009, discharge proportional, total concentration	FR	Bressy et al. (2012)
	0.015 – 0.15			storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.061			storm water, 21 events, July 2011- May 2013, discharge proportional, event mean concentration, total concentration	FR	Gasperi et al. (2012)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.82 0.11			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.1		n.n. – 1	storm water, 72 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	<0.1			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Di-(2-ethylhexyl)phthalat	3.3	3	0.9 – 7	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.05 – 8.5	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	<1			storm water sewer, single value, June + October 2006, discharge proportional, total concentration	SE	Björklund et al. (2009)
			<0.35 – 1.9	storm water, 19 samples, June - December 2012, volume	AT	Clara et al. (2014)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				proportional, total concentration		
	3 2.3			storm water sewer, single value	SE	Kalmykova et al. (2013)
	1.67		n.n. – 14	storm water, 92 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
HBCDD	0.00745	<0.005	<0.005 – 0.024	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0013 <0.001			storm water treatment tank, October 2009 - June 2010, grab sample, total concentration	SE	Kaj et al. (2011)
	<0.005			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
PFOS	0.0023	0.002	<0.001 – 0.005	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	<0.003 0.419 0.235			urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Anthracen	0.0086	0.00975	<0.001 – 0.019	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.84	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.03		n.n. – 0.24	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
Fluoranthen	0.1225	0.105	0.021 – 0.29	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.55	storm water, 8 samples, October - November 2008,	DK	Birch et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				grab sample, total concentration		
	0.03 0.12			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.084 0.057 <0.01			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Benzo[a]anthracen	0.043	0.0455	0.0069 – 0.094	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.066	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.00053 – 0.0017	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.14		n.n. – 0.65	storm water, 92 samples, May 2014 - June 2015, volume	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				proportional, total concentration		
Benzo[b]fluoranthen	0.0645	0.0625	0.01 – 0.17	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.138			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.0013 – 0.0041	storm water treated, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.16		n.n. – 0.64	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
Benzo[a]pyren	0.05	0.0495	0.0072 – 0.14	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.06	storm water, 8 samples, October - November 2008,	DK	Birch et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				grab sample, total concentration		
			0.0038 – 0.013	storm water not treated, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.09		n.n. – 0.77	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.046 0.016 <0.010			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Indeno[1,2,3-cd]pyren	0.051	0.047	0.0072 – 0.14	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.27			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				concentration, total concentration		
			<0.01 – 0.12	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.00027 – 0.00073 0.00035 – 0.0077	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.07		n.n. – 0.37	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	<0.01 0.015			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Benzo[g,h,i]perylene	0.062	0.059	0.0091 – 0.13	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.124 (total) 1,055 ng/g (particulate)			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration	FR	Becouze-Lareure et al. (2019)
	<0.01 – 0.16			storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.00026 – 0.00072 0.00063 – 0.00097	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.02 0.05			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.06		n.n. – 0.46	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.029 0.04 <0.10			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Atrazine	<0.01	<0.1	<0.1	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				proportional, total concentration		
	<0.05			storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erftverband (2013)
	0.0013			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
Diuron	0.0965	0.0245	<0.01 – 0.56	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.019			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.027 (Oct) <0.01 (Nov)			storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	0.08		n.n. – 0.06	storm water, 94 samples, May 2014 - June 2015, volume	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
				proportional, total concentration		
	<0.01			storm water, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
		0.007		storm water, 191 samples, 12 events, October 2011 - June 2012, discharge proportional, total concentration	DK	Bollmann et al. (2014)
			<0.05 – 0.7	storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erftverband (2013)
Isoproturon	0.0276	0.0075	<0.01 – 0.18	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0016			storm water treatment tanks, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	<0.01			storm water, 1 sample, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.0028 – 0.028	storm water (street only, not treated), 4 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.088			storm water, 19 samples, July 2011- May 2013, discharge proportional, event mean concentration, total concentration	FR	Gasperi et al. (2012)
	0.02		n.n. – 0.12	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
			<0.05 – 0.22	storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erftverband (2013)
		0.002		storm water, 191 samples, 12 events, October 2011 - June 2012, discharge proportional, total concentration	DK	Bollmann et al. (2014)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Terbutryn	0.0457	0.027	0.012 – 0.18	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.05 – 0	storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erftverband (2013)
	0.05		n.n. – 0.36	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
		0.052		storm water, 191 samples, 12 events, October 2011 - June 2012, discharge proportional, total concentration	DK	Bollmann et al. (2014)

Table A P6. 2 Metal loads in urban run-off on the country level (Comber et al., 2021)

Country	Aluminium kg/day	Arsenic kg/day	Cadmium kg/day	Copper kg/day	Nickel kg/day	Silver kg/day	Zink kg/day
Albania	190	0.4	0.09	11	1.7	0.06	47
Austria	1,005	2.1	0.48	57	8.8	0.29	247
Belgium	1,310	2.7	0.63	74	11.5	0.38	321
Bosnia	2,250	4.6	1.08	127	19.8	0.66	552
Bulgaria	846	1.7	0.41	48	7.4	0.25	207
Croatia	811	1.7	0.39	46	7.1	0.24	199
Cypris	79	0.2	0.04	4	0.7	0.02	19
Czech	971	2.0	0.47	55	8.5	0.28	238
Denmark	954	1.9	0.46	54	8.4	0.28	234
Estonia	425	0.9	0.20	24	3.7	0.12	104
Finland	237	0.5	0.11	13	2.1	0.07	58
France	9,530	19.5	4.58	537	83.9	2.78	2,338
Germany	12,307	25.1	5.91	693	108	3.59	3,020
Greece	711	1.5	0.34	40	6.3	0.21	174
Hungary	1,160	2.4	0.56	65	10.2	0.34	285
Iceland	96	0.2	0.05	5	0.8	0.03	23
Ireland	756	1.5	0.36	43	6.7	0.22	185
Italy	7,451	15.1	3.58	420	65.6	2.18	1,828
Kosovo	66	0.1	0.03	4	0.6	0.02	16
Latvia	575	1.2	0.28	32	5.1	0.17	141
Lithuania	773	1.6	0.37	44	6.8	0.23	190
Luxembourg	56	0.1	0.03	3	0.5	0.02	14
Malta	12	0.0	0.01	1	0.1	0.00	3
Netherlands	2,172	4.4	1.04	122	19.1	0.63	533
N. Macedonia	124	0.3	0.06	7	1.1	0.04	30

Norway	451	0.9	0.22	25	4.0	0.13	111
Poland	4,808	9.8	2.31	271	42.3	1.40	1,180
Portugal	1,468	3.0	0.70	83	12.9	0.43	360
Romania	1,369	2.8	0.66	77	12.1	0.40	336
Serbia	611	1.2	0.29	34	5.4	0.18	150
Slovakia	440	0.9	0.21	25	3.9	0.13	108
Slovenia	184	0.4	0.09	10	1.6	0.05	45
Spain	2,991	6.1	1.44	168	26.3	0.87	734
Sweden	1,144	2.3	0.55	64	10.1	0.33	281
Switzerland	2,214	4.5	1.06	125	19.5	0.65	543
UK	5,528	11.3	2.65	311	48.7	1.61	1,356
EU27	54,545	111	26	3,071	480	16	13,383

Annex P7

Table A P7. 1 Statistical values – Literature check – measured pollutant concentration values in urban storm waters

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Lead	6.5	5.9	1.2 – 16	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	12.3			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.3 – 7.4	storm water, 8 samples, October - November 2008, total concentration	DK	Birch et al. (2011)
			<5 – 6.4	storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
			67.5 – 780	storm water sewer, 119 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
			3.11 – 19	storm water sewer, 28 samples, May 2014 - June 2015, volume proportional, dissolved concentration	DE	Wicke et al. (2016)
Cadmium	0.088	0.079	0.33 – 0.31	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.49			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
			0.0045 – 0.63	storm water, 8 samples, October - November 2008	DK	Birch et al. (2011)
			<0.05 – 0.14	storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.61		n.n. – 4	storm water, 69 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.15		n.n. – 0.72 (dissolved)	storm water, 28 samples, May 2014 - June 2015, volume proportional, dissolved concentration	DE	Wicke et al. (2016)
	<0.2 0.28			storm water, 1 sample, October 2009 - June 2010, grab sample, total concentration	SE	Kaj et al. (2011)
			<0.05 – 0.13	urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
	0.16 (storm water) 0.05 (meltwater)			storm water, 1 sample, March - May 2010, grab sample, total concentration	EE	Körgmaa et al. (2011)
	<0.10 0.06			storm water, 1 sample, November 2009 - April 2010, grab sample, total concentration	FI	Huhtala et al. (2011)
	0.9			storm water, 1 sample, September 2010, grab sample, total concentration	LV	Strāķe et al. (2011)
	<0.05			storm water, 1 sample, November 2009 - June 2010, grab sample, total concentration	LT	Manusadžianas et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	18.05 0.20			storm water, composite sample out of 5 samples, December 2009 - October 2010, grab sample, total concentration	PL	Fochtman et al. (2011)
Nickel	4.7	4.5	2 – 7.1	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	9.6			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.91 – 40.5	storm water, 8 samples, October - November 2008, total concentration	DK	Birch et al. (2011)
			<2 – 4	storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	7.81		n.n. – 37	storm water, 37 samples, May 2014 - June 2015, volume proportional, total concentration	De	Wicke et al. (2016)
	2.07		n.n. – 8.2 (dissolved)	storm water, 28 samples, May 2014 - June 2015, volume proportional, dissolved concentration	DE	Wicke et al. (2016)
	2.8 8.8 4.1			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Mercury	0.0144	0.0125	0.004 – 0.032	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			0.0043 – 0.046	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
4-iso-Nonylphenol	0.0822	0.0585	<0.04 – 0.46	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			0.17 – 0.43	storm water, 3 sites, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	>0.02			storm water sewer, single value, June + October 2006, discharge proportional, total concentration	SE	Björklund et al. (2009)
		0.47		storm water sewer, 11 events, January 2008 - April 2009, discharge proportional, total concentration	FR	Bressy et al. (2012)
	0.4	0.398	0.27 – 0.53	storm water sewer, 4 events, July - October 2011, time proportional, total concentration	FR	Cladière et al. (2013)
	0.76 – 0.77			storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.359			storm water, 21 events, July 2011- May 2013, discharge proportional, event mean concentration, total concentration	FR	Gasperi et al. (2012)
	1.1 0.27			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	2.17		n.n. – 15	storm water, 72 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.19			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
4-tert.-Oktylphenole	0.1135	0.0615	<0.02 – 0.3	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.42 (dissolved)			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, dissolved concentration	FR	Becouze-Lareure et al. (2019)
		0.036		storm water sewer, 11 events, January 2008 - April 2009, discharge proportional, total concentration	FR	Bressy et al. (2012)
	0.015 – 0.15			storm water, 6 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.061			storm water, 21 events, July 2011- May 2013, discharge proportional, event mean concentration, total concentration	FR	Gasperi et al. (2012)
	0.82 0.11			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.1		n.n. – 1	storm water, 72 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	<0.1			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Di-(2-ethylhexyl)phthalat	3.3	3	0.9 – 7	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.05 – 8.5	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	<1			storm water sewer, single value, June + October 2006, discharge proportional, total concentration	SE	Björklund et al. (2009)
			<0.35 – 1.9	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	3 2.3			storm water sewer, single value	SE	Kalmykova et al. (2013)
	1.67		n.n. – 14	storm water, 92 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
HBCDD	0.00745	<0.005	<0.005 – 0.024	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0013 <0.001			storm water treatment tank, October 2009 - June 2010, grab sample, total concentration	SE	Kaj et al. (2011)
	<0.005			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
PFOS	0.0023	0.002	<0.001 – 0.005	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	<0.003 0.419 0.235			urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Anthracen	0.0086	0.00975	<0.001 – 0.019	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
			<0.01 – 0.84	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.03		n.n. – 0.24	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
Fluoranthen	0.1225	0.105	0.021 – 0.29	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.55	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	0.03 0.12			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.084 0.057 <0.01			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Benzo[a]anthracen	0.043	0.0455	0.0069 – 0.094	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.066	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.00053 – 0.0017	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.14		n.n. – 0.65	storm water, 92 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
Benzo[b]fluoranthen	0.0645	0.0625	0.01 – 0.17	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.138			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.0013 – 0.0041	storm water treated, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.16		n.n. – 0.64	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
Benzo[a]pyren	0.05	0.0495	0.0072 – 0.14	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.01 – 0.06	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.0038 – 0.013	storm water not treated, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.09		n.n. – 0.77	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.046 0.016 <0.010			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Indeno[1,2,3-cd]pyren	0.051	0.047	0.0072 – 0.14	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.27			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			<0.01 – 0.12	storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.00027 – 0.00073 0.00035 – 0.0077	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	<0.02 0.02			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.07		n.n. – 0.37	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	<0.01 0.015			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Benzo[g,h,i]perylene	0.062	0.059	0.0091 – 0.13	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.124 (total) 1,055 ng/g (particulate)			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration	FR	Becouze-Lareure et al. (2019)
	<0.01 – 0.16			storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.00026 – 0.00072 0.00063 – 0.00097	storm water, 19 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.02 0.05			storm water sewer, single value, total concentration	SE	Kalmykova et al. (2013)
	0.06		n.n. – 0.46	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	0.029 0.04 <0.10			urban storm water, 3 samples, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Atrazine	<0.01	<0.1	<0.1	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	<0.05			storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erfverband (2013)
	0.0013			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Diuron	0.0965	0.0245	<0.01 – 0.56	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.019			storm water, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.027 (Oct) <0.01 (Nov)			storm water, 8 samples, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
	0.08		n.n. – 0.06	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
	<0.01			storm water, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
		0.007		storm water, 191 samples, 12 events, October 2011 - June 2012, discharge proportional, total concentration	DK	Bollmann et al. (2014)
			<0.05 – 0.7	storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erftverband (2013)
Isoproturon	0.0276	0.0075	<0.01 – 0.18	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0016			storm water treatment tanks, 14 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	<0.01			storm water, 1 sample, October - November 2008, grab sample, total concentration	DK	Birch et al. (2011)
			0.0028 – 0.028	storm water (street only, not treated), 4 samples, June - December 2012, volume proportional, total concentration	AT	Clara et al. (2014)
	0.088			storm water, 19 samples, July 2011- May 2013, discharge proportional, event mean concentration, total concentration	FR	Gasperi et al. (2012)
	0.02		n.n. – 0.12	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)
			<0.05 – 0.22	storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erfverband (2013)
		0.002		storm water, 191 samples, 12 events, October 2011 - June 2012, discharge proportional, total concentration	DK	Bollmann et al. (2014)
Terbutryn	0.0457	0.027	0.012 – 0.18	2 storm water treatment tanks (outlet), 20 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
			<0.05 – 0	storm water treatment tanks, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erfverband (2013)
	0.05		n.n. – 0.36	storm water, 94 samples, May 2014 - June 2015, volume proportional, total concentration	DE	Wicke et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
		0.052		storm water, 191 samples, 12 events, October 2011 - June 2012, discharge proportional, total concentration	DK	Bollmann et al. (2014)

Table A P7. 2 Statistical values - Literature check – measured pollutant concentration values in combined storm water overflows (CSO)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Lead	8.7	4.9	1.1 – 66	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	5.1	3,5	0.66 – 44	CSO, 10 facilities 127 samples, 2017-2019, volume proportional, event mean concentration (Bavaria), total concentration	DE	Nickel et al. (2021)
	5.3			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	19.2			CSO, 1 sample, (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			46 – 175 (particulate)	combined wastewater, July - September 2010, discharge proportional, particulate concentration	FR	Gasperi et al. (2012)
			<5 – 12	combined wastewater (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			<5 – 23	combined wastewater (treated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
		3	n.n. – 220	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony) , total concentration	DE	Engelmann et al. (2016)
Cadmium	0.466	0.12	0.02 – 4.8	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.085	0.062	0.018 – 0.59	CSO, 10 facilities, 127 samples, 2017-2019, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0,27 <0,2			CSO, 1 sample, November 2009 - June 2010, discharge proportional, total concentration	DE	Bachor et al. (2011)
	0.27 0.17 <0.05 0.14 (grab sample) 0.28 (grab sample)			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
	0.09			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.28			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			0.055 – 0.12	combined wastewater (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			<0.05 – 0.12	combined wastewater (treated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
		<0.3	n.n. – 12	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony) , total concentration	DE	Engelmann et al. (2016)
Nickel	6.3	3.7	<1 – 37	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	3.66	2.5	0.24 – 30	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria) , total concentration	DE	Nickel et al. (2021)
	2.4			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	13.4			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			<2 – 5.4	combined wastewater (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			<2 – 20	combined wastewater (treated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
	8.3 4.5 <1 2.6 (grab sample) 9.3 (grab sample)			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
	0.037		0.0053 – 0.67	combined wastewater (untreated), 6 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
		<5 - <7	n.n. – 45	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony) , total concentration	DE	Engelmann et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Mercury	0.032	0.022	<0.001 – 0.19	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0162	0.012	0.002 – 0.064	CSO, facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria) , total concentration	DE	Nickel et al. (2021)
	0.15		0.014 – 0.083	combined wastewater (treated), 7 sample, June - December 2012, total concentration	AT	Clara et al. (2014)
		<0.05 – <0.3	n.n. – 0.063	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony), total concentration	DE	Engelmann et al. (2016)
4-iso-Nonylphenol	0.1	0.11	<0.4 – 0.31	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.138			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	<0.1			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
	0.46		0.16 – 1	combined waste water (treated), single values, June - December 2012, total concentration	AT	Clara et al. (2014)
	1		0.2 – 3.6	combined waste water (untreated), single values, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.96 0.45			combined waste water, July- September 2010, discharge proportional, particulate, total concentration	FR	Gasperi et al. (2012)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	1.89 0.4					
	0.39 0.33 0.3 0.24			combined waste water, July- September 2010, discharge proportional, dissolved, total concentration	FR	Gasperi et al. (2012)
	0.41	0.46	0.08 – 0.6	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart) , total concentration	DE	Launay et al. (2016)
	0.28 <0.1 0.51			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
4-tert.- Oktylphenol	0.02	0.023	<0.02 – 0.037	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	3.2			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.053 – 0.067			combined waste water (treated), single values, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.12 – 0.13			combined waste water (untreated), single values, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.099 0.022 0.21 0.045			combined waste water, July - September 2010, discharge proportional, particulate, total concentration	FR	Gasperi et al. (2012)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	<0.1			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Di-(2-ethylhexyl)phthalat	4.6	3.7	0.74 – 11	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	2.6	1.8	0.24 – 11	CSO, facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	57			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			<0.35 – 0.98	combined waste water (untreated), 6 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			<0.35 – 5.1	combined waste water (treated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			3.75 – 14.82	combined waste water, July - September 2010, discharge proportional, particulate	FR	Gasperi et al. (2012)
	2.643	2.108	0.7 – 5.4	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
HBCDD	0.0099	0.008	<0.005 – 0.086	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	< LoQ 0.0066			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
PFOS	0.0023	0.002	<0.001 – 0.007	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	<0.005			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Naphthalin	0.029	0.022	<0.01 – 0.12	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0254	0.021	<0.01 – 0.15	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
Anthracen	0.008	0.0068	0.0018 – 0.022	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0091	0.0055	<0.001 – 0.13	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.128			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.22			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
			0.0047 – 0.021	combined waste water (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			0.014 – 0.031 (partikulate) 0.007 – 0.009 (dissolved)	combined waste water, July - September 2010, discharge proportional	FR	Gasperi et al. (2012)
	0,027	0,016	0,014 - 0,067	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
Fluoranthen	0.087	0.079	0.022 – 0.17	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.1	0.073	0.012 – 1.1	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.0882			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	2			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			0.003 – 0.02	combined waste water (treated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
			0.0071 – 0.024	combined waste water (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			0.009 – 0.025 (dissolved) 0.111 – 0.364 (partikulate)	combined waste water, July - September 2010, discharge proportional	FR	Gasperi et al. (2012)
	0.175	0.139	0.073 – 0.340	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
	0.19 0.041 (grab sample) 0.22 (grab sample)			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Benzo[a]anthracen	0.03	0.029	0.0077 – 0.083	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.035	0.02	0.0016 – 0.47	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	1			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			0.0022 – 0.0024	combined waste water (treated), 5 samples, June - December 2012, total concentration	AT	Clara et al. (2014)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
			0.0056 – 0.0057	combined waste water (untreated), 7 Proben, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.174 0.105 0.168 0.054			combined waste water, July - September 2010, discharge proportional, particulate	FR	Gasperi et al. (2012)
	0.091	0.056	0.038 – 0.220	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
Benzo[b]fluoranthene	0.04	0.035	0.0082 – 0.1	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.046	0.029	0.0018 – 0.52	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.035			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.00066 – 0.004	combined waste water (treated), 5 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			0.0017 – 0.0045	combined waste water (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.286 0.17			combined waste water, July - September 2010, discharge proportional, particulate	FR	Gasperi et al. (2012)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.371 0.098					
	0.157	0.109	0.067 – 0.360	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
Benzo[k]fluoranthene	0.017	0.014	0.0041 – 0.046	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0214	0.013	<0.001 – 0.26	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.044			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
			0.0014 – 0.0047	combined waste water (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.062	0.044	0.025 – 0.160	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
Benzo[a]pyren	0.03	0.028	0.0076 – 0.082	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0353	0.021	0.0014 – 0.44	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	1.6			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
	0.138 0.1 0.203 0.057			combined waste water, July - September 2010, discharge proportional, particulate, total concentration	FR	Gasperi et al. (2012)
	0.003 0.001 0.005			combined waste water, July - September 2010, discharge proportional, dissolved	FR	Gasperi et al. (2012)
	0.091	0.08	0.03 – 0.21	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
	0.092 0.014 (grab sample) 0.083 (grab sample)			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Indeno[1,2,3-cd]pyren	0.03	0.025	0.0064 – 0.1	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.0364	0.02	0.0015 – 0.52	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.0381			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	2.6			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			0.0014 – 0.0015	combined waste water (treated), 5 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			0.0017 – 0.0019	combined waste water (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.133 (particulate) 0.102 (particulate) 0.245 (particulate) 0.06 (particulate) 0.008 (dissolved)			combined waste water, July - September 2010, discharge proportional, total concentration	FR	Gasperi et al. (2012)
	0.088	0.045	0.034 – 0.211	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
	0.072 <0.01 (grab sample) 0.067 (grab sample)			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Benzo[g,h,i]perylene	0.032	0.03	0.0074 – 0.089	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.0383	0.023	0.019 – 0.46	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.251			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.01			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			0.0016 – 0.0017	combined waste water (treated), 5 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
			0.0025 – 0.0026	combined waste water (untreated), 7 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.143 (particulate) 0.104 (particulate) 0.259 (particulate) 0.06 (particulate) 0.006 (dissolved)			combined waste water, July - September 2010, discharge proportional	FR	Gasperi et al. (2012)
	0.094	0.073	0.059 – 0.18	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.11 <0.010 (grab sample) 0.099 (grab sample)			CSO, 1 sample, September 2009 - June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)
Atrazin	<0.01	<0.01	<0.01 – 0.021	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	<0.1	<0.1	<0.01 – 0.045	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.0023			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.03			combined waste water, July- September 2010, discharge proportional, dissolved	FR	Gasperi et al. (2012)
Diuron	0.019	0.012	<0.01 – 0.14	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional	DE	Toshovski et al. (2020)
	0.019	<0.01	<0.01 – 0.2	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.0722			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.48			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			0.11 – 0.21	combined waste water (untreated), 4 sample, June - December 2012, total concentration	AT	Clara et al. (2014)
			<0.05 – 0.22	combined waste water (treated), 6 sample, June - December 2012, total concentration	AT	Clara et al. (2014)
	0.321	0.26	0.068 – 0.681	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
			<0.05 – 2.68	CSO, 1 facility, 370 samples, September 2010 - September 2012, time proportional, total concentration	DE	Erftverband (2013)
	0.47 0.37 0.05 0.19			combined waste water, July - September 2010, discharge proportional, total concentration	FR	Gasperi et al. (2012)
		0,1 0,21		CSO September 2007 - October 2008, discharge proportional, wet conditions (rainfall), total concentration	FR	Lamprea and Ruban (2011)
		0.16 0.1		CSO, September 2007 - October 2008, discharge proportional, dry conditions, total concentration	FR	Lamprea and Ruban (2011)
	0.037			CSO, 1 sample, September 2009 – June 2010, discharge proportional, total concentration	DK	Nielsen et al. (2011)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
	0.043 0.055			CSO, 1 sample, September 2009 - June 2010, grab sample, total concentration	DK	Nielsen et al. (2011)
		<0.01 – 0.07	n.n. – 0.23	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony), total concentration	DE	Engelmann et al. (2016)
Isoproturon	0.012	<0.01	<0.01 – 0.047	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional, total concentration	DE	Toshovski et al. (2020)
	0.017	<0.01	<0.01 – 0.17	CSO, 10 facilities, 127 samples 10 RÜB, 2017-2019, volume proportional, event mean concentration, (Bavaria), total concentration	DE	Nickel et al. (2021)
	0.0015			CSO, 12 samples, March 2008 - September 2009, discharge proportional, event mean concentration, total concentration	FR	Becouze-Lareure et al. (2019)
	0.2			CSO, 1 sample (single value), September 2009, volume proportional, total concentration	DK	Birch et al. (2011)
			<0.05 – 6.37	CSO, 1 facility, 370 samples, September 2010 - September 2012, time proportional discharge proportional, wet conditions (rainfall), total concentration	DE	Erftverband (2013)
	0.04 0.04 0.02 0.02			Combined waste water (untreated), July-September 2010, discharge proportional, dissolved	FR	Gasperi et al. (2012)
	0.098	0.093	0.025 – 0.18	CSO, 7 samples, July-October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)

Parameter	Arithmetic average (µg/L)	Median (µg/L)	Min - Max (µg/L)	Comment	Country	Reference
Terbutryn			0.02 – 0.04	Combined waste water (untreated), 4 samples, June - December 2012, total concentration	AT	Clara et al. (2014)
		<0.1	n.n. – 0.25	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony), total concentration	DE	Engelmann et al. (2016)
	0.033	0.028	<0.01 – 0.1	CSO, 6 facilities, 27 samples, 2018-2019, volume proportional	DE	Toshovski et al. (2020)
	0.026	0.02	<0.01 – 0.099	CSO, 10 facilities, 127 samples, 2017-2019, volume proportional, event mean concentration (Bavaria)	DE	Nickel et al. (2021)
			<0.05	CSO, 1 facility, 370 samples, September 2010 - September 2012, tie proportional, total concentration	DE	Erftverband (2013)
	0.085	0.083	0.055 – 0.122	CSO, 7 samples, July - October 2014, volume proportional, event mean concentration, (Stuttgart), total concentration	DE	Launay et al. (2016)
		<0.01	n.n. – 0.78	CSO, 11 facilities, 48 samples, 2001-2010, (Saxony), total concentration	DE	Engelmann et al. (2016)

Table A P7. 3 Metal loads in urban run-off on the country level (Comber et al., 2021)

<i>Substance</i>	<i>Aluminium kg/day</i>	<i>Arsenic kg/day</i>	<i>Cadmium kg/day</i>	<i>Copper kg/day</i>	<i>Nickel kg/day</i>	<i>Silver kg/day</i>	<i>Zink kg/day</i>
<i>Albania</i>	190	0.4	0.09	11	1.7	0.06	47
<i>Austria</i>	1,005	2.1	0.48	57	8.8	0.29	247
<i>Belgium</i>	1,310	2.7	0.63	74	11.5	0.38	321
<i>Bosnia</i>	2,250	4.6	1.08	127	19.8	0.66	552
<i>Bulgaria</i>	846	1.7	0.41	48	7.4	0.25	207
<i>Croatia</i>	811	1.7	0.39	46	7.1	0.24	199
<i>Cypris</i>	79	0.2	0.04	4	0.7	0.02	19
<i>Czech</i>	971	2.0	0.47	55	8.5	0.28	238
<i>Denmark</i>	954	1.9	0.46	54	8.4	0.28	234
<i>Estonia</i>	425	0.9	0.20	24	3.7	0.12	104
<i>Finland</i>	237	0.5	0.11	13	2.1	0.07	58
<i>France</i>	9,530	19.5	4.58	537	83.9	2.78	2,338
<i>Germany</i>	12,307	25.1	5.91	693	108	3.59	3,020
<i>Greece</i>	711	1.5	0.34	40	6.3	0.21	174
<i>Hungary</i>	1.160	2.4	0.56	65	10.2	0.34	285
<i>Iceland</i>	96	0.2	0.05	5	0.8	0.03	23
<i>Ireland</i>	756	1.5	0.36	43	6.7	0.22	185
<i>Italy</i>	7,451	15.1	3.58	420	65.6	2.18	1,828
<i>Kosovo</i>	66	0.1	0.03	4	0.6	0.02	16
<i>Latvia</i>	575	1.2	0.28	32	5.1	0.17	141
<i>Lithuania</i>	773	1.6	0.37	44	6.8	0.23	190
<i>Luxembourg</i>	56	0.1	0.03	3	0.5	0.02	14
<i>Malta</i>	12	0.0	0.01	1	0.1	0.00	3

<i>Netherlands</i>	2,172	4.4	1.04	122	19.1	0.63	533
<i>N. Macedonia</i>	124	0.3	0.06	7	1.1	0.04	30
<i>Norway</i>	451	0.9	0.22	25	4.0	0.13	111
<i>Poland</i>	4,808	9.8	2.31	271	42.3	1.40	1,180
<i>Portugal</i>	1,468	3.0	0.70	83	12.9	0.43	360
<i>Romania</i>	1,369	2.8	0.66	77	12.1	0.40	336
<i>Serbia</i>	611	1.2	0.29	34	5.4	0.18	150
<i>Slovakia</i>	440	0.9	0.21	25	3.9	0.13	108
<i>Slovenia</i>	184	0.4	0.09	10	1.6	0.05	45
<i>Spain</i>	2,991	6.1	1.44	168	26.3	0.87	734
<i>Sweden</i>	1,144	2.3	0.55	64	10.1	0.33	281
<i>Switzerland</i>	2,214	4.5	1.06	125	19.5	0.65	543
<i>UK</i>	5,528	11.3	2.65	311	48.7	1.61	1,356
<i>EU27</i>	54,545	111	26	3,071	480	16	13,383

Table A P7. 4 Metal loads in urban wastewaters (D – domestic, S – Services, I – Industry, n/d – no data) on the country level (Comber et al., 2021)

Substance	Aluminium kg/day			Arsenic kg/day			Cadmium kg/day			Copper kg/day			Nickel kg/day			Silver kg/day			Zink kg/day		
	D	S	I	D	S	I	D	S	I	D	S	I	D	S	I	D	S	I	D	S	I
Albania	377	31	n/d	1.2	n/d	n/d	0.25	0.01	n/d	70	5	7.6	1.5	0.4	n/d	0.24	0.016	n/d	64	10	n/d
Austria	1,500	1,166	n/d	3.3	n/d	n.d.	0.77	0.44	0.056	221	30	1.5	5.3	16.1	1.4	0.53	0.615	n/d	238	373	1,046
Belgium	1,106	304	n/d	3.6	n/d	0.102	0.78	0.11	0.033	173	27	2.1	5.4	4.2	0.1	0.58	0.160	n/d	219	97	5.0
Bosnia	129	45	n/d	0.4	n/d	n/d	0.09	0.02	n/d	20	62	92.4	0.6	0.6	n/d	0.07	0.024	n/d	27	14	n/d
Bulgaria	710	104	228	2.4	n/d	n/d	0.49	0.04	0.35	113	23	0.5	3.4	1.4	3.3	0.37	0.055	0.239	121	33	25
Croatia	293	937	51	1.0	n/d	0.07	0.20	0.35	0.014	49	22	0.3	1.3	13.0	0.2	0.16	0.495	0.054	56	300	0.6
Cypris	165	18	n/d	0.5	n/d	n/d	0.11	0.01	n/d	31	2	n/d	0.6	0.2	n/d	0.11	0.009	n/d	21	6	n/d
Czech	943	1,073	571	3.2	n/d	0.015	0.67	0.40	0.47	133	2	16.9	5.1	14.8	14.55	0.48	0.567	0.599	171	344	165
Denmark	700	116	n/d	2.4	n/d	0.04	0.50	0.04	n/d	118	17	n/d	3.2	1.6	n/d	0.40	0.061	n/d	134	37	n/d
Estonia	129	30	n/d	0.4	n/d	n/d	0.09	0.01	n/d	21	12	1.1	0.6	0.4	n/d	0.07	0.016	n/d	23	10	n/d
Finland	717	114	n/d	2.9	n/d	0.14	0.60	0.04	n/d	132	4	2.0	3.5	1.6	1.0	0.59	0.060	n/d	109	36	2.0
France	8,049	1,385	n/d	27.4	n/d	0.23	5.84	0.52	0.25	1,528	353	4.8	36.6	19.1	3.0	4.82	0.731	n/d	1,280	443	12
Germany	10,687	343	3,064	27.7	n/d	1.36	6.65	0.13	5.3	1,861	305	137.6	46.9	4.7	12	4.30	0.181	3.211	1,794	110	242
Greece	3,493	222	n/d	11.7	n/d	0.19	2.27	0.08	n/d	665	20	1.4	13.0	3.1	0.2	2.34	0.117	n/d	547	71	n/d
Hungary	922	238	n/d	3.6	n/d	0.02	0.66	0.09	0.083	143	15	0.7	4.5	3.3	2.0	0.49	0.126	n/d	188	76	30
Iceland	67	8	n/d	0.2	n/d	n/d	0.04	0.003	n/d	12	3	1.6	0.3	0.1	n/d	0.04	0.004	n/d	12	2	n/d
Ireland	385	100	n/d	1.3	n/d	n/d	0.27	0.04	n/d	65	28	0.8	1.8	1.4	0.1	0.21	0.053	n/d	74	32	1.0
Italy	10,542	1,647	n/d	31.8	n/d	2.78	6.91	0.62	0.34	1,887	120	3.4	44.3	22.8	20	5.89	0.870	n/d	1,866	527	36
Kosovo	123	11	n/d	0.4	n/d	n/d	0.09	0.00	n/d	19	2	48.2	0.6	0.2	n/d	0.06	0.006	n/d	25	4	n/d
Latvia	278	118	57	0.9	n/d	n/d	0.19	0.04	0.05	47	16	1.1	1.2	1.6	0.6	0.16	0.063	0.060	52	38	14
Lithuania	244	131	30	0.8	n/d	n/d	0.18	0.05	0.02	36	21	1.2	1.3	1.8	0.3	0.12	0.069	0.031	71	42	8.0
Luxembourg	88	9	n/d	0.3	n/d	n/d	0.06	0.003	n/d	16	2	0.6	0.3	0.1	n/d	0.05	0.005	n/d	12	3	n/d
Malta	64	10	n/d	0.2	n/d	n/d	0.04	0.004	n/d	11	0	3.6	0.3	0.1	n/d	0.04	0.005	n/d	12	3	n/d
Netherlands	2,329	305	479	6.3	n/d	n/d	1.51	0.11	0.014	452	76	7.6	9.8	4.2	2.0	0.89	0.161	0.502	464	97	7.0
N. Macedonia	454	7	n/d	1.4	n/d	n/d	0.29	0.003	n/d	85	3	2.3	1.6	0.1	n/d	0.30	0.004	n/d	65	2	n/d

Norway	1,085	111	n/d	3.5	n/d	n/d	0.70	0.04	n/d	169	16	0.8	4.2	1.5	n/d	0.78	0.058	n/d	135	35	n/d
Poland	3,039	423	n/d	10.4	n/d	1,662*	2.21	0.16	8.9	481	136	98.9	15.5	5.8	34	1.56	0.223	n/d	649	135	216
Portugal	1,578	9	n/d	5.4	n/d	1.87	1.05	0.004	0.69	277	47	7.0	6.5	0.1	5.0	0.93	0.005	n/d	254	3	5.0
Romania	1,030	1,258	1,070	3.4	n/d	n/d	0.74	0.47	0.89	156	38	0.7	5.3	17.4	0.3	0.50	0.664	1.121	213	403	0.5
Serbia	594	320	102	2.0	n/d	n/d	0.41	0.12	0.08	100	17	1.3	2.7	4.4	1.1	0.34	0.169	0.106	100	102	n/d
Slovakia	440	27	611	1.4	n/d	n/d	0.34	0.01	0.51	69	7	0.7	2.1	0.4	6.4	0.24	0.014	0.641	107	9	4.0
Slovenia	131	27	n/d	0.4	n/d	n/d	0.09	0.01	n/d	20	5	n/d	0.7	0.4	n/d	0.06	0.014	n/d	27	9	n/d
Spain	7,312	1,127	n/d	23.6	n/d	0.73	4.81	0.42	0.25	1,277	116	3.4	32.5	15.6	4.0	4.14	0.595	n/d	1,167	361	25
Sweden	1, 654	399	n/d	5.5	n/d	0.02	1.09	0.15	n/d	249	27	0.9	7.3	5.5	0.4	1.16	0.211	n/d	219	128	1.0
Switzerland	1,291	177	n/d	3.2	n/d	n/d	0.76	0.07	0.033	213	4	0.4	5.0	2.4	0.5	0.46	0.094	n/d	225	57	2.6
UK	8,441	1,032	137	26.7	n/d	1.21	5.45	0.39	0.14	1,701	386	10.0	39.0	14.3	9.0	4.79	0.545	0.143	1,479	330	28
EU27	58,527	11,641	6,162	182	n/d	1,670	39	4	18	10,232	1,469	299	258	161	111	31	6	6	10,086	3,726	1,845

* This e-PRTR value for As in Poland, although reported seem anomalous

Table A P7. 5 Pollutant concentrations in 5 German UWWTP (Toshovski et al. 2020)

Substance	Number values	Number values > LoQ	LoQ (µg/L)	Minimum (µg/L)	Median (µg/L)	Mean (µg/L)	Maximum (µg/L)
Lead	96	95	0.1	< LoQ	3.1	3.9	30
Cadmium	96	95	0.002	< LoQ	0.11	0.12	0.49
Nickel	96	96	1	1.4	6.3	8.2	32
Mercury	96	95	0.001	< LoQ	0.029	0.036	0.17
4-iso-Nonylphenol	96	95	0.1	< LoQ	0.24	0.28	0.94
4-tert.-Oktylphenol	96	11	0.05	< LoQ	< LoQ	< LoQ	0.38
Di-(2-ethylhexyl)phthalat	96	96	0.25	3.7	14	16	90
HBCDD (Summe)	96	36	0.01	< LoQ	< LoQ	0.01	0.1
Perfluorooctansulfonat	96	12	0.01	< LoQ	< LoQ	0.0117	0.17
1H,1H,2H,2H-Perfluorooctansulfonat	96	10	0.01	< LoQ	< LoQ	0.0195	0.58
Naphthalin	96	56	0.025	< LoQ	0.028	0.034	0.39
Fluoranthen	96	96	0.0025	0.02	0.047	0.082	1,1
Benzo[a]anthracen	96	96	0.0025	0.0049	0.0145	0.0293	0.48
Benzo[b]fluoranthen	96	96	0.0025	0.0045	0.015	0.028	0.39
Benzo[k]fluoranthen	96	88	0.0025	< LoQ	0.0062	0.0125	0.17
Benzo[a]pyren	96	96	0.0013	0.0035	0.011	0.025	0.34
Indeno[1,2,3-cd]pyren	96	96	0.0013	0.0025	0.0096	0.0204	0.26
Benzo[g,h,i]perylene	96	96	0.0013	0.0038	0.012	0,022	0.25
Aclonifen	96	1	0.05	-	-	-	0.098
Atrazin	96	1	0.01	-	-	-	0.03
Bifenox	96	0	0.02	-	-	-	-
cis-Heptachlorepoxyd	96	0	0.01	-	-	-	-
Cybutryn	96	0	0.025	-	-	-	-
Cypermethrin, gesamt	96	15	0.013	< LoQ	< LoQ	0.009	0.057
Dichlorvos	96	0	0.05	-	-	-	-
Dicofol	96	0	0.05	-	-	-	-
Diuron	96	43	0.01	< LoQ	< LoQ	0.0135	0.052
Heptachlor	96	0	0.01	-	-	-	-
Isoproturon	96	79	0.01	< LoQ	0.0275	0.033	0.13
Quinoxifen	96	0	0.01	-	-	-	-
Terbutryn	96	89	0.01	< LoQ	0.0515	0.06	0.38
trans-Heptachlorepoxyd	96	0	0.01	-	-	-	-

Annex P8

Table A P8. 1 Statistical values of EQS-Directive substances frequently found in UWWTP effluents

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
Category A substances (see chapter 3, page 5 in this document)								
Lead, and its compounds (EQS: 1.2 µg/L (bioavailable fraction))	LoQ: 0.1	0.14	0.18	0.05 – 7	11.6	49 UWWTP, n=1,000, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 2.0	1.0	1.27	0.001 – 119	43.2	477 UWWTP, n=2,639, 2018-2020, found in 6.3 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.5	< LoD		0 – 1,400		34 UWWTP with tertiary treatment, n=122, 2011-2019, found in 28 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.5	1.1		0 – 65		19 small UWWTP with only mechanical treatment, n=101, 2011-2019, found in 72 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.063 LoQ: 0.13	0.9	1.0	0.25 – 2.2		12 UWWTP (9 countries), n=12, 2017, found in all samples,	RO, RS, HR, SK, SI, HU, CZ,	SOLUTION S EU FP7 project & ICPDR (2017) (Danube)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						total concentration	AT, DE	
	LoD: 0.063 LoQ: 0.13	0.27	0.378	< LoD – 1.4		11 UWWTP (11 countries), n=11, 2019, found in 9 samples > LoQ; in one sample < LoD and in one sample < LoQ, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LOQ: 0.05	0.24	0.39	< 0.05 – 4.4	-	54 UWWTPs with at least secondary treatment, 2013-14, found in 94 % of samples, total concentration	FI	Vieno (2014)
		0.2	7.9			91 UWWTP (Saxony), 2001-2010	DE	Engelmann et al. (2016)
	LoD: 0.7 LoQ: 1.4	1.1	1.2	< LoQ – 3.7	-	total concentration	AT	Clara et al. (2009)
		1.2			-	9 UWWTP, 1 year, older than 2010, total concentration	AT	Clara et al. (2012)
	LoD: 0.1 LoQ: 0.5	0.25	0.069 – 0.38	0 – 0.5	-	8 UWWTP, not detected in 10 out of 32 samples, 22 out of 32 values < LoQ, median < LoQ, total concentration	AT	Clara et al. (2017)
		0.64	1.118	0 – 27	18	25 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 2.5 LoQ: 5	< LoQ	0.278	0 – 760		331 UWWTP (Flanders), 6.3 % of values > LoD,	BE	VMM, Wastewater Monitorin

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						total concentration		g Network, 2010-2019
		0.649	0.905			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
		0.86				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
Cadmium and its compounds (EQS: 0.08 – 0.25 µg/L)	LoQ: 0.002	0.006	0.009	< 0.001 – 1	0.5	49 UWWTP, n=1,000, 2017-2019, (emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.1 – 0.5	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 1.0	0.5	0.55	0.0005 – 100	21.3	461 UWWTP, n=2,544, 2018-2020, found in 3.3 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.05	< LoD		0 – 0.17		34 UWWTP with tertiary treatment, n=122, 2011-2019, found in 7.4 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.05	< LoD		0 – 1.6		19 small UWWTP with only mechanical treatment, n=100, 2011-2019,	DK	Miljøstyrelsen (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in 45 % of samples, total concentration		
	LoD: 0.063 LoQ: 0.13	0.51	0.35	< 0.063 – 0.51		12 UWWTP (9 countries), n=12, 2017, found in 5 out of 12 samples > LoQ and in one more sample > LoD, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoD: 0.063 LoQ: 0.13	not found				11 UWWTP (11 countries), n=11, 2019, not found > LoD total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LOQ: 0.01	0.02	0.09	< 0.01 – 2.4	-	54 UWWTPs with at least secondary treatment, 2013-14, found in 80 % of samples, total concentration	FI	Vieno (2014)
			0.00083 – 0.013			2 UWWTP, total concentration	AT	Clara et al. (2014)
		< 0.03 – 0.5		n.n. – 24		91 UWWTP, (Saxony), 2001-2010	DE	Engelmann et al. (2016)
		0.010	0.094			9 UWWTP, 1 year, older than 2010, total concentration	AT	Clara et al. (2012)
	LoD: 0.02 LoQ: 0.05		0.0056 – 0.028	0 – 0.05		8 UWWTP, not detected in 23 out of 32 samples, 9 out of 32 values < LoQ, total concentration	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.03	< LoQ	0.0297	0 – 0.56	0.521	25 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.4 LoQ: 0.8	< LoQ	0	0 – 24		331 UWWTP (Flanders), 0.5 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
		0.027	0.043			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
		< LoQ (0.1)				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
Nickel and its compounds (EQS: 4 µg/L (bioavailable fraction))	LoQ: 1.0	4.4	4.786	0.5 – 18	365	49 UWWTP, n=1,000, 2017-2019, (emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50% of samples), total concentration	DE	Toshovski et al. (2020)
	LoD: 0.13 LoQ: 0.25	3.75	5.1	0.93 – 9.9		12 UWWTP (9 countries), n=12, 2017, found in all samples, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTION S EU FP7 project & ICPDR (2017) (Danube)
	LoD: 0.13 LoQ: 0.25	2.5	4.47	1.2 – 18		11 UWWTP (11 countries), n=11, 2019, not found in all samples, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 1	3.4		0 – 29		34 UWWTP with tertiary treatment, n=127, 2011-2019, found in 95 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 1	2.4		0 – 34		19 small UWWTP with only mechanical treatment, n=102, 2011-2019, found in 77 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LOQ: 0.05	8.6	11.7	2.7 – 71	-	54 UWWTPs with at least secondary treatment, 2013-14, found in 100 % of samples, total concentration	FI	Vieno (2014)
	LoQ: 5	2.5	4.2	0.001 – 1,230	119	476 UWWTP, n=2,636, 2018-2020, found in 18 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 1 – 2.3	4.5	8.1	<LOD – 41		total concentration	AT	Clara et al. (2009)
			4.4 – 4.7			2 UWWTP, total concentration	AT	Clara et al. (2014)
		4.3		n.n. – 200		91 UWWTP (Saxony), 2001-2010	DE	Engelmann et al. (2016)
		4.1	5.6			9 UWWTP, 1 year, older than 2010, total concentration	AT	Clara et al. (2012)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 1 LoQ: 4	5.5	7 – 8.2	0 – 30		8 UWWTP, not detected in 1 out of 32 samples and 16 out of 36 values <LoQ, total concentration	AT	Clara et al. (2017)
		3.8	6.304	0 – 57	284	25 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 2.5 LoQ: 8	< LoQ	2.66	0 – 2,800		331 UWWTP (Flanders), 29 % of values > LoD), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
		3.05	4.29			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical- investigations- programme (CIP2))
		4.8				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
Mercury and its compounds (Biota EQS)	LoQ: 0.001	0.002	0.006	0.0005 – 1.1	0.2	49 UWWTP, n=1,000, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50% of samples), total concentration	DE	Toshovski et al. (2020)
	LoD: 0.002 – 0.05	< LoD		0 – 1.4		34 UWWTP with tertiary treatment, n=124, 2011-2019, found in 40 % of samples, total concentration	DK	Miljøstyrelsen (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.002 – 0.05	< LoD		0 – 0.95		19 small UWWTP with only mechanical treatment, n=100, 2011-2019, found in 48 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.063 LoQ: 0.13	not found				12 UWWTP (9 countries), n=12, 2017, Found in only one sample > LoD total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoD: 0.063 LoQ: 0.13	not found				11 UWWTP (11 countries), n=11, 2019, not found > LoD, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LOQ: 0.004	< 0.004 (<LOQ)	0.005	< 0.004 – 0.038	-	54 UWWTPs with at least secondary treatment, 2013-14, found in 35 % of samples, total concentration	FI	Vieno (2014)
	LoQ: 0.2	0.1	0.08	0.0005 – 21.4	2.9	478 UWWTP, n=2,646, 2018-2020, found in 5.7% of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 0.1–0.25			n.n. – < LOD		total concentration	AT	Clara et al. (2009)
			0.01			2 UWWTP, total concentration	AT	Clara et al. (2014)
	LoD: 0.0003	0.015	0.019	0.0055 – 0.067		8 UWWTP,	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.001					all values (35) > LoQ), total concentration		
		< 0.02 – 0.2		n.n. – 0.5		91 UWWTP (Saxony), 2001-2010	DE	Engelmann et al. (2016)
		0.01				9 UWWTP, 1 year, total concentration	AT	Clara et al. (2012)
	LoQ: 0.01	< LoQ	0.01075	0 – 0.12	0.255	32 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.075 LoQ: 0.2	< LoQ	0.00000287	0 – 6		331 UWWTP (Flanders), 2.5 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
		0.0039	0.0084			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
4-iso-Nonylphenols (EQS: 0.3 µg/L)		0.0007				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
	LoQ: 0.04	0.043	0.115	0.02 – 3.4	3.6	49 UWWTP, n=999, 2017-2019, (emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.5	0.25	0.25	0.02 – 2.82	10.5	478 UWWTP, n=2,646, 2018-2020,	FR	French Database “RSDE-STEUE” (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in 3.6 % of samples, total concentration		
	LoD: 0.01	not found				53 UWWTP (34 with tertiary and 19 with only mechanical treatment), n=36+29, 2004-2019, total concentration	DK	Miljøstyrelsen (2021)
				< 0,03 – 7.8		world-wide literature study	Sever al	Luo et al. (2014)
			0.267			7 samples	CH	Miropoll project (in Loos et al. 2012)
	LoQ: 0.09	0.22	0.34	n.n. – 1.8		total concentration	AT	Clara et al. (2009)
		0.18	0.25			9 UWWTP, 1 year, older than 2020, total concentration	AT	Clara et al. (2012)
	variable LoQ	0.017	0.086	0 – 0.93		257 UWWTP > 10.000 p.e., 2015/2016, data assessment: all values < LoQ set to 0, total concentrations	AT	Data base AT
	LOQ: 0.05	0.05	0.09	< 0.05 – 0.34		56 UWWTPs with at least secondary treatment, 2013-14, found in 45 % of samples, CAS number 84852-15-3, total concentration	FI	Vieno (2014)
		0.14	0.19	0.025 – 0.77		3 UWWTP (Baden-Württemberg), 2012/2013,	DE	Lambert et al. (2014)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						total concentration		
	LoQ: 0.02	< LoQ	0.0004651	0 – 0.02		11 UWWTP, 2015-2019, found only in a few samples, total concentration	NL	Data base NL (2020)
	LoD: 0.024 LoQ: 0.048	not found				1 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoD: 0.002 LoQ: 0.006	not found				11 UWWTP (11 countries), n=11, 2019, not found > LoD, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
			0.364 0.37 0.285			3 UWWTP, total concentration	AT	Clara et al. (2005)
		0.093	0.144			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
Di(2-ethylhexyl)-phthalate (DEHP) (EQS: 1.3 µg/L)		0.2				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
	LoQ: 0.1	1.7	3.12	0.05 – 12	141	49 UWWTP, n=999, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50% of samples), total concentration	DE	Toshovski et al. (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 1	0.5	0.79	0.2 – 62.7	25.1	481 UWWTP, n=2,655, 2018-2020, found in 8.9 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.1	0.33		0 – 27		34 UWWTP with tertiary treatment, n=149, 2006-2019, found in 70 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.1	6.3		0 – 81		19 small UWWTP with only mechanical treatment, n=102, 2008-2019, found in 94 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.000561 LoQ: 0.0017	not found				11 UWWTP (11 countries), n=11, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoD: 0.000561 LoQ: 0.0017	0.013	0.094	< 0.002 – 0.762		12 UWWTP (9 countries), n=12, 2017, found in 11 out of 12 samples, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LOQ: 0.3	0.47	1.17	< 0.3 – 20	-	58 UWWTPs with at least secondary treatment, 2013-14, found in 69 % of samples, total concentration	FI	Vieno (2014)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
			< 2				DE	Schütte et al. (2017)
				0.0001 – 54		world-wide literature study	Several	Luo et al. (2014)
	LoQ: 0.5	< LoQ	0.1474	0 – 3.2		17 UWWTP, 2015-2018, found in only a few samples (10 out of 94), total concentration	NL	Data base NL (2020)
	LoD: 0.19 LoQ: 0.38	< LoQ	0.322	0 – 15		17 UWWTP (Flanders), 33.3 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
		0.24	0.32	0.05 – 2.3		3 UWWTP (Baden-Württemberg), 2012/2013, total concentration	DE	Lambert et al. (2014)
	LoQ: 0.12 – 0.26	0.5	1.6	< LOD – 6.6		total concentration	AT	Clara et al. (2009)
		0.52				9 UWWTP, 1 year, older than 2010, total concentration	AT	Clara et al. (2012)
		0.4377	0.6646			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
		0.78				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
PFOS (EQS: 00001.3 µg/L)	LoQ: 0.001	0.003	0.008	0.0005 – 0.82	0.2	49 UWWTP, n=1,000, 2017-2019, emission factor is based on median effluent concentrations	DE	Toshovski et al. (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						of 49 UWWTPs (found in more than 50 % of samples), total concentration		
	LoQ: 0.05	0.025	0.034	0.003 – 2.4	1.2	386 UWWTP, n=2,070, 2018-2020, found in 8.8 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.001	0.0046		0 – 0.28		34 UWWTP with tertiary treatment, n=105, 2008-2019, found in 87 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.001	0.0014		0 – 0.082		19 small UWWTP with only mechanical treatment, n=74, 2008-2019, found in 53 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.0003 LoQ: 0.001	< LoQ	0.0695	< LoD – 0.726		11 UWWTP (11 countries), n=11, 2019, found in 5 samples > LoQ, 6 values < LoD, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoD: 0.0003 LoQ: 0.001	0.015	0.016	0.002 – 0.042		12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
				0.005 – 0.04		40 UWWTP (Baden-Württemberg), 2015-2016,	DE	Rau und Metzger (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.005	0.005	0.026	< 0.005 – 0.088	-	total concentration 12 UWWTPs with at least secondary treatment, 2013-14, found in 50 % of samples, total concentration	FI	Vieno (2014)
			0.007					Maus et al. (2016)
			0.013			2 UWWTP, total concentration	AT	Clara et al. (2014)
	LoD: 0.0005 LoQ: 0.001	0.0062	0.015	0.0005 – 0.12		8 UWWTP, 1 value out of 34 < LoQ, found in 33 out of 34 samples > LoQ, total concentration	AT	Clara et al. (2017)
					1-8 µg per capita per day	6 UWWTP, 2010-2013	IT	Castiglioni et al. (2015)
				0.016 – 0.303		7 UWWTD	CH	Huset et al. (2008)
		0.0122	0.0625	2.101 (max)		Summary of analytical results for chemicals in EU UWWTP effluents (91 UWWTP)	Sever al	Loos et al. (2013)
	LoQ: 0.005	< LoQ	0.01926	0 – 0.43		40 UWWTP, 2015-2018, found in 74 samples out of 220, total concentration	NL	Data base NL (2020)
	LoD: 0.02 LoQ: 0.1	< LoQ	0.0371	0 – 3.75		18 UWWTP (Flanders), 6.9 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
			0.114			7 samples	CH	Miropoll project (CH, in Loos et al. 2012)
		0.0041	0.0227			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
				0.0073 – 0.017 0.096 – 0.462		2 UWWTP, 2006-2007	SGP	Yu et al. (2009)
Fluoranthene (EQS: 0.0063 µg/L)	LoQ: 0.001	0.0021	0.0037	0.0005 – 0.11	0.2	49 UWWTP, n=999, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50% of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.2	not found				total concentration	AT	Clara et al. (2009)
		not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 1 value > LoQ, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.01	0.005	0.0067	0.0025 – 2.75	0.2	480 UWWTP, n=2,648, 2018-2020, found in 5.2 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.01	< LoD		0 – 0.24		34 UWWTP with tertiary treatment, n=377, 1998-2019,	DK	Miljøstyrelsen (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in 14 % of samples, total concentration		
	LoD: 0.01	< LoD		0 – 0.16		19 small UWWTP with only mechanical treatment, n=93, 2011-2019, found in 18 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.0022 LoQ: 0.005		0.000071 – 0.0023	0 – 0.005		8 UWWTP, not detected in 30 out of 31 samples and 1 out of 31 < LoQ), total concentration	AT	Clara et al. (2017)
	LoQ: 0.005	< LoQ	0.0005195	0 – 0.02		22 UWWTP, 2015-2018, found in only a few samples (2 out of 77), total concentration	NL	Data base NL (2020)
	LoD: 0.025 LoQ: 0.04	< LoQ	0.00797	0 – 1.5		121 UWWTP (Flanders), 4.3 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
		0.003	0.003	0.002 – 0.005		3 UWWTP (Baden-Württemberg), 2012/2013, total concentration	DE	Lambert et al. (2014)
		0.0088	0.0126			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
		0.0063				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
Diuron (EQS: 0.2 µg/L)	LoQ: 0.01	0.016	0.023	0.005 – 0.59	1.3	49 UWWTP, n=1,000, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.001	0.015	0.017	< 0.001 – 0.05		11 UWWTP (11 countries), n=11, 2019, found in 8 samples, 3 values < LoD, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.001	0.004	0.016	< 0.001 – 0.074		12 UWWTP (9 countries), n=12, 2017, found in 11 out of 12 samples, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.05	0.036	0.087	0.01 – 50	1.6	480 UWWTP, n=2,659 2018-2020, found in 28% of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 0.005	-	0.0077	< 0.005 – 0.01	-	59 UWWTPs with at least secondary treatment, 2013-14, found in 12 % of samples, total concentration	FI	Vieno (2014)
	LoQ: 0.0063 – 0.015	0.041	0.06	n.n. – 0.21		total concentration	AT	Clara et al. (2009)
			0.094			2 UWWTP, total concentration	AT	Clara et al. (2014)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	variable LoQ	0.024	0.055	0 – 0.82		249 UWWTP > 10.000 p.e., 2015/2016, data assessment: all values <LoQ set to 0, total concentrations	AT	Data base AT
			0.32.			30 UWWTP (Andalusia), 2011	ES	Barco-Bonilla et al. (2013)
				0.002 – 2.53		world-wide literature study	several	Luo et al. (2014)
		0.014		n.n. – 6.6		92 UWWTP (Saxony), 2001-2010	DE	Engelmann et al. (2016)
		0.059	0.073	0.03 – 0.3		3 UWWTP (Baden-Württemberg), 2012/2013, total concentration	DE	Lambert et al. (2014)
			0.127			3 UWWTP (Catalonia), 2007-2009	ES	Köck-Schulmeyer et al. (2013)
			0.07±0.041			1 UWWTP, 2009-2010	CH	Margot et al. (2013)
		0.040	0.073			9 UWWTP, 1 year, older than 2010, total concentration	AT	Clara et al. (2012)
			0.19±0.23			1 UWWTP, 2009	CH	Morasch et al. (2010)
		0.0116	0.0617	1.426 (max)		Summary of analytical results for chemicals in EU UWWTP effluents (91 UWWTP)	Several	Loos et al. (2013)
	LoQ: 0.02	< LoQ	0.01687	0 – 0.32	1.2	32 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.05 LoQ: 0.1	< LoQ	0.315	0 – 74		38 UWWTP (Flanders), 36.1 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
			1.379			7 samples	CH	Miropoll project (CH, in Loos et al. 2012)
			0.025±0.004 0.182±0.015			2 UWWTP (Koblenz), 2009	DE	Wick et al. (2010)
Isoproturone (EQS: 0.3 µg/L)	LoQ: 0.01	0.019	0.047	0.005 – 5.2	1.6	49 UWWTP, n=1,000, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.05	0.025	0.040	0.01 – 21.4	1.1	480 UWWTP, n=2,656, 2018-2020, found in 2.7 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 0.0005	< LoQ	0.009	< LoQ – 0.037		11 UWWTP (11 countries), n=11, 2019, more than 50 % of values (6) < LoD total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.0005	0.006	0.012	< 0.0005 – 0.038		12 UWWTP (9 countries), n=12, 2017, found in 11 out of 12 samples, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
			0.084			88 UWWTP (Saxony), 2001-2010	DE	Engelmann (2016)
	LoQ: 0.0092 – 0.026		0.012	n.n. – 0.05		total concentration	AT	Clara et al. (2009)
				0.0063 – 0.031		2 UWWTP, total concentration	AT	Clara et al. (2014)
			0.050			30 UWWTP (Andalusia), 2011	ES	Barco-Bonilla et al. (2013)
		0.056	0.059	0.005 – 0.16		3 UWWTP (Baden-Württemberg), 2012/2013, total concentration	DE	Lambert et al. (2014)
		0.009		n.n. – 15		92 UWWTP (Saxony), 2001-2010	DE	Engelmann et al. (2016)
			0.039±0.032			1 UWWTP, 2009-2010	CH	Margot et al. (2013)
			0.013			3 UWWTP (Catalonia), 2007-2009	ES	Köck-Schulmeyer et al. (2013)
		0.022				9 UWWTP, 1 year, total concentration	AT	Clara et al. (2012)
			0.34±0.47			1 UWWTP, 2009	CH	Morasch et al. (2010)
	LoQ: 0.01	< LoQ	0.003576	0 – 0.16	1.6	33 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.05 LoQ: 0.1	< LoQ	0.0892	0 – 20.8		38 UWWTP (Flanders), 10.1 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
		0.0004	0.0101	0.27 (max)		Summary of analytical results for chemicals in EU UWWTP effluents	Sever al	Loos et al. (2013)
			0.058±0.005 0.05±0.002			2 UWWTP (Koblenz), 2009	DE	Wick et al. (2010)
Terbutryne (EQS: 0.0065 µg/L)	LoQ: 0.01	0.035	0.044	0.005 – 0.29	2.9	49 UWWTP, n=1,000, 2017-2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.0007	0.017	0.031	0.002 – 0.107		12 UWWTP (9 countries), n=12, 2017, found in all samples, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.0007	0.019	0.0342	< LoD – 0.079		11 UWWTP (11 countries), n=11, 2019, only 1 value < LoD total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.1	0.050	0.050	0.005 – 0.512	2.1	479 UWWTP, n=2,655, 2018-2020, found in 5.5 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
			0.190					Schütte et al. (2017)
				0.029 – 0.095		40 UWWTP (Baden-Württemberg), 2015-2016	DE	Rau und Metzger (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p. e.)	Comment	Country	Reference
			0.041			94 UWWTP (Saxony), 2001-2010	DE	Engelmann (2016)
	LoD: 0.025 LoQ: 0.05		0.0078 – 0.033	0 – 0.05		8 UWWTP, not detected in 22 out of 32 samples and 10 out of 32 values < LoQ, total concentration	AT	Clara et al. (2017)
	LOQ: 0.01	< 0.01	<0.01	< 0.01 – 0.02		12 UWWTPs with at least secondary treatment, 2013-14, found in 8 % of samples, total concentration	FI	Vieno (2014)
			0.054					Maus et al. (2016)
		0.024		n.n. – 0.64		94 UWWTP (Saxony), 2001-2010	DE	Engelmann et al. (2016)
			0.019±0.016			1 UWWTP, 2009-2010	CH	Margot et al. (2013)
	LoQ: 0.01	< LoQ	0.00307	0 – 0.07	0.389	32 UWWTP, 2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.025 LoQ: 0.05	< LoQ	0.0135	0 – 6.3	-	35 UWWTP (Flanders), 6.4 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
			0.39±0.53		-	1 UWWTP, 2009	CH	Morasch et al. (2010)
			0.028±0.004 0.0123±0.007		-	2 UWWTP (Koblenz), 2009	DE	Wick et al. (2010)
4-tert.-Octylphenol (EQS: 0.1 µg/L)	LoQ: 0.005–2	not found				2015-2018, total concentration	NL	Data base NL (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.08	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.1	0.050	1.18	0.005 – 2686	2.1	480 UWWTP, n=2,657, 2018-2020, found in 1.7 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.05 LoQ: 0.1	< LoQ	0.00661	0 – 0.38		21 UWWTP (Flanders), 5.4 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.025					3 UWWTP (Baden-Württemberg), 2012/2013, found in only a few samples (4 out of 23), total concentration	DE	Lambert et al. (2014)
	LoQ: 0.02	< LoQ	< LoQ	< LoQ – 0.2		49 UWWTP, n=1,000, 2017-2019, found in 27% of 1,000 values > LoQ, total concentration	DE	Toshovski et al. (2020)
		0.05	0.043			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
Benzo[a]pyrene (EQS: 0.0017 µg/L)	LoQ: 0.00001 – 0.2	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.05	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.01	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012,	FR	NORMAN data base (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						total concentration		
	LoQ: 0.01	0.005	0.005	0.0005 – 0.74	0.2	480 UWWTP, n=2,653, 2018-2020, found in 2.0 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.01	< LoD		0 – 0.09		34 UWWTP with tertiary treatment, n=367, 1998-2019, found in 7.1 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.01	0.77		0 – 260		19 small UWWTP with only mechanical treatment, n=93, 2011-2019, found in 69 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.0004 LoQ: 0.001		0.00011 – 0.0005	0 – 0.0029	-	8 UWWTP, found in only a few samples; not detected in 29 out of 31 samples, 1 out of 31 values < LoQ, 1 out of 31 values > LoQ, total concentration	AT	Clara et al. (2017)
	LoQ: 0.005					3 UWWTP (Baden-Württemberg), 2012/2013, found in only a few samples (1 out of 17), total concentration	DE	Lambert et al. (2014)
	LoQ: 0.0005	< LoQ	0.0007	< LoQ – 0.057		49 UWWTP, n=1,000, 2017-2019,	DE	Toshovski et al. (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in only 33 % of 1,000 values > LoQ, total concentration		
	LoD: 0.025 LoQ: 0.04	< LoQ	0.00286	0 – 0.86		121 UWWTP (Flanders), 2.0 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
		0.00376	0.00583			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
		0.0011				162 UWWTP, 2010-2013, total concentration	UK	Gardner et al. (2014)
Benzo[b]fluoranthene (PNEC _{wasser} : 0.017 µg/L)	LoQ: 0.00002 – 0.1	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.03	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.005			< LoQ – 0.005		1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 1 value > LoQ 2012, total concentration	FR	NORMAN data base (2021)
	LoQ 0.005	0.0025	0.004	0.0025 – 2		477 UWWTP, n=2,622, 2018-2020, found in 4.2 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.00086 LoQ: 0.001		0.00013 – 0.00094	0 – 0.0032		8 UWWTP, found in only a few samples, not detected in 29 out of 31 samples, 1 out of 31 values < LoQ,	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						1 out of 31 values > LoQ, total concentration		
	LoQ: 0.005					3 UWWTP (Baden-Württemberg), 2012/2013, found in only a few samples (4 out of 17), total concentration	DE	Lambert et al. (2014)
	LoD: 0.025 LoQ: 0.04	< LoQ	0.0042	0 – 0.89		121 UWWTP (Flanders), 4.3 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.001	< LoQ	0.001	< LoQ – 0.083		49 UWWTP, n=1,000, 2017-2019, found in only 15 % of values > LoQ, total concentration	DE	Toshovski et al. (2020)
Benzo[g,h,i]perylene (PNECwater: 0.0082 µg/L)	LoQ: 0.00002 – 0.2	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.005	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.005	0.025	0.44	0.0025 – 726	0.1	477 UWWTP, n=2,622, 2018-2020, found in 2.4 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 0.002					found only in 1 sample out of 15, total concentration	AT	Clara et al. (2009)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.01	< LoD		0 – 0.08		53 UWWTP with tertiary treatment, n=374, 1998-2019, found in 7.5 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.01	0.02		0 – 0.29		19 small UWWTP with only mechanical treatment, n=99, 2011-2019, found in 69 % of samples total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.00059 LoQ: 0.001		0.00049 – 0.001	0 – 0.013		8 UWWTP, found in only a few samples, not detected in 28 out of 31 samples, 1 out of 31 values < LoQ, 2 out of 31 values > LoQ, total concentration	AT	Clara et al. (2017)
	LoQ: 0.0005					3 UWWTP Baden-Württemberg), 2012/2013, found in only a few samples; (5 out of 17), total concentration	DE	Lambert et al. (2014)
	LoD: 0.025 LoQ: 0.04	< LoQ	0.00178	0 – 0.4		121 UWWTP (Flanders), 1.9 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.0005	< LoQ	0.0006	< LoQ – 0.05		49 UWWTP, n=1,000, 2017-2019, found in only 27 % of 1,000 values > LoQ, total concentration	DE	Toshovski et al. (2020)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
			0.001				UK	Gardner et al. (2014)
Indeno[1,2,3-cd]-pyrene (PNEC _{wasser} : 0.0027 µg/L)	LoQ: 0.00002 – 0.2	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.002	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.005	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.005	0.0025	0.008	0.0025 – 9.2	0.1 LoQ: 0.002 µg/l;	477 UWWTP, n=2,622, 2018-2020, found in 2.1 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.01	< LoD		0 – 0.06		34 UWWTP with tertiary treatment, n=374, 1998-2019, found in 7.2 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.01	0.066		0 – 3.1		19 small UWWTP with only mechanical treatment, n=93, 2011-2019, found in 63 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.00057 LoQ: 0.001		0.00017 – 0.00069	0 – 0.0022		8 UWWTP, found in only a few samples, not detected in 27 out of 31 samples, 2 out of 31 values < LoQ, 2 out of 31 values > LoQ,	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.0005					total concentration 3 UWWTP (Baden-Württemberg), 2012/2013, found in only a few samples (8 out of 17), total concentration	DE	Lambert et al. (2014)
	LoD: 0.025 LoQ: 0.04	< LoQ	0.00198	0 – 0.61		121 UWWTP (Flanders), 1.9 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.0005	< LoQ	0.0006	< LoQ – 0.053		49 UWWTP, n=1,000, 2017-2019, found in only 23% of 1,000 values > LoQ, total concentration	DE	Toshovski et al. (2020)
			0.0014				UK	Gardner et al. (2014)
Naphthalene (EQS: 2 µg/L)	LoQ: 0.001-10					2015-2018, found in only a few samples (2 out of 85), total concentration	NL	Data base NL (2020)
	LoQ: 0.05	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.005			< LoQ – 0.083		1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, found in only 1 sample, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.05	0.025	0.027	0.005 – 3.15	1.1	480 UWWTP, n=2,652, 2018-2020,	FR	French Database “RSDE-

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in 3.8 % of samples, total concentration		STEU" (2020)
	LoD: 0.01 – 0.05	< LoD		0 – 0.31		34 UWWTP with tertiary treatment, n=1655, 2004-2019, found in 37 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.01	0.02		0 – 0.29		19 small UWWTP with only mechanical treatment, n=99, 2011-2019, found in 69 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.002 LoQ: 0.0074	0.010	0.01 – 0.012	0 – 0.054		8 UWWTP, not detected in 8 out of 31 samples, 6 out of 31 values < LoQ, found in 17 out of 31 samples > LoQ, total concentration	AT	Clara et al. (2017)
	LoQ: 0.01					3 UWWTP (Baden-Württemberg), 2012/2013, found in 11 of 17 samples, total concentration	DE	Lambert et al. (2014)
	LoD: 0.04 LoQ: 0.05	< LoQ	0.0184	0 – 1.72		121 UWWTP (Flanders), 8.8 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.001	< LoQ	0.01	< LoQ – 0.065)		49 UWWTP, n=1,000, 2017-2019,	DE	Toshovski et al. (2020)



Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in only 43 % of 1,000 values > LoQ, total concentration		

Category B substances (see chapter 3, page 6 in this document)

Benzo[k]fluoranthene (PNEC _{wasser} : 0.017 µg/L)	LoQ: 0.00001 – 0.2	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.03	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.005	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.005	0.0025	0.063	0.0025 – 55	0.1	477 UWWTP, n=2,621, 2018-2020 found in 2.1 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.00044 LoQ: 0.001		0.00014 – 0.00055	0 – 0.003		8 UWWTP, not detected in 29 out of 31 samples, found in only a few samples (2 out of 31) > LoQ, total concentration	AT	Clara et al. (2017)
	LoD: 0.025 LoQ: 0.04	< LoQ	0.00152	0 – 0.43		121 UWWTP (Flanders), 1.6 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.005	not found				3 UWWTP (Baden-Württemberg), 2012/2013,	DE	Lambert et al. (2014)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.001					total concentration 49 UWWTP, n=1,000, 2017-2019, found in only a few samples (46 out of 1,000), total concentration	DE	Toshovski et al. (2020)
Anthracene (EQS: 0.1 µg/L)	LoQ: 0.00001 – 0.1	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.05	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.02	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.01	0.005	0.120	0.0025 – 55	0.2	480 UWWTP, n=2,654, 2018-2020, found in 1.5 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.01	< LoD		0 – 0.07		34 UWWTP with tertiary treatment, n=375, 1998-2019, found in 11 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.01	< LoD		0 – 0.71		19 small UWWTP with only mechanical treatment, n=93, 2011-2019, found in 27 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.00049		0.000032 – 0.0016	0 – 0.018		8 UWWTP,	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.018					not detected in 29 out of 31 samples, found in 2 out of 31 samples > LoQ, total concentration		
	LoD: 0.025 LoQ: 0.04	< LoQ	0.00121	0 – 0.33		121 UWWTP (Flanders), 2.0 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.005					3 UWWTP (Baden-Württemberg), 2012/2013, found in only a few samples (1 out of 17), total concentration	DE	Lambert et al. (2014)
	LoQ: 0.001					49 UWWTP, n=1,000, 2017-2019, found in only a few samples (38 out of 999), total concentration	DE	Toshovski et al. (2020)
Atrazine (EQS: 0.6 µg/L)	LoQ: 0.001 – 2					2015-2018, found in only a few samples (9 out of 158), total concentration	NL	Data base NL (2020)
	LoQ: 0.0084 – 0.24					found in only a few samples (4 out of 33 samples > LoQ), total concentration	AT	Clara et al. (2009)
	LoQ: 0.001	< LoQ	0.00145	< LoD – 0.008		11 UWWTP (11 countries), n=11, 2019, only 3 values > LoD total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.001	0.008	0.009	< 0.001 – 0.017		12 UWWTP (9 countries), n=12, 2017 found in 11 of 12 samples, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.01					3 UWWTP (Baden-Württemberg), 2012/2013, found in only a few samples (3 out of 23), total concentration	DE	Lambert et al. (2014)
	LoD: 0.025 LoQ: 0.05	< LoQ	0.0191	0 – 14.3		38 UWWTP (Flanders), 3.5 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.01					49 UWWTP, n=1,000, 2017-2019, found in only a few samples (41 out of 1,000), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.03	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	varying LoQ	0.0022	0.0042			Summary of analytical results for chemicals in EU UWWTP effluents	EU	Loos et al. (2013)
Hexabromocyclodecanes (HBCDD) (EQS: 0.0016 µg/L)		not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.025 LoQ: 0.05	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.1 LoQ: 0.2	not found				17 UWWTP (Flanders) 0 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.005					49 UWWTP, n=1,000, 2017-2019, found in only a few samples (8 out of 1,000), total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.0016	0.0056 76	0.009			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical- investigations- programme (CIP2))
Cybutryne (EQS: 0.0025 µg/L)		not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.025 LoQ: 0.05	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)
	LoD: 0.01 LoQ: 0.02	not found				35 UWWTP (Flanders), 0 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.0003			< LoD – 0.002		11 UWWTP (11 countries), n=11, 2019, only one value > LoD total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.0003			< LoD – 0.0008		12 UWWTP (9 countries), n=12, 2017, found in only one sample > LoQ (0.002 µg/L), total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTION S EU FP7 project & ICPDR (2017) (Danube)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.025	0.0125	0.012	0.005 – 0.060	0.5	386 UWWTP, n=2,129, 2018-2020, found in 1.1 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 0.005					49 UWWTP, n=1,000, 2017-2019, found in only a few samples (35 out of 1,000), total concentration	DE	Toshovski et al (2020)
Heptachlor (EQS: 0.0000002 µg/L)	LoD: 0.0001 – 0.05	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.004	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.020	0.010	0.015	0.0025 – 10	0.4	478 UWWTP, n=2,647, 2018-2020, found in 0.8 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.004	not found				49 UWWTP, n=1,000, 2017-2019, total concentration	DE	Toshovski et al. (2020)
Dichlorvos (EQS: 0.0006 µg/L)	LoQ: 0.0001 – 0.05	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.025 LoQ: 0.05	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)
	LoQ: 0.02	not found				12 UWWTP (9 countries), n=12,	RO, RS, HR,	SOLUTIONS EU FP7 project &

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						2017, total concentration	SK, SI, HU, CZ, AT, DE	ICPDR (2017) (Danube)
	LoQ: 0.001	not found				11 UWWTP (11 countries), n=11, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.05	0.025	0.025	0.010 – 0.060	1.1	478 UWWTP, n=2,650, 2018-2020, found in 0.8 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoQ: 0.01					49 UWWTP, n=1,000, 2017-2019, found in only a few samples (4 out of 1,000), total concentration	DE	Toshovski et al. (2020)
	LoD: 0.01 LoQ: 0.02					23 UWWTP (Flanders), 0.2 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Dicofol (EQS: 0.0013 µg/L)	LoQ: 0.001 – 0.1	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoQ: 0.05	0.025	0.030	0.010 – 10	1.1	478 UWWTP, n=2,646, 2018-2020, found in 0.8 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.0005 LoQ: 0.001		0.000097 – 0.00058	0 – 0.0031		8 UWWTP, not detected in 31 out of 32 samples, found in only 1 sample	AT	Clara et al. (2017)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p. e.)	Comment	Country	Reference
						(1 out of 32) > LoQ), total concentration		
	LoD: 0.025 LoQ: 0.05	not found				16 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoD: 0.002 LoQ: 0.006	not found				11 UWWTP (11 countries), n=11, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.02	not found				49 UWWTP, n=1,000, 2017-2019, total concentration	DE	Toshovski et al. (2020)
Cypermethrin (EQS: 0.00008 µg/L)	LoQ: 0.003 – 0.06	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.0005 LoQ: 0.001	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)
	LoD: 0.05 LoQ: 0.1	not found				16 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.005	not found				49 UWWTP, n=1,000, 2017-2019, total concentration	DE	Toshovski et al. (2020)
	LoQ: 0.00031	< LoQ	0.000329	< LoQ – 0.00166		11 UWWTP (11 countries), n=11, 2019, only 3 values > LoQ,	RO, HR, CZ, SK, SI, RS, BG, HR,	Joint Danube Survey 4 (JDS4), ICPDR

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						large volume solid-phase extraction total concentration	UA, AT, DE	
	LoQ: 0.02	0.010	1.77	0.010 – 3400	0.4	478 UWWTP, n=2,647, 2018-2020, found in 1.6 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoQ: 0.00008	0.000166	0.000572			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
cis-Heptachlorepoxide and trans-Heptachlorepoxide² (EQS: 0.0000002 µg/L)	LoQ: 0.0001 – 0.05	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.004	not found				49 UWWTP, n=1,000, 2017-2019, total concentration	DE	Toshovski et al. (2020)
Aclonifen (EQS: 0.12 µg/L)	LoQ: 0.002 – 1					2015-2018, found in only 1 sample (1 out of 123), total concentration	NL	Data base NL (2020)
	LoQ: 0.1	0.050	0.050	0.010 – 0.18	2.1	479 UWWTP, n=2,654, 2018-2020, found in 0.9 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.025	< LoQ	0.000774	0 – 0.144		16 UWWTP (Flanders),	BE	VMM, Wastewater

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.05					0.9 % of values > LoD, total concentration		Monitoring Network, 2010-2019
	LoD: 0.001 LoQ: 0.003	not found				12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoD: 0.002 LoQ: 0.006	not found				11 UWWTP (11 countries), n=11, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoD: 0.025 LoQ: 0.05	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)
	LoQ: 0.01					49 UWWTP, n=1,000, 2017-2019, found in only 1 sample (1 out of 1,000), total concentration	DE	Toshovski et al (2020)
BifenoX (EQS: 0.012 µg/L)	LoQ: 0.002 – 0.2					2015-2018, found in only a few samples (2 out of 110), total concentration	NL	Data base NL (2020)
	LoQ: 0.1	0.050	0.096	0.010 – 27	2.1	480 UWWTP, n=2,656, 2018-2020, found in 0.8 % of samples, total concentration	FR	French Database "RSDE-STEUE" (2020)
	LoD: 0.002 LoQ: 0.006	not found				11 UWWTP (11 countries), n=11, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG,	Joint Danube Survey 4 (JDS4), ICPDR

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
							HR, UA, AT, DE	
	LoD: 0.0005 LoQ: 0.001	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)
	LoD: 0.001 LoQ: 0.003	not found				12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.004	not found				49 UWWTP, n=1,000, 2017-2019, total concentration	DE	Toshovski et al. (2020)
	LoD: 0.025 LoQ: 0.05	not found				16 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Quinoxifen (EQS: 0.15 µg/L)	LoQ: 0.01 – 0.05	not found				2015-2018, total concentration	NL	Data base NL (2020)
	LoD: 0.025 LoQ: 0.05	not found				8 UWWTP, total concentration	AT	Clara et al. (2017)
	LoQ: 0.001	not found				12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.001	not found				11 UWWTP (11 countries), n=11, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HU, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.1	0.050	0.1	0.005 – 27	2.1	478 UWWTP, n=2,653, 2018-2020, found in 0.8 % of samples, total concentration	FR	French Database “RSDE-STEUE” (2020)
	LoD: 0.01 LoQ: 0.02			0 – 0.065		22 UWWTP (Flanders), 0.1 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.01	not found				49 UWWTP, n=1,000, 2017-2019, total concentration	DE	Toshovski et al. (2020)

Category C substances (see chapter 3, page 6/7 in this document)

Alachlor (EQS: 0.3 µg/L)	LoQ: 0.05	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.02	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN), n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoD: 0.001 LoQ: 0.003			< LoD – 0.0914		12 UWWTP (9 countries), n=12, only 1 value > LoQ, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTION S EU FP7 project & ICPDR (2017) (Danube)
	LoD: 0.002 LoQ: 0.006	not found				11 UWWTP (11 countries), n=11, 2019, all values < LoD total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoD: 0.05 LoQ: 0.1	< LoQ	0.00321	0 – 1.35		38 UWWTP (Flanders),	BE	VMM, Wastewater Monitoring

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						1.3 % of values > LoD, total concentration		g Network, 2010-2019
Benzens (EQS: 10 µg/L)	LoQ: 0.879	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.02 – 0.05	< LoD		0 – 0.64		34 UWWTP with tertiary treatment, n=293, 1998-2019, found in 13 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.02	< LoD		0 – 0.16		19 small UWWTP with only mechanical treatment, n=93, 2011-2019, found in 18 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoQ: 0.51 – 1	not found				5 facilities, n=59 2011-2017 found in only a few samples total concentration	FR	NORMAN data base (2021)
	LoD: 0.62 LoQ: 1.24	< LoQ	0.000216	0 – 0.12		16 UWWTP (Flanders), 0.2 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
BDE	LoQ: 0.24 – 1.4					found in only a few samples, total concentration	AT	Clara et al. (2009)
	LoQ: 0.0000078 – 0.00001	0.000005	0.0000039 – 0.000010	0 – 0.000039		BDE 28: 22 values out of 34 < LoQ, 12 values out of 34 > LoQ, total concentration		Clara et al. (2017)
	LoQ: 0.0001 – 0.00028	0.00014	0.00011 – 0.00032	0 – 0.00098		BDE 47, 27 values out of 34 < LoQ, 7 values		



Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.000099 – 0.00016	0.00005	0.000078 – 0.00016	0 – 0.00048		out of 34 > LoQ, total concentration		
	LoQ: 0.000021 – 0.000034	0.000015	0.000017 – 0.000039	0 – 0.00011		BDE 99, 24 values out of 34 < LoQ, 10 values out of 34 > LoQ, total concentration		
	LoQ 0.0000084 – 0.000027	0.0000046	0.0000069 – 0.000016	0 – 0.000081		BDE 100, 25 values out of 34 < LoQ, 9 values out of 34 > LoQ, total concentration		
	LoQ 0.0000069 – 0.000011	0.0000035	0.0000035 – 0.0000093	0 – 0.000028		BDE 153, 27 values out of 34 < LoQ, 7 values out of 34 > LoQ, total concentration		
			0.000022 – 0.00055	0 – 0.0016		BDE 154, 25 values out of 34 < LoQ, 9 values out of 34 > LoQ), total concentration		
						Sum of BDE 28, BDE 47, BDE 99, BDE 100, BDE 153 and BDE 154		
		0.000251 0.000315 0.0003 0.00025 0.00025 0.00025	0.00025 0.000467 0.000513 0.000257 0.000244 0.000318			600 UWWTP, n=605, 2015- 2020, total concentration BDE28 BDE47 BDE99 BDE100 BDE153 BDE154	UK	UK data base (chemical- investigations- programme (CIP2))

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.002/0.0025 LoQ: 0.004/0.005	< LoQ	0.0000048 – 0.00113	0 – 1.14		18 UWWTP (Flanders), 0.5 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.0001					3 UWWTP, 2012/2013, found in only a few samples, total concentration	DE	Lambert et al. (2014)
C10-C13 Chloralcanes (EQS: 0.4 µg/L)	LoQ: 0.1	not found				total concentration	AT	Clara et al. (2009)
Chlorfenvinphos (EQS: 0.1 µg/L)	LoQ: 0.011–0.022	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.05	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.001 LoQ: 0.0013	not found				12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.001	not found				11 UWWTP (11 countries), n=11, All values < LoD 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoD: 0.05 LoQ: 0.1	not found				13 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Chlorpyrifos (EQS: 0.03 µg/L)	LoQ: 0.005					found in only a few samples (2	AT	Clara et al. (2009)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						out of 15 and 9 out of 18), total concentration		
	LoQ: 0.02	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoD: 0.05 LoQ: 0.1	< LoQ	0.0029	0 – 0.24		23 UWWTP (Flanders), 4.1 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Cyclodiene pesticides (EQS: Sum 0.01 µg/L)	LoQ: 0.005–0.01	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.05	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
DDT total (EQS: 0.025 µg/L)	LoQ: 0.015	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
para-para-DDT (EQS: 0.01 µg/L)	LoQ: 0.005	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.025 LoQ: 0.05	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
								Network, 2010-2019
1,2-Dichloroethane (EQS: 10 µg/L)	LoQ: 1.252	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.5	not found				5 facilities, n=59 2011-2017 found in only a few samples total concentration	FR	NORMAN data base (2021)
	LoD: 1.13 LoQ: 2.26					17 UWWTP (Flanders), 0.1 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Dichloromethane (EQS: 20 µg/L)	LoQ: 1.328					found in only a few samples (2 out of 15), total concentration	AT	Clara et al. (2009)
	LoD: 0.1 - 2	< LoD		0 – 52		34 UWWTP with tertiary treatment, n=217, 1998-2019, found in 5.5 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.1	< LoD		0 – 0.25		19 small UWWTP with only mechanical treatment, n=32, 2011-2019, found in 3.1 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoQ: 5	not found				5 facilities, n=59 2011-2017 found in only a few samples total concentration	FR	NORMAN data base (2021)
	LoD: 0.5 LoQ: 1		0.00443	0 – 1.86		17 UWWTP (Flanders),	BE	VMM, Wastewater Monitoring

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						0.3 % of values > LoD, total concentration		g Network, 2010-2019
Endosulfan (EQS: 0.005 µg/L)	LoQ: 0.01	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.025 LoQ: 0.05		0.00321	0 – 1.966		17 UWWTP (Flanders), 0.5 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoD: 0.001 LoQ: 0.003	not found				12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoD: 0.002 LoQ: 0.006	not found				11 UWWTP (11 countries), n=11, All values < LoD 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.02	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoQ: 0.001	not found				3 UWWTP, 2012/2013, total concentration	DE	Lambert et al. (2014)
Hexachlorobenzene	LoQ: 0.005	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.01	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.002	not found				3 UWWTP, 2012/2013, total concentration	DE	Lambert et al. (2014)
Hexachlorobutadiene	LoQ: 0.005	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.005	not found				3 UWWTD, 2012/2013, total concentration	DE	Lambert et al. (2014)
Hexachlorocyclohexane (EQS: 0.02 µg/L)	LoQ: 0.02	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.01 LoQ: 0.02		0.000601	0 – 0.265		17 UWWTP (Flanders), 0.4 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.005/0.002	0.004	0.0043	0.0023 – 0.01		3 UWWTP, n=17, 2012/2013, only γ-Hexachlorocyclohexane was found in all samples, total concentration	DE	Lambert et al. (2014)
Pentachlorobenzene (EQS: 0.007 µg/L)	LoQ: 0.01	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.005 – 0.05	not found				53 UWWTP (34 with tertiary and 19 with only mechanical treatment),	DK	Miljøstyrelsen (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						n=142, 1998-2010 + 4, 2005-2019, total concentration		
	LoQ: 0.01	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Pentachlorophenol (EQS: 0.4 µg/L)	LoQ: 0.66 – 1.4	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.01 – 0.05	< LoD		0 – 0.24		34 UWWTP with tertiary treatment, n=278, 1998-2010, found in 12 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.02	not found				19 small UWWTP with only mechanical treatment, n=4, 2005, total concentration	DK	Miljøstyrelsen (2021)
	LoQ: 0.1	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoD: 0.03 LoQ: 0.06	< LoQ	0.000648	0 – 0.16		21 UWWTP (Flanders), 0.7 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 0.1	not found				3 UWWTD, 2012/2013, total concentration	DE	Lambert et al. (2014)
Simazine (EQS: 1 µg/L)	LoQ: 0.041 – 0.18			0 – 0.22		found in only 1 sample (out of 15 and out of 18), total concentration	AT	Clara et al. (2009)
	LoD: 0.001 LoQ: 0.003	not found				12 UWWTP (9 countries), n=12, 2017, total concentration	RO, RS, HR, SK, SI, HU, CZ, AT, DE	SOLUTIONS EU FP7 project & ICPDR (2017) (Danube)
	LoQ: 0.001	not found				11 UWWTP (11 countries), n=11, All values < LoD, 2019, total concentration	RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE	Joint Danube Survey 4 (JDS4), ICPDR
	LoQ: 0.03	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN), n=4, 2012, Total concentration	FR	NORMAN data base (2021)
	LoD: 0.025 LoQ: 0.05	< LoQ	0.0116	0 – 2.85		38 UWWTP (Flanders), 5.0 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Tetrachloroethylene (EQS: 10 µg/L)	LoQ: 0.01	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.02 – 0.1	< LoQD		0 – 0.59		34 UWWTP with tertiary treatment, n=265, 1998-2019, found in 17 % of samples, total concentration	DK	Miljøstyrelsen (2021)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoD: 0.02	< LoD		0 – 0.46		19 small UWWTP with only mechanical treatment, n=95, 2011-2019, found in 46 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoQ: 0.5			< LoQ – 2.2		5 facilities, n=59 2011-2017 found in only a few samples total concentration	FR	NORMAN data base (2021)
	LoD: 0.67 LoQ: 1.34	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Trichloroethylene (EQS: 10 µg/L)	LoQ: 1.463	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.02 – 0.1	< LoD		0 – 0.51		34 UWWTP with tertiary treatment, n=262, 1998-2019, found in 8.8 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.02	< LoD		0 – 0.1		19 small UWWTP with only mechanical treatment, n=93, 2011-2019, found in 6.5 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoQ: 0.5			1.6 (max)		5 facilities, n=59 2011-2017 found in only 1 sample total concentration	FR	NORMAN data base (2021)
	LoD: 0.64	not found				17 UWWTP (Flanders),	BE	VMM, Wastewater

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
	LoQ: 1.28					total concentration		European Monitoring Network, 2010-2019
Tributyltin compounds (EQS: 0.0002 µg/L)	LoQ: 0.0002		0.0018 and 0.00022	0.0052 and 0.002		found 6 out of 15 samples > LoQ and 15 out of 45 samples > LoQ, total concentration	AT	Clara et al. (2009)
		0.000147	0.000205			600 UWWTP, n=605, 2015-2020, total concentration	UK	UK data base (chemical-investigations-programme (CIP2))
	LoD: 0.001 – 0.004	not found				34 UWWTP with tertiary treatment, n=67, 2013-2018, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.001 – 0.004	< LoD		0 – 0.005		19 small UWWTP with only mechanical treatment, n=62, 2011-2019, found in 8.1 % of samples, total concentration	DK	Miljøstyrelsen (2021)
	LoD: 0.0001 LoQ: 0.0002		0.000013 – 0.00011	0 – 0.00035		8 UWWTP, not detected in 32 out of 34 samples, 1 out of 34 values < LoQ, found in only 1 sample (1 out of 32) > LoQ, total concentration	AT	Clara et al. (2017)
						18 UWWTP (Flanders), 20.6 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.00005	< LoQ	0.00004	< LoQ – 0.00014		3 UWWTP, 2012/2013, total concentration	DE	Lambert et al. (2014)

Parameter	LoD/LoQ (µg/L)	Median (µg/L)	Arithmetic average (µg/L)	Min - Max (µg/L)	Emission factor (mg/p.e.)	Comment	Country	Reference
						found in only 4 sample (out of 19), total concentration		
Trichlorobenzenes (EQS: 0.4 µg/L)	LoQ: 1.622	not found				total concentration	AT	Clara et al. (2009)
	LoD: 0.38 LoQ: 0.76	< LoQ	0.028	0 – 2.91		17 UWWTP (Flanders), 1.6 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
Trichloromethane (EQS: 2.5 µg/L)	LoQ: 1.483					found in only 1 sample (out of 15), total concentration	AT	Clara et al. (2009)
	LoD: 0.51 LoQ: 1.02	< LoQ	0.0562	0 – 11.2		17 UWWTP (Flanders), 3.5 % of values > LoD, total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019
	LoQ: 0.1	not found				3 UWWTP, 2012/2013, total concentration	DE	Lambert et al. (2014)
Trifluraline (EQS: 0.03 µg/L)	LoQ: 0.005	not found				total concentration	AT	Clara et al. (2009)
	LoQ: 0.01	not found				1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4, 2012, total concentration	FR	NORMAN data base (2021)
	LoD: 0.05 LoQ: 0.1	not found				17 UWWTP (Flanders), total concentration	BE	VMM, Wastewater Monitoring Network, 2010-2019



Annex P9

Table A P9. 1 Substance specific reduction efficiency in urban waste water treatment plants (literature study)

Substance	Reduction efficiency (%)	Comment	Country	Source
Lead	94	5 UWWTP, n=93, 2017-2019	DE	Toshovski et al. (2020)
	90 – 100	2 UWWTP	AT	Clara et al. (2014)
	90	16 UWWTP, 2010-2011	UK	Gardner et al. (2013)
Cadmium	92	5 UWWTP, n=93, 2017-2019	DE	Toshovski et al. (2020)
	92 – 100	2 UWWTP	AT	Clara et al. (2014)
	88	16 UWWTP, 2010-2011	UK	Gardner et al. (2013)
Nickel	44	5 UWWTP, n=94, 2017-2019	DE	Toshovski et al. (2020)
	25 – 30	2 UWWTP	AT	Clara et al. (2014)
	29	16 UWWTP, 2010-2011	UK	Gardner et al. (2013)
Mercury	89	5 UWWTP, n=93, 2017-2019	DE	Toshovski et al. (2020)
	90	2 UWWTP	AT	Clara et al. (2014)
	79	16 UWWTP, 2010-2011	UK	Gardner et al. (2013)
4-iso-Nonylphenol	78	5 UWWTP, n=93, 2017-2019	DE	Toshovski et al. (2020)
	~ 22 – 99	literature study	world-wide	Luo et al. (2014)
	89; 81; 78	3 UWWTP	AT	Clara et al. (2005)
Di-(2-ethylhexyl)phthalat (DEHP)	88	5 UWWTP, n=94, 2017-2019	DE	Toshovski et al. (2020)
	87		DE	Schütte et al. (2017)
	63		DE	Schütte et al. (2016)



Substance	Reduction efficiency (%)	Comment	Country	Source
	25 – 97	literature study	world-wide	Luo et al. (2014)
Perfluorooctanesulfonate	67	5 UWWTP, n=12, 2017-2019	DE	Toshovski et al. (2020)
	38	40 UWWTP, 2015-2016, Baden-Württemberg	DE	Rau und Metzger (2017)
	73		DE	Maus et al. (2016)
	40	2 UWWTP	AT	Clara et al. (2014)
Diuron	13	5 UWWTP, n= 42, 2017-2019	DE	Toshovski et al. (2020)
	49	16 UWWTP, 2011	ES	Campo et al. (2013)
	1	2 UWWTP	AT	Clara et al. (2014)
	~ 27 – ~ 72	literature study	world-wide	Luo et al. (2014)
	46 (±16)	literature review		Luo et al. (2014)
	10 (±16)	n=9, 2009-2010		Margot et al. (2013)
	15		CH	Abegglen und Siegrist (2012)
	22		AT	Clara et al. (2012)
Isoproturon	0		DE	Seel et al. (1994)
	15	5 UWWTP, n=77, 2017-2019	DE	Toshovski et al. (2020)
	~ 56	16 UWWTP, 2011	ES	Campo et al. (2013)
	27 (±22)	n=16, 2009-2010		Margot et al. (2013)
	0 – 35			Abegglen und Siegrist (2012)
	9		AT	Clara et al. (2012)
	15			Seel et al. (1994)

Substance	Reduction efficiency (%)	Comment	Country	Source
Terbutryn	29	5 UWWTP, n=87, 2017-2019	DE	Toshovski et al. (2020)
	1	40 UWWTP, 2015-2016	DE	Rau und Metzger (2017)
	ca. 30	1 UWWTP, 2015	DE	Schütte et al. (2017)
	35	1 UWWTP	DE	Maus et al. (2016)
	< 20	6 UWWTP	DE	LUBW (2014)
	65	16 UWWTP, 2011 2011, grab sample or 24-h composite sample	ES	Campo et al. (2013)
	49 (±25)	n=37, 2009-2010, 24-h composite sample		Margot et al. (2013)
	38	biological treatment without nitrification	CH	Abegglen und Siegrist (2012)
	48	biological treatment with nitrification	CH	Abegglen und Siegrist (2012)
	47	1 UWWTP, n=7, 2009, 24-h composite sample	CH	Morasch et al. (2010)
	72 (±14)	1 UWWTP	CH	Singer et al. (2010)

Annex P10

Measurement/calculation/estimation of releases to surface water (summary from E-PRTR ⁽⁷³⁾):
For the indication of whether the reported release and transfer data is based on measurement, calculation or estimation a simplified system with three classes identified with a letter code is required, referring to the methodology used to determine the data:

Class M

Release data are based on measurements ("M"). Additional calculations are needed to convert the results of measurements into annual release data. For these calculations the results of flow determinations are needed. "M" should also be used when the annual releases are determined based on the results of short term and spot measurements. "M" is used when the releases of a facility are derived from direct monitoring results for specific processes at the facility, based on actual continuous or discontinuous measurements of pollutant concentrations for a given release route.

Class C

Release data are based on calculations ("C"). "C" is used when the releases are based on calculations using activity data (fuel used, production rate, etc.) and emission factors or mass balances. In some cases, more complicated calculation methods can be applied, using variables like temperature, global radiance etc.

Class E

Release data are based on non-standardised estimations ("E"). "E" is used when the releases are determined by best assumptions or expert guesses that are not based on publicly available references or in case of absence of recognised emission estimation methodologies or good practice guidelines.

⁽⁷³⁾ https://ec.europa.eu/environment/industry/stationary/e-prtr/pdf/en_prtr.pdf⁽⁷³⁾
https://ec.europa.eu/environment/industry/stationary/e-prtr/pdf/en_prtr.pdf

Annex P13

Table A P13. 1 Background ⁽⁷⁴⁾ PAH₁₆ and B(a)P concentrations in German top soils (90th percentile); (LABO 2015).

Humus content class	B(a)P (µg/kg)	PAH ₁₆ (µg/kg)	B(a)P (µg/kg)	PAH ₁₆ (µg/kg)	B(a)P (µg/kg)	PAH ₁₆ (µg/kg)	B(a)P (µg/kg)	PAH ₁₆ (µg/kg)
	Field*		Pasture*		Deciduous forest**		Coniferous forest**	
< 1%	-	-	-	-	-	-	-	-
1 - < 2%	20.6	221	-	-	-	-	-	-
2 - < 4%	34.3	484	14.0	196	-	-	26.0	675
4 - < 8 %	61.5	885	46.7	430	61.4	1,035	36.4	832
8 - < 15%	-	-	42.2	295	83.6	1,663	47.6	1,200
15 - < 30%	-	-	-	-	140.6	3,069	99.1	1,774
> 30%	-	-	(25.2)	(413)	-	-	-	-

() small number of samples (< 20); * in top soil; ** in 0-5 cm

⁽⁷⁴⁾ Background concentration is meant as natural background concentration including ubiquitous pollutant distribution