# PREPARATION OF AN INVENTORY OF EMISSIONS AND LOADINGS OF PRIORITY SUBSTANCES TO DANISH RIVER BASINS

Scientific Report from DCE – Danish Centre for Environment and Energy No. 255 2018

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# Data sheet


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| Abstract: | This report reviews the preparation of an inventory of emissions and loadings of priority substances to Danish river basins. It outlines the methods in the EU Guidance Document No. 28, Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances, Technical Report – 2012-058, which can be used to develop the inventory. |
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# Contents

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# Introduction

The aim of this report is to provide Danish Environmental Protection Agency with a methodology and data overview needed in order to comply with the requirements in section 6, subsection 2, of the Statutory Order on Analysis and Reviews (*bekendtgørelse om basisanalyser*)[1], concerning the determination of priority substances emissions to receiving Danish waters. The statutory order stipulates that the authority shall assess and identify significant point sources and diffuse sources of priority substances to surface waters.

EU Guidance Document No. 28, Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances, Technical Report – 2012-058[2] (GD#28), provides a methodology to assess point and diffuse emissions of priority substances to surface waters in Europe. We therefore provide an overview of the technical aspects covered in the guidance report and illustrate how these can be applied in a Danish context. GD#28 is a guidance document for national information and use, it is in other words not mandatory to implement and follow the guidance.

It is clear that extensive amounts of data are needed for generating the assessments and the inventory. This also means that there will be data gaps, and that a complete overview of these are beyond the scope of this report, as these are both substance and site specific and should be assessed in Step 3 and 4 in the inventory compilation (see description further down).

To avoid any misinterpretations of GD#28 Part 1 of the report is a direct quote-based summary of the purely technical parts of the Guidance Document – if in doubt please consult the Guidance Document for further details. Part 2 of the report is the application of the guidance in a Danish context.

The compilation of the inventory is a tiered and iterative process, which should assist in establishing and implementing targeted reductions of emissions, discharges and losses of priority substances to receiving waters. Eventually the work should be leading to the cessation of emissions, discharges and losses of priority hazardous substances (e.g. by identifying the main sources, their relative share with respect to pollution and, their pathways) to receiving waters (GD#28).

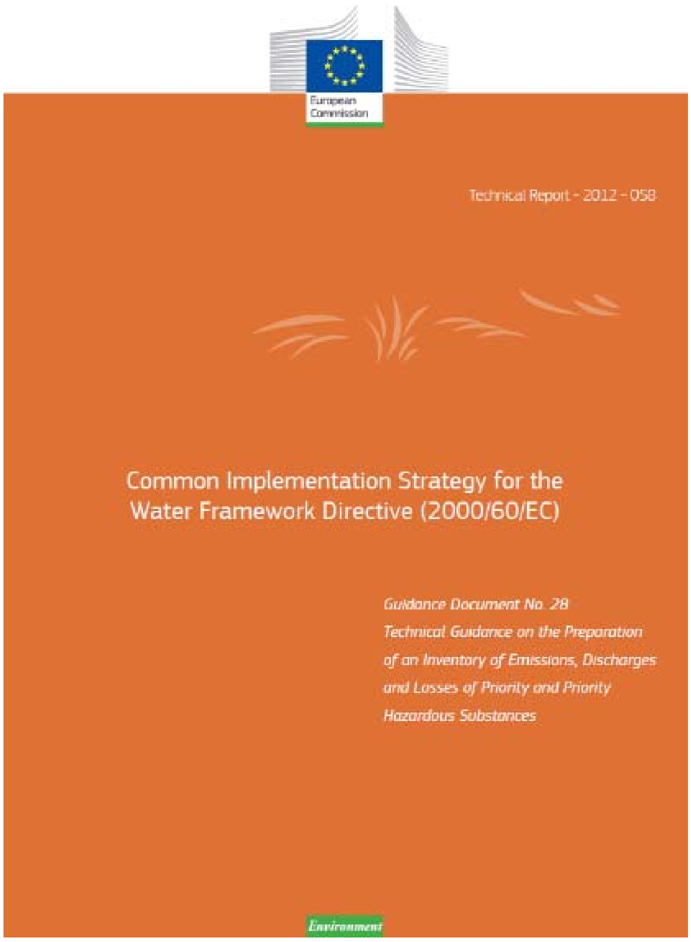
[1] https://www.retsinformation.dk/Forms/R0710.aspx?id=181972
[2] https://circabc.europa.eu/sd/a/6a3fb5a0-4dec-4fde-a69d-5ac93dfbbadd/Guidance%20document%20n28.pdf

# 1 Part 1: Background and definitions from the Guidance Document No. 28

### 1.1.1 Definitions

According to Article 5 of the Directive 2008/105/EC on Environmental Quality Standards in the Field of Water Policy (the EQS Directive), Member States (MS) are obliged to establish an inventory of emissions, discharges and losses of all Priority Substances (PS) and pollutants listed in Part A of Annex I to this Directive. Article 5 of Directive 2000/60/EC (the WFD) requires MS to provide for each river basin district (RBD), an analysis of its characteristics, a review of the impact of human activity on the status of surface waters and on groundwater, and an economic analysis of water use. Reports prepared under WFD Article 5 need to include, amongst other things:

- assessment of the likelihood that surface water bodies within the RBD will fail to meet the WFD ecological and chemical status objectives;
- identification of significant point source pollution from urban, industrial, agricultural and other installations and activities; and
- identification of significant diffuse source pollution from urban, industrial, agricultural and other installations.



The European Pollution Transport Register (E-PRTR) is the starting point in Europe for assessing releases to the environment. E-PRTR not only builds upon but also extends the principles of the European Pollutant Emission Register (EPER), requiring the reporting of pollutant ‘releases’ to water from industrial and other facilities, provided certain specified thresholds are exceeded. Other data sources in addition to the E-PRTR, include monitoring data collected for other purposes (e.g. research studies, compliance monitoring for wastewater discharges by Competent Authorities) describing, for example, substance concentrations in water, sediment and biota, and trend information. It also includes information describing the production and use of a substance and, if and when it has been banned or whether restrictions on its use have been implemented. A two-step analysis, which allows for a prioritization of resources to compile the inventory, is recommended.

## 1.2 Step 1: Relevance analysis

As a first step, an assessment of current relevance of the substances at the RBD level should be undertaken. The aim of the first step is to identify those substances, which are clearly of minor relevance for the RBD at present and in the foreseeable future and to concentrate the efforts of subsequent inventory development on the remaining substances. Consequently, the criteria for this first selection round must not be too strict. With this information in mind, a set of transparent criteria should be applied for this initial assessment. A substance should be included for in-depth inventory compilation if at least one of the following possible criteria is met when considering data from the last 3-5 years:

- The substance causes a failure of good chemical status in at least one water body
- The level of concentration for a substance is above half of the EQS in more than one water body
- Monitoring results show an increasing trend of concentration, which may cause problems within the next river basin management plan (RBMP) cycles
- PRTR data show releases, which might lead to concentrations matching the criteria above
- Known sources and activities causing inputs in the RBD exist, which might lead to concentrations matching the criteria above.

## 1.3 Step 2: Survey of available information needed for the different tiers

The second step for the substances, which pass the relevance criteria, is a more detailed analysis using a tiered approach. It should aim at providing further estimates of emissions, discharges and losses from point and diffuse sources, as well as loads transported in rivers.

As a minimum requirement for the first inventory, point discharges of priority substances (PS) from industrial facilities and municipal wastewater plants should be provided, as a basic or approximate estimation of diffuse inputs, via, for example, the calculation of riverine loads. For the first inventory, one year's worth of data is required between 2008 and 2010. Since diffuse inputs are strongly and positively correlated with rainfall / river flow (diffuse inputs can increase markedly in wet years) this has to be taken into account.

For the purpose of the inventory, the term “discharges, emissions and losses” means that the inventory has to address all inputs of the relevant substances into the environment that are likely to reach surface water, irrespective of the compartment involved. For example, a restriction to point sources only, without a comprehensive justification of why this would be the only relevant input route to the aquatic environment, clearly would not meet the requirement of the EQS Directive. For pragmatic reasons, it is useful to distinguish between point and diffuse sources:

- A **point source** is a single localized point of discharge of wastewater containing one or more pollutant(s). The most important ones are industrial facilities, wastewater treatment plants (although strictly speaking the plant itself is not the source), untreated sewage, waste disposal systems and mining sites. Some of these sources can also be modelled as diffuse sources due to data restrictions.
- **Diffuse sources** are defined as the many smaller or scattered sources from which pollutants may be released to land, air or water, whose combined impact on those media may be significant and for which it is impractical to collect reports from each individual source. Diffuse sources include agricultural activities, some urban related emissions, atmospheric deposition, and rural dwellings. Typically, they are more variable in space and time than point sources. Regarding Plant Protection Products (PPPs) in agriculture, the definition of point source and diffuse source is different from that described above due to the specific temporal and spatial context.
- **Point source for PPPs** includes any spills of concentrated or diluted PPP during transport, storage, filling, spraying, cleaning, management of residual spray and maintenance. In particular, it includes use or handling in areas not covered by approved label recommendations for spraying or guidance / codes of practice for correct filling, cleaning or disposal. It also includes uncontrolled release of an excessive amount of PPP during treatment (overdosing).
- **Diffuse source for PPPs** is related to undesired movement of PPPs in soil, water or air following application on crops and within areas agreed for use according to approved label recommendations. These definitions may be relevant to pesticides other than PPPs, e.g. certain biocides, depending upon their mode of use. Due to the discrepancies in the definitions of diffuse and point sources, whether an input is dealt with as a diffuse or a point source, it must be documented in the inventory.

Once the sources have been identified, the quantification of these can begin. Below, key concepts in this process are outlined briefly:

Pathways are the means or routes by which specific substances can migrate or be transported from their various sources to the aquatic environment. In surface waters, a wide range of processes occurs, e.g. sorption on suspended particles, degradation, biodegradation, biotransformation or bioaccumulation in plants or animals.

Riverine loads describe the mass of a contaminant transported per unit of time, typically expressed as kilo or tonnes per year. Their calculations have value with respect to establishing a PS emissions inventory for two reasons: 1) The load for any given contaminant reflects the sum of inputs upstream of the monitoring point at which these are calculated. As such, these provide a check or means of validation – the sum of inputs from individual and separate sources should broadly equate to the total riverine load; and 2) Riverine loads can be used to estimate and / or verify the contribution from diffuse sources.

Emissions: An emission factor is a coefficient linking the estimated average quantity of emission of a given pollutant during a representative time interval to an easily accessible emission variable, also called characteristic unit (inhabitants, PE, cars, ha of land…) with the following formula:

*Estimated emission = number of characteristic units x emission factor*

Most emission factors are developed by taking the average measured pollutant quantity, measured at easily accessible points (stack, discharge point…), for a representative sample of the targeted sources, during a representative time interval.

## 1.4 The Inventory

The inventory consists of a tiered approach to document the principal sources of PS to the RBD. It has a source oriented entry point (air emissions, agriculture, transport and infrastructure, construction materials, households, industry, former mines, inland navigation, natural background). The next step is to determine the pathway oriented flow and transport from the sources to the riverine loading.

### Spatial and temporal dimensions of the inventories

The current reporting practice for the RBMP requests information on the subunit scale to improve pan-European comparability (5000 to 50000 km²). For RBMP purposes, e.g. for identifying hot spots (areas with high specific inputs of substances) or estimating the effectiveness of measures, a significantly higher spatial resolution (~100 to ~1000 km²) is desirable. To support water management at a local scale, an even higher spatial resolution is necessary.

The inventories aim to provide information on the yearly inputs of the PS at a certain point in time (reference period). Inventories of inputs of PPPs need to consider 3 - 5 years average so as to minimize the yearly variation in emission due to variation of climatic conditions involving variation of pest pressure and thereby significant difference in yearly use of PPPs. Nominally the reference period is the start of the RBMP cycles, providing information at the beginning of each cycle on the effects of the measures taken in the previous cycle. All data may be used if they are required in order to draw an adequate picture of the emission situation in the reference period. The selection of data should be justified by expert judgment and documented in the inventory.

### *Tiered approach*

The in-depth analysis for the relevant substances can be performed with different approaches. The approaches described in this guidance document vary in their complexity in order to account for the wide range of information and data sources available across member states (MS). A tiered (or level) approach is presented and hence the complexity increases with each progressive rise in the tier. Associated with a tier rise, is an increase in the understanding of sources and pathways, resolution and detail, all of which aids the identification of appropriate measures. For the identified relevant substances after the first tier (tier 1), the next first two approaches of Step 2 (Point source information; Riverine loading approach) must be undertaken in order to meet the requirements of the first round of reporting. It is anticipated that methodologies will generally become more sophisticated with later reporting cycles; however, a member state may already choose to adopt a higher tier approach for the first round of reporting. Where methods are improved over time using higher tier approaches, re-calculation of the more basic estimates for earlier reporting dates should be undertaken and reported. In this way, not only will the quality of the original estimate be improved but also the consistency in methodology over time will be maintained.

The first tier (step 1) is the assessment of relevance resulting in lists of relevant and less relevant PS from each RBD. The next step (2) for the relevant substances includes Point source information, Riverine loading approach, Pathway oriented approach and Source orientated approach.

**Tier 1: Point Source Information:**
This tier focuses on point source information. It uses readily available statistical data, including point source information reported under E-PRTR.

**Tier 2: Riverine Load Approach**
Riverine load approach is based on concentration (both for the water and the suspended solids phase) and discharge data in rivers considering the basic processes of transport, storage or temporary storage and degradation of substances.

**Tier 3: Pathway Oriented Approach**
This tier uses more specific information about the land use, hydrology and basic transport processes involved.

**Tier 4: Source Oriented Approach**
Tier 4 is based on substance-specific information on production, sales and consumption, which to some extent are available through REACH. It allows the drawing of a comprehensive picture of the life cycle of a substance.

# 2 Inventory methods

Below is a summary of the estimation methods used to compile the inventory.

## 2.1 Point source

The main method for the point sources is the use of readily available statistical data from E-EPTR as well as readily available national point source data sources regarding agriculture, transport and infrastructure, construction materials, households, industry, mines, inland navigation and air emissions of these and other sources.

## 2.2 Riverine loads

Riverine loads describe the mass of a contaminant transported per unit of time, typically expressed as kilo or tons per year. The load of a contaminant transported by a river is estimated by taking the product of the mean flow weighted concentration and the total river flow, expressed by the following formula:

$$Ly = \frac{Qd}{Qmeas} * (\frac{1}{n} \sum Ci * Qi * Uf) \qquad \text{Eq (1)}$$

Ly = annual load (t/yr)

Qd = arithmetic mean of daily flow ($m^3/s$)
Qmeas = arithmetic mean of all daily flow data with concentration measurement ($m^3/s$)
Ci = concentration (mg/l)
Qi = measurement of daily flow ($m^3/s$)
Uf = correction factor for the different location of flow and water quality monitoring station
n = number of data with measurements within the investigation period

### 2.2.1 Diffuse loads

Riverine loads can be used to calculate diffuse and unknown inputs of PS providing that point source information is available. In the most basic approach, the diffuse load can be estimated as the difference between the total load and the load discharged from point sources, as follows:

LDiff = Ly – Dp Eq (2)

Where, for a given contaminant, LDiff is the anthropogenic diffuse load, Ly is the total annual riverine load, and Dp is the total point source discharge.

A more detailed formulation will be necessary where in-stream processes and natural background loads are thought to be significant as expressed by:

LDiff = Ly - Dp – LB + NP Eq (3)

Where, for a given contaminant, LB is the natural background load of the contaminant, and NP is the net outcome of in-river processes upstream of the monitoring point.

However, diffuse inputs from different sources are lumped into a single value and it is not possible, for example, to distinguish between inputs arising from agriculture and those from urban runoff. Hence, a pathway-oriented approach is needed to get this information.

## 2.3 Pathway and source oriented approaches

Not all potential pathways are important for all substances under consideration. To keep track, the pathways can be classified into three blocks:

- Pathways depend on point-source
- Pathways depend on diffuse non-urban sources, and
- Pathways depend on diffuse urban sources.

Point sources: The calculation of emissions from point sources can be straightforward if data on effluent concentration and the amount of treated wastewater are available or can be derived from statistical data with the required accuracy.

Diffuse non-urban: The inputs caused by diffuse sources, are the result of more or less complex interactions with different interfaces, including temporal storage, transformation and losses. These processes have to be integrated into the approaches adequately. Pathways from agricultural diffuse sources include erosion, surface run off, tile drainage, seepage and spray drift. With regard to the transported masses and the complexity of processes involved, erosion is most suitable to illustrate the principles of pathway-oriented approaches, particularly as PS, including PPPs, can readily attach to soil and eroded sediment. The initial process of pollutant inputs via erosion is the mobilization of top soil caused by heavy rainfall. At a river basin scale, the soil loss from arable land is commonly calculated using an adapted version of the Universal Soil Loss Equation (USLE), which considers the slope, rainfall (energy input), soil characteristics, land cover and cultivation as well as active erosion protection measures. In the second step, the proportion of eroded soil entering the surface water is calculated (sediment delivery ratio). Based on a Geographical Information System (GIS)-supported sub model, individual areas within a catchment can be identified where eroded soil reaches a water body, enabling a relationship between sediment delivery and catchment characteristics to be obtained. The enrichment of a substance in the erosion material is described by the enrichment ratio (EnR), which is the ratio between the substance concentration in the top soil and in the sediment reaching the water body.

Diffuse urban: Combined sewer overflows in urban settings can account for large percentages of releases of PS. The calculation of pollutant load discharged via storm sewers can be based on a regionalised and area specific surface load (e.g. kg / $km^2$) for any pollutant under consideration. This specific surface load is derived from observed runoff concentrations and precipitation data and it is assumed that it is realised every year independent of the interannual variation of precipitation. For combined sewer systems, the overflow rate and the proportion of discharged wastewater that is mixed up with the storm water should be estimated. The overflow rate is strictly dependent on the storage volume realised in the catchment and the hydraulic capacity of the wastewater treatment plant.

Source Oriented Approach (SOA): Is a source oriented approach and a method of analyzing the flows of a substance in a well-defined system, including through industries producing and using it, households, wastewater treatment plants and all connected media, such as soil, air and water.

Substance Flow Analysis (SFA): Information on how to construct Substance Flow Analysis (SFA) can be derived from different sources such as inventories of goods and their PS concentrations, statistical data on the use of PSs in different economic sectors and concentration of PSs in raw materials and production data. In cases where data are not available, emission factors, release rates and other statistical information can be used for estimation. Even though national data may be of high quality because they were compiled accurately, downsizing to the regional level can incorporate errors. Particularly for PSs, use and emission figures can decrease steeply in the space of a few years, so that the corresponding emission factors become worthless. As a result, it is necessary for a SFA to cite information about the time and regional frame for each figure used.

## 2.4 Data input sources

For the generation of an inventory, the EQS Directive requires the use of data obtained by implementing Articles 5 and 8 of Directive 2000/60/EC, Regulation (EC) No 166/2006 and from other available sources. The different data management systems can be operated on regional, national or international level. Besides the data management systems based on EU-legislation, other data sources can be available from other legal national and international data-flows or based on voluntary data management systems. The following legislatively based reporting obligations are the core sources for the data needed for the inventory on emissions, discharges and losses:

- Reporting under the WFD (Art. 5 and 8)
- Reporting schemes under the Urban Waste Water Treatment Directive
- Reporting under the European Pollutant Release and Transfer Register (E-PRTR).
- Reporting under the Dangerous Substances Directive

There are several additional international data-flows, e.g. organised by EUROSTAT, Organisation for Economic Cooperation and Development (OECD), OSPAR Convention, the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM), the Stockholm Convention on Persistent Organic Pollutants (POP), WISE (Water Information System for Europe), as well as the REACH program. Here is a list of examples of relevant types and sources of data:

- Permit data
- Wastewater and emission monitoring data
- Water quality monitoring data
- Statistical data (inhabitants, connection rates to sewer systems, tourism data, ...)
- Wastewater charges
- Subsidies data on investment and operation of water and wastewater facilities
- Case studies/research data
- Environmental reports
- Other data:

- hydrological data
- soil data
- (hydro-) geological data
- production data
- import / export data
- deposition data
- agricultural data
- substance application data

## 2.5 Inventory compilation

As the compilation of the inventory is a demanding task, which blends the information from various sources in a structured way, an iterative approach is necessary, which also reflects longer-term objectives. The needed six steps are outlined below.

### 2.5.1 Step 1: Relevance analysis

- Identification of the "relevant" substances for the RBD
- Identification of the information outputs required from the inventory / preliminary method selection (substance specific)

However, as the different methodologies provide different levels of detail in the results, it is recommended as a second step (2) to identify the information needs for the next RBMP tasks.

### 2.5.2 Step 2: Survey of available information needed for the selected tiers

Point source: Data can be taken from the E-PRTR system. However, evaluations of the E-PRTR indicate that it may cover only part of the relevant point source emissions. Derivation of specific emission factors are often needed and requires high-quality concentration measurements and a careful evaluation of these results. This is an area where close cooperation between the member state and scientific institutions may be useful.

Riverine approach: The application of the riverine load approach requires data on discharges and on average concentrations of the substances in whole water if available (in the dissolved phase and in suspended solids). This information should be available in the quality required by the Commission Directive 2009 / 90 / EC for most substances, at least at the confluence of the most important tributaries and on "border" monitoring stations.

Pathway-oriented approaches require: Substance invariant regionalized data on topology, geology, land use etc., which can be taken from various maps or statistical sources; Substance-specific concentrations (if possible also regionalised) at the various transfer points are required.

Source-oriented approaches require: Data on production, consumption use and emission into different environmental media, which might be available from chemical management institutions as well as infrastructure and other statistical data. Furthermore, information on storage and transfer processes in the environment is required. Here, data collected by the authorities for the management of chemicals, PPPs or biocides, national inventories and international information, e.g. from different OECD activities, are valuable sources of information.

The next four steps (3-6) are post-technical-analysis (Step 1&2) evaluations for improving the analysis and decision-making, and are hence more RBD and PS specific and hence have less direct technical guidance.

**Step 3: Identification of data gaps for the selected tiers and assessment of efforts needed to close the identified data gaps**

**Step 4: Final decision on method selection (substance-specific) for the current inventory compilation**

**Step 5: Formulation of tasks for the next river basin management plan (RBMP (substance-specific), if improvements are necessary in the inventory, e.g. by use of higher-tier approaches**

**Step 6: Preparation, check and refinement of the substance-specific inventories**

# 3 Part 2: Guidance Document No. 28 in a Danish context

The provisions on the establishment and reporting of an inventory of emissions, discharges and losses of priority substances (PS) and other pollutants are laid down in Section 6 of Statutory Order No 837 of 27 June 2016 (*bekendtgørelse om basisanalyser*), stipulating the obligations for Danish EPA. Part 2 of the present report describes how Danish EPA can meet the obligations in the said Section 6 and provides information on possible gaps in the underlying data.

## 3.1 Danish and international data input sources

To operationalize GD#28 for Danish conditions, we list databases and information sources that have data of high quality and that are reliable, transparently reported and readily accessible, see Table 1. Furthermore, data that are comprehensive and reported in a uniform and comparable form are preferred. This is required to avoid an unnecessary large effort in data preparation and in understanding the basic conditions and assumptions that were used for producing the data. Only the NOVANA database is developed specifically for supporting river basin management. All other data sources have multiple other objectives and targets.

In Step 2 Tier 3 (Pathway oriented approach) and Tier 4 (Source Oriented Approach) it may be necessary to search and compile information and data from scientific studies or from producers and industrial facilities, and for this the following additional sources can be consulted.

Web of science[3], which is an online subscription-based scientific citation indexing service that provides a comprehensive citation search and gives access to multiple databases.

SciFinder[4], which is a research discovery application that provides access to comprehensive and authoritative source of references, substances and reactions in chemistry and related sciences.

Google Scholar[5], which is a freely accessible comprehensive web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines. The Google Scholar index includes peer-reviewed online academic journals and books, conference papers, theses and dissertations, preprints, abstracts, technical reports and other scholarly literature.

The Water Framework Directive reference spatial data sets include information about European river basin districts (RBD), river basin district subunits, surface water bodies, groundwater bodies and monitoring sites used in the first and second River Basin Management Plans. The data sets are part of

3 Web of science: https://clarivate.com/products/web-of-science/
4 SciFinder: http://www.cas.org/products/scifinder
5 Google Scholar: http://scholar.google.dk/

the Water Information System for Europe (WISE)[6] and compile information reported by the EU Member States and Norway to the European Commission and the European Environment Agency (EEA) since 2010. The WISE Marine section also includes updated indicators from OSPAR and HELCOM[7]. WISE, OSPAR and HELCOM can be used to supplement with additional information to the data from the Danish surface water database (ODA).

[6] WISE: http://water.europa.eu/marine-and-freshwater-water/#
[7] OSPAR and HELCOM: http://water.europa.eu/marine/data/indicator-catalogue

Table 1 Data input sources for Danish inventory.

| Database | Description and content relevant for this assessment | Application | Link |
|---|---|---|---|
| ODA | The surface water database (ODA) is the ministry's and DCE's (Aarhus University) shared database for surface water with quality assured data from surveillance and monitoring of water courses, lakes, sea and land surveillance catchment areas. ODA is updated once a day from certain topic systems (fagsystemer). ODA comprises locations and chemical concentrations in water, sediment and biota for the sea, lakes, water courses. For water courses also monthly transport in kg, daily water flow rate in $m^3/s$, catchment area in $km^2$, are given. | Step1: RA[1)]<br>Step2: RIA[3)]<br>Step2: SOA[5)] | https://oda.dk/<br>Contact Danmarks Miljøportals Brugeradministration (www.miljoeportal.dk/myndighed/brugeradministration) for access to data |
| DK-PRTR | The Danish Pollutant Release and Transfer Registers (PRTR) hold key environmental data from industrial facilities incl. WWTPs and rain related discharges in accordance with the statutory order BEK nr 1172 af 13/10/2015. Reporting from emitters is done to the relevant national authorities for releases of waste and pollutants that exceed pollutant specific thresholds values. The PRTRs have data on point source releases in kg/y to air, water (recipient) and water (sewage) on a sector, activity and facility level. | Step1: RA<br>Step2: PSI[2)]<br>Step2: SOA | https://miljoeoplysninger.mst.dk/PrtrPublicering/Index |
| WISE | For users from environmental administrations WISE provides input to thematic assessments in the context of EU water related policies. For water professionals and scientists WISE facilitates access to reference documents and thematic data, which can be downloaded for further analyses. WISE illustrates a wide span of water related information by visualizations on interactive maps, graphs and indicators. | Step1: RA<br>Step2: PSI<br>Step2: SOA | http://water.europa.eu/ |
| E-PRTR | In the European Pollutant Release and Transfer Registers (E-PRTR) there are data on point source releases in kg/y to air, water and soil on a sector, activity and facility level. These are also given for RBDs. Furthermore, diffuse releases from certain sectors are given to RBD sub units in kg/ha, and to air in kg/grid cell and shown in maps. | Step1: RA<br>Step2: PSI<br>Step2: SOA | http://prtr.ec.europa.eu/#/home |
| PULS | In relation to authorization, surveillance and monitoring (NOVANA) the Danish point source database (PULS) holds data on concentrations in discharges to recipients and annual water flow rates from WWTPs, industries with WWTPs, rain related discharges, aquaculture and fish farms and their locations. | Step2: PSI<br>Step2: SOA | https://puls.miljoeportal.dk/<br>Contact Topic center for point sources, Østjylland |
| SD | Statistics Denmark (SD) has data on the Danish society and manufacturing and trading industries on production, import and export amounts of pollutants and pollutant containing products. Import and export figures are available on a monthly basis from 1990 to present and contain trade information from 272 countries worldwide. Production figures are reported quarterly as "industrial commodity statistics by commodity group and unit" from 1990 to present. | Step1: RA<br>Step2: SOA | http://www.statistikbanken.dk/statbank5a/default.asp?w=1920 |
| SPIN | The Nordic Substances in Preparations in the Nordic Countries (SPIN) database holds information on use amounts of various pollutants in products and activities, i.e. Use Categories Nordic (UCN), and on use in industrial categories, i.e. according to the standard nomenclature for economic activities (NACE) system. SPIN collaborates with the Danish Working Environment Authority (WEA) who is administrating the registrations of chemicals and products to the Danish product register. | Step1: RA<br>Step2: SOA | www.spin2000.net |
| DEP | Atmospheric deposition (DEP) in $\mu g/m^2$, based on the background monitoring (NOVANA) of air quality and atmospheric deposition, is reported in annual reports by the DCE, Aarhus University. There are deposition data for heavy metals on 6 locations, and for xenobiotic organic substances on 2 locations. | Step2: POA[4)]<br>Step2: SOA | http://dce2.au.dk/pub/SR204.pdf |
| MSC-E | Meteorological Synthesizing Centre - East (MSC-E) is one of the international research centers of the EMEP programme under the LRTAP Convention of UNECE. MSC-E has annual total depositions in $kg/km^2$ for the whole country, to and from DK and contributions from foreign sources for some heavy metals and organic substances. | Step1: RA<br>Step2: PSI<br>Step2: POA<br>Step2: SOA | http://msceast.org/index.php/denmark |

Table 1 Data input sources for Danish inventory *(continued)*.

| Database | Description and content relevant for this assessment | Application | Link |
|---|---|---|---|
| REACH | Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals. REACH has information and data supplied by producers on chemical and toxicological properties, produced amounts and use categories. | Step1: RA<br>Step2: SOA | https://echa.europa.eu/guidance-documents/guidance-on-reach |
| SJ | The EPA administers the pesticide Spray Journals (Sprøjtejournaler, SJ). The SJs are unique, i.e. other countries do not have such detailed information. They are available from 2011 for the Danish farms on a CVR level. SJs comprise information on amounts of used product (handelsmiddel) for each crop type reported by farmers. From this, the amount of active ingredient can be estimated for each year and farm. Spills of pesticides during transport, storage, filling, spraying, cleaning, management of residual spray and maintenance or overdosing are not covered in any database. | Step1: RA<br>Step2: POA<br>Step2: SOA | Contact DK-EPA for access to documents |
| FC | The Danish agricultural agency (Landbrugsstyrelsen) has information on types and locations of fields and crops (FC) in Denmark. FC is used together with SJs to estimate the locations of use of active ingredients. | Step2: POA<br>Step2: SOA | Contact the Danish agricultural agency for access to data |
| Jupiter | Jupiter is GEUS' nationwide database for groundwater, drinking water, raw materials, environmental and geotechnical data. The database contains information about more than 280,000 wells, including technical structure of the well, geographical location, administrative information, geological description, water level measurements and groundwater chemical tests and analyses. Additionally, the database contains information about more than 35,000 water abstraction plants (waterworks, irrigation systems, etc.) including: geographical location, administrative information, drinking water chemical tests and analyses, abstracted water volumes and permits for water abstraction. | Step2: SOA | http://www.geus.dk/DK/data-maps/jupiter/Sider/default.aspx |
| GERDA | The GEophysical Relational DAtabase (GERDA) is a GEUS database comprising a wide range of geophysical, geo-electrical and electromagnetic data collected from Denmark. A query form allows the user to select datasets according to type of data, UTM area, client, data collector, project name, purpose, investigation area or time for collection. | Step1: RA | http://www.geus.dk/UK/data-maps/gerda/Pages/default.aspx |
| GRD | The GEUS groundwater reports database (GRD) contains 8,000 geo-referenced reports primarily focused on mapping and action planning for the Danish groundwater environment. | Step2: POA | http://jupiter.geus.dk/Rapportdb/GrundvandsrapportList.seam |
| ModelDB | The Model Database (ModelDB) comprises geological, hydro-stratigraphic and hydrological / groundwater models stored in the GEUS model database. The models are mainly formulated in connection with the national groundwater mapping. | Step2: SOA | http://gerda.geus.dk/Modeldb/modelQuery |
| SSM | Surface sediment map (SSM) of Denmark 1:200 000 is an interpreted overview map of surface geology in Denmark. The map shows a countrywide classification and distribution of sediment types (mostly glacial and postglacial sediments) at the surface of Denmark. The digital map is mainly based on the systematical geological mapping of Denmark in 1:25 000. This information is supplemented with geological data from GEUS drilling database, information from the quaternary literature, geomorphological mapping and photo-geological interpretation. | Step2: POA | http://www.geus.dk/UK/data-maps/Pages/j200-dk.aspx |

1) RA: Relevance Analysis; [2] PSI: Point Source Information; [3] RIA: Riverine Approach; [4] POA: Pathway Oriented Approach; [5] SOA: Source Oriented Approach.

# 4 Compilation of the Danish inventories

## 4.1 Step 1: Relevance analysis

The first step in the analysis is to evaluate the relevance of the Priority Substances (PS) for each RBD. This is done in Step 1: Relevance Analysis where a substance should be included for in-depth inventory compilation if at least one of the following five criteria (when considering data from the last 3-5 years) is met (GD#28):

1. The substance causes a failure of good chemical status in at least one water body
2. The level of concentration for a substance is above half of the EQS in more than one water body
3. Monitoring results show an increasing trend of concentration which may cause problems within the next river basin management plan (RBMP) cycles
4. PRTR data show releases, which might lead to concentrations matching the criteria above
5. Known sources and activities causing inputs exist which might lead to concentrations matching the criteria above (GD #28).

The first step is to review if the PS in question is on the NOVANA list. If it is on the list, the next step is to assess if it fulfills one or more of the first three criteria (1-3). If it does, it is relevant for further analysis. The review of criteria 4 and 5 consists of determining whether a PS is released to the environment or produced, imported or used in any activities or consumer products. This is done based on a review of the DK-PRTR, E-PRTR, SPIN, SD, SJ, MSC-E, REACH and GERDA databases. PSs that meet these criteria should move to step 2. If the PS does not fulfill any of the five criteria, then the PS is not relevant for further analysis.

PSs that are not on the NOVANA list, ODA or PULS databases but fulfill the criteria 4 or 5, should move to step 2. Assessment of fulfillment of the criteria is based on a review of the DK-PRTR, E-PRTR, SPIN, SD, SJ, MSC-E, REACH and GERDA databases. If in doubt, move the PS to step 2. See Figure 1.

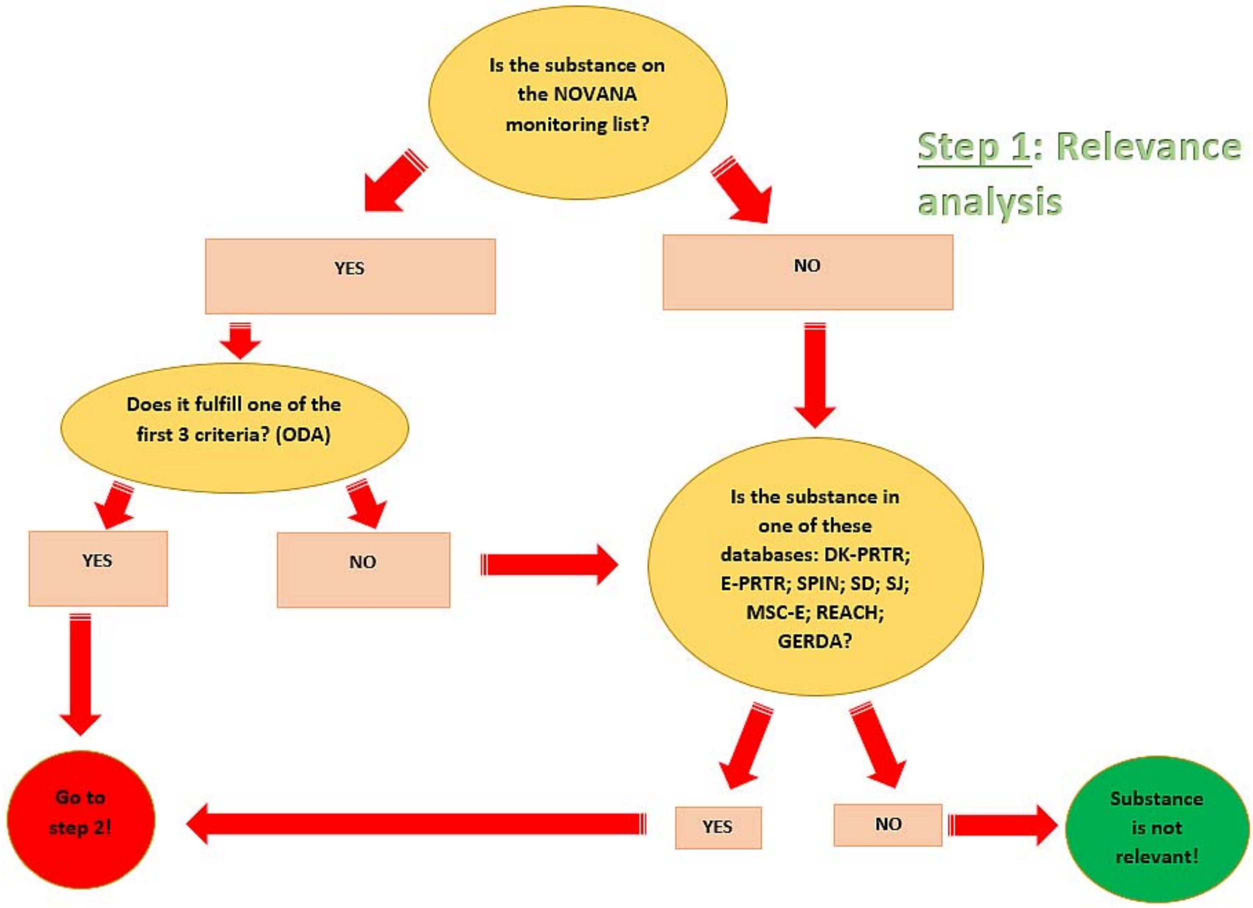



Figure 1 Step 1: Relevance analysis.

## 4.2 Step 2: Survey of methods and available information needed for further analysis of Priority Substances

For generating the inventories, the reference period for the establishment of values in the updated inventories shall be the year before the analysis is to be completed. For Plant Protection Products (PPPs), also the average of the three years before completion may be used. Member states shall publish the updated inventories in their updated river basin management plans. If necessary, they should be updated at the latest 13 years after the date of entry into force of the WFD Directive and every six years thereafter.

### 4.2.1 Tier 1: Point source information

In this tier for the point sources, readily available data of releases directly to surface waters are used. E-EPTR should be consulted first, as it comprises releases in kg/y on a RBD level. However, the E-PRTR may not be as comprehensive as DK-PRTR and PULS, therefore these must be checked for additional sources and releases to surface waters. DK-PRTR comprises releases in kg/y to recipient surface water, which subsequently must be attributed to one of the four Danish RBDs. PULS has concentrations in discharges and annual water flow rates, which together will give releases in kg/y to recipient surface water that subsequently can be attributed to a RBD. Up until 2014/2015, the data in DK-PRTR were from the *Grønne Regnskaber*, and hereafter reporting demands to DK-PRTR have been more lenient as release threshold values are used. To ensure a more complete estimate of releases, a survey of smaller emissions, not included in the PRTRs, can be undertaken primarily by using PULS data.

### 4.2.2 Tier 2: Riverine approach

Calculation of riverine loads and diffuse loading to rivers and any body of water is based on the Eq 1-3. The following anthropogenic sectors should be included: agriculture, transportation and infrastructure, energy production, construction materials, households, industry, mines, inland navigation and air emissions of these and other sources. The approach requires site and substances specific data on discharges and on average concentrations of the substances in whole water, if available (in the dissolved phase and in suspended solids) (GD# 28). NOVANA data for the water compartment for organic PS are from unfiltered samples and thus represent total concentrations. Metal data in NOVANA are from filtered samples and represent the dissolved phase. These reflect the phases in the environmental quality standards for the respective PS. Riverine loading information should be available in the quality required by the Commission Directive 2009/90/EC.

The total annual load transported by a river (Ly in t/y), comprising contributions from all point and diffuse sources, is calculated from:

$$Ly = \frac{Qd}{Qmeas} * (\frac{1}{n}\sum Ci * Qi * Uf) \qquad \text{Eq (1)}$$

Where

Qd = arithmetic mean of daily river flow ($m^3/s$)
Qmeas = arithmetic mean of all daily flow data with concentration measurement ($m^3/s$)
Ci = concentration (mg/l)
Qi = measurement of daily flow ($m^3/s$)
Uf = correction factor for the different location of flow and water quality monitoring stations. When an additional load of PS occurs between the two stations, the location specific correction factor accounts for the difference in concentrations between the two stations
n = number of data with measurements within the investigation period

In a Danish context, these data are direct measurements and can be obtained primarily from ODA.

When the total load discharged from point sources (Dp in t/y) is available, the anthropogenic diffuse and unknown loads of PS (LDiff in t/y) can, in the most basic approach, be estimated from:

$$LDiff = Ly - Dp \qquad \text{Eq (2)}$$

Diffuse non-urban and diffuse urban sources are explained in more detail below for Tier 3: Pathway oriented approach.

A more detailed formulation will be necessary for substances with natural background loads (LB in t/y) and when the net outcome of in-river processes upstream of the monitoring point, such as sedimentation, remobilization and degradation (NP in t/y), are taken into account. All of these variables are substance and site specific (GD# 28):

$$LDiff = Ly - Dp - LB + NP \qquad \text{Eq (3)}$$

For example, metals such as nickel[8] and to a lesser extent cadmium have natural origin in soils[9] and Polyaromatic Hydrocarbons (PAHs) can be naturally formed from forest fires[10].

Degradation of PS in the water and sediment compartments can be estimated as first order degradation of the dissolved PS ($PS_{diss}$):

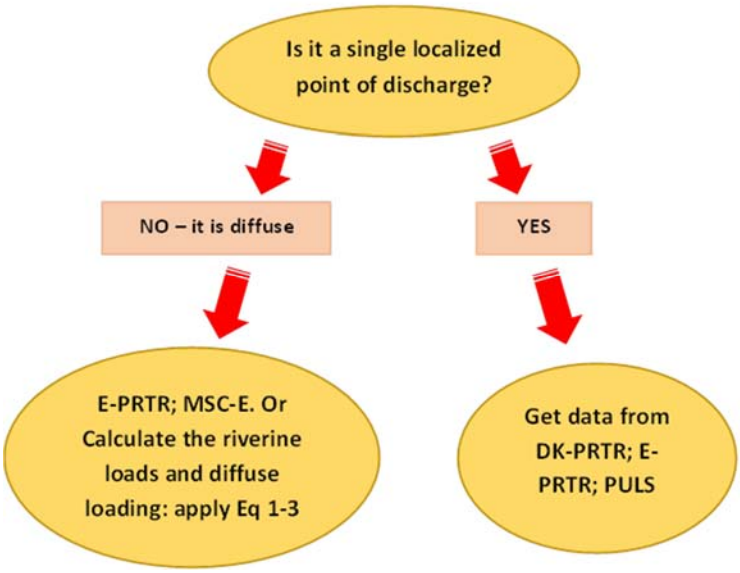
$$k_1 * PS_{diss} = k_1 * PS_{total} * \frac{X}{\theta + f_{OC} * K_{OC} * X} \text{ (mg/L/s)} \qquad \text{Eq (4)}$$

Where $k_1$ is the first order degradation rate, $PS_{total}$ is the total measured concentration, e.g. from NOVANA, X is the particle density in the water and sediment compartments, respectively. θ is the pore volume fraction in the sediment and unity in the water compartment, $f_{OC}$ is the fraction of organic carbon in the particles in the water and sediment compartments, respectively, and $K_{OC}$ is the sorption coefficient between organic carbon and water. The coefficients $f_{OC}$, X and θ are site specific and can be derived from measurements. $K_{OC}$ and $k_1$ are substance specific and should be retrieved from PS standardised data sheets. Retention times for lakes and water courses can be estimated from "Hav, søer, vandløb, 1984"[11].

Since diffuse inputs are strongly and positively correlated with rainfall/river flow (diffuse inputs can increase markedly in wet years), this has to be taken into account (GD# 28).

There are different definitions for PPPs and other substances for the point sources and riverine load analysis process (GD#28). There are no specific data on spills of PPPs during transport, storage, filling, spraying, cleaning, management of residual spray and maintenance or overdosing. These are included in the diffuse load in the riverine approach. To further distinguish between inputs of PPPs from e.g. agriculture and urban runoff, a pathway oriented approach is needed (GD# 28).

8 http://mst.dk/media/121329/52-baggrundsniveau-for-barium-zink-kobber-nikkel-og-vanadium-i-fersk-og-havvand.pdf
9 Tungmetaller i danske jorder: http://www.dmu.dk/1_viden/2_Miljoe-tilstand/3_jord/4_tungmetaller/tungmetaller.htm
10 Kilder til jordforurening med tjærestoffer (PAH): http://www.miljoeogressourcer.dk/filer/lix/2244/2244.pdf
11 Hav, søer, vandløb, 1984: https://www2.mst.dk/Udgiv/publikationer/1984/87-503-4862-0/pdf/87-503-4862-0.pdf




## Step 2: Point sources and Riverine loads

Figure 2 Point source information and Riverine approach.

If the calculated riverine load is equal to or less than the point source load, and the databases, especially regarding concentration data, provide reliable information, then the requirements for an inventory might be met. If high pollutant concentrations, an increasing trend or a high relevance of diffuse sources point to the recipient, then a more detailed analysis using the pathway oriented (Tier 3) and the source oriented approaches (Tier 4) is required (GD# 28).

### 4.2.3 Tier 3: Pathway oriented approach

The pathway-oriented approach is highly site and substance specific and can be sorted in three blocks; pathways depended on point sources, diffuse non-urban and urban sources. The point sources are determined based on the preceding tiers (point source information and riverine approach) (GD# 28), see above.

**Diffuse non-urban**

Diffuse non-urban comprises temporal storage, transformation and losses of the substance. Pathways from agricultural diffuse sources include erosion, surface run off, tile drainage, seepage and spray drift. Erosion is most suitable to illustrate the principles of pathway-oriented approaches. Using the Universal Soil Loss Equation (USLE), to determine soil loss from arable land, the average annual soil erosion is:

$$A = R*K*L*S*C*P \qquad \text{Eq (5)}$$

Where, A = average annual soil loss in t / a (tons per acre); R = rainfall erosivity index; K = soil erodibility factor; LS = topographic factor - L is for slope length & S is for slope; C = cropping factor (vegetation); P = conservation practice factor (land use) (GD# 28).

Data and examples for the geographical parameters (R; K; LS) can be found in: Leek and Olsen (2000)[12]; Schønning et al. (2009)[13]; Andersen (2016)[14]. The following databases can also be useful entry points: JRC[15], GEUS-SSM (see Table 1), and precipitation data[16].

The next step in the diffuse non-urban losses estimation is to determine the proportion of eroded soil entering the surface water (sediment delivery ratio (SDR)) (GD# 28).

$$SDR = SY / E \qquad \text{Eq (6)}$$

Where, SY = sediment yield and E is the gross erosion.

The SDR is of course also highly site specific. An older reference addressing this issue in Denmark is Kronvang et al. (1995)[17].

There are many different ways and models to assess SDR. The most simple is a generalized SDR curve, which build upon the correlation between the size of the watershed and SDR. *The curves vary from site to site and require significant empirical data to be predictive and accurate.*

The relationships and predictive models of the USLE and SDR[18] are site specific and need adaptation to local conditions. Based on a Geographical Information System (GIS) supported sub-model, individual areas within a catchment can be identified where eroded soil reaches a water body, enabling a relationship between sediment delivery and catchment characteristics to be obtained (GD# 28) – an example of this can be found in Lee and Kang (2013)[19].

The enrichment of a substance in the erosion material is described by the enrichment ratio (EnR), which is the ratio between the substance concentration in the top soil and in the sediment reaching the water body (GD# 28). The ratio is dependent upon the partitioning of the substance between soil, sediment and water, which is a function of the hydrophobicity of the substance and the fraction of organic content (foc) in the sediment and soil. The mobility of a substance can be determined based on the Log Koc of the substance and the foc of the soil and sediment. In addition to assessing the sorption and partitioning (Kd), degradation, bio-degradation, -transformation or -accumulation in plants or animals needs to be assessed to determine the routes and amounts that are transported in the pathways. Data on these properties can be obtained from the substances dossiers and the choice of entry values should be standardized.

Direct discharge and spray drift to surface waters can be estimated for PPPs. From the pesticide spray journals (Sprøjtejournaler, SJ), information on

[12] Leek and Olsen (2000): http://onlinelibrary.wiley.com/doi/10.1111/j.1475-2743.2000.tb00175.x/epdf
[13] Schønning et al (2009): http://pure.au.dk/portal/files/83111602/Threats_to_Soil_Quality_in_Denmark_chapters_7_and_8.pdf
[14] Andersen (2016): http://projekter.aau.dk/projekter/files/239534851/master.pdf
[15] JRC: https://esdac.jrc.ec.europa.eu/content/ls-factor-slope-length-and-steepness-factor-eu
[16] Precipitation data: http://www.dmi.dk/klima/klimaet-frem-til-i-dag/danmark/
[17] Kronvang et al (1995): http://www.dmu.dk/1_Viden/2_Publikationer/3_fagrapporter/rapporter/FR178.pdf
[18] USLE and SDR: http://www.iwr.msu.edu/rusle/sdr/sag-sdr.htm
[19] Lee and Kang (2013): https://www.ncbi.nlm.nih.gov/pubmed/23823548

amounts of used product (handelsmiddel) for each crop type is used to derive the amount of active ingredient used for each year and farm. The Danish Agricultural Agency (Landbrugsstyrelsen) has information on types and locations of fields and crops (FC) in Denmark, which together with SJs is used to estimate the locations of use of active ingredients (PS). Spills of pesticides during transport, storage, filling, spraying, cleaning, management of residual spray and maintenance or overdosing are not covered in any database.

Diffuse atmospheric depositions in kg / km$^2$ from Danish and foreign sources are found in MSC-E for a limited number of PS and sources. From this and information on area of surface waters, the direct atmospheric depositions to surface waters can be calculated. Atmospheric indirect loads to surface waters, e.g. via sewer systems are calculated as point sources (shown above for point source information), and via soil as erosion or surface run-off.

Regarding the contribution of PS to surface waters from the groundwater, there is an ongoing project, a collaboration between GEUS, DCE / AU and the Danish EPA, with the purpose to develop a method to identify watercourses and coastal areas that have a significant inflow of groundwater. Furthermore, the project will investigate if pollutants in the groundwater contribute significantly to the concentration of pollutants, e.g. PS, in the surface waters, and if the water quality standards are exceeded (good chemical status). The project is finalized medio 2018, where data will be available for implementation in the strategy presented here.

**Diffuse urban**

Combined sewer overflows in urban settings account for large percentages of releases of PS. The calculation of pollutant load discharged via storm sewers may be based on a regionalized and area specific surface load (e.g. kg / km$^2$) for any pollutant under consideration (GD# 28) see the PRTR and PULS databases. This specific surface load is derived from observed runoff concentrations, which are retrievable from the PULS, PRTR database and site-specific precipitation data, which is retrievable from the Danish Meteorological Institute (DMI)[20]. It is assumed, that it is realized every year independent of the inter-annual variation of precipitation (GD# 28).

For combined sewer systems, the overflow rate and the proportion of discharged wastewater that is mixed up with the storm water should be estimated. The overflow rate is strictly dependent on the storage volume realized in the catchment and the hydraulic capacity of the wastewater treatment plant (GD# 28). The wastewater treatment plant specifications can be retrieved from PULS, PRTR and from the local WWTP.

### 4.2.4 Tier 4: Source Oriented Approach and Substance Flow Analysis

The source oriented approach is a method for analyzing the flows of a substance in a well-defined system, including through industries producing and using it, consumer use in households, energy production, road and ship transport, agriculture, waste and wastewater treatment plants and all connected media such as soil, air and water. Substance use amounts can be assigned to activities and product uses and allocated to the activities or sectors where the activities occur or products are used. Multiplication with emission factors that describe the release fraction, will estimate releases to the environmental media for each PS and activity. Commercial and use activity data can

20 DMI: www.DMI.dk

be derived from inventories of goods and their PS concentrations, statistical data on the use of PS in different economic sectors and concentration of PS in raw materials and production data. Data can be compiled from SPIN, Statistics Denmark (SD), EUROSTAT[21], DK-PRTR, E-PRTR, REACH and specifically from local trade organizations as needed on industrial data.

Emission factors for releases to air can be compiled from the EMEP/EEA air pollutant emission inventory guidebook[22]. Additional emission factors can be estimated by investigating EU Risk Assessments and REACH Annex XV dossiers, registrations under REACH and the OECD Emission Scenario Documents (ESDs)[23]. For the standardized supply chain communication of environmental assessments under REACH, a number of industry sector groups and trade associations have developed Specific Release Categories (SPERCs)[24], which describe typical operational conditions that are relevant with regard to the emissions of substances to the environment.

An advantage of the source-oriented approach is that if all fluxes are known, it is possible to identify the most efficient emission reduction (GD# 28). However, the requirements in terms of data compilation and availability, as well as the description of the often complex spatial and temporal systems (sources, use amounts, emissions, flows), can be significant.

An important method to implement the analysis is the Substance Flow Analysis (SFAs) (GD# 28), which is a simplified life cycle analysis (LCA) based on the principle of substance mass balance:

$$\text{Input} + \text{formation} = \text{output} + \text{degradation} + \text{accumulation} \qquad \text{Eq (7)}$$

The procedure of estimating releases from point and diffuse sources from activity data and emission factors also applies here. Lassen and Hansen (2000) provide a framework from SFA in Denmark[25], as well as a case study (Lassen and Hansen, 2001)[26].

The SOCOPSE[27] project is an example of European sources and fluxes and endpoints in the environment for selected PSs (GD# 28).

In cases where data are not available, releases can be modelled based on the fugacity model SimpleTreat[28] combined with site-specific wastewater treatment plant specific data, as required in the model. Emission factors can also be assessed.

It is important to note that even though national data may be of high quality because they were compiled accurately; downsizing to the regional level can

21 EUROSTAT: http://ec.europa.eu/eurostat
22 EMEP/EEA air pollutant emission inventory guidebook: https://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep
23 OECD Emission Scenario Documents (ESDs): http://www.oecd.org/env/ehs/risk-assessment/emissionscenariodocuments.htm
24 SPERC: http://www.cefic.org/Documents/IndustrySupport/REACH-Implementation/Guidance-and-Tools/SPERCs-Specific-Envirnonmental-Release-Classes.pdf
25 Lassen and Hansen (2000): http://mst.dk/service/publikationer/publikationsarkiv/2000/dec/paradigm-for-substance-flow-analyses/
26 Lassen and Hansen (2001): http://onlinelibrary.wiley.com/doi/10.1162/108819802766269601/pdf
27 SOCOPSE: www.socopse.se
28 SimpleTreat: http://www.rivm.nl/en/Topics/S/Soil_and_water/SimpleTreat

incorporate errors. Particularly for PSs, use and emission figures can decrease steeply in the space of a few years, so that the corresponding emission factors become worthless. As a result, it is necessary for a SFA to cite information about the time and regional frame for each figure used (GD# 28).

#### 4.2.5 Step 3: Identification of data gaps for the selected tiers and assessment of efforts needed to close the identified data gaps

The assessor needs to address the identified data gaps as well as the efforts needed to close these – e.g. more research in finding the data, or if new research is needed, to develop the data.

#### 4.2.6 Step 4: Final decision on method selection (substance-specific) for the current inventory compilation

Based on the previous steps, the assessor will decide and qualify the methods applied for the specific PS for each RBD.

#### 4.2.7 Step 5: Formulation of tasks for the next river RBMP (substance-specific), if improvements are necessary in the inventory, e.g. by use of higher-tier approaches

The inventory should assess the required tasks for the next RBMP based on the analysis in the preceding four steps and determine the need to move to higher-tier approaches of the analysis.

#### 4.2.8 Step 6: Preparation, check and refinement of the substance-specific inventories.

The inventories should be completed and assessments should be updated with the relevant frequency determined by the authority. The inventory should be able to assist in establishing and implementing targeted reduction of emissions, discharges and losses of PS eventually leading to the cessation of emissions, discharges and losses of Priority Hazardous Substances (PHS) (e.g. by identifying the main sources, their relative share with respect to pollution and, their pathways) (GD# 28).

- Demonstrate the efficacy of RBMP Programmes of Measures (PoM)
- Assess if or to what extent monitored concentrations are caused by natural sources or processes (e.g. geo-genic background) or long-range transport processes
- Support the Commission in checking compliance with the environmental objectives under the WFD
- Assist in checking the effectiveness of measures implemented to achieve the reduction and phasing out of emissions required by the provisions of the WFD
- Identify gaps in knowledge and hence where there is a need to develop new strategies / policies
- Assist with the implementation of the Marine Strategy Framework Directive (MSFD)
- An emissions inventory can therefore assist in a range of ways with the implementation of the WFD (GD# 28)

# 5 Theoretical case example

To illustrate the procedure outlined in this report, a demonstration of the first two steps with substance A. Substance A is on the NOVANA list. The example comprises loads to RBD 1 and the surface water bodies therein.

## 5.1 Step 1: Relevance analysis

Substance A is on the **NOVANA** list and found in a watercourse (see Fig. 1).

Search (**ODA**: vandløb (watercourse): vandkemi (water chemistry): miljøfarlige stoffer (pollutants): latest 3-5 years: substance A).

Search result: Substance A fulfills criterion 2, i.e. the concentration exceeds half of the EQS, see statutory order 439[29], in more than one water body.

Hence, the substance is relevant - proceed to step 2 below.

## 5.2 Step 2: Survey of method and available information needed for the different tiers

### 5.2.1 Tier 1: Point Source Information

Search (**E-PRTR**: search the register: pollutant releases: RBD: latest year: all sectors: all activities: substance A: water).

Search result: X1 kg/y release from one facility to RBD 1. The recipient surface water body can be identified from information on the location of the facility.

Search (**DK-PRTR**: substance A: water (recipient): latest year).

Search result: In addition to the facility identified in E-PRTR, there is an additional facility that releases X2 kg/y. Identify the receiving surface water body and check if it is in RBD 1, from information on the location of the facility[30].

Check **PULS** through the **Topic Center for Point Sources**, Østjylland, for further information on releases to surface water bodies from point sources, e.g. WWTP and rain related discharges. For additional point sources, multiply the concentration of substance A in the discharge with the annual water flow and attribute the resulting release in kg/y to the relevant surface water body. Check if this is in RBD 1 from information of location of the point sources.

[29] https://www.retsinformation.dk/Forms/R0710.aspx?id=180241

[30] In principle, the facilities in E-PRTR should be included in DK-PRTR and the releases from facilities occurring in both PRTR's should be identical. However, this should be checked and furthermore, the E-PRTR has additional information on the recipient RBD, which may be useful when estimating total releases to RBDs.

### 5.2.2 Tier 2: Riverine Approach:

For each surface water body that receives point source releases of substance A, calculate the sum of point source releases (Dp) in kg/y.

Find measured concentrations of substance A in the surface water body from **ODA**.

Search (ODA: retrieve data: vandløb (watercourse): vandkemi (water chemistry): miljøfarlige stoffer (pullutants): latest 3-5 years: substance A).

Search (ODA: retrieve data: vandløb (watercourse): hydrometric (hydrology): døgnvandføring (daily water flow)).

Search results: concentration of substance A in mg/L, daily flow in $m^3/s$, location of water quality monitoring station.

For each surface water body that has measured concentrations of substance A; calculate the total annual load of substance A (Ly) in t/y, from Eq 1 and the ODA search results.

If information on the natural background load of substance A and the net outcome of in-river processes upstream of the monitoring points are available, then calculate these as LB (in t/y) and NP (in t/y), respectively.

For each water course that has measured concentrations of substance A, calculate the anthropogenic diffuse and unknown loads of substance A from Eq 3: LDiff = Ly – Dp (– LB + NP) in t/y.

Table 2 shows an overview of the emission estimates from point and anthropogenic diffuse sources (incl. scattered settlements) and unknown loads of substance A. The natural background and net outcome of in-river processes are also indicated in the table.

The contributions of these sources and processes in percent relative to the total annual load of substance A in the water bodies 1 and 2, respectively, are stated in Table 3.

Table 2 Overview of the point and diffuse emissions and riverine loads in kg/year of substance A in water bodies 1 and 2 in RBD1.

| Emissions and loads | | RBD1 | |
|---|---|---|---|
| | | Water body 1 | Water body 2 |
| Point sources | Facility 1 (E-PRTR) | X1 | - |
| | Facility 2 (DK-PRTR) | - | X2 |
| | Sum point sources (Dp) | Dp1=X1 | Dp2=X2 |
| Natural background (LB) | | LB1 | LB2 |
| In-river processes (NP) | | NP1 | NP2 |
| Anthropogenic diffuse and unknown (LDiff) (Eq 2 or 3) | | LDiff1 | LDiff2 |
| Total annual load (Ly) (Eq 1) | | Ly1 | Ly2 |

Table 3 Contribution of sources and processes in % relative to the total annual load.

| Emissions and loads | | RBD1 | |
|---|---|---|---|
| | | Water body 1 | Water body 2 |
| Point sources | Facility 1 (E-PRTR) | x1 % | - |
| | Facility 2 (DK-PRTR) | - | x2 % |
| | Sum point sources (Dp) | dp1 % | dp2 % |
| Natural background (LB) | | lb1 % | lb2 % |
| In-river processes (NP) | | np1 % | np2 % |
| Anthropogenic diffuse and unknown (LDiff) (Eq 2 or 3) | | ldiff1 % | ldiff2 % |
| Total annual load (Ly) (Eq 1) | | 100 % | 100 % |

### 5.2.3 Tier 3: Pathway Oriented Approach

The pathway-oriented approach is site and substance specific. The procedure is to combine the point sources derived in Tier 1 with a higher degree of differentiation of the diffuse sources. These are now divided in diffuse non-urban and diffuse urban sources including scattered dwellings.

This means that Table 2 can be expanded with diffuse non-urban loads from the direct discharge and spray drift to surface water bodies for Plant Protection Products (PPPs) by using the pesticide spray journals (Sprøjtejournaler, SJ) and geographic information on crop (FC). Non-urban sources also include indirect loads of PPPs to surface waters via erosion, surface run-off, tile drainage and seepage, where erosion is described above.

Furthermore, atmospheric deposition from Danish and foreign sources directly to surface waters can be found in MSC-E, see Table 1. Atmospheric indirect loads to surface waters, e.g. via sewer systems, are included in the point sources, and via soil as erosion or surface run-off. Diffuse loads to surface waters from the groundwater are currently being investigated and the results will be available after the finalization of the project, medio 2018.

Diffuse urban loads from combined sewer overflows, where the overflow rate and the proportion of discharged wastewater that is mixed up with the storm water, should be estimated. The calculation of pollutant load discharged via storm sewers can be based on a regionalized and area specific surface loads derived from observed run-off concentrations, which are retrievable from the PULS and PRTR databases, and site-specific precipitation data, which is retrievable from the Danish Meteorological Institute (DMI) (GD# 28).

This tier allows identification of the main sources and regional hot-spots of emissions, and will therefore provide the basis for an accurate inventory. The tier always requires process studies and input data, which allow for the formulation of sub-models. Due to the fact that these process studies may be limited, the identification of the necessary variables, in a way that enables wide application of such models, may prove challenging (GD#28).

### 5.2.4 Tier 4: Source Oriented Approach and Substance Flow Analysis

The level of detail is increased further in this tier as it is based on substance specific information on production, sales and consumption. This information and data are used to calculate emissions from activities by using substance and activity specific emission factors, and modelling the flow of substance in the environment to surface water bodies.

Substance flow analysis requires in-depth analysis of data and development of flow models and offer the possibility to identify and quantify primary sources and to give a complete overview of the substance cycle, see examples above. Review the REACH, SPIN and Statistics Denmark databases to determine the uses, sources and commercial flows of the substance. With this information increase granularity of the data by retrieving local information via trade organizations, local business organizations and associations.

# 6 Discussion

This report provides an overview of the technical guidance in the EU Guidance Document No. 28; Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances Technical Report – 2012-058 – the EU Water Directors endorsed the Guidance Dec 8-9 2011. Moreover, the report provides information on data sources that are relevant for establishing inventories for Danish river basin districts. Data needs and model complexity increases as one moves through the steps of the compilation. Significant amounts of site-specific data are currently not available in the databases and thus will need to be developed on a case-by-case basis for the inventory generation. Gathering this data can be work intensive and it is beyond the scope of this report to document all the data gaps.

For practical purposes, we have illustrated the procedure of step 1 and 2 of tier 2 of the inventory in a theoretical case example of a specific priority substance at the NOVANA list. Steps 3-6 are qualitative and substance and site-specific and a result of the outcome of step 1 and 2 analyses, hence they will not be further elaborated on here. It is, however, important to note that the inventory analysis is iterative and should provide input to the subsequent river basin specific programmes of measures (PoM).

The compilation of the inventory is an iterative process leading to more priority substances and site-specific recommendations for the river basin management plans for limiting the releases of priority substances to surface waters. Achieving this requires a significant effort and detailed analyses and calculations. Much of the data and models needed are available in a Danish context, but there are also gaps, which need to be addressed. There are temporal and spatial extrapolation uncertainties in the available data, which will require further analytical work, among others downscaling to the specific / local river basin district of interest – e.g. scattered dwellings in Denmark. Local data often require direct contact to local experts, e.g. regarding farming practices and other site specific matters that govern releases (e.g. soil type, precipitation, etc.) in developing local substance flow analysis.

In conclusion, performing the first step (relevance analysis) and the two first tiers in step 2 is straightforward in a Danish context, and the listed databases can supply high quality data to be used herein. However, the spatial and temporal coverage of data varies significantly for the different priority substances. For some priority substances, there is a relatively large amount of data and here the challenge lies in compiling, preparing and analyzing these. For other priority substances, there is a relatively limited amount of data and here searching information and generating data, from the literature and from producers, manufacturers and industries releasing priority substances, are needed.

Performing Step 1 and 2 of the inventory will reveal data gaps and accessibility of data, and will thus reveal, which substances are more readily inventoried at present than others are. A rapid initial review of all priority substances in the relevance analysis (Step 1) would help prioritize the priority substances. The list could moreover be reviewed in terms of the substance's general risk profile. Subsequently the results of these analyses could be checked against data availability prior to inventorying.

In the longer-term, a GIS-based model such as the WEISS system[31] developed in Belgium to support their emission and losses inventory compilation seems potentially to be a transparent and cost-effective solution for generic data entries. The conceptual model behind the system could be considered replicated in a Danish context to streamline revisions and updates to assessments and inventories.

The EU Guidance Document No. 28; Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances Technical Report – 2012-058[32] provides the most comprehensive methodology needed to assess point and diffuse emissions of priority substances to surface waters in Europe. Following these guidelines represents best practice to fulfill the statutory order section 6, subsection 2[33], concerning the determination of priority substances emissions to Danish surface waters by assessing and identifying significant point sources and diffuse sources of priority substances being emitted, discharged or lost to surface waters in Denmark.

31 http://weiss.vmm.be/geoloket/

32 https://circabc.europa.eu/sd/a/6a3fb5a0-4dec-4fde-a69d-5ac93dfbbadd/Guidance%20document%20n28.pdf

33 https://www.retsinformation.dk/Forms/R0710.aspx?id=181972

PREPARATION OF AN INVENTORY OF EMISSIONS AND LOADINGS OF PRIORITY SUBSTANCES TO DANISH RIVER BASINS

This report reviews the preparation of an inventory of emissions and loadings of priority substances to Danish river basins. It outlines the methods in the EU Guidance Document No. 28, Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances, Technical Report – 2012-058, which can be used to develop the inventory.

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