ETC/ICM Report 3/2022

# Calculating emissions to water – a simplified method

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## List of abbreviations

| | |
|---|---|
| AR | Activity Rate |
| CSO | Combined Sewer Outflow |
| DEHP | Diethylhexyl phthalate |
| EC | European Commission |
| EEA | European Environment Agency |
| EF | Emission Factor |
| EFTA | European Free Trade Association |
| 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 |
| p.e. | Population equivalent |
| 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) |

## List of CAS-Numbers

| | |
|---|---|
| 1,2-Dichloroethane | 107-06-2 |
| 1H,1H,2H,2H-Perfluoroctansulfonat | 27619-97-2 |
| 4-iso Nonylphenols | 104-40-5 |
| 4-tert.-Octylphenol | 140-66-9 |
| Acenaphthene | 83-32-9 |
| Acenaphthylene | 208-96-8 |
| Aclonifen | 74070-46-5 |
| Alachlor | 15972-60-8 |
| Aluminum | 7429-90-5 |
| Anthracene | 120-12-7 |
| Arsenic | 7440-38-2 |
| Atrazine | 1912-24-9 |
| BDE | 32534-81-9 |
| Benzene | 71-43-2 |
| Benzo(a)anthracene | 56-55-3 |
| Benzo(a)pyrene | 50-32-8 |
| Benzo(b)fluoranthene | 205-99-2 |
| Benzo(g,h,i)perylene | 191-24-2 |
| Benzo(k)fluoranthene | 207-08-9 |
| Bifenox | 42576-02-3 |
| C10-C13 Chloralkanes | 85535-84-8 |
| Cadmium | 7440-43-9 |
| Carbo-tetrachloride | 56-23-5 |
| Chlorfenvinphos | 470-90-6 |
| Chlorpyrifos | 2921-88-2 |
| Chromium | 7440-47-3 |
| Chrysene | 218-01-9 |
| cis-Heptachlorepoxide and trans-eptachlorepoxide | 1024-57-3 |
| Copper | 7440-50-8 |
| Cybutryne | 28159-98-0 |
| Cyclodiene pesticides | 309-00-2, 60-57-1, 72-20-8, 465-73-6 |
| Cypermethrin | 52315-07-8 |
| DDT total | 50-29-3 |
| DEHP | 117-81-7 |
| Di(2-ethylhexyl)-phthalate (DEHP) | 117-81-7 |
| Dibenzo(a,h)anthracene | 53-70-3 |
| Dichloromethane | 75-09-2 |
| Dichlorvos | 62-73-7 |
| Dicofol | 115-32-2 |
| Diuron | 330-54-1 |
| Endosulfan | 115-29-7 |
| Fluoranthene | 206-44-0 |
| Fluorene | 86-73-7 |
| HBCDD | 25637-99-4 |
| Heptachlor | 76-44-8 |
| Hexachlorobenzene | 118-74-1 |

| | |
|---|---|
| Hexachlorobutadiene | 87-68-3 |
| Hexachlorocyclohexane | 608-73-1 |
| Indeno[1,2,3-cd]-pyrene | 193-39-5 |
| Isoproturon | 34123-59-6 |
| Lead | 7439-92-1 |
| Mercury | 439-97-6 |
| Naphthalene | 91-20-3 |
| Nickel | 7440-02-0 |
| PAH16 | 130498-29-2 |
| Para-para-DDT | 50-29-3 |
| Pentachlorobenzene | 608-93-5 |
| Pentachlorophenol | 87-86-5 |
| PFOS (Perfluorooctanesulfonic acid) | 1763-23-1 |
| Phenanthrene | 85-01-8 |
| Pyrene | 129-00-0 |
| Quinoxyfen | 124495-18-7 |
| Silver | 7440-22-4 |
| Simazine | 122-34-9 |
| Terbutryn | 886-50-0 |
| Tetrachloroethylene | 127-18-4 |
| Trans-Heptachlorepoxid | 1024-57-3 |
| Tributyltin compounds | 36643-28-4 |
| Trichlorobenzenes | 12002-48-1 |
| Trichloroethylene | 79-01-6 |
| Trichloromethane | 67-66-3 |
| Trifluraline | 1582-09-8 |
| Zinc | 7440-66-6 |

## Executive summary

Information on the quantities of pollutants released – emissions – is important for understanding whether control measures are successful. The European Green Deal established the Zero Pollution Ambition (EC, 2019) which relies on baseline information by which to determine whether pollution is being reduced. Unfortunately, despite decades of effort within countries, we still lack good information on the total emissions of pollutants released to water across Europe.

The Water Framework Directive (WFD) (EC, 2000) requires Member States to report an inventory of emissions, discharges and losses of priority substances. Technical guidance on preparing the emissions inventory has been published (EC, 2012), but experience from the electronic reporting of the second River Basin Management Plans showed that Member States needed further information to help them report in a more consistent and comparable way.

This report is aimed at those preparing inventories of emissions to water. It provides a simplified method for calculating the emissions to water and is intended to help where there is currently limited emissions information available, as well as providing a benchmark for those already with some knowledge. It describes quantification methods for the 13 pathways for emissions to surface waters referred to in the WFD Technical Guidance (EC, 2012), with factsheets giving an overview of each pathway and detailing specific calculation methods. Efforts have been made to gather as much information on priority substance concentrations and emission factors, relevant to European countries, as possible.

Each factsheet starts with an introduction describing the pathway and the substances most relevant to that pathway. Calculation methods to quantify the emissions from that pathway are then explained, followed by conclusions. Detailed annexes contain data about emission factors and calculated emissions per country.

The proposed methods can contribute to the harmonisation of the methods used for the quantification of emissions to water, and in that way improve the comparability of reported emission data between countries. However, the proposed emission factors are often averages based on data from different countries and may differ from actual emissions, depending on specific local or regional situations. This is why the work is offered as support in cases where no better local information is available. Note also that the advice provided in this report is not required to be applied by countries.

As experience with emissions accounting improves, it invariably highlights where previous estimates were flawed. This means that it is necessary that inventories can be retrospectively updated with new knowledge. The aim of this work is to facilitate the production of European estimates of emissions of substances to water, in full knowledge that later work will update them with better information. “Starting somewhere”, we aim to make possible comparisons with other data and so towards a fuller understanding of the real picture.

This activity started under the WFD’s Common Implementation Strategy work programme (2019–2021) under the Working Group Chemicals. The participation of Member States and stakeholder experts was essential in its development. Finalisation of the work has been undertaken by the European Topic Centre for Inland, Coastal and Marine Waters, consulting EIONET.

# 1 Introduction

## 1.1 Background

Information on the quantities of pollutants released – emissions – is important for understanding whether control measures are successful. The European Green Deal established the Zero Pollution Ambition (EC, 2019) which relies on baseline information by which to determine whether pollution is being reduced. Releases reducing significantly over time would indicate that controls are taking effect, while no change or increases should demand further attention.

Unfortunately, despite decades of effort within countries, we still lack good information on the total emissions of pollutants released to water across Europe. Emissions can be assessed in different ways and since many rely on calculation and estimation, attempts to produce estimates comparable at European level have been confounded. Several projects showed serious problems regarding the consistency, completeness ([1]) and quality of the reported emission data, both in Europe and beyond (Roovaart et al., 2013; Roovaart et al., 2016; ETC/ICM, 2017; EEA, 2018a, 2018b; OECD 2017; Damania et al., 2019).

The issues identified in the projects mentioned are wide-ranging and require action from a number of different groups, including reporters, regulators, facility managers and legislators. The issues are summarised here as:

- poor information on diffuse sources, owing to gaps in reporting,
- incomplete reporting of urban wastewater treatment plant (UWWTP) effluents – not all UWWTPs, not all relevant pollutants,
- incomplete reporting of industrial sources – not all facilities, not all relevant pollutants,
- inconsistent reporting in time and space – few comparable and consistent time ranges and not all river basin districts reported,
- long time frames for updating of reporting obligations – which delays information-gathering on newly-recognised pollutants.

As a consequence of these issues there is:

- no EU wide overview of relevant emission sources/pollutants,
- no consistent time series of data from which to calculate trends,
- limited insight into the effects of emission reduction measures,
- no clear relation between emissions and water quality,
- no insight which measures are needed to meet the water quality targets.

## 1.2 Aim of this report

The aim of this report is to support those reporting the emissions inventory under the WFD, WISE-1 emissions ([2]) and other data collections. Technical Guidance Document (TGD) No. 28 was developed for the WFD Emissions Inventory (EC, 2012). However, electronic reporting of 2nd River Basin Management Plans (RBMPs) showed only a few MS succeeded in reporting on diffuse sources and for more than a few pollutants (EEA, 2018b).

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 harmonisation 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.

([1]) Completeness i.e. including all the relevant sources and all the relevant substances
([2]) http://dd.eionet.europa.eu/datasets/latest/Emissions

It is not intended that these simple methods override more detailed approaches already being used by countries. The use of the proposed methods is not mandatory. Rather, the report is targeted towards those who currently lack data and/or methods, e.g. with limited data or capacity to develop quantification methods; and to those already reporting emissions, providing the possibility to benchmark emission factors and quantification methods.

This activity started under the WFD's Common Implementation Strategy work programme (2019–2021) under the Working Group Chemicals – subgroup on the Inventory of Emissions to water. The participation of Member States and stakeholder experts has been essential in its development. Finalisation of the work has been undertaken by the European Topic Centre for Inland, Coastal and Marine Waters, broadening the work to include Eionet countries. We are most grateful for their contributions.

# 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 lefthand 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).

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.

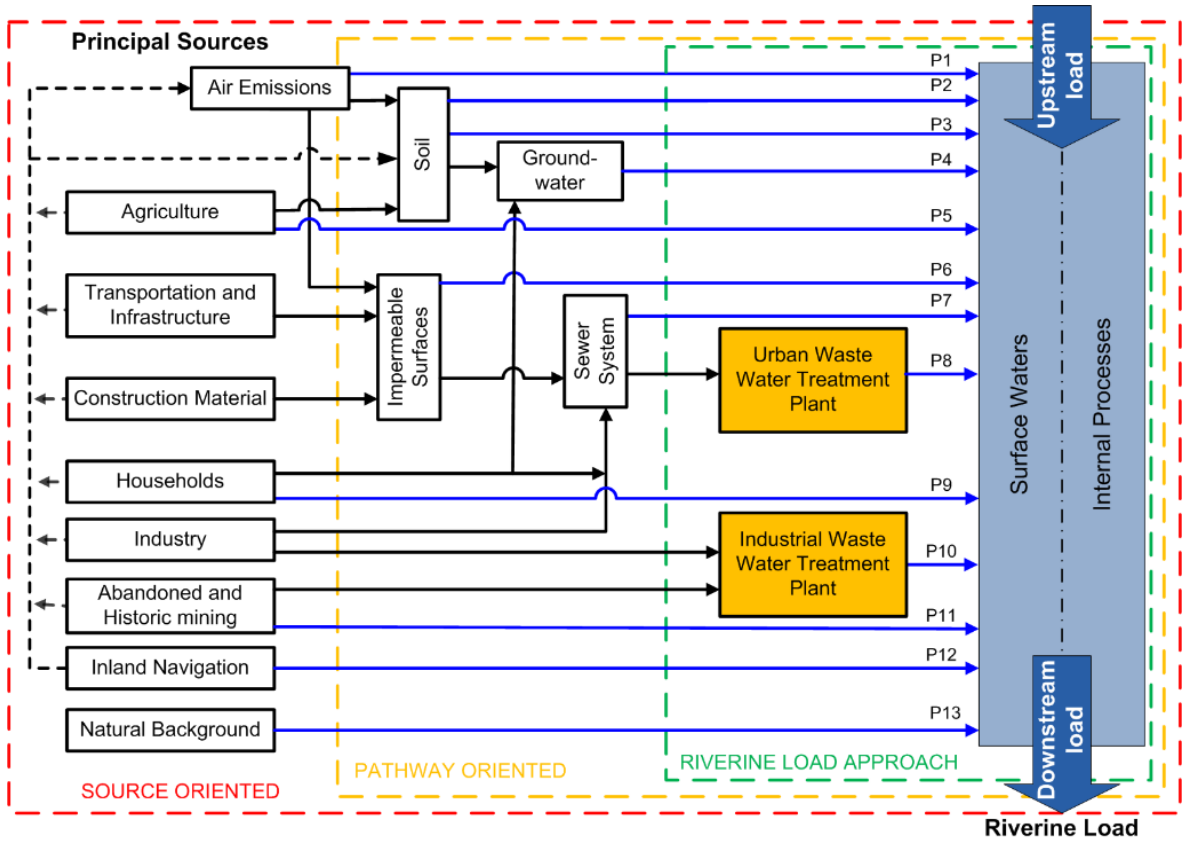
Several countries use the riverine approach instead of the pathway approach for the quantification of emissions. The riverine approach can help to assure the quality of the pathway approach but lacks insight into the different sources behind the pathways and leads to less accurate calculations. This makes it difficult to make a connection to possible mitigation measures. This proposal will therefore focus on the quantification of the pathways P1–P13.

The factsheets in this report give an overview of each pathway and elaborate on the specific calculation methods. Each factsheet has the same structure. It starts with an introduction in which the pathway and the most relevant substances for that pathway are described. In the next paragraph the calculation methods to quantify the emissions from the specific pathway are explained. Finally, conclusions are drawn. Detailed data about emission factors and calculated emissions per country are added as Annexes. Literature references for all the pathways are combined into one reference list.

To provide more insight into which mitigation measures are possible to reduce the emissions, it helps to have information on the primary sources (e.g. use of products, processes) within households and small and medium enterprises (SME's) ([3]), which end up in sewers and UWWTP's. As this is a rather complicated exercise, it is likely to be more appropriate in the more advanced stages of emission inventories.

([3]) Small enterprises: less than 50 employees; medium enterprises: less than 250 employees

**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)

## 2.2 Simplified emission factor

This report proposes the use of 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 well 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 including nutrients and Polycyclic Aromatic Hydrocarbons (PAHs) (Besozzi et al., 2003; ICBR, 2016; 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 and key substance combinations, covering the EU Member States and the European Free Trade Association (EFTA) countries (Iceland, Liechtenstein, Norway and Switzerland) on a River Basin District sub-unit scale (Roovaart et al., 2013). Emission factors are often used in emission inventories, both for air and water (Pulles and Heslinga, 2007). For the simplified quantification of emissions in this report, the 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, where the AR is

the number of inhabitants producing waste water and the EF for a pollutant, e.g. zinc, the annual load of zinc 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 emissions calculated in this way are referred to as the total emissions for that substance. For an activity where all the emissions are released directly into surface waters e.g. P12 (Inland Navigation), the total emission is the same as the net emission to surface waters. However, more commonly only part of the calculated emissions end up in surface waters, so an extra factor needs to be introduced to account for the other part, e.g. in soil, to describe the percentage of the emissions actually reaching surface waters.

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 (Atmospheric deposition directly to surface water) and P3 (Surface runoff from unsealed areas)) models were used, e.g. MONERIS ([4]), 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 into relevant sub pathways, but all these models make use of emission factors.

To refine or complement the reported emission factors, the Danube Hazard m3c project provides a database on concentrations of hazardous substances and pathways of emissions to surface waters ([5]). The results ("Inventory of Concentrations on Hazardous Substances") will be available by the end of 2022. This research project also highlights the benefits of a transnational assessment (on a European level), showing that joint measurements can be comprehensive and effective. Especially in areas, where higher pollution loads are more likely to occur and when the monitoring procedure is standardized ([6,7,8,9]).

### *2.2.1 Activity Rates (AR)*

This report proposes the use of AR's, to make use of freely available statistical data which are updated on a regular basis, e.g. the Eurostat Database ([10]). This approach facilitates the regular updating of the emission inventory and limits the overall burden of emission reporting. Examples of an activity rate are: population size; population equivalent (p.e.); the distance driven by cars (km). The chosen AR should be relevant for the specific activity or process (e.g. the number of people connected to an Urban Waste Water Treatment Plant (UWWTP). In the following chapters more specific references are listed.

In some cases, appropriate data for the ideal AR are not available or the available data sets might contain gaps for specific areas or time periods. In such cases a "proxy variable" can help to derive at least a rough estimate of the AR. Such a proxy variable 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 (Pullis and Heslinga, 2007).

([4]) https://www.igb-berlin.de/en/moneris
([5]) https://www.interreg-danube.eu/approved-projects/danube-hazard-m3c
([6]) http://icpdr.org/main/activities-projects/joint-danube-survey-1
([7]) http://www.danubesurvey.org/jds2/
([8]) http://www.danubesurvey.org/jds3/
([9]) http://www.danubesurvey.org/jds4/about
([10]) 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 the 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 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 ($m^3$/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 $10^6$ $m^3$/year, we can calculate an emission of lead to surface water of 0.73 * $10^{-9}$ (µg to kg) * $10^6$ * $10^3$ ($m^3$ 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 country level, as a lot of statistical data are available on a countrywide scale. Emission sources are in general not evenly distributed. Specific emission sources or pathways can occur much more in one place or in a specific region of a country.

For countries who are in the early stages of developing emission inventories, or developing into new areas, more detailed calculations to the level of River Basin Districts (RBD) may be made once capacity and expertise improve. For the WFD, an emission inventory on the level of RBD will be more useful than on a country level and can be seen as "an ultimate goal".

Where data are presented on a country level in this report and its annexes, the intention is to cover the full list of EIONET members and cooperating countries (38 countries). If data have not been found 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*

For this report, we focused on the priority substances and other pollutants listed under the WFD (EQS Directive, EC (2008)). Previous work had investigated the 15 pollutants most frequently reported as causing failure to achieve good chemical status under the WFD (Table 2.1) (EEA, 2018b). Despite many years of the monitoring of point sources, there were still rather few Member States reporting diffuse sources of metals, with even fewer reporting emissions of other pollutants.

Monitoring data, providing concentrations of substances for particular pathways or sources, were found from literature searches and studies, particularly for the pathways P6 (Surface run-off from sealed areas), P7 (Stormwater outlets/combined sewer overflows/unconnected sewers), P8 (Urban waste water treated) and P9 (Individual – treated and untreated – household discharges). Data are most commonly found for metals and PAHs. It was possible to provide data only for a limited number of pesticides in the pathways P2–P5.

As the focus of this activity was on WFD priority substances, not nutrients, future work could include gathering information on total nitrogen and total phosphorus. In the calculations, both the dissolved substances and substances in the sediment phase are included. No distinction has been made between these two in the calculations.

**Table 2.1 EEA Report No 18/2018 Chemicals in European Waters (EC, 2018b)**

**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**

| | Source or pathway | | |
|---|---|---|---|
| **Pollutant** | **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 in 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 PCB153.

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 ([11]) 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 emissions and legacy contribution from past agricultural uses. PAH can also be expected from natural sources like, for example, forest fires and volcanic activities. In addition, PAHs are formed unintentionally during combustion. They are present in fossil fuels and enter the environment during incomplete combustion in, for example, coke ovens and motor vehicles as well as through cigarette smoke and small-scale wood burning.

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.

([11]) https://www.msceast.org/j-stuff/content/list-layout/regional

## 3.2 Calculation methods

EMEP distinguishes two types of modelling:

1. Modelling of ecosystem dependent deposition including land cover. The deposition flux on water bodies and wetlands is calculated in kg/km$^2$/year for cadmium, lead, and mercury (see chapter 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/km$^2$/year for the other substances (see chapter 3.2.2 and 3.2.3).

The EMEP modelling results are based on the EMEP 0.1º x 0.1º longitude-latitude grid. Shapefiles ([12]) 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/km$^2$/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 ([13]) in the Ecosystem-specific information datasets. The area (km$^2$) of the grids differs 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_km$^2$ * Water Fraction

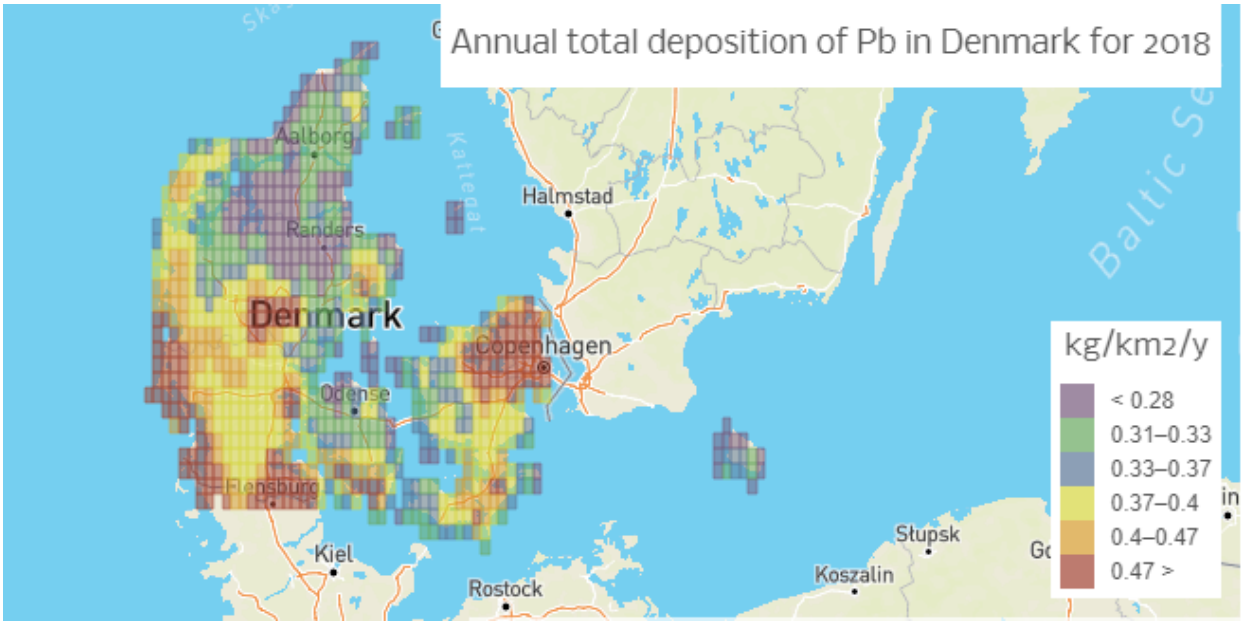
   Deposition to wetland = Flux to wetland* Area_km$^2$ * Wetland Fraction

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 are available as well, Figure 3.1 gives an example for Denmark.

([12]) https://www.ceip.at/the-emep-grid/grid-definiton
([13]) https://www.msceast.org/pollution-assessment/local-pollution-menu

**Figure 3.1: Lead flux atmospheric deposition(kg/km²/year) in Denmark for 2018 (EMEP)**




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

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

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

Calculation:

- Deposition on surface water by the total flux per EMEP-grid:
  Total deposition = Total flux * Area_km² * (Water + Wetland fraction)
- 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 of surface water per country can be calculated with the water and wetland fraction per EMEP grid.

### *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.

([14]) https://www.msceast.org/pollution-assessment/emep-domain-menu/data-hm-pop-menu
([15]) https://www.msceast.org/pollution-assessment/local-pollution-menu
([16]) http://ebas.nilu.no/

**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, pollutant loads to surface water can be quantified more accurately.

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

“Emission data is one of the most important types of model input information greatly determining the results of the modelling of pollutants long-range transport. Reliable values of emission at the model input are vital for estimating realistic levels of pollution using the models.

Since wind re-suspension is dependent on a large number of local-scale environmental parameters, model estimates of re-suspension in the EMEP region are subject to high uncertainty. In addition to this, natural emission and re-emission of elemental mercury is also considered in calculations.”

# 4 Erosion (P2), surface runoff from unsealed areas (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. There are multiple, diffuse, anthropogenic emissions to surface water, among which agricultural practices play a major role. Metals and pesticides from agricultural land will reach the surface water by one or more of these pathways and their loads are related. 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. In the calculations, both the dissolved substances and substances in the sediment phase are included. No distinction has been made between these two in the calculations.

The focus here is on agricultural sources with a large contribution to the loads to surface water. Note that not all existing primary sources are covered in this chapter: other sources, less significant at European level, such as surface runoff from more natural areas, are not included. It may be appropriate for countries with large sectors such as forestry to gather more specific emissions data on those activities.

### *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 can foster erosion processes, due to long periods where soils are left without vegetation cover that serves as a protection against weathering. Furthermore, anthropogenic climate change enhances erosive processes caused by increasing numbers of heavy rainfall events and longer dry periods, as plant cover 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 rapidly, causing a serious loss of topsoil.

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 absorbed into 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 can infiltrate the land surface or be held up by the land (Figure 4.1). 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.

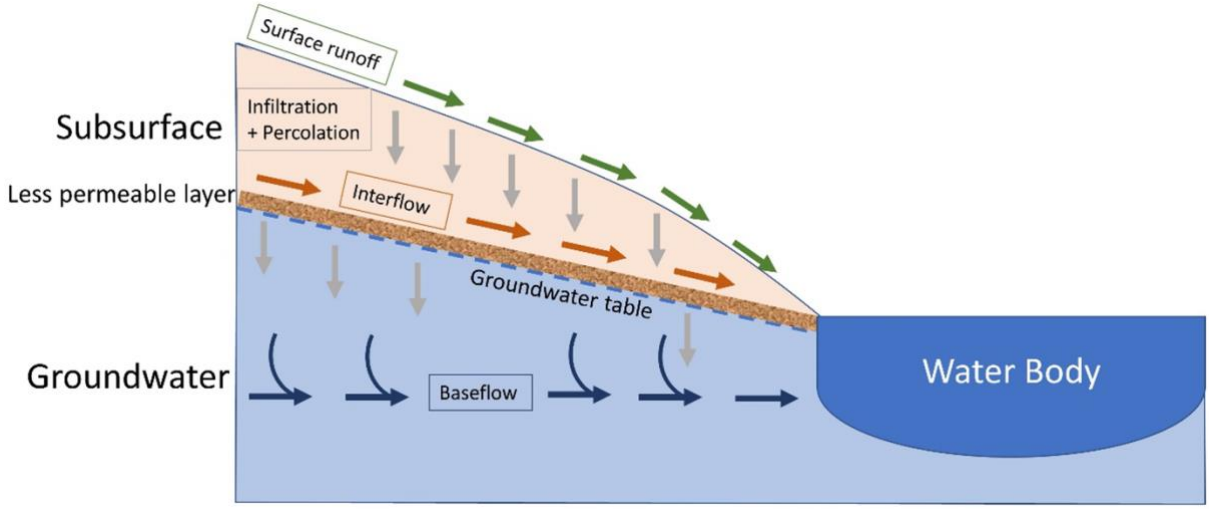
Runoff from agricultural fields may contain several pollutants, e.g. nutrients (phosphate, nitrate), pesticides, pathogenic bacteria and veterinary antibiotics (from animal manure), as well as metals (from inorganic fertilizers or natural background concentrations in the soil itself). Depending on pollutant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

### 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 interflow is a relatively rapid subsurface 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*
  As water moves down towards the groundwater, it leaches pollutants from the soil particles, dissolving them and carrying into the groundwater.

**Figure 4.1: Schematic overview of surface runoff, interflow and baseflow in a catchment**




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

Pathway 5 covers the direct discharges and drifting of pollutants which can reach surface waters. Here, it is mainly understood to concern pesticides, fertilisers and manure.

- *Direct discharges:* When fertilisers, manure or pesticides are handled on farms, a part of it may cause unintended pollution of ditches/streams via spillages on hard surfaces or direct input from application machinery (e.g. overspray).
- *Drifting:* Drift or spray drift can occur during the application of fertilizers or Plant Protection Products (PPP) in the field. It is the airborne movement of fertilizers or pesticides from a treated area to any unintended site. Drift can happen during application, when droplets are transported away from the target site, or after the application, when some chemicals become vapours that can move off-site. This so called 'vapour drift,' and an important factor for the quantification of vapour drift can be calculated with the pesticide's vapour pressure. Spray drift can be important under specific conditions and also affects soil and surface water. Examples are where one field is sprayed with herbicides and the drift affects the growth of a crop in a neighbouring field. Spray drift is more important for pesticides, than fertilizers. In section 4.3 (calculation methods – pesticides) we only consider spray drift directly reaching surface water.

### *4.1.5 Modelling the pathways P2 – P5*

Without detailed models, it is not possible to distinguish between pathways P2 to P5. Therefore, we have chosen to discuss these pathways together in this factsheet. Estimation is made of the land-based sources and then these are combined with an (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: aclonifen, bifenox and cypermethrin ([18]), and a number of pesticides identified as River Basin Specific Pollutants (RBSPs).

## 4.2 Calculation methods – metals

Concerning metals, this factsheet describes the two pathways of soil erosion and leaching to surface waters, and 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 factsheet 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 soilTable 4.2).

Comber (2021) calculates (Table 4.2) that all the soil loss will end up in the surface water as a worst-case assumption (so %sw in Equation 4.1 is 100 %). There are indications from DE that only a 6 % of the soil loss, especially the smallest particles, will reach the surface water ([22]). Borelli et al. (2018) gives a European average percentage of soil loss transferred to the riverine system of 15 %. Hungary reported an average sediment delivery ratio of 2.2 %, calculated by the MONERIS model (Behrendt, 2003; Jolánkai et al., 2015). Finland modelled erosion with the help of the RUSLE model (Lilja et al., 2013). Calculations are frequently based on the USLE (Universal Soil Loss Equation) approach, which describes the loss of soil from certain agricultural lands (Canadian Ministry of Agriculture, Food and Rural Affairs, 2015). The amount of erosion and the percentage reaching surface water vary remarkably between different study areas as it is very site-specific. In the case where no additional information is available, we advise to use the European average percentage of 15 % from Borelli et al. (2018).

([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)
([22]) Mean value for Germany (results of the MoRE model) which means that there are regions with higher and lower values mostly depending on elevation, soils, distance to surface waters and barriers.

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

$$L_{so} = \frac{ConcSoil * SoilLoss * AgrArea}{1{,}000{,}000} * \%sw$$

where:

$L_{so}$ = Total load of soil erosion to surface water (t/year)

ConcSoil = Background concentration for the ind

Individual metals per country, Table 4.1 (mg/kg)

SoilLoss = Total annual soil loss per country (t/ha/year)

AgrArea = Agricultural land per country (ha)

%sw = % surface water, part of the annual soil loss by erosion that ends up in surface water per country

**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 |
| Croatia | 35.5 | 19.7 | 0.33 |
| 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 |
| Ireland | 22 | 19.5 | 0.51 |
| Italy | 83.4 | 35.6 | 0.37 |
| Latvia | 8.1 | 8.2 | 0.09 |
| Lithuania | 7.5 | 8.7 | 0.11 |
| Netherlands | 9.3 | 26.9 | 0.29 |
| Norway | 12.4 | 8.1 | 0.09 |
| Poland | 7.4 | 10.7 | 0.17 |
| Portugal | 13.2 | 18.2 | 0.08 |
| 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 |
| *Mean* | *51.7* | *21.9* | *0.31* |

Eionet Members and cooperating countries. No data available for Bosnia and Herzegovina, Bulgaria, Cyprus, Iceland, Kosovo**, Liechtenstein, Luxembourg, Malta, Montenegro, North Macedonia, Romania, Serbia and Turkey.

** Under UN Security Council Resolution 1244/99

*** http://weppi.gtk.fi/publ/foregsatlas/ForegsData.phps

**Table 4.2 Cd, Ni and Pb average loss to surface water from European soils (Comber, 2021)**

| Country* | Agricultural areas and natural grassland total annual soil loss [b] (t/ha/year) | Agricultural area [c] (*$10^5$ ha) | Load [a] (kg/day) | | |
|---|---|---|---|---|---|
| | | | Cadmium | Nickel | Lead |
| Albania | 3.2** | 11.74 | 4 | 536 | 140 |
| Austria | 7 | 26.54 | 19 | 1,283 | 1,376 |
| Belgium | 1.6 | 13.56 | 5 | 177 | 195 |
| Bosnia and Herzegovina | 3.2** | 17.80 | 5 | 813 | 344 |
| Bulgaria | 3.3 | 50.30 | 14 | 2,349 | 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 | 4,334 | 6,637 |
| Germany | 1.75 | 166.45 | 27 | 1,339 | 2,069 |
| Greece | 4.9 | 52.88 | 59 | 12,131 | 2,784 |
| 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 | 32,263 | 13,773 |
| 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 | 7,972 | 3,376 |
| Serbia | 3.2** | 34.87 | 9 | 1,592 | 674 |
| Slovakia | 3.8 | 19.20 | 6 | 458 | 690 |
| Slovenia | 14.8 | 4.78 | 12 | 771 | 565 |
| Spain | 4.6 | 242.02 | 78 | 7,802 | 8,212 |
| Sweden | 1 | 30.00 | 1 | 53 | 82 |
| Switzerland | 3.2** | 15.15 | 7 | 740 | 484 |
| Turkey | 3.2** | 382.39 | 103 | 17,461 | 7,393 |

*Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro.
**Mean value of 3.2 t/ha/year is used for calculations
***Under UN Security Council Resolution 1244/99

[a] Load to water from soil background is still being reviewed by the metal's associations.
[b] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_soiler&lang=en
[c] https://ec.europa.eu/eurostat/databrowser/view/tag00025/default/table?lang=en

### *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 the 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
    - Sewage sludge (biosolids)

      calculation of loads to arable land based on the amount of sludge to land (ton/year/dry matter) used as fertilizer at country level and mean metal concentrations in sludge (mg/kg/dry matter) (see Comber, 2021 Table 1),
    - 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
    - Farmyard manure (FYM), organic fertilizer

      calculation of loads to arable land based on mean concentrations in the manure (mg/kg) and animal numbers at 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 easily available and comparable between countries.
- Atmospheric deposition
  calculation of loads to arable land based on annual rainfall (mm), agricultural used area ($km^2$) and metal concentrations in rainfall (ug/l) (see Comber, 2021 Table 8). This data only refers 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 |
| $L_{agr}$ | = Loads to agricultural land (kg/day), Table 4.4 |
| %sw | = % surface water, part of the total loads to agricultural land that ends up in surface water by leaching |

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. One should take into account that these coefficients are an indication and are still highly dependent on e.g. the type of soil, soil depth and the runoff-pathway length.

**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 | 0.079 |

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. The total load of soil loss and 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 (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 |
| 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 |

| Country* | Load (kg/day) | | |
|---|---|---|---|
| | Cadmium | Nickel | Lead |
| 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 |

*Eionet Members and cooperating countries. No data available for Liechtenstein and Montenegro
**Under UN Security Council Resolution 1244/99

### *4.2.3 Total sum of the emissions of metals to surface water*

There are two pathways for the loss of metals from agricultural land (Table 4.5):

1. Erosion, Soil loss

A reported loss of soil multiplied by a concentration of metals (broadly speaking assumed to be particulate) depends on the agricultural practices. This should not be confused with the natural background of the soil (see chapter 4.2.1).

2. Leaching, total loss based on source inputs

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

**Table 4.5 Total cadmium, nickel and lead loads to surface water in t/year, via erosion and 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 |

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

**Under UN Security Council Resolution 1244/99

## 4.3 Calculation methods – pesticides

Pesticides include both active substances from plant protection products and biocides. Thus, pesticides can enter surface waters through point sources (e.g. UWWTP) 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 the diffuse input, concentration peaks contributing to the load are event-driven 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 European Food Safety Authority provides guidelines for a mixture assessment (for intended mixtures) as part of the 1107/2009 substance revies and as part of the product authorizations to assess the combined toxicity for humans and the environment (EFSA, 2019).

Since numerous pesticides are identified as River Basin Specific Pollutants (RBSP) and regulated on a national level, data is not easily comparable between MS. The number of monitoring stations and pesticides reported to the EEA shows high differences between the MS too, as well as the quality of this data. 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. Important information to know about this is the percentage of land bordering to surface waters, where pesticides are applied. However, 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 local use, 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 ([23]) can be used as a user-friendly shell that connects different models relevant to the pathways P2-P5. It connects 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 at treated area level. Both methods must be seen as a first step in the quantification of the 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.

([23]) https://esdac.jrc.ec.europa.eu/projects/swash

**Equation 4.3 Loads to surface water**

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

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 ([24]) 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 the 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 at country level, the sale of individual pesticides might be known as well in countries 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 |
| 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 |

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

| Member State | Fungicides and bactericides | Herbicides, haulm destructors and moss killers | Insecticides and acaricides | Molluscicides | Plant growth regulators | Other plant protection products | Total |
|---|---|---|---|---|---|---|---|
| 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**

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

where:

| | |
|---|---|
| $L_{sw}$ | = load to surface water per pollutant |
| Emission factor | = application rate per pollutant treatment is the weighted average dose rate over the different applications of the pesticide per treatment (in kg active substance per hectare) |
| Activity Rate 2 | = area where the pesticide has been applied in hectares |
| %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 ([25]) and for isoproturon on the EFSA website ([26]). If the surface of the area where the pesticides are used is known, an estimation of the loads used can be calculated. Information about the crop production in hectares is available on Eurostat ([27]). In Table 4.7 for most substances a maximum application rate is given for a number of different crops. In practice, the application rate may be crop specific.

([25]) Communication and Information Resource Centre for Administrations, Businesses and Citizens, provides a web-based application that is used to create collaborative workspaces
([26]) European Food Safety Authority
([27]) https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1/default/table?lang=en

**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 | Source |
|---|---|---|---|---|
| Aclonifen | Sunflower | 1 | 2.4 | EQS Dossier (2011) ([28]) |
| Isoproturon | Grass weeds, broadleaved weeds | 1 | 1.5 | EFSA (2015) ([29]) |
| Bifenox | Broadleaved weeds | 1 | 0.750 | EQS Dossier (2011) ([30]) |
| Quinoxyfen | Wheat and barley | 1 | 0.3 | EQS Dossier (2011) ([31]) |
| Dicofol | Fruit, vegetables, ornamental crops and field cultures and as a biocide | 1 | no info in Circabc | EQS Dossier (2011) ([32]) |
| Cypermethrin | Fruit, vegetables, ornamental crops and field cultures and As a biocide | 1 | no info in Circabc | EQS Dossier (2011) |
| Alachlor | Weed control on corn, soybeans, sorghum, peanuts, and beans | | 1.8 (USA) | EPA (1998) ([33]) |
| Atrazine | No information | | | |

### *4.3.3 Percentage loads to surface water*

For both methods 1 and 2, an estimation has to be made of the percentage of the used pesticides reaching the surface water. This percentage will be determined by many 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 locally-specific and differ in time and space, it is almost impossible to give an average percentage in this report. If there is no surface water, the pesticides will stay in the soil and degrade with time, reach the atmosphere or leach into groundwater. If the soil is drained, part of the applied amount may go through the drains ultimately reaching surface waters.

([28]) https://circabc.europa.eu/sd/a/b55c02ff-83b1-4a39-9a66-6d36988ffd86/Aclonifen %20EQS %20dossier %202011.pdf
([29]) https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2015.4206
([30]) https://circabc.europa.eu/sd/a/9badfa79-645d-414b-a77f-03c7d6868ccf/Bifenox %20EQS %20dossier %202011.pdf
([31]) https://circabc.europa.eu/sd/a/960dfe08-a463-44ba-aee9-d7675681e60f/Quinoxyfen %20EQS %20dossier %202011.pdf
([32]) https://circabc.europa.eu/sd/a/668ff210-4c7e-44bc-8c0f-20be8424e5d7/Dicofol %20EQS %20dossier %202011.pdf
([33]) https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/fs_PC-090501_1-Dec-98.pdf

It is difficult to find data of the percentage of used substances lost through drift and run-off to surface water. Therefore, below we present a number of examples, with estimations of percentage losses to surface water from different studies.

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, the distance between the top of the ditch bank and the centre of the first plant row, the distance between the last nozzle position and the 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 95$^{th}$ percentile of 1.65 % of the pesticide loads to surface water was derived from the NMI-model (Table 4.8). The 95$^{th}$ 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 the total amount of pesticide sold reaching the surface water (derived from Kruijne et al, 2021)**

| Substance | Average percentage of the 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 95$^{th}$ percentile loss as a percentage of the amount applied. The results for the 95$^{th}$ 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 95$^{th}$ percentile for the sum of the four fluxes, what will be more or less comparable to the sum of the pathways P2–P5, is 3.95 %.

Siimes and Mehtonen (2021) describe 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 inventory of emissions. 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 losses to surface water range from below 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 cultivation areas of relevant crops and typical pesticide usage on these crops. The typical values were taken from the national pesticide usage statistics for almost 20 crops from about 5000 farms, but expert assessments were needed to assess

missing pesticide usage values for several crops. In the first WFD emission inventory, for MCPA (2-Methyl-4-ChlorPhenoxyAcetic) a loss fraction of 0.16 % has been used as a mean value of a range from 0 to 0.48 %. In the second WFD emission inventory, a value of 0.5 % was used as the loss fraction for all agricultural pesticides. A general value was needed because reliable loss fractions were not possible to calculate for all relevant substances due to limited monitoring data (number of samples and detection limits found in monitoring data). The selected value of 0.5 % was estimated to be realistic, but more likely too high than too small in most cases (substance, site & hydrological year). 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.

From the different literature, a generic worst-case range (using the 95$^{th}$ percentile) for the percentage of pesticides used ending up in the surface water can be derived, which ranges from 0 %, where no surface water is present, to 5 % as a maximum. Combined with data or rough estimations of pesticide sale or use, this percentage can be used to give a first indication of pesticide loads to surface waters.

## 4.4 Conclusions

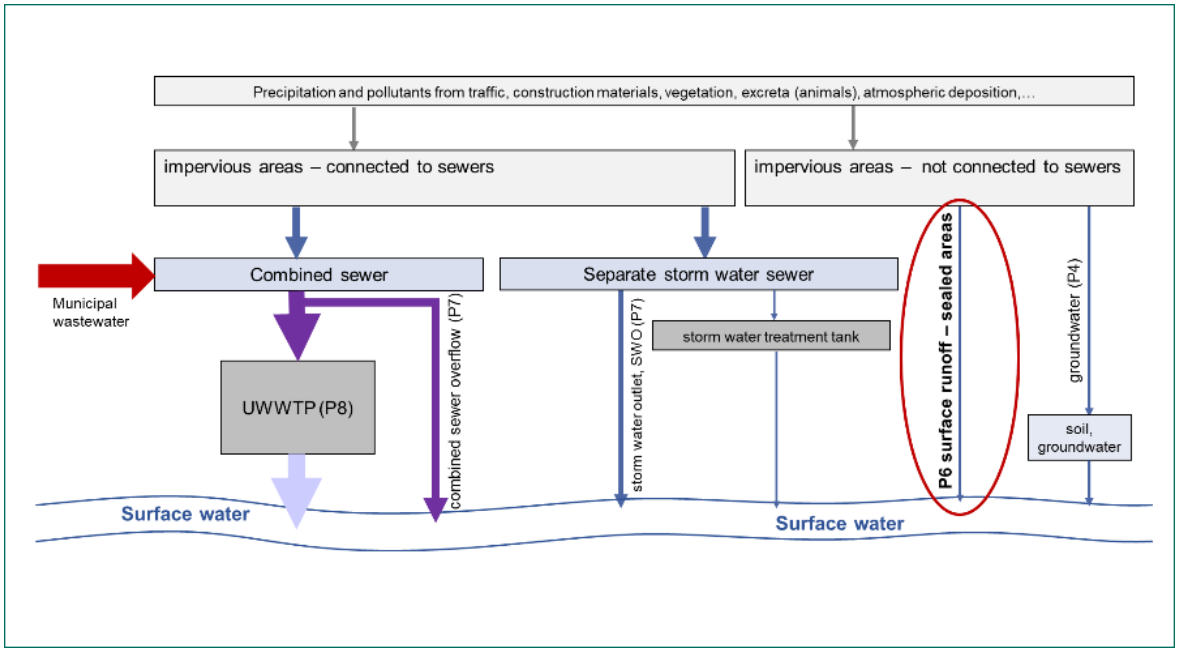
Metals and pesticides from agricultural land can reach the surface water by one or more of the pathways P2 to P5. Many factors influence the transport to surface waters both for metals and pesticides, such as timing and intensity of precipitation, hydrology, area ratios, and the general presence of surface water bodies. We have chosen to discuss these pathways together because the loads to surface waters are related, and without detailed models, it is not possible to distinguish between them. To provide a first approximation, the method uses estimation of land-based sources combined with the averaged loss (as a proportion of the total) 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 permeable 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 into 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. 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. To calculate loads, it is necessary to have information about annual stormwater run-off volume. In most countries this information (volume of stormwater) is not known at river basin or even at national level. To estimate loads on a local level a simplified method can be applied.

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

**Equation 5.1 Annual load in storm water sewer**

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

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 m³/a |
| $C_{swo}$ | = substance concentration in stormwater run-off in g/m³ |
| 1,000 | = conversion factor (g in kg) |

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

**Equation 5.2 Annual stormwater run-off from impervious urban area not connected to separate storm water sewers**

$$Q_{sw\_nc} = A_{c,sw\_nc} * P_a * 10 * R_{coeff}$$

where:

| | |
|---|---|
| $Q_{sw\_nc}$ | = annual stormwater run-off from impervious urban area not connected to sewers in m³/a |
| $A_{c,sw\_nc}$ | = contributing drainage area not connected to sewer 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 coefficient for urban impervious areas typically range between 0.4 to 0.9 (U.S. Department of Transportation, 2001). For a first estimate, a run-off coefficient of 0.6 seems to be suitable.

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

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

$$A_{c,sw\_nc} = A_{urb} * \frac{R_{imp}}{100} * \frac{R_{con\_sw\_nc}}{100}$$

where:

| | |
|---|---|
| $A_{c,sw\_nc}$ | = contributing drainage area connected to sewer in ha |
| $A_{urb}$ | = impervious urban area in ha |
| $R_{imp}$ | = rate of imperviousness in % |
| $R_{con\_sw\_nc}$ | = connection rate to sewer (not connected) in % |

The rate of imperviousness ($R_{imp}$) is introduced to determine the run-off producing areas, whereas $R_{coeff}$ considers the run-off generation of different materials. Data sets to derive the rate of imperviousness are described below, examples for imperviousness of different urban land use classes in different countries are given in Table 5.2.

**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 P6.1 and Table A P6.2 in the Annex P6.

Furthermore, Comber et al. (2021) derived mean values for metal concentration in urban run-off at national and European level (Table 5.1). The derived concentrations comprise sources such as atmospheric deposition (wet and dry), rainwater concentrations, road run-off (traffic) including tyre, 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 (rainwater 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 ([34])). The data set can be downloaded from the site 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 at national level e.g. for modelling 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.

([34]) https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-gridded-observations-europe?tab=overview

**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 ([35]). To account for urban impervious land surfaces the European-wide data set (imperviousness) provided by the EEA (European Environment Agency) can be used ([36]). Both GIS-datasets (land use and imperviousness) need to be merged using a GIS-program.

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.

**Table 5.2 Statistical values for imperviousness of different urban Corine (CLC) land use classes at 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 | 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 |

**Connection rate to sewer ($R_{con\_sw\_nc}$):**

The share of impervious area connected to sewer systems can locally and nationally differ. If regionalized information is not available, a national default value (estimated value) should be used.

If no information as described above is available Comber et al. (2021) derived mean loads at country level (Annex P7 Table A P7.3) using the source-oriented approach.

## 5.2 Conclusions

This factsheet describes simple methods for the calculation of substance loads to surface waters washed off from sealed areas that are not connected to sewer systems. Several European data sets are available and mean concentration values for metals are provided as well. Note that this pathway for loads transported to surface waters is usually not significant in comparison to those via erosion or groundwater discharge.

([35]) Corine 2018: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018
([36]) https://www.eea.europa.eu/data-and-maps/dashboards/imperviousness-in-europe

# 6 Stormwater outlets/combined sewer overflows/unconnected sewers (P7)

## 6.1 Introduction

The urban wastewater system collects domestic ([37]) 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, tyre 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
    - separate storm water sewer and
    - separate urban waste water sewer
- Combined sewer systems (see Figure 6.2) collecting both storm water and urban wastewater 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. from 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. In some cases, the stormwater is treated in e.g. sedimentation tanks, infiltration systems or retention soil filter systems before.

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)
- Biocides
- Pharmaceuticals
- 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.

([37]) 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"

**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**

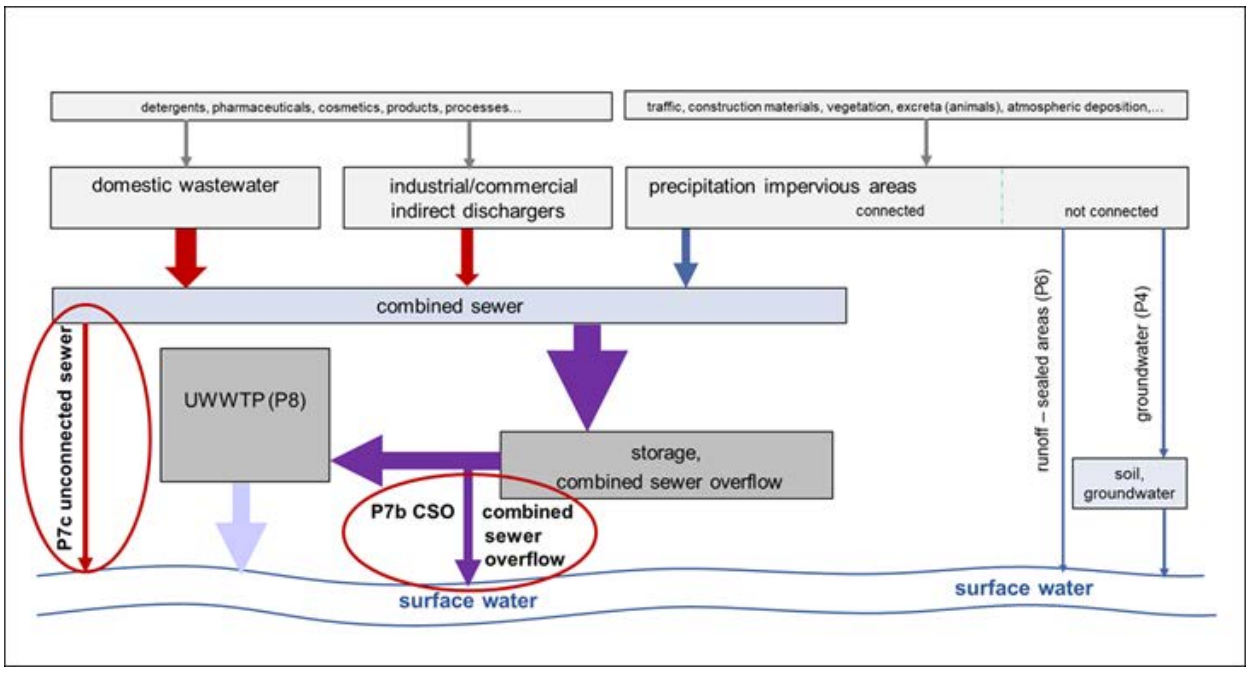
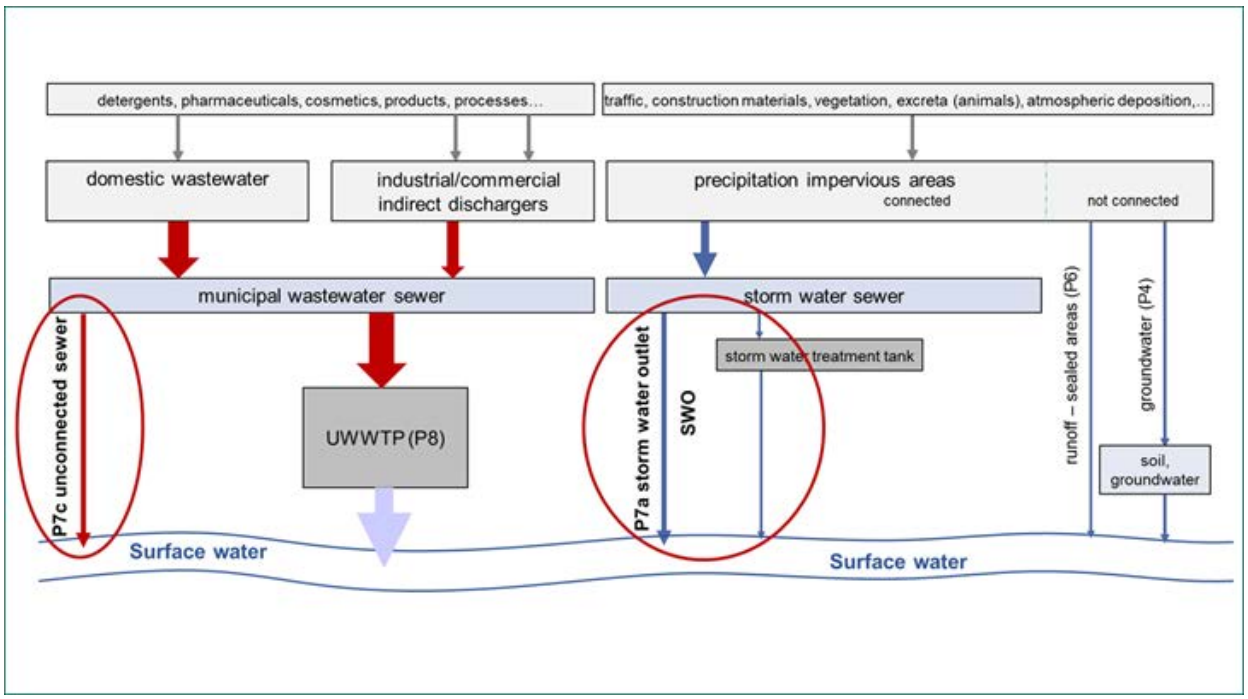



**Figure 6.2: Schematic overview of emissions to surface waters via combined sewer systems including combined sewer overflows (CSO) and unconnected combined wastewater sewer**



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 are discharged directly to surface waters and
- P7c: unconnected sewers (separate urban wastewater sewers and combined sewers not connected to UWWTPs).

The main objective of this factsheet 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 either a combined or 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 at national level is very limited. Therefore, simplified approaches to estimate the annual loads from storm water outlets $L_{swo}$ (chapter 6.2.1), combined sewer overflows $L_{cso}$ (chapter 6.2.2 and unconnected sewers $L_{nc}$ (chapter 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 areas 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 areas 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.

Furthermore, Comber et al. (2021) derived mean values for metal concentration in urban run-off at a national and European level (Table 6.1). The derived concentrations comprise of sources such as atmospheric deposition (wet and dry), rainwater concentrations, road run-off (traffic) including tyre, 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 (rainwater 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 a European scale is available (E-OBS data set; daily gridded meteorological data for Europe ([38])). The E-OBS data are often used at national level (e.g. for modeling activities).

**Connection rate to storm water sewer ($R_{con\_swo}$):**

The share of impervious areas connected to the different sewer systems can locally and nationally differ. Regionalized statistical information might be available at national level. If regionalized information is not available in a country, Table 6.2 provides an overview (an approximation) at national level given by Milieu Ltd. (2016), based on sewer length. In the report it 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 centres 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)) at 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) |

([38]) https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-gridded-observations-europe?tab=overview

| Country* | Percentage of separate sewers | Percentage of combined sewers |
|---|---|---|
| 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 at country level (Annex P7 Table 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 ([39]). To account for urban impervious land surfaces the European-wide data set (imperviousness) provided by the EEA can be used ([40]). Both datasets (land use and imperviousness) need to be intersected.

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 6.3.

([39]) Corine 2018: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018
([40]) https://www.eea.europa.eu/data-and-maps/dashboards/imperviousness-in-europe

**Table 6.3 Statistical values for imperviousness of different urban Corine (CLC) land use classes at country level**

| CLC land use class | Germany | | Portugal continental | | Romania | |
|---|---|---|---|---|---|---|
| | 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 |

### *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)

**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 P7can 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 systems) and services (light industrial estates, car washes, and town centre 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 UWWTPs (Comber et al. 2021)**

| Substance | Concentration in domestic wastewater (µg/L) | | Concentration from trade* wastewater (µg/L) | | Concentration from light industrial wastewater (µg/L) | | Concentration from services (µg/L) | |
|---|---|---|---|---|---|---|---|---|
| | total (µg/L) | dissolved (µg/L) | total (µg/L) | dissolved (µg/L) | total (µg/L) | dissolved (µg/L) | total (µg/L) | dissolved (µg/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 (Aurb) 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 areas 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 ([41]) > 2,000 p.e.

**Average annual overflow rate (Rover):**

In Germany, during the duration period of one year, approximately 50 % of surface run-off from impervious surfaces discharged into surface waters ($R_{over}$ = 0.5). These overflow events released between 1 – 2 % of the 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 at country level (Annex P7 Table 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 load 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).

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

**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 6.5 (chapter 6.2.4). Examples for emission factors per capita at country level derived by Comber (2021) using the source-oriented approach are given in Table 6.6 (chapter 6.2.4).

**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 at national level. For this, the information on rates of inhabitants connected might be available from at least European statistics (EUROSTAT, 2021a) ([42]).

If information on the entire number of inhabitants is not available, EU-UWWTD (Urban Waste Water Directive) data referring to person equivalent (p.e.)([43]), could be used. Under UWWTD Member States report the rate (%) of generated load (p.e.) in agglomerations ([44]) > 2,000 p.e. which areconnected to a 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 a 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: aggGenerated)* |
| $R_{con\_sewer}$ | = rate of generated nominal load of the agglomeration connected to a sewer in % *(UWWTD-attribute: aggC1)* |
| $R_{con\_uwwtp}$ | = rate of generated nominal load of the agglomeration not connected (treated) in % *(UWWTD-attribute: aucPercEnteringUWWTP)* |

([42]) https://ec.europa.eu/eurostat/databrowser/view/ten00020/default/table?lang=en

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

([44]) 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"

**Load in unconnected combined sewers**

To calculate loads from unconnected combined sewers, the above proposed equations for loads from combined sewer overflows (see chapter 6.2.2) and input data also have validity. The Equations 6.6 to 6.7 determine the total annual flow in the combined system, and it also has to be in regard to whether the sewer ends 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 m³/a |
| $C_{cso}$ | = substance concentration in combined sewer (combined sewer overflow) in g/m³ |
| 1,000 | = conversion factor (g in kg) |

The volume of annual stormwater run-off from impervious urban areas connected to a combined sewer ($Q_{nc\_combined}$) not connected to an UWWTP is calculated using Equation 6.10.

**Equation 6.10 Volume of annual stormwater run-off from impervious urban areas connected to combined sewers not connected to an UWWTP**

$$Q_{nc\_combined} = P_a * A_{c,nc\_combined} * R_{coeff}$$

where:

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

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

**Equation 6.11 Discharge relevant impervious urban areas connected to a combined sewer not connected to an UWWTP**

$$A_{c,nc\_combined} = A_{urb} * \frac{R_{imp}}{100} * \frac{\left(R_{con\_sewer} - R_{con\_uwwtp}\right)}{100}$$

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 a 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 factsheet P9). Under UWWTD Member States report the rate (%) of generated load (person equivalent (p.e.)) in agglomerations > 2,000 p.e. which are connected to the sewer system but not connected to an 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. 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 inter-national 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, the model MoRE (Modelling of Regionalized Emissions) ([45]) 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 at country level (Table 6.6).

([45]) https://isww.iwg.kit.edu/MoRE.php

**Table 6.6 Metal load (Cadmium, Nickel, Lead) entering septic tanks on a per capita basis at country level (Comber 2021)**

| Country* | Cadmium concentration (mg/capita/day) | | Nickel concentration (mg/capita/day) | | Lead concentration (mg/capita/day) |
|---|---|---|---|---|---|
| | Based on calculated | Based on measured | Based on calculated | Based on measured | 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 | 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 |
| 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 the 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 wastewater 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 at national level data is rarely 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 wastewater treatment plants (UWWTPs) can be important sources for emissions to water. In particular, the urban wastewater 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 many pollutants outside the scope of routine national monitoring programmes, especially where those are present at very low concentrations in urban wastewater, which can require complex analytical chemical techniques.

The main objective of this factsheet is to provide recent information on emissions from UWWTPs. This document focuses on the first step into 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. The capacity threshold for UWWTP (100,000 population equivalent (p.e.) in the E-PRTR means that plants below that capacity are not required to report under E-PRTR, while there are also pollutant thresholds (Annex II of the EPRTR Regulation) below which releases do not need to be reported.

Note that at the time of writing (November 2022) both the E-PRTR and the UWWT Directive are under revision.

## 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
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 (e.g. primary, secondary, tertiary treatment),
- Different sizes of UWWTP etc.

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

### 7.2.1 Example – effluent concentrations

Assuming that the mean pollutant concentration represents the mean situation in a country or a River Basin District (RBD) and information about annual treated wastewater flows ([46]) 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 an RBD/country ($m^3$/year)

**Example UWWTP(X):**

$F_{effluent-UWWTP(X)}$ = 37,896,680 $m^3$/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. ([47]) the following equation (Equation 7.2) can be used to calculate annual UWWTP effluent loads both at country level or RBD level.

([46]) 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).

([47]) 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 wastewater treatment as amended by Commission Directive 98/15/EC and Regulations 1882/2003/EC and 1137/2008/EC (UWWTD)

[b)] Pursuant Article 2 (4) of UWWTD 'agglomeration' means an area where the population and/or economic activities are sufficiently concentrated for urban wastewater to be collected and conducted to an urban wastewater 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.

**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 review, recommendations on mean UWWTP effluent concentrations and available emission factors are given in the following section.

Related to the WFD priority substances ([48]), several monitoring campaigns for different countries with a 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
- differing analytical methods applied, for instance, regarding sensitivity (LoD/LoQ) or analysing of dissolved or total concentration.

Unfortunately, not all of 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.

([48]) EQS-Directive, Annex I, Part A

**Table 7.1 A set of substances for which a large number of monitoring data is available. For 11 of the 19 substances mean UWWTP effluent concentrations have been derived.**

| Number[49] | CAS-number | Substance | Number | CAS-number | Substance |
|---|---|---|---|---|---|
| (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 the measured values were above the 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 UWWTPs. 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.

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 a pathway for emissions to surface waters. Analytical LoQs are larger than EQS values (Annex P8).

([49]) Substance number – EQS-Directive (Annex I, Part A)

**Table 7.2 A set of substances for which the majority of UWWTP effluent concentrations are below LoQ and for which no mean UWWTP effluent concentrations have been derived**

| Number[50] | CAS-number | Substance | Number | CAS-number | Substance |
|---|---|---|---|---|---|
| (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-Heptachlorepoxide and trans-Heptachlorepoxide** |
| (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 | Quinoxyfen |
| (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 as of “minor relevance” at RBD level. Reasons might be a ban on production and application. In this case, detailed analyses are not required according to the technical guidance (EC, 2012).
- For some substances UWWTP effluent is not a relevant pathway because of their specific use and application (e.g. pesticides like DDT, which in Europe was mainly used in the agricultural sector). For these substances, mean concentrations have not been derived.

**Table 7.3 A set of substances for which scarce data is collected of UWWTP effluent concentrations and for which no mean UWWTP effluent concentrations have been derived**

| Number[51] | CAS-number | Substance | Number | CAS-number | Substance |
|---|---|---|---|---|---|
| (1) | 15972-60-8 | Alachlor | (16) | 118-74-1 | Hexachlorobenzene |
| (4) | 71-43-2 | Benzene | (17) | 87-68-3 | Hexachlorobutadiene |
| (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 |

[50] Substance number – EQS-Directive (Annex I, Part A)
[51] Substance number – EQS-Directive (Annex I, Part A)

| Number[51] | CAS-number | Substance | Number | CAS-number | Substance |
|---|---|---|---|---|---|
| (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 | | | |

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

This section explains how mean effluent concentrations and emission factors were derived.

**Mean effluent concentrations**

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

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

Statistical values derived from monitoring studies refer to the whole group of investigated UWWTPs in each study. More detailed information about UWWTPs (meta-data like size or treatment type) were not available for all studies. Therefore, further differentiation between, for instance, treatment types, was not possible.

Bearing this in mind, calculated UWWTP effluent loads using the average concentrations derived from all these different studies (based on median concentration values of the different studies) should only be seen as a first approximation. Regional peculiarities or even special situations for single UWWTPs (regarding e.g. treatment type, sewage composition) are not considered. Nevertheless, where no other data are available, the loads calculated using the derived mean concentrations should provide an indication of the relevance of UWWTPs as an emission pathway to surface waters.

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

- Making the assumption that the distribution of monitored effluent values is right skewed (Median < Mean), the median concentration values from the studies were used rather than the mean.
- At least two median values from two different studies were required.
- Only studies from 2010 and more recent 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 of how to proceed when 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)**

| Substance | 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 | |
| | 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 | ½ LoQ |

| Substance | Median (µg/L) concentration | Reference | Comment |
|---|---|---|---|
| | | (LoQ: 5 µg/L), 2010–2019, total concentration, BE | |
| | 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)**

| Substance | 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 |
| 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) |

| Substance | Average median concentration (µg/L) | Comment |
|---|---|---|
| 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. Further differentiation for treatment types was not possible based on the available information. 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 wastewater 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 the 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 (We don´t want to give a recommendation on which values should be used. Users need to assess what is relevant to use in their own situation based e.g., on the individual situation in the country.

Table 7.6 and Annex P8). Reasons might include differences in the database used, differences in the method used to derive the emission factor etc.

For these reasons, recommended values are not provided here. 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. We don´t want to give a recommendation on which values should be used. Users need to assess what is relevant to use in their own situation based e.g., on the individual situation in the country.

**Table 7.6 Emission factors for UWWTP effluents (results from a literature study) ([52]). TT = tertiary treatment, ST = secondary treatment**

| Substance | Emission factor (µg per capita per day) | Emission factor (g per p.e. per year) | | | | |
|---|---|---|---|---|---|---|
| | Italy (TT, ST)([53]), Castiglioni et al. 2015 | France (TT, ST)([54]) national data base 2020 | Germany (TT, ST)([55]), Toshovski et al 2020 | Netherlands (TT, ST); national data base | PRTR (EU)([56]) (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-** | - | 0.0105 | 0.0036 | - | | - |
| **DEHP** | - | 0.0251 | 0.141 | - | 0.04 | 0.36 |
| **PFOS** | 1 – 8 | 0.0012 | 0.0002 | - | | - |
| **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

([52]) For mean effluent concentrations in UWWTP with only mechanical treatment see Kjøholt et al. (2021).
([53]) 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).
([54]) 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.
([55]) The emission factor is based on i) monitored median effluent concentrations (long term samples; ca. 1,000 vales 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 the monitoring values were > LoQ. Therefore, the German emission factors refer to the number of treated p.e. in Germany.
([56]) Based on PRTR data 2011–2015, differentiated by treatment type (Roovaart and Duijnhoven 2018).

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 wastewater 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 wastewater 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

"In 2017, approximately 11 % of the EU population was not connected to wastewater collection" (Grebot et al., 2019). The fate and destination of sewage discharges from such households are considered in legislation, though naming and definitions may differ:

- In the WFD, they are termed 'non-connected dwellings' ([57]) (2000/60/EC),
- In the UWWTD, the term used is 'individual appropriate systems (IAS) ([58])' (91/271/EEC) and
- Under the HELCOM reporting for the Baltic Sea, the term is 'scattered dwellings' ([59]) (Helsinki Commission).

The main similarity between these definitions is to look at generated and treated or untreated wastewater which is not collected in centralised systems. This factsheet also considers the direct discharges of mainly domestic ([60]) wastewater from residential settlements/individual households neither connected to a sewer system or to an urban wastewater treatment plant (UWWTP) (see Figure 8.1). Such emissions do not include non-domestic emissions from small-scale industry.

Under the UWWTD, where a collecting system is not in place, 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. wastewater 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 wastewater discharges (e.g.) (Grebot et al. 2019).
Contained systems like wastewater storage tanks (impervious without outlet) should be periodically emptied and the wastewater taken to an UWWTP and treated. These individual systems don´t need to be further considered for P9, as these pollutant loads are included in P8 (urban wastewater 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.

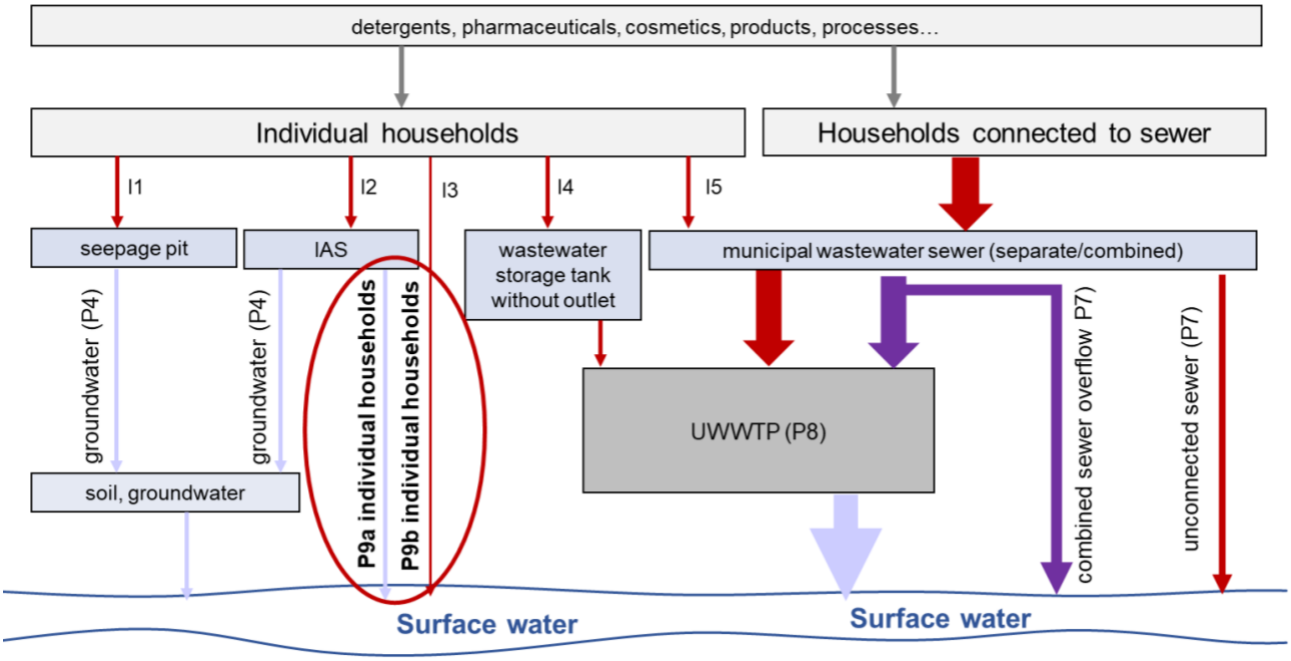
However, a certain portion of the individual households has no appropriate systems, which means that the untreated domestic wastewater and its pollutant loads are directly discharged to surface waters or probably in most cases infiltrate into soil (see Figure 1, paths I1 and I3). An example is a seepage pit, which drains directly into 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 wastewater (liquids) leaches and pollutants may reach the groundwater (diffuse pollution). Therefore, it is related to the groundwater pathway (P4). If the untreated wastewater discharges directly to surface waters it needs to

([57]) non-connected dwellings: "…dwellings not connected to a central wastewater collection system. In many cases, these dwellings apply on-site wastewater treatment systems known as individual or other appropriate systems (IAS). Alternatively, they apply no treatment at all." (Grebot et al. 2019, p. 9)
([58]) appropriate treatment under UWWTD means: "…treatment of urban wastewater 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"
([59]) scattered dwellings: "…on-site wastewater systems which receive domestic or similar wastewater from single family homes, small businesses or settlements outside urban wastewater collection systems…" (HELCOM RECOMMENDATION 28E/6)
([60]) Domestic wastewater under UWWTD is defined as: "… waste water from residential settlements and services which originates predominantly from human metabolism and from household activities"

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 possible for individual households to be connected to the sewer system, but the sewer system is not connected to an UWWTP (Figure 8.1; path I5), for example when the sewerage network is being developed. 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 wastewater 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 wastewater contains a mixture of different potential WFD substances such as:

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

Individual household discharges can represent a significant diffuse pollution pressure on water- and groundwater bodies (Grebot et al. 2019). In comparison, direct discharges to surface waters are of minor relevance.

## 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:
    - **P9a:** connected to IAS/e.g. package plants (Figure 8.1) or
    - **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 (chapter 8.2.2). 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 (chapter 8.2.2.).

**Number of inhabitants connected to IAS ($N_{inh\_st}$):**

The number of inhabitants connected to individual wastewater treatment systems (e.g. package plants) can differ both locally and nationally. Regionalized statistical information about rates of inhabitants connected to IAS/e.g. package plants might be available from European statistics (EUROSTAT, 2021a) ([61]) for example, Comber (2021) used the percentage of people connected to a sewer system reported in Eurostat, and using the difference between that and total population, calculated the share of people connected to IAS.

If information on the entire number of inhabitants is not available, EU-UWWTD (Urban Waste Water Directive) data, referring to person equivalent (p.e.) ([62]), could be used. Assuming that in IAS mainly domestic wastewater is collected and treated, using this information based on p.e. seems to be

([61]) https://ec.europa.eu/eurostat/databrowser/view/ten00020/default/table?lang=en. F

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

appropriate. Under UWWTD, Member States report the rate ( %) of generated load (p.e.) in agglomerations ([63]) > 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 wastewater in IAS is receiving:
  - primary treatment,
  - secondary treatment and/or
  - more stringent treatment.

IAS under UWWTD comprise septic tanks or package plants where wastewater is treated, or wastewater tanks without an outlet where the wastewater is periodically transported to UWWTPs (Grebot et al. 2019). MS report the rate of generated load of an agglomeration which is transported to UWWTP by trucks. 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 Wastewater 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 |
| $L_{WW\_AG}$ | = generated nominal load of the agglomeration in p.e. *(UWWTD-attribute: aggGenerated)* |
| $R_{IAS}$ | = rate of generated nominal load of the agglomeration addressed via IAS in % *(UWWTD-attribute: aggC2)* |
| $R_{truck}$ | = rate of generated nominal load of the agglomeration transported to UWWTP by truck in % *(UWWTD-attribute: aucPercC2T)* |

However, experience shows that the number of individual household discharges via IAS in smaller agglomerations can be higher and loads for a certain area (Member State/River Basin/Subunit) could be underestimated using this data, especially since agglomerations under 2000p.e. are not required to report under the UWWTD. Nevertheless, the approach proposed can provide a first approximation.

Based on the calculated load generated by individual households connected to IAS, the next step is to estimate the load released to surface water. Therefore, pollutant retention in the IAS i.e. separated into the sludge needs to be considered. To calculate the retention Equation 8.3 can be applied.

([63]) 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 wastewater treatment plant or to a final discharge point"

**Equation 8.3 Pollutant loads in IAS effluents**

$$L_{IAS\_eff} = L_{inh\_IAS} * \left(\frac{1 - R_{st}}{100}\right) L_{inh\_IAS} * \frac{R_{st}}{100}$$

where:

$L_{IAS\_eff}$ = annual pollutant load in IAS effluent in kg/a
$L_{inh\_IAS}$ = annual pollutant load generated by inhabitants connected to IAS in kg/a
$R_{st}$ = pollutant load retention/removing in e.g. package plants

For substances which tend to adsorb to particles, such as metals, a high removal/retention rate (stored in sewage sludge) can be expected. For substances which are mainly transported in dissolved form, retention might be very low. If no further information regarding retention in sludge is available, reduction efficiencies for urban wastewater treatment plants might be used as a first approximation. Examples are given in Annex P9. Depending on the substance reduction, efficiencies highly vary. Based on the given examples in Annex P9 (monitoring results) it can be assumed that the treatment efficiency is at least comparable to a secondary treatment phase:

- For metals listed in the EQS-Directive (Cd, Hg, Ni, Pb) the removal efficiency increases as follows Ni < Hg < Cd ≤ Pb
    - for cadmium and lead removal efficiency is around 90 % and higher,
    - for mercury removal efficiency is between 80 and 90 %,
    - for nickel removal efficiency is lower than 50 % (25 – 44 %).
- For pesticides Diuron, Isoproturon and Terbutryn the reduction efficiency is expected to be < 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 into soils and discharging directly to surface waters. There is little information available on this, either at national or catchment level. If it is assumed that most IAS effluents infiltrate into soil and not discharged to surface water, the emitted load will be minor.

### *8.2.2 Loads from individual households not connected (wastewater not treated (P9b))*

As described in chapter 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 Wastewater 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 households are not connected, the total amount of wastewater generated can be assumed to reach surface waters.

As described above regarding individual households connected to IAS (chapter 8.2.1), it can be assumed that the number of individual households not connected (wastewater not treated) in smaller agglomerations can be higher, meaning that loads for an area 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 wastewater); entering IAS e.g. package plants**

| Substance | Netherlands National Water Board 2011 | | Germany (national modelling activity) | | EU27 | |
|---|---|---|---|---|---|---|
| | 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 at national level the model MoRE (Modeling of Regionalised Emissions) ([64]) is used to calculate emissions to surface waters using the regionalised 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 at country level (Table 8.2).

**Table 8.2 Metal load (Cadmium, Nickel, Lead) entering septic tanks on a per capita basis at 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 | 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 |

([64]) https://isww.iwg.kit.edu/MoRE.php

| 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 |
| 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 |
| 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 wastewater components multiplied with the 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).We don´t want to give a recommendation on which values should be used. Users need to assess what is relevant to use in their own situation based e.g., on the individual situation in the country.

Table 7.6 (Urban wastewater 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 wastewater, 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 wastewater treatment plants. For certain substances, examples for emission per capita per day in generated domestic wastewater are given. Information on necessary statistical data and examples for data availability on a European scale are given in case national data are not available.

# 9 Industrial wastewater treated (P10)

## 9.1 Introduction

Pathway 10 (P10) is the pathway for all industrial wastewater loads discharging directly to surface water. In Europe this pathway is already covered by reporting under:

- EU – The European Pollutant Release and Transfer Register (E-PRTR) ([65])
- Eionet countries – The Water Information System for Europe for the State of the Environment on Emissions (WISE SoE – Emissions) ([66]).

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.

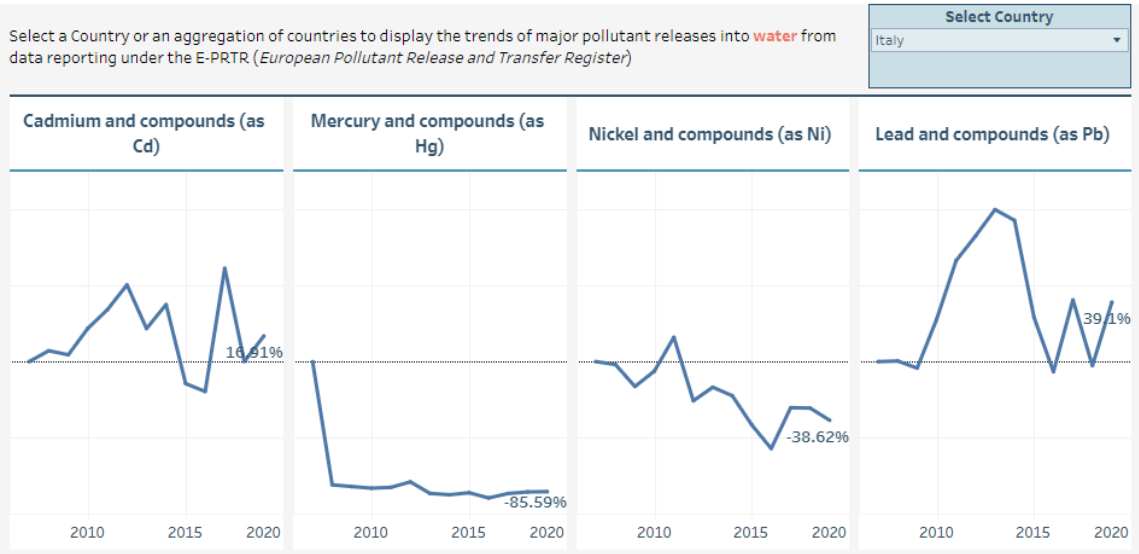
In Annex P10 a summary of the E-PRTR calculation method for loads to surface water is described. For reporting, the measured, calculated, or estimated value of a release is relevant.

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 at facility level.

The European industrial emissions portal (67) presents information on the largest industrial complexes in Europe. In its analysis viewer (68), 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.

([65]) https://ec.europa.eu/environment/industry/stationary/e-prtr/pdf/en_prtr.pdf; data can be explored in the emission portal: https://industry.eea.europa.eu/ or fully downloaded via: https://www.eea.europa.eu/ds_resolveuid/DAT-238-en
([66]) https://www.eea.europa.eu/data-and-maps/data/waterbase-emissions-10
([67]) https://industry.eea.europa.eu/analyse/pollutant
([67]) https://industry.eea.europa.eu/analyse/pollutant
([68]) https://industry.eea.europa.eu/analyse/pollutant

**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 a time series of the emissions of nutrients and hazardous substances to surface water, voluntarily reported by EEA member countries and cooperating countries. The data have been reported by Eionet countries, compiled and processed by the ETC/ICM and EEA.

The scope for reporting is on the River Basin District (RBD) or at 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.

For WISE ([69]) the releases to surface water are added up to a RBD per pollutant per year. Point sources for industrial wastewater are divided up into treated and untreated wastewater.

The WISE emissions dataset is available from the EEA website ([70]). The dataset contains a time series of the emissions of nutrients and hazardous substances to water, reported by EEA member countries and cooperating countries.

## 9.3 Conclusions

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

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

This extra information could be reported to WISE-1, although such information is limited at present. Adding this extra information would result in a more complete report of industrial loads to surface water in Europe.

([69]) http://dd.eionet.europa.eu/datasets/3351
([70]) 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 emission directly into surface water bodies. In this pathway, loads as a result of the natural background of metals are also 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 the Environment Agency UK documents (Prioritisation) 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 cases where there are 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, with a 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 prioritisation – e.g. catchments with an existing negative impact on biological quality elements and/or human health.

The final step is the formulation of priority lists with technical summaries of mining sites that are prone to the risks of mine water outbreaks and mining sites with surface waste issues that are connected to the Mining Waste Directive (Environment Agency UK, 2012).

Another method for the prioritisation of mining sites is implemented by Ireland, where mining districts and sites are assigned to one of five classes with the help of a scoring system. The scoring system counts hazards, the likelihood of release and takes the receptors into account. More information about this can be found on: https://www.epa.ie/publications/monitoring--assessment/assessment/historic-mine-sites---inventory-and-risk-classification-volume-1.php.

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 done under varying hydrological conditions, but preliminary a sampling and analysis campaign is recommended during baseflow conditions (if feasible).

For more detailed information see:
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 the Geochemical Atlas of Europe – a geochemical baseline across Europe (FOREGS) and can be used as a rough source of information about how much of the metals could be leached from former mines. Because mines are situated in areas with a higher content of metals in the rock, the 90$^{th}$ percentile seems to be the better statistic to use rather than the 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 the 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 the monitoring of flow rates and metal 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 into national and 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. This factsheet focuses on PAHs because for other substances (like TBT and copper) not enough data on regulation, use and emission factors is available.

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 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 the activity rate is chosen for 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 ([71]) (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-kilometers performed by all vessels' 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*

This section explains how EU inland navigation emission factors can be obtained.
The generic method shown here uses Dutch data, dividing the 2019 emissions by the number of ton-kilometres traversed (ER, 2021). In this way, an implied emission factor for inland navigation has been 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). Dutch references report 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 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 also plays 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

([71]) https://ec.europa.eu/eurostat/databrowser/view/ttr00007/default/table?lang=en (Accessed 28.06.2022)

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 the 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) are expressed in g/kg of the AR.

To obtain emission factors per pollutant, emissions for all sources, mentioned in the Dutch references, 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 kg/$10^6$ 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 g/$10^6$ ton-kilometres**

| Substance | Emission to surface water (g/$10^6$ ton-km) | | | |
|---|---|---|---|---|
| | 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 |

### *11.2.3 Emissions to water*

Emissions from coatings result from the contact of ships with surface water. Accordingly, these emissions are directly (100 %) released into surface waters. Emissions of bilge water are assumed to be partly collected and partly released into surface waters. Collected bilge water is usually treated; the pollutants therein are not released into the environment. The discharged part (EF for bilge water, Table 11.2) however, is assumed to be directly released into surface waters, as well as oil spills. Therefore, the emissions from inland navigation are 100 % released into surface waters.

## 11.3 Conclusions

Due to the lack of data for other substances, only PAHs are considered in this factsheet. Emission factors described are derived from international literature, used for the Netherlands and have also been applied in the Rhine catchment. The emission factors can also be applied to RBDs in other countries. In the case where there should be more (country specific) information available on the use of PAH coatings, the collection of bilge water or the occurrence (amount and size) of oil spills, these can be adjusted.

# 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 ([72]) 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 the sum of the 16 EPA ([73]) 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 onto land and directly onto 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).

## 12.2 Calculation methods

The 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 made to estimate natural background loads. Three different ways are described to get an impression of the natural background loads.

([72]) Related to a period without any anthropogenic activity.
([73]) US Environmental Protection Agency

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

The requirement to apply the described river load approach is that information on total anthropogenic diffuse loads and total point source 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. the sum of industrial and communal discharges and storm water overflows.

### *12.2.2 Surface water data approach*

Another possibility available for the calculation of 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 (draft CIS Technical Guidance on Implementing Environmental Quality Standards (EQS) for Metals; 2019, unpublished ([74])). According to the recommendations of this draft guidance, 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 NBCs[75] can be confidently estimated for trace metals."* (Page 63). According to the draft Guidance, natural background concentrations only need to be considered if EQS values are exceeded.

([74]) https://circabc.europa.eu/sd/a/2f0bdbe9-9161-4c8d-8503-d221ab93d718/WD2019–2-3_Implementing%20Metals%20EQS%20DRAFT%20guidance%20WD%20meeting%2026%20Nov%202019.pdf
([75]) NBCs – natural background concentrations

As a data source that can be used 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 a 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 a catchment or sub-catchment scale (Equation 12.2).

**Equation 12.2: Natural background load (LB) calculation**

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

where:

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

Q = is the 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 themselves. 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.

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

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

Natural metal background concentrations in soils were considered by Comber (2021) in a European wide study to assess diffuse sources for the metals cadmium (Cd), nickel (Ni) and lead (Pb) to calculate emissions to water from natural erosion processes. He used the FOREGS ([76]) database to provide mean (natural) soil

([76]) FOREGS – EuroGeoSurveys Geochemical Baseline Databasehttp://weppi.gtk.fi/publ/foregsatlas/ForegsData.php (part of the electronic publication version of the Geochemical Atlas of Europe; Salminen et al. 2005)

concentrations for several countries (see Table 4.1). The FOREGS database is focused on sites with low anthropogenic input e.g. to target unamended soil and therefore reflects the natural geology of the different regions. To calculate the background loads from erosion processes, soil losses and sediment inputs to surface waters are needed (see also factsheet P2 Erosion). Ideally, information referring to pristine conditions (e.g. forested areas without any agricultural use) are used.

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

To give two national examples:
For Austria, national topsoil concentrations for metals were derived based on monitoring data (Freudenschuß et al. 2007). The values are land use specific (forest, pasture and arable land). Monitoring data were analysed considering e.g. pH values, clay content, geology formation. The values are land use specific and regionalisation of topsoil concentration was carried out based on geological formations (bedrock for soil genesis).

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 regionalisation of topsoil 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 that the higher the humus content, the higher the PAH concentration (see Table A P13.1, Annex P1).

### *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 provides 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)). EMEP modelling results contain natural background as well as anthropogenic emissions. A study by Richardson et al. (2001) provides further information about the global metal fluxes of Cd, Cu, Pb, Ni and Zn.

### *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 the 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. Even if the simplest methods are of a 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 the applied modelling approach it needs to be mentioned, that natural background is mainly included in the calculated pollutant loads of different pathways.

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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 waterbodies. Per grid the fluxes in kg/km$^2$/year in freshwater 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 to calculation 1.
    - Deposition to water = Flux to water * Area_km$^2$ * Water Fraction
    - Deposition to wetland = Flux to wetland* Area_km$^2$* Wetland Fraction
- The calculated total deposition on freshwater 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 waterbodies.

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

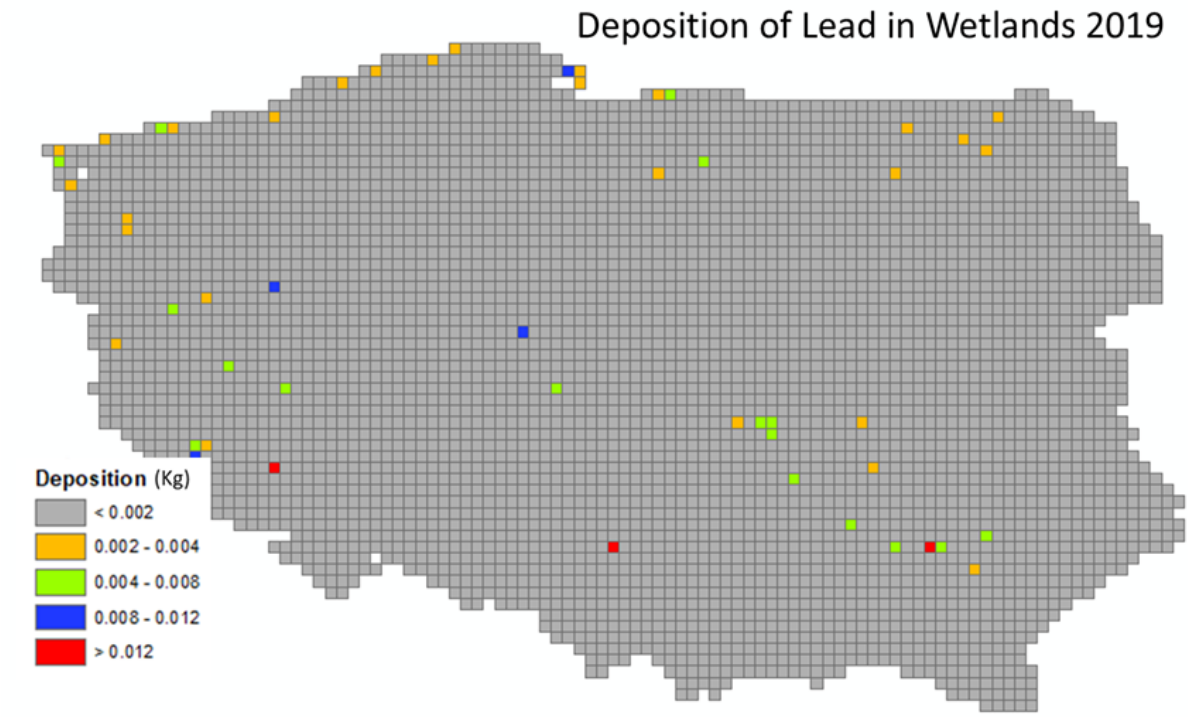
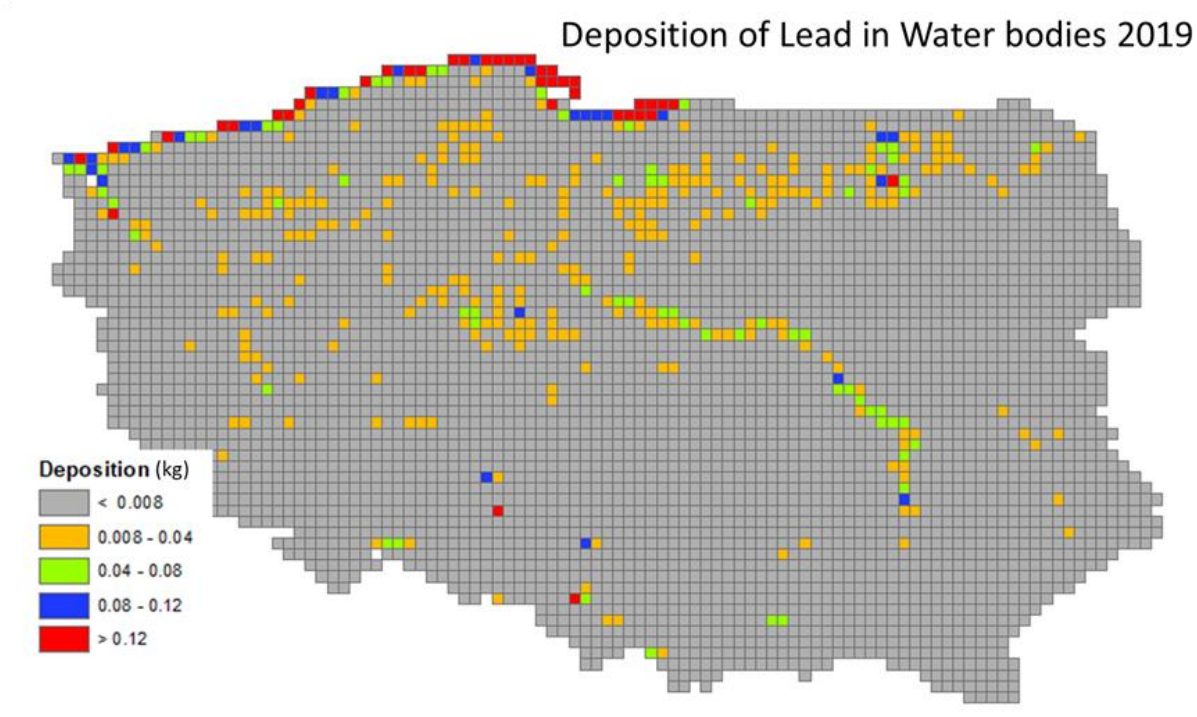



**Figure A P1.2: Annual deposition load per grid for lead in Poland in 2019 in water bodies**



**Total deposition flux PAHs (other than BaP):**

- The BaP fluxes per grid data in g/km$^2$/year are available in g/km$^2$/year. There is no distinction in the ecosystem dependent deposition.
- Calculate the fraction of surface water per grid with data requested at EMEP. The area (km$^2$) per grid is also reported in the requested file.
- Calculate the flux per grid for Poland according to calculation 3
  - Deposition to water = Total flux * Area_km$^2$ * (Water + Wetland fraction)
- The calculated total deposition on freshwater surface water for BaP in Poland is 384kg in 2019.
- With the derived ratio factors for the 16 EPA PAHs compared to BaP the deposition for the other PAHs is 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 |

## Annex P2-P5

**Table A P2-5.1 Total Cadmium 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 | 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** |

**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** |

**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 |

## Annex P6

**Table A P6.1 Statistical values – Literature check – measured substance concentration values in urban storm waters**

| Substance | 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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, dissolved concentration | DE | Wicke et al. (2016) |
| | < 0.2<br>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)<br>0.05 (meltwater) | | | Storm water, 1 sample, March – May 2010, grab sample, total concentration | EE | Kõrgmaa et al. (2011) |
| | < 0.10<br>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) |
| Cadmium | 18.05<br>0.20 | | | Storm water, composite sample out of 5 samples, December 2009 – October 2010, grab sample, total concentration | PL | Fochtman et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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<br>8.8<br>4.1 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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-Nonyl-phenol | 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<br>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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 4-tert.-Oktyl-phenole | 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<br>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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Di-(2-ethylhexyl)phthalate | 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 proportional, total concentration | AT | Clara et al. (2014) |
| | 3<br>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<br>< 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<br>0.419<br>0.235 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Anthracene | 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<br>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) |
| Fluoran-thene | 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<br>0.12 | | | Storm water sewer, single value, total concentration | SE | Kalmykova et al. (2013) |
| | 0.084<br>0.057<br>< 0.01 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |
| Benzo[a]ant hracene | 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<br>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 proportional, total concentration | DE | Wicke et al. (2016) |
| Benzo[b]flu oranthene | 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| | 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]-pyrene | 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<br>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<br>0.016<br>< 0.010 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Indeno[1,2,3-cd]pyrene | 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<br>0.00035 – 0.0077 | Storm water, 19 samples, June – December 2012, volume proportional, total concentration | AT | Clara et al. (2014) |
| | < 0.02<br>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<br>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) |
| | 0.124 (total)<br>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<br>0.00063 – 0.00097 | Storm water, 19 samples, June – December 2012, volume proportional, total concentration | AT | Clara et al. (2014) |
| | 0.02<br>0.05 | | | Storm water sewer, single value, total concentration | SE | Kalmykova et al. (2013) |
| Benzo[g,h,i]perylene | 0.06 | | n.n. – 0.46 | Storm water, 94 samples, May 2014 – June 2015, volume proportional, total concentration | DE | Wicke et al. (2016) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| | 0.029<br>0.04<br>< 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 | 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) |

| Substance | 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)<br>< 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) |
| | < 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Isoproturon | 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) |
| 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 at 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 substance concentration values in urban storm waters**

| Substance | 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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, dissolved concentration | DE | Wicke et al. (2016) |
| | < 0.2<br>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)<br>0.05 (meltwater) | | | Storm water, 1 sample, March – May 2010, grab sample, total concentration | EE | Kõrgmaa et al. (2011) |
| | < 0.10<br>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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Cadmium cont. | 18.05<br>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<br>8.8<br>4.1 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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) |
| | | 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<br>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) |

| Substance | 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<br>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) Phthalate | 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 proportional, total concentration | AT | Clara et al. (2014) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Di-(2-ethylhexyl) Phthalate cont. | 3<br>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<br>< 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<br>0.419<br>0.235 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |
| Anthracene | 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<br>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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Fluoranthene | 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<br>0.12 | | | Storm water sewer, single value, total concentration | SE | Kalmykova et al. (2013) |
| | 0.084<br>0.057<br>< 0.01 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |
| Benzo[a]anthracene | 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<br>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 proportional, total concentration | DE | Wicke et al. (2016) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Benzo[b]fluoranthene | 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]pyrene | 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<br>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) |
| | 0.46<br>0.016<br>< 0.010 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Indeno[1,2,3-cd]pyrene | 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<br>0.00035 – 0.0077 | Storm water, 19 samples, June – December 2012, volume proportional, total concentration | AT | Clara et al. (2014) |
| | < 0.02<br>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<br>0.015 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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) |
| | 0.124 (total)<br>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<br>0.00063 – 0.00097 | Storm water, 19 samples, June – December 2012, volume proportional, total concentration | AT | Clara et al. (2014) |
| | 0.02<br>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<br>0.04<br>< 0.10 | | | Urban storm water, 3 samples, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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 | 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)<br>< 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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) |
| | < 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, Sept. 2010 – Sept. 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) |
| 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 P7.2 Statistical values – Literature check – measured substance concentration values in combined storm water overflows (CSO)**

| Substance | 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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) |
| | 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<br>< 0,2 | | | CSO, 1 sample, November 2009 – June 2010, discharge proportional, total concentration | DE | Bachor et al. (2011) |
| | 0.27<br>0.17<br>< 0.05<br>0.14 (grab sample)<br>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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Nickel | 6.3 | 3.7 | < 1 – 37 | CSO, 6 facilities, 27 samples, 2018–2019, volume proportional, total concentration | DE | Toshovski et al. (2020) |
| | 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<br>4.5<br>< 1<br>2.6 (grab sample)<br>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) |

| Substance | 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 wastewater (treated), single values, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | 1 | | 0.2 – 3.6 | Combined wastewater (untreated), single values, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | 0.96<br>0.45<br>1.89<br>0.4 | | | Combined wastewater, July- September 2010, discharge proportional, particulate, total concentration | FR | Gasperi et al. (2012) |
| | 0.39<br>0.33 | | | Combined wastewater, July- September 2010, discharge proportional, dissolved, total concentration | FR | Gasperi et al. (2012) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 4-iso-Nonylphenol cont. | 0.3<br>0.24 | | | | | |
| | 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<br>< 0.1<br>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 wastewater (treated), single values, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | 0.12 – 0.13 | | | Combined wastewater (untreated), single values, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | 0.099<br>0.022<br>0.21<br>0.045 | | | Combined wastewater, July – September 2010, discharge proportional, particulate, total concentration | FR | Gasperi et al. (2012) |
| | < 0.1 | | | CSO, 1 sample, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Di-(2-ethylhexyl)phthalate | 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 wastewater (untreated), 6 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | < 0.35 – 5.1 | Combined wastewater (treated), 7 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | 3.75 – 14.82 | Combined wastewater, 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) |
| | < 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Naphthalene | 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) |
| Anthracene | 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) |
| | | | 0.0047 – 0.021 | Combined wastewater (untreated), 7 samples, June – December 2012, Total concentration | AT | Clara et al. (2014) |
| | | | 0.014 – 0.031 (partikulate) 0.007 – 0.009 (dissolved) | Combined wastewater, 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Fluoranthene | 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 wastewater (treated), 7 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | 0.0071 – 0.024 | Combined wastewater (untreated), 7 samples, June – December 2012, Total concentration | AT | Clara et al. (2014) |
| | | | 0.009 – 0.025 (dissolved) 0.111 – 0.364 (partikulate) | Combined wastewater, 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Benzo[a]anthracene | 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 wastewater (treated), 5 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | 0.0056 – 0.0057 | Combined wastewater (untreated), 7 Proben, June – December 2012, Total concentration | AT | Clara et al. (2014) |
| | 0.174<br>0.105<br>0.168<br>0.054 | | | Combined wastewater, 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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 wastewater (treated), 5 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | 0.0017 – 0.0045 | Combined wastewater (untreated), 7 samples, June – December 2012, Total concentration | AT | Clara et al. (2014) |
| | 0.286<br>0.17<br>0.371<br>0.098 | | | Combined wastewater, July – September 2010, discharge proportional, particulate | FR | Gasperi et al. (2012) |
| | 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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Benzo[k]fluoranthene cont. | | | 0.0014 – 0.0047 | Combined wastewater (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]pyrene | 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 con-centration, (Bavaria), total concentration | DE | Nickel et al. (2021) |
| | 1.6 | | | CSO, 1 sample (single value), September 2009, volume proportional, total concentration | DK | Birch et al. (2011) |
| | 0.138<br>0.1<br>0.203<br>0.057 | | | Combined wastewater, July – September 2010, discharge proportional, particulate, Total concentration | FR | Gasperi et al. (2012) |
| | 0.003<br>0.001<br>0.005 | | | Combined wastewater, 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<br>0.014<br>(grab sample)<br>0.083<br>(grab sample) | | | CSO, 1 sample, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Indeno[1,2,3-cd]pyrene | 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) |
| | 2.6 | | | CSO, 1 sample (single value), September 2009, volume proportional, total concentration | DK | Birch et al. (2011) |
| | | | 0.0014 – 0.0015 | Combined wastewater (treated), 5 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | 0.0017 – 0.0019 | Combined wastewater (untreated), 7 samples, June – December 2012, Total concentration | AT | Clara et al. (2014) |
| | 0.133 (particulate)<br>0.102 (particulate)<br>0.245 (particulate)<br>0.06 (particulate)<br>0.008 (dissolved) | | | Combined wastewater, 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<br>< 0.01<br>(grab sample)<br>0.067<br>(grab sample) | | | CSO, 1 sample, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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) |
| | 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 wastewater (treated), 5 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | 0.0025 – 0.0026 | Combined wastewater (untreated), 7 samples, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | 0.143 (particulate)<br>0.104 (particulate)<br>0.259 (particulate)<br>0.06 (particulate)<br>0.006 (dissolved) | | | Combined wastewater, 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) |
| | 0.11<br>< 0.010<br>(grab sample)<br>0.099<br>(grab sample) | | | CSO, 1 sample, September 2009 – June 2010, discharge proportional, total concentration | DK | Nielsen et al. (2011) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| 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 wastewater, 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) |
| | 0.48 | | | CSO, 1 sample (single value), September 2009, volume proportional, total concentration | DK | Birch et al. (2011) |
| | | | 0.11 – 0.21 | Combined wastewater (untreated), 4 sample, June – December 2012, total concentration | AT | Clara et al. (2014) |
| | | | < 0.05 – 0.22 | Combined wastewater (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, | DE | Erftverband (2013) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Diuron cont. | | | | total concentration | | |
| | 0.47<br>0.37<br>0.05<br>0.19 | | | Combined wastewater, July – September 2010, discharge proportional, total concentration | FR | Gasperi et al. (2012) |
| | | 0,1<br>0,21 | | CSO September 2007 – October 2008, discharge proportional, wet conditions (rainfall), total concentration | FR | Lamprea and Ruban (2011) |
| | | 0.16<br>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) |
| | 0.043<br>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) |

| Substance | Arithmetic average (µg/L) | Median (µg/L) | Min – Max (µg/L) | Comment | Country | Reference |
|---|---|---|---|---|---|---|
| Isoproturon cont. | | | < 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<br>0.04<br>0.02<br>0.02 | | | Combined wastewater (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) |
| | | | 0.02 – 0.04 | Combined wastewater (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) |
| Terbutryn | 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 at 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 |
|---|---|---|---|---|---|---|---|
| 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 |

**Table A P7.4 Metal loads in urban wastewaters (D – domestic, S – Services, I – Industry, n/d – no data) at 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 seems anomalous

**Table A P7.5 Substance concentrations in 5 German UWWTPs (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)phthalate | 96 | 96 | 0.25 | 3.7 | 14 | 16 | 90 |
| HBCDD (sum) | 96 | 36 | 0.01 | < LoQ | < LoQ | 0.01 | 0.1 |
| Perfluoroctansulfonate | 96 | 12 | 0.01 | < LoQ | < LoQ | 0.0117 | 0.17 |
| 1H,1H,2H,2H- | 96 | 10 | 0.01 | < LoQ | < LoQ | 0.0195 | 0.58 |
| Naphthalene | 96 | 56 | 0.025 | < LoQ | 0.028 | 0.034 | 0.39 |
| Fluoranthene | 96 | 96 | 0.0025 | 0.02 | 0.047 | 0.082 | 1,1 |
| Benzo[a]anthracene | 96 | 96 | 0.0025 | 0.0049 | 0.0145 | 0.0293 | 0.48 |
| Benzo[b]fluoranthene | 96 | 96 | 0.0025 | 0.0045 | 0.015 | 0.028 | 0.39 |
| Benzo[k]fluorantheen | 96 | 88 | 0.0025 | < LoQ | 0.0062 | 0.0125 | 0.17 |
| Benzo[a]pyrene | 96 | 96 | 0.0013 | 0.0035 | 0.011 | 0.025 | 0.34 |
| Indeno[1,2,3-cd]pyrene | 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-Heptachlorepoxide | 96 | 0 | 0.01 | - | - | - | - |
| Cybutryn | 96 | 0 | 0.025 | - | - | - | - |
| Cypermethrin (sum) | 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 |
| Quinoxyfen | 96 | 0 | 0.01 | - | - | - | - |
| Terbutryn | 96 | 89 | 0.01 | < LoQ | 0.0515 | 0.06 | 0.38 |
| trans-Heptachlorepoxide | 96 | 0 | 0.01 | - | - | - | - |

# Annex P8

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

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | 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-STEU" (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 | Miljøstyrel-sen (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 | Miljøstyrel-sen (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, total concentration | RO, RS, HR, SK, SI, HU, CZ, AT, DE | SOLUTIONS EU FP7 project & ICPDR (2017) (Danube) |
| | 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 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Lead, and its compounds** (EQS: 1.2 µg/L (bioavailable fraction)) cont. | 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, total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | | 0.649 | 0.905 | | | 600 UWWTP, n=605, 2015–2020, total concentration | UK | UK data base (chemical-investi-gations-programme (CIP2)) |
| | | 0.86 | | | | 162 UWWTP, 2010–2013, total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (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 | Miljøstyrel-sen (2021) |
| | LoD: 0.05 | < LoD | | 0 – 1.6 | | 19 small UWWTP with only mechanical treatment, n=100, 2011–2019, found in 45 % of samples, total concentration | DK | Miljøstyrel-sen (2021) |
| | 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, | FI | Vieno (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Cadmium and its compounds** (EQS: 0.08 – 0.25 µg/L) cont<br><br>. | | | | | | 2013–14, found in 80 % of samples, total concentration | | |
| | | | 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<br>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) |
| | 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<br>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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 | SOLUTIONS 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 |
| | LoD: 1 | 3.4 | | 0 – 29 | | 34 UWWTP with tertiary treatment, n=127, 2011–2019, found in 95 % of samples, total concentration | DK | Miljøstyrel-sen (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 | Miljøstyrel-sen (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, | FR | French Database "RSDE-STEU" (2020) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Nickel and its compounds** (EQS: 4 µg/L (bioavailable fraction)) cont. | | | | | | total concentration | | |
| | 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) |
| | 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-investi-gations-programme (CIP2)) |
| | | 4.8 | | | | 162 UWWTP, 2010–2013, total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 | Miljøstyrel-sen (2021) |
| | 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-STEU" (2020) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Mercury and its compounds** (Biota EQS) cont. | 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 LoQ: 0.001 | 0.015 | 0.019 | 0.0055 – 0.067 | | 8 UWWTP, all values (35) > LoQ), total concentration | AT | Clara et al. (2017) |
| | | < 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-investi-gations-programme (CIP2)) |
| | | 0.0007 | | | | 162 UWWTP, 2010–2013, total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **4-iso-Nonylphenols** (EQS: 0.3 µg/L) | 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, found in 3.6 % of samples, total concentration | FR | French Database "RSDE-STEU" (2020) |
| | LoD: 0.01 | not found | | | | 53 UWWTP (34 with tertiary and 19 with only mechanical treatment), n=36+29, 2004–2019, total concentration | DK | Miljøstyrel-sen (2021) |
| | | | | < 0,03 – 7.8 | | world-wide literature study | Several | 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, | FI | Vieno (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **4-iso-Nonylphenols** (EQS: 0.3 µg/L) | | | | | | total concentration | | |
| | | 0.14 | 0.19 | 0.025 – 0.77 | | 3 UWWTP (Baden-Württemberg), 2012/2013, total concentration | DE | Lambert et al. (2014) |
| | 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-investi-gations-programme (CIP2)) |
| | | 0.2 | | | | 162 UWWTP, 2010–2013, total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Di(2-ethylhexyl)-phthalate (DEHP)** (EQS: 1.3 µg/L) | 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) |
| | 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-STEU" (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 | Miljøstyrel-sen (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 | Miljøstyrel-sen (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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Di(2-ethylhexyl)-phthalate (DEHP)** (EQS: 1.3 µg/L) cont. | | | < 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-investi-gations-programme (CIP2)) |
| | | 0.78 | | | | 162 UWWTP, 2010–2013, total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 of 49 UWWTPs (found in more than 50 % of samples), total concentration | DE | Toshovski et al. (2020) |
| | 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-STEU" (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 | Miljøstyrel-sen (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, total concentration | DE | Rau und Metzger (2017) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **PFOS** (EQS: 00001.3 µg/L) cont. | LOQ: 0.005 | 0.005 | 0.026 | < 0.005 – 0.088 | - | 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) | Several | 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 |
| | | | 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-investi-gations-programme (CIP2)) |
| | | | | 0.0073 – 0.017 0.096 – 0.462 | | 2 UWWTP, 2006–2007 | SGP | Yu et al. (2009) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (2020) |
| | LoD: 0.01 | < LoD | | 0 – 0.24 | | 34 UWWTP with tertiary treatment, n=377, 1998-2019, found in 14 % of samples, total concentration | DK | Miljøstyrel-sen (2021) |
| | 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 | Miljøstyrel-sen (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), | NL | Data base NL (2020) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Fluoranthene** (EQS: 0.0063 µg/L) cont. | | | | | | total concentration | | |
| | LoD: 0.025<br>LoQ: 0.04 | < LoQ | 0.00797 | 0 – 1.5 | | 121 UWWTP (Flanders),<br>4.3 % of values > LoD,<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | | 0.003 | 0.003 | 0.002 – 0.005 | | 3 UWWTP (Baden-Württemberg),<br>2012/2013,<br>total concentration | DE | Lambert et al. (2014) |
| | | 0.0088 | 0.0126 | | | 600 UWWTP, n=605,<br>2015–2020,<br>total concentration | UK | UK data base (chemical-investi-gations-programme (CIP2)) |
| | | 0.0063 | | | | 162 UWWTP,<br>2010–2013,<br>total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | 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-STEU" (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) |
| | 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 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Diuron** (EQS: 0.2 µg/L) | | | 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) |
| | 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) |
| | LoQ: 0.01 | 0.019 | 0.047 | 0.005 –5.2 | 1.6 | 49 UWWTP, n=1,000, | DE | Toshovski et al. (2020) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Isoproturone** (EQS: 0.3 µg/L) | | | | | | 2017–2019, emission factor is based on median effluent concentrations of 49 UWWTPs (found in more than 50 % of samples), total concentration | | |
| | 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-STEU" (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) |
| | | | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Isoproturone** (EQS: 0.3 µg/L) Cont. | | | 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 |
| | | 0.0004 | 0.0101 | 0.27 (max) | | Summary of analytical results for chemicals in EU UWWTP effluents | Several | Loos et al. (2013) |
| | | | 0.058±0.005 0.05±0.002 | | | 2 UWWTP (Koblenz), 2009 | DE | Wick et al. (2010) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (2020) |
| | | | 0.190 | | | | | Schütte et al. (2017) |
| | | | | 0.029 – 0.095 | | 40 UWWTP (Baden-Württemberg), 2015–2016 | DE | Rau und Metzger (2017) |
| | | | 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, | FI | Vieno (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Terbutryne** (EQS: 0.0065 µg/L) cont. | | | | | | total concentration | | |
| | | | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **4-tert.-Octylphenol** (EQS: 0.1 µg/L) | LoQ: 0.005–2 | not found | | | | 2015–2018, total concentration | NL | Data base NL (2020) |
| | 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-STEU" (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-investi-gations-programme (CIP2)) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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, total concentration | FR | NORMAN data base (2021) |
| | 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-STEU" (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, | DE | Toshovski et al. (2020) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Benzo[a]pyrene** (EQS: 0.0017 µg/L) cont. | | | | | | 2017–2019, 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-investi-gations-programme (CIP2)) |
| | | 0.0011 | | | | 162 UWWTP, 2010–2013, total concentration | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Benzo[b]fluoranthene** (PNECwasser: 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-STEU" (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, 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 (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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Benzo[g,h,i] perylene** (PNECwasser: 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-STEU" (2020) |
| | LoQ: 0.002 | | | | | found only in 1 sample out of 15, total concentration | AT | Clara et al. (2009) |
| | 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 | Miljøstyrel-sen (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 | Miljøstyrels en (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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Benzo[g,h,i] perylene** (PNECwasser: 0.0082 µg/L) | LoD: 0.025<br>LoQ: 0.04 | < LoQ | 0.00178 | 0 – 0.4 | | 121 UWWTP (Flanders),<br>1.9 % of values > LoD,<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | LoQ: 0.0005 | < LoQ | 0.0006 | < LoQ – 0.05 | | 49 UWWTP, n=1,000,<br>2017–2019,<br>found in only 27 % of 1,000 values > LoQ,<br>total concentration | DE | Toshovski et al. (2020) |
| | | | 0.001 | | | | UK | Gardner et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Indeno[1,2,3-cd]-pyrene** (PNECwasser: 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-STEU" (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 | Miljøstyrel-sen (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 | Miljøstyrel-sen (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, total concentration | AT | Clara et al. (2017) |
| | LoD: 0.0005 | | | | | 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), | BE | VMM, Wastewater Monitoring |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Indeno[1,2,3-cd]-pyrene** (PNECwasser: 0.0027 µg/L) cont. | | | | | | 1.9 % of values > LoD, total concentration | | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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, found in 3.8 % of samples, total concentration | FR | French Database "RSDE-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 | Miljøstyrel-sen (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 | Miljøstyrel-sen (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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Naphthalene** (EQS: 2 µg/L) cont. | LoD: 0.04<br>LoQ: 0.05 | < LoQ | 0.0184 | 0 – 1.72 | | 121 UWWTP (Flanders),<br>8.8 % of values > LoD,<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | LoQ: 0.001 | < LoQ | 0.01 | < LoQ – 0.065) | | 49 UWWTP, n=1,000,<br>2017–2019,<br>found in only 43 % of 1,000 values > LoQ,<br>total concentration | DE | Toshovski et al. (2020) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Category B substances (see chapter 3, page 6 in this document)** | | | | | | | | |
| **Benzo[k] fluoranthene** (PNECwasser: 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-STEU" (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, total concentration | DE | Lambert et al. (2014) |
| | LoQ: 0.001 | | | | | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (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 | Miljøstyrel-sen (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 | Miljøstyrel-sen (2021) |
| | LoD: 0.00049 LoQ: 0.018 | | 0.000032 – 0.0016 | 0 – 0.018 | | 8 UWWTP, not detected in 29 out of 31 samples, found in 2 out of 31 samples > LoQ, total concentration | AT | Clara et al. (2017) |
| | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 |
| | 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 e t 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Hexabromocyclododecanes (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) |
| | 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 | 0.005676 | 0.009 | | | 600 UWWTP, n=605, 2015–2020, total concentration | UK | UK data base (chemical-investi-gations-programme (CIP2)) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 vale > 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 | SOLUTIONS EU FP7 project & ICPDR (2017) (Danube) |
| | 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-STEU" (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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (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, 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, 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-STEU" (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 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (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 (1 out of 32) > LoQ), total concentration | AT | Clara et al. (2017) |
| | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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, only3 values > LoQ, large volume solid-phase extraction total concentration | RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE | Joint Danube Survey 4 (JDS4), ICPDR |
| | 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-STEU" (2020) |
| | LoQ: 0.00008 | 0.000166 | 0.000572 | | | 600 UWWTP, n=605, 2015–2020, total concentration | UK | UK data base (chemical-investigations-programme (CIP2)) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **cis-Heptachlorepoxide and trans-Hepta-chlorepoxide**[2] (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-STEU" (2020) |
| | LoD: 0.025 LoQ: 0.05 | < LoQ | 0.000774 | 0 – 0.144 | | 16 UWWTP (Flanders), 0.9 % 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, 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-STEU" (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, HR, UA, AT, DE | Joint Danube Survey 4 (JDS4), ICPDR |
| | 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 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Quinoxyfen** (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, HR, UA, AT, DE | Joint Danube Survey 4 (JDS4), ICPDR |
| | 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-STEU" (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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 | SOLUTIONS EU FP7 project & ICPDR (2017) (Danube) |
| | LoD: 0.002 LoQ: 0.006 | not found | | | | 11 UWWTP (11countries), 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), 1.3 % of values > LoD, total concentration | BE | VMM, Wastewater Monitoring 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: 0.5 1–1 | 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 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| BDE | LoQ: 0.24 – 1.4 | | | | | found in only a few samples, total concentration | AT | Clara et al. (2009) |
| | LoQ: 0.0000078 – 0.00001<br>LoQ: 0.0001 – 0.00028<br>LoQ: 0.000099 – 0.00016<br>LoQ: 0.000021 – 0.000034<br>LoQ 0.0000084 – 0.000027<br>LoQ 0.0000069 – 0.000011 | 0.000005<br>0.00014<br>0.00005<br>0.000015<br>0.0000046<br>0.0000035 | 0.0000039 – 0.000010<br>0.00011 – 0.00032<br>0.000078 – 0.00016<br>0.000017 – 0.000039<br>0.0000069 – 0.000016<br>0.0000035 – 0.0000093<br>0.00022 – 0.00055 | 0 – 0.000039<br>0 – 0.00098<br>0 – 0.00048<br>0 – 0.00011<br>0 – 0.000081<br>0 – 0.000028<br>0 – 0.0016 | | BDE 28: 22 values out of 34 < LoQ, 12 values out of 34 > LoQ, total concentration<br>BDE 47, 27 values out of 34 < LoQ, 7 values out of 34 > LoQ, total concentration<br>BDE 99, 24 values out of 34 < LoQ, 10 values out of 34 > LoQ, total concentration<br>BDE 100, 25 values out of 34 < LoQ, 9 values out of 34 > LoQ, total concentration<br>BDE 153, 27 values out of 34 < LoQ, 7 values out of 34 > LoQ, total concentration<br>BDE 154, 25 values out of 34 < LoQ, 9 values out of 34 > LoQ), total concentration<br>Sum of BDE 28, BDE 47, BDE 99, BDE 100, BDE 153 and BDE 154 | | Clara et al. (2017) |
| | | 0.000251<br>0.000315<br>0.0003<br>0.00025 | 0.00025<br>0.000467<br>0.000513<br>0.000257<br>0.000244<br>0.000318 | | | 600 UWWTP, n=605, 2015–2020, total concentration<br>BDE28<br>BDE47<br>BDE99<br>BDE100<br>BDE153 | UK | UK data base (chemical-investi-gations-programme (CIP2)) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **BDE** cont. | | 0.00025<br>0.00025 | | | | BDE154 | | |
| | LoD: 0.002/0.0025<br>LoQ: 0.004/0.005 | < LoQ | 0.0000048 – 0.00113 | 0 – 1.14 | | 18 UWWTP (Flanders),<br>0.5 % of values > LoD,<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | LoQ: 0.0001 | | | | | 3 UWWTP,<br>2012/2013,<br>found in only a few samples,<br>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,<br>2012,<br>total concentration | FR | NORMAN data base (2021) |
| | LoQ: 0.001<br>LoQ: 0.0013 | not found | | | | 12 UWWTP (9 countries), n=12,<br>2017,<br>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,<br>All values < LoD<br>2019,<br>total concentration | RO, HR, CZ, SK, SI, RS, BG, HR, UA, AT, DE | Joint Danube Survey 4 (JDS4), ICPDR |
| | LoD: 0.05<br>LoQ: 0.1 | not found | | | | 13 UWWTP (Flanders),<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Chlorpyrifos** (EQS: 0.03 µg/L) | LoQ: 0.005 | | | | | found in only a few samples (2 out of 15 and 9 out of 18), 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: 0.05 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 Network, 2010–2019 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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<br>2011–2017<br>found in only a few samples<br>total concentration | FR | NORMAN data base (2021) |
| | LoD: 1.13<br>LoQ: 2.26 | | | | | 17 UWWTP (Flanders),<br>0.1 % of values > LoD,<br>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),<br>total concentration | AT | Clara et al. (2009) |
| | LoD: 0.1 - 2 | < LoD | | 0 – 52 | | 34 UWWTP with tertiary treatment, n=217,<br>1998-2019,<br>found in 5.5 % of samples,<br>total concentration | DK | Miljøstyrel-sen (2021) |
| | LoD: 0.1 | < LoD | | 0 – 0.25 | | 19 small UWWTP with only mechanical treatment, n=32,<br>2011–2019,<br>found in 3.1 % of samples,<br>total concentration | DK | Miljøstyrel-sen (2021) |
| | LoQ: 5 | not found | | | | 5 facilities, n=59<br>2011–2017<br>found in only a few samples<br>total concentration | FR | NORMAN data base (2021) |
| | LoD: 0.5<br>LoQ: 1 | | 0.00443 | 0 – 1.86 | | 17 UWWTP (Flanders),<br>0.3 % of values > LoD,<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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) |
| | 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) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Hexa-chlorobutadiene** | LoQ: 0.005 | not found | | | | total concentration | AT | Clara et al. (2009) |
| | LoD: 0.05<br>LoQ: 0.1 | not found | | | | 17 UWWTP (Flanders),<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | LoQ: 0.005 | not found | | | | 3 UWWTD,<br>2012/2013,<br>total concentration | DE | Lambert et al. (2014) |
| **Hexa-chlorocyclohexane** (EQS: 0.02 µg/L) | LoQ: 0.02 | not found | | | | total concentration | AT | Clara et al. (2009) |
| | LoD: 0.01<br>LoQ: 0.02 | | 0.000601 | 0 – 0.265 | | 17 UWWTP (Flanders),<br>0.4 % of values > LoD,<br>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,<br>2012/2013,<br>only y-Hexachlorocyclohexane was found in all samples,<br>total concentration | DE | Lambert et al. (2014) |
| **Penta-chlorobenzene** (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), n=142, 1998-2010 + 4,<br>2005–2019,<br>total concentration | DK | Miljøstyrel-sen (2021) |
| | LoQ: 0.01 | not found | | | | 1 facility (SORTIE STEP BELLECOMBE URBAIN) n=4,<br>2012,<br>total concentration | FR | NORMAN data base (2021) |
| | LoD: 0.05<br>LoQ: 0.1 | not found | | | | 17 UWWTP (Flanders),<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Penta-chlorophenol** (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 | Miljøstyrel-sen (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 |
| | LoQ: 0.1 | not found | | | | 3 UWWTD, 2012/2013, total concentration | DE | Lambert et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 (11countries), 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 |
| **Tetra-chloroethylene** (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) |
| | 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 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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 | Miljøstyrel-sen (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 | Miljøstyrel-sen (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 LoQ: 1.28 | not found | | | | 17 UWWTP (Flanders), total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **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-investi-gations-programme (CIP2)) |
| | LoD: 0.001 – 0.004 | | | | not found | 34 UWWTP with tertiary treatment, n=67, 2013–2018, total concentration | DK | Miljøstyrel-sen (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 | Miljøstyrel-sen (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, found in only 4 sample (out of 19), total concentration | DE | Lambert et al. (2014) |

| Substance | LoD/LoQ (µg/L) | Median (µg/L) | Arithmetic average (µg/L) | Min – Max (µg/L) | Emission factor (mg/ p.e.) | Comment | Coun-try | Reference |
|---|---|---|---|---|---|---|---|---|
| **Trichlorobenzenes** (EQS: 0.4 µg/L) | LoQ: 1.622 | not found | | | | total concentration | AT | Clara et al. (2009) |
| | LoD: 0.38<br>LoQ: 0.76 | < LoQ | 0.028 | 0 – 2.91 | | 17 UWWTP (Flanders),<br>1.6 % of values > LoD,<br>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),<br>total concentration | AT | Clara et al. (2009) |
| | LoD: 0.51<br>LoQ: 1.02 | < LoQ | 0.0562 | 0 – 11.2 | | 17 UWWTP (Flanders),<br>3.5 % of values > LoD,<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |
| | LoQ: 0.1 | not found | | | | 3 UWWTP,<br>2012/2013,<br>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,<br>2012,<br>total concentration | FR | NORMAN data base (2021) |
| | LoD: 0.05<br>LoQ: 0.1 | not found | | | | 17 UWWTP (Flanders),<br>total concentration | BE | VMM, Wastewater Monitoring Network, 2010–2019 |

# Annex P9

**Table A P9.1 Substance specific reduction efficiency in urban wastewater 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)phthalate (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) |
| | 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) |

| Substance | Reduction efficiency (%) | Comment | Country | Source |
|---|---|---|---|---|
| | 15 | | CH | Abegglen und Siegrist (2012) |
| | 22 | | AT | Clara et al. (2012) |
| | 0 | | DE | Seel et al. (1994) |
| Isoproturon | 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) |
| 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<br>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 ([77]):
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 the absence of recognised emission estimation methodologies or good practice guidelines.

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

## Annex P13

**Table A P13.1 Background ([78]) $PAH_{16}$ and B(a)P concentrations in German topsoils (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 topsoil; ** in 0–5 cm

([78]) Background concentration is meant as natural background concentration including ubiquitous pollutant distribution

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