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List of abbreviations

CF	Characterisation factors
CLTAP	Convention on long-range transboundary air pollution
EMEP	European monitoring and evaluation programme
E-PRTR	European pollutant and releases transfer register
GDP	Gross domestic products
HMs	Heavy metals
NFs	Normalisation factors
NMVOC	Non methane volatile organic compounds
WWTP	Waste water treatment plant

Executive summary

Normalisation is an optional step of Life Cycle Assessment (LCA) that may help the assessment of the relative magnitude of a certain impact category relative to that of a reference system. Compared to other impact categories, toxicity-related normalization factors were considered less robust, especially due to a limited substance coverage.

This work presents an extyended set of normalization references for Europe and the world, adopting USEtox as impact assessment model. The base year for the inventory is 2010, with some documented exceptions due to lack of updated data. Emission data was extracted from several sources at a European level and from relevant sources from USA, Canada, Japan and Australia. European emission data was combined with available data from the rest of the world in order to obtain the most complete picture of emissions taking place at a world scale. Emissions of substances available only at European level were complemented by substances for which data was available in sources gathered in the rest of the world. The overall extrapolation strategy was based on both GDP (gross domestic product) and CO_2 emission. The inventory sets were characterized with the characterization factors (CFs) calculated with the USEtox model and database. The analysis was based on the CFs which were reported by USEtox, including those referred to as recommended and those defined as interim. Variation in the coverage and in the assumptions for the different datasets was detected, and may have led to discrepancies in the inventory. The current study acquired more up-to-date emission and extraction data compared to earlier efforts, extending where possible the quality of the emission data. It represents the most updated set of normalization references for Europe and the world.

Development of normalization factors for human toxicity (cancer and non-cancer) and eco toxicity using ILCD 2011 characterization factors

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1 Introduction

The present deliverable aims at documenting the establishment of an emission inventory relevant for toxicity-related impact assessments. The inventory has been further used for calculating normalisation references and associated factors (NFs) for Europe and the world for the toxicity-based impact categories, i.e. freshwater ecotoxicity, human toxicity (cancer effects) and human toxicity (non-cancer effects) – adopting USEtox as impact assessment model (www.usetox.org/ ; Rosenbaum et al. 2008).
The emission inventory for Europe is developed for the year 2010 and primarily covers the EU-27+3 countries. It covers releases to all emission compartments, i.e. soil, water, air.
The report is organized as follows: firstly, we present the state of the art in normalization studies; secondly, we show the result of the inventory at European and Global level; lastly, the methodology for extrapolation are reported and discussed.
An overview of the inventory divided in its major elements is provided in section 2.1. Data sources are given in the main table. Detailed documentation for each inventory element is provided in sub-sections 3.
The inventory for EU-27+3 has been used as a basis for extrapolation to world emissions according to the criteria defined in section 3.3.1.
Normalisation references for the year 2010 are available in Table 11 and Table 12 of this report. The inventory of flows are reported in supplementary material.

1.1 State of the art in normalization

According to ISO 14044 (ISO 2006), normalization is an optional interpretation step of a complete LCA study. Normalisation allows the practitioner to express results after characterization using a common reference impact (Laurent at al. 2011a) and it may be particularly of help if results need to be communicated to policy makers. Using normalization references in combination with weighting factors, the relative magnitude of an impact may be related to other impacts in the life cycle with a common unit. Although, in this case the interpretation needs to carefully consider the changes introduced into the results by the normalisation step. A reference region is commonly chosen to represent the background environmental burden related to all activities (e.g. economic, production activities), in that region. During the inventory phase, data is collected to represent all production activities that are, more or less, dominant in the region. In the case of this work, the inventory has been put together gathering information from several sources on toxic substances which are emitted at the European (i.e. EU-27+3) and the world level. Data at the European scale was collected first. It was then complemented by data available for the most significant non-EU countries in terms of contribution to the world GDP for which data was available (i.e. USA, Canada, Japan, Australia). At a EU-27+3 level as well as world level the reference year of choice was

2010. In all cases where data was not available for this reference year, meaningful assumptions were necessary to quantify the data for 2010.

Normalisation values need to be regularly updated to be meaningful and to provide normalization references that can be used by practitioners. Several normalization efforts are available to date. Starting from the reference year 2000, Sleeswijk et al. (2008) produced normalization references for European and the global economic systems. The work considered fifteen different impact categories for the year 2000. For the toxic emissions, the ReCiPe (Heijungs et al. 2003) LCIA model was used. Different criteria, according to the different impact categories under consideration, were used for the extrapolation of European emissions to the Globe. For toxic substances the extrapolation was based on GDP of the countries for which data was available.

Laurent and co-authors (2011b) developed normalization references for Europe and North America using USEtox impact categories, in a similar fashion as in the present study. The reference year considered for the EU was 2002, while 2002/2008 was considered for North America. The inventory for Europe covers 38 countries from a number of databases and monitoring bodies across countries. In Laurent et al. (2011a) EDIP97 and EDIP2003 are used as an LCIA model for the year 2004 for Europe.

The work by Lautier et al. (2010) focused on the calculation of normalization references for North America using the IMPACT2002+ LCIA model. This work was also used as a basis for the modeling of North America by Laurent and co-authors.

Additionally, EC-JRC has recently released the results of the LC-indicator project (EC-JRC 2012a, b) in which normalization references are calculated for 2004, 2005 and 2006 accounting for the territorial emissions and identifying emissions due to import and exports of products (EC-JRC 2012c).

2 European inventory and world inventory

2.1 Overview of European emission inventory for reference year 2010

In order to establish an European inventory, as comprehensive and complete as possible, several sources have been analysed and processed. Table 1 provides an overview of the inventory coverage in terms of substance groups/emission sources and countries, highlighting the major advancements compared to previous normalization studies.

Compared to earlier works, more data, particularly with regard to emissions to water and soil, have been made available via different sources such as databases (e.g. the European Pollutant and Releases Transfer Register, E-PRTR; EEA, 2012) and reports (e.g. from the EU Commission). Along with documenting data sources, Table 1 presents a synthesis of the different consistency/completeness gains compared to earlier works for each of the major elements of the emission inventory (in last column). In the course of the inventory development, a number of limitations were also identified and key points for enhancing the completeness and robustness of the inventory were listed. Full documentation for each inventory element, including identified limitations and improvement potentials, is provided in following sections.

Table 1. Overview of substance groups, related data sources, limitations in European emission reports and planned refinements

Substance groups	Data sources	Coverage estimate (countries /subst.)*	Reference year	Uncertainties and/or limitations	Importance in total inventory §	Further work	Added value compared to existing inventories
Air emissions							
Heavy metals (HM)	CLTAP/EMEP (EMEP 2013)	Good	2010	- Gaps for few countries	Minor	- Check with gap-filled reports by EMEP for discrepancies (country totals only) - Fill in gaps using adequate extrapolation/interpolation parameter - Inclusion of emissions of other metals from other inventories (e.g. US inventory)	- Similar to previous works, except for some heavy metals (e.g. V, Al, Tl...) included in Wegener Sleeswijk et al. (2008) using data from regions outside EU.
Organics (non-NMVOC): e.g. dioxins, PAH, HCB…	- CLTAP/EMEP (EMEP 2013) - E-PRTR (EEA 2012)	- Good (EMEP) - Medium/Poor (E-PRTR)	2010	- Gaps for some countries (substance-specific coverage)	Minor	- Check with gap-filled reports by EMEP for discrepancies (country totals only) - Fill in gaps using adequate extrapolation/interpolation parameter (for data from both sources) - Inclusion of emissions of other organics from other inventories	- Similar to previous works, except for substances from E-PRTR not covered in Laurent et al. (2011a; 2011b). - Substance form E-PRTR used in in LC Indicator project (EC-JRC 2012 a,b,c) but

Substance groups	Data sources	Coverage estimate (countries /subst.)*	Reference year	Uncertainties and/or limitations	Importance in total inventory §	Further work	Added value compared to existing inventories
							accounting for fewer substances (as the coverage for 2006 was limited).
NMVOC	Total NMVOC per sector from EMEP/CORINAIR (EMEP 2013)	Good	2010	No major uncertainties identified (see further details in Annex I)	/	/	- Not existing in earlier works with such consistency and completeness
	- Literature sources (speciation per sectors) - Databases + CORINAIR for sector activity modelling	Good	- Different assumptions/ sources for speciation profiles - 2010 (sector activity data)				
Water emissions							
Industrial releases of HM + organics	- E-PRTR (EEA 2012) - Waterbase (EEA 2013)	- Good (HM) - Medium/Low (Organics)	- 2010 (E-PRTR) - 2009 (Waterbase)	- Gaps for many countries (organics mainly) - Existence of minimum thresholds for reporting	Medium/Large	- Fill in gaps using adequate extrapolation/interpolation parameter(s) - Inclusion of emissions of other metals and organics from other inventories?	- Less completeness and consistency in previous inventories: - Raw data from EPER (very incomplete)

Substance groups	Data sources	Coverage estimate (countries /subst.)*	Reference year	Uncertainties and/or limitations	Importance in total inventory §	Further work	Added value compared to existing inventories
				industrial releases, leading to underestimations (partly filled in using the Waterbase data)			used in Wegener Sleeswijk et al. 2008 - Riverine inputs to seas (very uncertain) used in Laurent et al. (2011a) - No inclusion of industrial releases in LC Indicator project.
Urban WWTP (HM + organics)	- Waterbase, OECD (2013), EUROSTAT (2013)	Poor (EU-27+3 covered via extrapolations from very few countries)	2009	- Raw data only available for few countries, with NL and RO being the most documented - Extrapolation based on emission archetype per inhabitant	Medium/Large	- Refinement of the approach, testing of the assumptions - Assess the feasibility and relevance of extrapolations in time to increase substance coverage and test assumptions - Inclusion of emissions of other metals and organics from other inventories?	- See above cell for treatment in Wegener Sleeswijk et al. 2008 (EPER) and Laurent et al. 2011a (riverine inputs). - Use of similar approach based on shares of population connected to WWTP and Waterbase

Substance groups	**Data sources**	**Coverage estimate (countries /subst.)***	**Reference year**	**Uncertainties and/or limitations**	**Importance in total inventory §**	**Further work**	**Added value compared to existing inventories**
							emission data in LC Indicator project
Oil compounds	- CONCAWE sources.	/	/	- Not checked (direct emissions to marine environment left out) - Speciation of oil can be difficult (large variability) - Allocation to countries can be difficult	/	/	- /
Soil emissions							
Industrial releases (HM, POPs)	E-PRTR (EEA 2012)	Poor	2010/2009	Territorial coverage very limited (total of 8 countries)	Minor/Medium	- Fill in gaps using adequate extrapolation/interpolation parameter - Inclusion of emissions of other metals and organics from other inventories?	- Not covered in Laurent et al. (2011a). In LC Indicator project (EC-JRC 2012 a, b, c) emission to soil are related to imported products only. Included in

Substance groups	**Data sources**	**Coverage estimate (countries /subst.)***	**Reference year**	**Uncertainties and/or limitations**	**Importance in total inventory §**	**Further work**	**Added value compared to existing inventories**
							Wegener Sleeswijk et al. 2008 from raw data for The Netherlands and Canada
Sewage sludge (containing organics and metals)	- EEA (2012) + EUROSTAT (2013) for usage - EC (2010) for HM composition - EC (2001) for dioxins	Good (HM)	- 2009/2010 for sewage sludge applied to agriculture; - HM speciation: 2006/5 - Mid – 90s for dioxins composition	- None for HM. - Substance groups are typically reported for organics (EC 2001) - Out-of-date data for organics	Minor	- Need to find organic species profiles (if possible, country-specific). - Refinement on organics could be coupled with Urban WWTP releases (?)	- Heavy metals covered in Laurent et al. (2011a) with same approach; no organics covered. - Not covered in Wegener Sleeswijk et al. (2008)
Manure	FAOSTAT(2013), Amlinger et al. (2004), Chambers et al. (2001)	Good (HM)	- 2010 for manure use - Older than 2004 for composition	- Out-of-date composition data - Composition data provided as ranges covering several European countries - Organics missing	Minor/Medium	- Refinements of estimation techniques for dry matter on land - HM composition to differentiate and update, if possible - Need to find organic species profiles (if possible, country-specific).	- Heavy metals covered in Wegener Sleeswijk et al. (2008) from data for the Netherlands - Not covered in Laurent et al. (2011a) nor in LC Indicator

Substance groups	**Data sources**	**Coverage estimate (countries /subst.)***	**Reference year**	**Uncertainties and/or limitations**	**Importance in total inventory §**	**Further work**	**Added value compared to existing inventories**
				- Calculation for estimating dry matter (dm) applied to land			project
Pesticides							
Active ingredients (AI) breakdown	- Use of EC (2007) - Pesticide usage data: FAO (2012) (F, H, I, O + chemical classes) + EUROSTAT (2013) for second check - Use of extrapolations for AI differentiations - EUROSTAT (2013) for crop harvested areas	Poor/Medium	- Usage stats: 2009-2010 for many EU-27+3 countries (FAOSTAT/EUROSTAT data) - Dosages taken for 2003 (assumed applicable to 2010) - Crop data from 2010	- Incomplete data because only top-5 AI per crop reported (when not confidential) - Substantial category “Others” (>25w% total); some a.i. with low dosage but high toxicity may thus not appear in inventory - Extrapolations from 2003 to 2010 only based on harvested area - BG and RO not reported	Major	- Need for establishing consistent framework to determine inventories of applied AI that reach the soil or the plant (using available data)	- Breakdowns of AI in Laurent et al. (2011a) extrapolated from data in DK only (very uncertain) - Breakdowns in Wegener Sleeswijk et al. (2008) from data in The Netherlands, UK and USA (very uncertain) - Use of similar approach (combination of AI data with PestLCI1.0 or 2.0 with crude assumptions) in Laurent et al.

Substance groups	Data sources	Coverage estimate (countries /subst.)*	Reference year	Uncertainties and/or limitations	Importance in total inventory §	Further work	Added value compared to existing inventories
				- Inconsistencies with pesticide use reported by FAO			(2011a) and LC Indicator project; Wegener Sleeswijk et al. (2008) considered the emissions to agricultural soil equal to total pesticides applied on land.
Fate technosphere → biosphere	- PestLCI model (Dijkman et al. 2012) - Soil data - Climate data - Agri land data	/	Data representative for year 2010	- PestLCI not operational for such large scale assessment (country, soil, substance coverage) and need refinements before being operational	Major	Selection of the emission model needs to be justified. PestLCI needs to be made operational Collection of the necessary data, incl. climate data, crop-specific treated areas per country, substance data, etc.	
Human toxicity from plant uptake	- Fantke et al. 2011	NA	NA	- Left out for now (also not part of USEtox yet)	/	To be considered in future the inclusion of human toxicity assessment based on model by Fantke et al. 2011 (not included in ILCD, but may be option to include it later)	/

* completeness of the background data in terms of geographical coverage in Europe. The coverage of the emission data are estimated with respect to countries covered (out of EU-27) and substances included (e.g. number of substances considered) based on 'expert judgment';

§ Estimate of influence of data gaps or limitations on the completeness and consistency of the inventory. The "Importance in total inventory" is estimated based on knowledge from contribution analyses of previous normalisation works (e.g. Laurent et al. 2011b with USEtox; Wegener Sleeswijk et al. 2008)

2.2 Data gap filling framework

The analysis of the inventory data collected for EU-27+3 for the reference year 2010 highlighted, for certain substances, a limited availability of emission data. With regard to waterborne emissions, data for 62 substances (9 HM, 53 organics) could be retrieved. Large discrepancies in the country coverage occurred, due to the results of variations in industrial activities from one country to another or due to incomplete reporting for some countries. In the case of e.g. 1,1,1-trichloroethane, only the emission value for Norway was reported (i.e. 1,07E-09 kg to water in the year 2010). In this case, as for others in the inventory list, the extremely low value of the emission (~ 1µg) may hint to under-reporting of emission data.

As stated in Sleeswijk et al. (2008), depending on the type of emission to be assessed, many different types of estimation factors are possible. To fill the data gaps for certain countries, GDP (gross domestic product; World Bank 2012) was used and assumed to be related to the industrial production and the relative releases. GDP was used to interpolate in space (i.e. across countries) the available emission data from E-PRTR, in order to obtain a more sensible estimate of the emission of substances to the level of the EU-27+3 region as a whole. In the already above-mentioned case of 1,1,1-trichloroethane a total of 3,23E-08 kg was calculated as a total emission to water for EU-27+3 for the year 2010. Similarly, total emission values for other substances were extrapolated from the country level to the EU level.

For those emissions for which data were obtained from European statistical data (i.e. from EEA, EUROSTAT, EU, EMEP), the number of countries reporting a certain emission was used as a proxy for the calculation of the European region as a whole. For a matter of consistency, a spatial GDP-based extrapolation was conducted, using the available information. Emission data for e.g. arsenic (i.e. 2,42E+05 kg to air) originate from EMEP (2013). In this case, data gaps were identified, since emissions from Greece, Luxembourg, Slovenia, and Austria were not available or not reported. Therefore, considering that emissions were recorded by EMEP for EU-27+3, the GDP of the covered countries was used as a proxy for the calculation of the emission of arsenic for those missing countries.

2.3 Cross-comparisons with other inventories

A spatial extrapolation strategy was also applied for the extrapolation of EU values to the world level. The national PRTRs (Pollutant Release and Transfer Registers) of the United States, Canada, Japan and Australia (respectively: US-EPA, 2012 ; Environment Canada, 2012 ; NITE, 2012; AG-DEH,2012) were collected. These constituted the most important data sources for the extrapolation. Data was extrapolated for the compartments: air, freshwater, industrial soil, and natural soil (including landfill).

The inventory for EU was matched with all the other inventories based on an automated search using CAS numbers. When no CAS number was available, each substance was searched by name in the different database and added consequently. In all cases, where no match was found (e.g. misspelled name, or different acronym), substances were searched “by hand” in the different registers and added to the inventory. A greater coverage was available in other registries than the EU one, leading to the addition of a few substances in the total inventory. In general, the US-EPA register provided the biggest coverage. For the Japanese database it was possible to integrate the percentage of facilities (e.g. factory outlet in a specific area of the island of Honshu) that reported emissions for each substance. In all those cases a value for the EU was extracted and the inventory updated accordingly.

3 Detailed documentation on emissions and criteria for extrapolations

3.1 Emissions in the EU

3.1.1 Air-borne emissions

Airborne emissions are typically the most available data because of the effort of several monitoring institutions. Reported groups of substances relevant to toxic impact categories are heavy metals (HM), persistent organic pollutants (POPs) and non-methane volatile compounds (NMVOC). The first two groups are documented together in the section below as data originate from the same source.

Heavy metals and POPs

Emission data for 9 HMs were extracted from the EMEP/CEIP Centre (http://www.ceip.at/). Data were available for 9 HM (As, Pb, Hg, Cu, Cd, Cr, Ni, Se, Zn) and 20 organics, including PAHs, PCBs and dioxins. 11 compounds, primarily pesticides such as endrin or DDT, were set to 0 as their emissions were reported either as “not applicable”, “not occurring” or “not relevant” since 2007. In fact, the use of most of these compounds has been banned in Europe. Additional emission reports for a number of substances, i.e. pentabromodiphenyl ether (PentaBDE), perfluorooctane sulfonate (PFOS), polychlorinated naphthalenes (PCN), pentachlorobenzene (PeCBz), hexachlorobutadien (HCBD), octabromodiphenyl ether (OctaBDE) and short chain chlorinated paraffins (SCCP), are foreseen to be made available via the amended Protocol on Persistent Organic Pollutants (not yet entered into force; UNECE, 2010).

Table 2. Coverage of airborne emissions of HM and POPs

HM	POPs covered	Banned substances (pesticides)
Arsenic	benzo(b) fluoranthene	Chlordecone
Lead	PAH	Endrin
Mercury	Polychlorinated biphenyl (PCB)	DDT
Copper	benzo(a) pyrene	PCP
Cadmium	benzo(k) fluoranthene	Toxaphene
Chromium	Dioxins	Chlordane
Nickel	Hexachlorobenzene (HCB)	Aldrin
Selenium	Hexachlorocyclohexane (HCH)	Heptachlor
Zinc	Indeno (1,2,3-cd) pyrene	Mirex
		Dieldrin
		Hexabromobiphenyl

The EMEP/CEIP Centre provides two sets of emission data: the “Officially reported emission data”, which are emission data that each party is committed to report, and “emissions as used in EMEP models”, where official reports undergo a 3-step gap-filling procedure[3]. In the latter, only the major pollutants are treated, i.e. three main heavy metals (Cd, Hg and Pb) and 3 POPs (PAH or benzo(a)pyrene, PCDD/PCDF and HCB). Some inconsistencies between the two sets may arise because parties submit recalculations of their inventories, including of the previous years, each year whereas the gap-filling procedure is only applied once to the latest reporting year and thus is not updated with the most recent recalculations. For these two reasons, official reports were used.

The completeness of “Officially reported emission data” differs from one country to another and from one sector to another (reports are provided using the NFR09 sectors nomenclature[4]). Uncertainties are strongly dependent on which aggregation level is used. Because only totals for the whole EU-27+3 region are used, without further country and sector disaggregation, these uncertainties are believed to be negligible.

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[3] The procedure involves the Task Force on Emission Inventories and Projections (TFEIP), the European Environmental Agency (EEA), the Centre on Emission Inventories and Projections (CEIP), and the European Topic Centre on Air and Climate Change (ETC ACC), and includes (1) an initial check of the timeliness and completeness of the Party submissions, (2) a synthesis and assessment of the consistency and comparability of the national reports followed by recommendations for data quality improvement, (3) an in-depth review at pollutant and sector levels of emissions from selected Parties.

[4] Nomenclature for Reporting (NFR09) reporting format agreed by UNECE/EMEP is documented in the 2009 UNECE/EMEP Emission Reporting Guidelines (HHUUECE/EB.AIR/97UUHH)

Current limitations are related to: i) the limited coverage of substances (organics and heavy metals); ii) gap-filling, e.g. using emission data following the gap-filling procedure conducted by EMEP, not accounted for in the current inventory; iii) Greece and Luxembourg as well as a few other countries typically do not report their emissions, depending on the substance.

Three aspects may represent a future enhancement, namely: a) a comparison with EMEP gap-filled emission data for the available substances; b) filling in gaps for GR, LU and other relevant countries based on the most adequate extrapolation/interpolation parameter (e.g. check the EMEP technique); c) assessing the possibility and relevance to include additional substances using extrapolations based on reporting of specific sectors from other regions' inventories (e.g. US inventory).

Non-methane volatile organic compounds (NMVOC)

NMVOC emissions are typically reported as a group and not as species profiles, which are distributions of single substances composing NMVOC emissions from a considered source. The occurrence and magnitude of single substance emissions can vary considerably depending on the emission sources. Hence, a bottom-up approach was applied to use NMVOC speciation profiles per sector of activities.

The total NMVOC emission data were retrieved from the EMEP/CEIP Centre (http://www.ceip.at/) using "Officially reported emission data". Data were extracted at country- and sector-disaggregated levels. 117 sectors (NFR09 codes) are distinguished –see Appendix I. Ten sectors were disregarded because they either relate to NMVOC emissions from natural sources (e.g. forest fires) or because no emissions of NMVOC are reported for any countries (10-yr time series were also checked for potential occurrences; e.g. road abrasion or tyre and break wear). Emissions in the category "7 B - Other not included in national total of the entire territory" were also disregarded.

Speciation profiles (i.e. breakdown of NMVOC single substances) were allocated to each of the remaining 107 sectors, following the methodology for speciation modelling proposed by Laurent et al. (2013). Speciation profiles were retrieved from different literature sources as well as from CORINAIR emission inventory reports (2007, 2009), which provide documentation on a sector basis for a number of pollutants. Theloke and Friedrich (2007) provided a database of 86 speciation profiles for Europe using the SNAP97 code nomenclature; it was used for all sectors NFR09 1, NFR09 2 and NFR09 3. Other literature sources were used for the sectors NFR09 4 and NFR09 6 (such as Lemieux et al. 2004, Allen et al. 1997).

Most of the available speciation profiles are source-oriented, e.g. for "coal combustion" processes, and do not always match the scope of the sector activities, e.g. "public electricity and heat production". A substantial number of NFR09-coded sectors thus did not link to the availability of the speciation profiles, e.g. reported in Theloke and Friedrich (2007). A framework was developed by Laurent et al. (2013) to assign combinations of several available speciation profiles based on specific activity data within the concerned sectors.

A number of NFR09 sectors did not match the availability of the speciation profiles, e.g. from Theloke et al. (2007). A number of assumptions were thus necessary. Additionally, in some relevant sectors, for which activities vary considerably across countries, it was deemed necessary to differentiate the generic NMVOC speciation provided by Theloke and Friedrich at country level. For example, speciation profiles for stationary combustion or public electricity and heat production (NFR09 1 A 1 a) were adapted to the proportions of fossils used in each EU country in the reporting year (see section 3). Such regionalisation of the speciation profiles was also performed on road-transport-related sectors, which are important contributors to total national NMVOC emissions –see section 4 in Appendix I.

Two situations occurred in the allocation of species profile to the sectors:

- A number of sectors could be directly assigned a species profile corresponding to the activities within the sector code. In such cases, the references from which the species profiles were extracted are documented in Appendix I.

- For other sectors (marked in light orange in Appendix I), direct assignation could be made and combinations of several speciation profiles were performed using activity data (e.g. country-specific mix of fossils + biomass in electricity and heat production used to combine the speciation profiles per types of fuels for sector 1 A 1).

Industrial emissions of heavy metals and organics

The data considered here are taken from the E-PRTR database (http://prtr.ec.europa.eu/; EEA 2012), which contains information on releases from industries[5]. Accidental releases are also included in the source database. In a normalization context, this may pose a problem if these releases led to a substantial emission peak in the considered reference year compared to the situation in other years, thus ultimately resulting in a bias. For this reason, most accidental releases are disregarded in a normalization inventory. However, if accidental releases occur on an annual basis and in similar quantities, their inclusion could be valid because they would then reflect a typical background load to the environment (no bias from one year to the other). The nature and emissions of the accidents included in the E-PRTR would require to be checked to elude this point.

The scope of the EMEP, which covers all industrial activities and the transport sector, is larger than that of the E-PRTR, which only reports chemical emissions due to specific sectors (as reported in Annex I of the EU regulation 166/2006) and when those emissions are above certain thresholds, as reported in Annex II of the mentioned regulation. In addition, the EMEP reports are related to substances having a long range transport potential; the E-PRTR database does not have such restrictions on substance coverage. Therefore, the EMEP database can be expected to provide more complete data on a limited number of substances, whereas the E-PRTR can be expected to document more substances, but with less completeness in their emission reports. As a result, the E-PRTR data were disregarded in the inventory of air emissions wherever the substance was already covered in the EMEP database. The substances identified as not present in the data extracted from EMEP but reported in E-PRTR were added in the inventory – see Table 4.

Unluckily, so far the country coverage is limited to few countries and few substances and the fact that accidental releases could occur in the inventory may bias the final figure.

This could be object of further research, in order to evaluate the risk of substantial emission peaks due to accidents (e.g. by comparing emission reports from several years)other to operational releases. Additionally, future research may assess the possibility and relevance to include additional substances using extrapolations from other regions' inventories.

Table 4. Additional organic substances from E-PRTR

Substances	Country coverage
1,1,1-trichloroethane	FR, UK
1,1,2,2-tetrachloroethane	BE, GR, UK
1,2-dichloroethane (DCE)	AT, BE, CZ, DE, ES, FR, IT, NL, NO, PL, SE, SK, UK
Anthracene	BE, ES, IT, NL, NO, UK
Di-(2-ethyl hexyl) phthalate (DEHP)	BE, CZ, ES, HU, IT, PL, UK
Dichloromethane (DCM)	BE, CH, CZ, DE, GR, ES, FI, FR, HU, IE, IT, LV, NL, PL, SE, SI, SK, UK
Ethylene oxide	DE, ES, FR, PL, SK, UK
Fluoranthene	NO
Pentachlorobenzene	BE, LU
Trichlorobenzenes (TCBs) (all isomers)	CH, FR, UK
Hydrogen cyanide (HCN)	AT, BE, CZ, DE, DK, ES, FR, HU, IT, PL, RO, SK, UK

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[5] E-PRTR was established through Regulation (EC) No 166/2006. It contains data on the main pollutant releases to air, water and land of about 28,000 industrial facilities across the European Union and EFTA countries. These data represent the total annual emission releases during normal operations and accidents.

3.1.2 Water-borne emissions

Industrial emissions of heavy metals and organics

Data on water-borne emissions of HMs and organics were extracted from the E-PRTR database (http://prtr.ec.europa.eu/), which contains information on releases from industries. In the E-PRTR website, it is claimed that more than 90% of emissions are covered. Emissions to the air compartment were disregarded as NNMVOC, HM and POPs are fully covered by data from the EMEP/CEIP Centre.

With regard to waterborne emissions, data for 62 substances (9 HM, 53 organics) could be retrieved. However, large discrepancies in the country coverage occurred. This may be the results of variations in industrial activities from one country to another. It may also be due to incomplete reporting for some countries. Table 4 provides an overview of the country coverage per substance. Also in this case, the country and substance coverage is relatively limited.

Table 4. Coverage of waterborne industrial releases from E-PRTR (year 2010) [a]

Substance	Country coverage	Substance	Country coverage	Substance	Country coverage
Heavy metals		Chlorfenvinphos	1	Organotin compounds (as Sn)	3
Arsenic and compounds (as As)	28	DDT	2	PCDD + PCDF (dioxins + furans) (as Teq)	12
Cadmium and compounds (as Cd)	26	Di-(2-ethyl hexyl) phthalate (DEHP)	18	Pentachlorobenzene	2
Chromium and compounds (as Cr)	27	Dichloromethane (DCM)	12	Pentachlorophenol (PCP)	8
Copper and compounds (as Cu)	30	Dieldrin	2	Phenols (as total C)	23
Cyanides (as total CN)	23	Diuron	11	Polychlorinated biphenyls (PCBs)	9
Lead and compounds (as Pb)	28	Endosulphan	2	Polycyclic aromatic hydrocarbons (PAHs)	14
Mercury and compounds (as Hg)	27	Endrin	1	Simazine	4
Nickel and compounds (as Ni)	30	Ethyl benzene	8	Tetrachloroethylene (PER)	11
Zinc and compounds (as Zn)	30	Ethylene oxide	1	Tetrachloromethane (TCM)	12
Organics		Fluoranthene	13	Toluene	10
1,1,1-trichloroethane	1	Halogenated organic compounds (as AOX)	18	Toxaphene	2
1,2,3,4,5,6-hexachlorocyclohexane (HCH)	4	Heptachlor	1	Tributyltin and compounds	4
1,2-dichloroethane (DCE)	17	Hexabromobiphenyl	2	Trichlorobenzenes (TCBs) (all isomers)	9
Alachlor	3	Hexachlorobenzene (HCB)	1	Trichloroethylene	10
Aldrin	1	Hexachlorobutadiene	7	Trichloromethane	14

		(HCBD)			
Anthracene	8	Isodrin	3	Trifluralin	1
Asbestos	1	Isoproturon	7	Triphenyltin and compounds	3
Atrazine	2	Lindane	4	Vinyl chloride	9
Benzene	11	Naphthalene	8	Xylenes	9
Benzo(g,h,i)perylene	7	Nonylphenol and Nonylphenol ethoxylates (NP/NPEs)	17		
Brominated diphenylethers (PBDE)	3	Octylphenols and Octylphenol ethoxylates	13		

[a] Substances with a coverage above 20 EU countries highlighted in light grey.

Releases of wastewater from non-industrial sources

The Waterbase (EEA 2012) was used to estimate the releases into freshwater of heavy metals and organics via wastewater. The database also includes wastewater releases from industries covered in the E-PRTR; these were addressed with care to avoid double counting. Data for 2009 were used as they were more complete than the year 2010 (likely not yet fully compiled).

The Waterbase is structured according to releases from: 1) point sources and 2) diffuse sources. Sources are differentiated into several types –these are reported in Table 5a and 5b. Risk of double counting was avoided wherever relevant, e.g. where data available for U1 (as total for U1x) the values of U11, U12, U13, U14 were not reported.

Table 5a. Differentiation of point sources (Waterbase codes and definitions) [a]

Code	Definitions	Further description
D0	Direct Discharges to Coastal and Transitional Water total	
G7	Point Sources to Groundwater total	
I	Industrial Waste Water Discharges total	
I3	Industrial Waste Water Treated Discharges	Refers only to the discharge of treated industrial waste water from independently operated industrial WWTPs and not that discharged from municipal treatment plants
I4	Industrial Waste Water Untreated Discharges	Refers to discharges of industrial wastewater that remain untreated
O	Other Waste Water Discharges total	
O5	Other Waste Water Treated Discharges	
O6	Other Waste Water Untreated Discharges	
PT	Point Sources to Inland Surface Water total	
R	Riverine Input to Coastal Water	
U	Urban Waste Water Discharges total	
U1	Urban Waste Water Untreated Discharges total	Refers to municipal wastewater that is collected but discharged without treatment
U11	Urban Waste Water Untreated Discharges < 2 000 p.e.	
U12	Urban Waste Water Untreated Discharges 2	

	000 >= p.e. <= 10 000	
U13	Urban Waste Water Untreated Discharges 10 000 > p.e.<= 100 000	
U14	Urban Waste Water Untreated Discharges > 100 000 p.e.	
U2	Urban Waste Water Treated Discharges total	Refers to the discharge of municipal waste water following treatment in an UWWTP. Such wastewater may have come originally from domestic and industrial sources. In addition, it includes any urban runoff, generated during rainfall, which is collected and d
U21	Urban Waste Water Treated Discharges < 2 000 p.e.	
U22	Urban Waste Water Treated Discharges 2 000 >= p.e. <= 10 000	
U23	Urban Waste Water Treated Discharges 10 000 > p.e.<= 100 000	
U24	Urban Waste Water Treated Discharges > 100 000 p.e.	

[a] Source: EEA (2012)

Table 5b. Differentiation of diffuse sources (Waterbase codes and definitions) [a]

Code	Definitions	Further description
NP	Total Diffuse Emissions to Inland Waters	
NP1	Agricultural Emissions	
NP2	Atmospheric Deposition	
NP3	Un-Connected Dwellings Emissions	
NP4	Urban Diffuse Emissions	Refers only to those emissions of pollutants in urban runoff that are not connected to a collecting system
NP5	Storm Overflow Emissions	Refers to discharges/emissions to a receiving water following exceedance of the storage capacity of the collecting/treatment system during heavy 'storm' rainfall
NP6	Abandoned Industrial Site Emissions	
NP7	Other Diffuse Emissions	
NP8	Background Emissions	

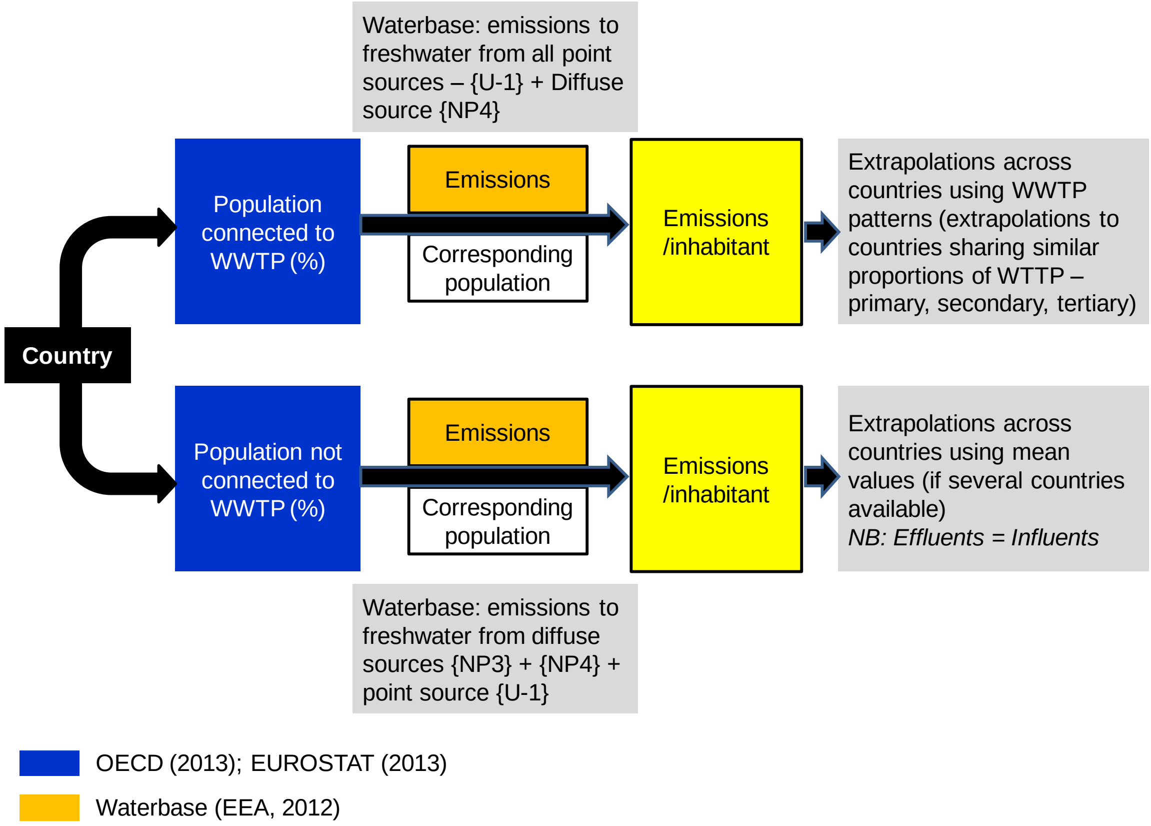
[a] Source: EEA (2012)

Principles of release estimations

A framework was developed to estimate releases from households and institutional/commercial activities. It relies on the assumption that releases can be defined on a per-capita basis, accounting for a differentiation into: 1) countries, and 2) percentage of population connected to waste water treatment plants (WWTP).

The emissions reported in the Waterbase are aggregated at country level and regarded as profiles, which are normalized with the population either connected or not to WWTP. These normalized numbers are used for extrapolating to unreported countries. Figure 1 describes the developed framework. The assumptions and data treatments are further detailed in the following sub-sections.

Figure 1. Framework for estimating non-industrial water-borne emissions



Population connected to WWTP

Data from OECD (2013) were primarily used. They were complemented with EUROSTAT (2013) figures for EU members not part of the OECD. Although, both EUROSTAT and OECD uses the same joint questionnaire to collect the original data, the reported OECD data are more updated and detailed (e.g. in types of wastewater treatment) than those by EUROSTAT.

The reporting of both also differ as OECD uses a main disaggregation into population connected to public sewerage, which does not necessarily imply a wastewater treatment, while EUROSTAT emphasizes the connection of population to wastewater treatment (regardless of public sewerage connection or not). As a consequence, gaps exist for some countries to identify the proportion of the population connected to public sewerage without treatment and that not connected to public sewerage. They are not considered to influence significantly the results because both are assumed to be direct discharges into the environment.

The population connected to wastewater treatment was considered to be the proportion of population connected to public sewage treatment (primary, secondary, tertiary). The population not connected to wastewater treatment was assumed to include the proportion of population connected to public sewerage without treatment and that of population not connected to public sewerage. Although, independent systems, e.g. septic tanks, may have different emission patterns than direct discharges of sewage, they were considered in the proportions of population not connected to wastewater treatment. Further work may refine this assumption. Table 6 documents the derived data on population connected to WWTP.

One major data gap subsists as available data for Italy does not allow to accurately differentiate the proportion of population connected or not to wastewater treatment; an assumption was made to enable bridging this gap (marked in red in Table 6). An inconsistency was also identified for Portugal (marked in orange in Table 6), for which the reported total of public treatment (70%) did not equal the sum of primary, secondary and tertiary treatments (amounting to 59%); the different proportions were scaled up to match the reported total. Other uncertainties additionally stem from the age of the data used. For some countries, available data are only reported for years 2004 (FR), 2005 (CH, IS, CY), 2006 (HU, SE), 2007 (DE, LV). For other countries, some data were also taken from the years 2008 and 2010 when the year 2009 was not reported; these are considered of minor influence. The influence of the data age is only relevant when the country does not have a majority of the population connected to WWTP. For example, data for Germany and Switzerland are rather old, but they report very high proportions of population connected to public WWTP (95% and 97%, respectively). The situation in 2010 for those two countries is very likely to be the same although these proportions may have slightly increased since the considered reference year. The out-of-date nature of the data is therefore not believed to have any consequences in these cases. Countries marked in grey in Table 6 are the ones, for which more up-to-date data should be sought. Finally, several data gaps (marked by “NA” in Table 6) exist in the differentiation of the types of treatment, e.g. primary, secondary and tertiary treatments, or split between independent sewage system and other systems, the latter including direct discharges. These were not obstacles for the current estimation techniques although they may be if the framework is further developed in the future.

Table 6. Data on percentage of population connected to wastewater handling [a]

Countries	Data sources	Reference year	Public sewerage with treatment				No treatment total	Public sewerage without treatment	Not connected to public sewerage		
			Total	Primary	Secondary	Tertiary			Total	Independent	Others [b]
Austria	OECD	2008	93	0	1	92	7	0	7	7	0
Belgium	OECD	2008	71	0	8	63	29	17	12	NA	NA
Bulgaria	EUROSTAT	2009	46	3	42	1	54	NA	NA	NA	NA
Cyprus	EUROSTAT	2005	30	NA	NA	NA	70	NA	NA	NA	NA
Czech Republic	OECD	2008	76	0	20	56	24	6	18	NA	NA
Denmark	OECD	2009	90	2	2	86	10	0	10	10	0
Estonia	OECD	2009	82	1	16	65	18	0	18	5	13
Finland	OECD	2010	83	0	0	83	17	0	17	17	0
France	OECD	2004	80	1	37	42	20	2	18	16	2
Germany	OECD	2007	95	0	2	93	5	2	3	2	1
Greece	OECD	2009	67	0	6	61	33	0	33	NA	NA
Hungary	OECD	2006	57	2	30	25	43	8	35	NA	NA
Iceland	OECD	2005	58	56	2	0	42	32	10	6	4
Ireland	OECD	2009	75	4	60	11	25	2	23	NA	NA
Italy	OECD	2008	82	3	24	55	18	NA	18	NA	NA
Latvia	EUROSTAT	2007	65	NA	NA	NA	35	NA	NA	NA	NA
Lithuania	EUROSTAT	2009	71	4	14	53	29	NA	NA	NA	NA
Luxembourg	OECD	2010	96	4	62	30	4	0	4	3	1
Malta	EUROSTAT	2009	48	0	13	35	52	NA	NA	NA	NA
Netherlands	OECD	2009	99.3	0	4	95,3	0.7	0	0.7	0.7	0
Norway	OECD	2009	80	21	2	57	20	0	20	16	4
Poland	OECD	2009	62	0	15	47	38	0	38	25	13
Portugal	OECD	2009	70	5	46	19	30	11	19	NA	NA
Romania	EUROSTAT	2009	29	8	21	0	71	NA	NA	NA	NA

Slovakia	OECD	2009	58	NA	NA	NA	42	2	40	NA	NA
Slovenia	OECD	2009	53	0	29	24	47	10	37	35	2
Spain	OECD	2008	92	4	37	51	8	4	4	2	2
Sweden	OECD	2006	86	0	5	81	14	0	14	14	0
Switzerland	OECD	2005	97	0	20	77	3	0	3	2	1
United Kingdom	OECD	2009	97	0	49	48	3	0	3	NA	NA

[a] Countries marked in red: critical data gap (a share of 82% of the population is connected to public sewerage, but no data is available on the proportion of this share that do not include treatment; here this latter is assumed to be set at 0%); countries in grey: use of out-of-date data; cells in purple: proportions of population connected or not to wastewater treatment used in emission evaluations

[b] Deducted from subtraction between total proportions of not connected to public sewerage and proportions of independent sewage system.

[c] Figures were scaled up to match the total of 70% (from 4%, 39% and 16% for primary, secondary and tertiary treatments, respectively)

3.1.2.1 Waterbase data treatment

As Figure 1 illustrates, emissions from the Waterbase need to be differentiated between those corresponding to the population connected to WWTP and those corresponding to direct discharges to the environment.

Using the information on the differentiation of sources, the following was assumed:

Population connected to WWTP: emissions from all point sources U2 (untreated discharges), G7 (groundwater), D0 (Coastal and Transitional Water) and O (Others; negligible). In addition the diffuse source NP4 (urban run-off) was included.

Population not connected to WWTP: emissions from point sources U1 (untreated discharges), and addition of the diffuse sources NP4 (urban run-off) and NP3 (unconnected population)

In the Waterbase, the report of an emission data in the E-PRTR is flagged as “Yes”, “No”, “Both” or with no indication. Emissions with no flag (for U and G7) were given the benefit of the doubt and hence kept in the inventory. The flag “Both” means that part of the reported emission is present in the E-PRTR. A source-specific treatment with regard to the inclusion of emissions flagged with a “Both” was thus performed:

Urban point sources U2 were assumed to be dominated by non-industrial emissions, and were thus included

Point sources D0 and G7 were excluded because amounts were believed to be dominated by industry releases. Further work could check the appropriateness of this assumption.

To avoid double counting, the point sources U (as urban WW discharge total) were disregarded wherever the point sources U1 and U2 were available. The same applies to U1 and U2 for U1x and U2x (e.g. RO). When only U as a whole was reported, the split between U1 and U2 was estimated using the proportions of population connected to WWTP.

With regard to diffuse sources, only NP3 for the Netherlands was reported for the year 2009.

Extrapolations

All retrieved emission data were normalized by the population corresponding to the situation. For example, only the population connected to WWTP was considered in the normalization of the emissions for wastewater treatment. The representativeness of the emissions was overall assumed, i.e. the emission data were considered to stem from the entire population fitting the scope of the data (e.g. population connected to WWTP). A rough check was performed by comparing normalized results across countries. That led to discarding data for Latvia, for which very low normalized emissions (several orders of magnitude lower) are observed compared to all other countries across point/diffuse, connected/non-connected sources. It is believed to reflect a significant incompleteness in the emission reports. Likewise, one value for Belgium (point sources, WWTP-connected population) for Cadmium was disregarded as the indicated emissions were 3-4 orders of magnitude lower than emissions reported for other countries (without possible explanation for such outlier). Two other values, which were negative, were also ruled out (Lithuania).

Two sets of emission data, termed “profiles” in the following, could eventually be built, one for the population connected to WWTP and the other for non-connected population, which can be further differentiated into point and diffuse sources.

WWTP-connected population: the profile is based on data for NL, SE, SI, RO, BE, LT. Large variations in substance coverage occur across countries. Typically, metals are the substances covered the most across countries. Most organics only have 1 or 2 data points. Unlike other countries, the Netherlands present a full coverage of substances.

Non-connected population: the profile was derived from data for Romania and the Netherlands. Other countries were not documented.

With a sufficiently comprehensive data set, an attempt could be performed in order to obtain profiles for different countries and extrapolate to other countries based on the similarities of wastewater handling, i.e. similar proportions of populations linked to the different treatment of Table 6. Likewise, a differentiation could be attempted between diffuse sources and point sources and try to assign them to the population connected to public sewerage without treatment and the category “Others” or to the population having an independent system, e.g. septic tanks. However, because of lack of data, this was not possible here. For non-connected population, only information from the Netherlands (diffuse sources) and from Romania (point sources) was used. For connected population, geometric means of the normalized emissions were considered. Table 7 documents the calculated emission profiles used in the final inventory. The extrapolations were done to EU-27+3.

For the emissions from WWTP-connected population, geometric standard deviations were calculated, attesting of an acceptable agreement across countries. The use of the geometric mean for extrapolating to population connected to wastewater treatment may thus be more robust than using country-specific patterns. For example, normalized profiles for the Netherlands turn out to be similar than that for Romania and Sweden while their wastewater treatment patterns differ considerably (proportions of primary, secondary and tertiary treatments; see Table 6). Although, only few countries are covered, they span different geographical and societal (e.g. cultural) patterns, which may have some influence on the emission intensities. However, the relatively low obtained standard deviations, particularly for heavy metals, may suggest that the emission patterns from WWTP are relatively insensitive to the country in which they occur (at least within Europe). Assuming this is the case, a single emission profile of a country could be used as a proxy for other European countries, thus reducing considerably the need for data. The viability of this finding however should be validated by increasing the number of data points used for determining each substance emission mean (and extending to other substances, if possible).

With respect to emissions from the population not connected to WWTP, the substance coverage is lower than that for WWTP-connected population (see Table 7). The completeness of the emission figures per substance is also very limited: for most substances, only emissions from diffuse sources could be retrieved. This explains the abnormally lower per-capita emissions from the population not connected to WWTP relative to those from the WWTP-connected population. However, for substances where emissions from point sources could be retrieved these inconsistencies do not occur (emissions from not-WWTP-connected population higher than those from WWTP-connected population). Finally, it should be noted that the emission profiles are derived from data for only two countries (NL for emissions from diffuse sources, RO for emissions from point sources), which may not necessarily be representative of other countries. Therefore, to bring consistency into the emission profiles for population not connected to WWTP, three priority steps should be undertaken: (1) emissions from point sources, which seem to dominate the profiles, need to be retrieved for all mapped substances as including only diffuse sources leads to large underestimations; (2) data for several countries should be collected so that variations across countries could be investigated (similar to the approach taken for emissions from WWTP-connected population); and (3) additional substances need to be added to the emission profile.

Table 7. Normalized emission profiles for population connected or not to WWTP

2009	Non-connected population [a]		Connected population		
	Total (kg/inhab)	**Scope**	**Geomean (kg/inhab)**	**St. dev. (geo)**	**Included countries**
1,1,2,2-tetrachloroethene	NA	NA	1,46E-04	-	NL
1,1,2-trichloroethene	NA	NA	1,35E-06	19,8	NL, SE
1,2-Dichloroethane	NA	NA	5,96E-06	2,9	NL, SE
Adsorbable organic halogens (AOX)	1,71E-04	Diffuse	1,35E-03	10,9	LT, NL, SE, SI
Anthracene	8,77E-08	Diffuse	6,44E-06	-	NL
Arsenic	2,28E-05	Diffuse	8,03E-05	1,2	BE, LT, NL
Benzene	1,07E-06	Diffuse	6,74E-05	-	NL
Benzo(a)pyrene	4,66E-07	Diffuse	1,91E-06	-	NL
Benzo(b)fluoranthene	NA	NA	1,46E-06	-	NL
Benzo(g,h,i)perylene	1,09E-07	Diffuse	1,39E-06	-	NL
Benzo(k)fluoranthene	1,85E-07	Diffuse	1,82E-06	-	NL
Cadmium	1,15E-05	Point + Diffuse	1,13E-05	5,0	NL, RO, SE
Chromium	2,28E-05	Diffuse	4,06E-05	2,7	BE, LT, NL, SE, SI
Copper	1,30E-03	Point + Diffuse	1,88E-04	3,5	BE, LT, NL, RO, SE, SI
Cyanides (as total CN)	9,90E-05	Diffuse	1,39E-04	11,0	NL, RO
Di (2-ethylhexyl) phthalate (DEHP)	1,29E-04	Diffuse	9,72E-06	2,7	NL, SE, SI
Dichloromethane	6,23E-05	Diffuse	2,93E-05	2,1	NL, SE
Diuron	NA	NA	6,11E-08	-	NL
Fluoranthene	3,22E-06	Diffuse	6,43E-05	-	NL
Hexachlorobenzene (HCB)	1,14E-07	Diffuse	1,13E-07	-	NL
Hexachlorobutadiene (HCBD)	NA	NA	1,11E-08	-	NL
Indeno(1,2,3-cd)pyrene	9,56E-08	Diffuse	5,35E-07	-	NL
Lead	3,49E-04	Point + Diffuse	1,94E-05	12,3	BE, LT, NL, RO, SE, SI
Mercury	1,92E-06	Diffuse	2,16E-06	2,4	BE, NL, SE
Naphthalene	2,24E-06	Diffuse	1,32E-04	-	NL
Nickel	2,57E-04	Point + Diffuse	1,52E-04	3,0	BE, LT, NL, RO, SE, SI
Para-tert-octylphenol	NA	NA	7,57E-07	-	LT
Pentachlorophenol	7,68E-07	Diffuse	5,83E-06	-	NL
Polyaromatic hydro-carbons (PAH) (sum)	NA	NA	3,39E-05	-	SE
Simazine	NA	NA	1,06E-07	-	NL
Tetrachloromethane	3,11E-06	Diffuse	1,51E-06	1,2	NL, SE
Toluene	2,45E-05	Diffuse	3,88E-05	-	NL
Trichloromethane	1,72E-05	Diffuse	4,76E-06	8,4	NL, SE
Zinc	9,26E-03	Point + Diffuse	1,73E-03	2,2	BE, LT, NL, RO, SE, SI

[a] NA: data not available. Cells marked in grey: emissions which includes both point and diffuse sources.

The current limitation of the inventory are related to the basis of the extrapolation. In fact, data were available mainly for NL and few other countries, in most of the case without a complete emission profile (e.g. in case of population not connected to WWTP). Furthermore, for many countries there are data gaps regarding the apportionment of different wastewater handling.

Further research may focus on obtaining emission data for more countries (for connected and non-connected population) to check the consistency of the extrapolations, e.g. whether a geometric mean is a better proxy than an extrapolation based on wastewater treatment similarities across countries. Data at a lower scale than the country can also be collected as long as the population corresponding to the emission intensities is known (to calculate normalized emission factors and enable comparisons with other available data). Additionally, a cross check of the derived emissions with other data sources, e.g. OSPAR or HELCOM for riverine inputs to the seas, could be performed in future research activities.

3.1.2.2 Additional industrial releases

The Waterbase database includes water emissions from all sources, including from industrial sources.

Some of them are reported in E-PRTR but others are not. The latter were included in the present inventory although their country coverage is limited –see Table 8. Emissions flagged as “Both” (i.e. emissions for which only a part is covered in the E-PRTR database) and emissions without indication of inclusion in E-PRTR or not (this is not always reported in the Waterbase) were included by default. It is equivalent to assuming that these emissions were predominantly not reported in E-PRTR. Double counting was avoided by removing I (industrial WW discharge total) wherever I3 and I4 were available (see definitions in Table 5a).

Table 8. Additional emissions from industrial sources (not covered in E-PRTR)

Substance	Country coverage
1,1,2,2-tetrachloroethene	NL, SE, SK
1,1,2-trichloroethene	CZ, NL, SE, SK
1,2-Dichloroethane	CZ, SK
Anthracene	CZ, SE, SK
Arsenic	BE, NL
Atrazine	BE
Benzene	BE, CZ, NL, SE, SK
Benzo(a)pyrene	CZ, SK
Benzo(b)fluoranthene	CZ, SE, SK
Benzo(g,h,i)perylene	CZ, SE, SK
Benzo(k)fluoranthene	CZ, SK
Cadmium	BE, CZ, NL, RO, SK
Chromium	BE, LT, NL
Copper	BE, CZ, LT, NL, SE, RO
Cyanides (as total CN)	BE, CZ, SE, RO
Di (2-ethylhexyl) phthalate (DEHP)	SE, SK
Dichloromethane	BE, NL
Fluoranthene	CZ, SK
gamma-HCH (Lindane)	CZ
Hexachlorobenzene (HCB)	CZ, SK
Hexachlorobutadiene (HCBD)	NL
Indeno(1,2,3-cd)pyrene	CZ, SK
Lead	BE, CZ, LT, NL, RO, SK
Mercury	BE, CZ, NL, RO, SK
Naphthalene	BE, NL, SE, SK
Nickel	BE, CZ, LT, NL, RO, SK
Pentachlorophenol	BE
Polyaromatic hydro-carbons (PAH) (sum)	BE, SE
Tetrachloromethane	NL
Toluene	BE, CZ, NL, SE
Trichloromethane	BE, CZ, NL, SE, SK
Zinc	BE, CZ, LT, NL, RO

3.1.2.3 Oil compounds

Oil compounds are mostly relevant in marine environment, where most spills occur. This has not been undertaken in the current work as ecotoxicity in marine ecosystems is not yet included in the toxicity-based impact categories of USEtox.

The primary data source is CONCAWE (http://www.concawe.be/), which reports annual spillages. It should be noted that an average speciation of oil compounds can be difficult to reach as the types of substances and their distribution are very location-specific (dependent on field extraction location) and large variations may occur. Additionally, emissions to marine environment are difficult to assign to a specific country. They can be location-based, activity ownership-based, user-based whether emissions are linked to the location of their occurrences, the activity responsible for them (and hence the exploitant) or the consumer of the oil products. All three approaches present obstacles to properly attribute the emissions to countries.

3.2 Soil-borne emissions

3.2.1 Industrial releases

Data were extracted from the E-PRTR database (http://prtr.ec.europa.eu/), which contains information on releases from industries. It is claimed that more than 90% of emissions are covered. Emissions to air compartment were disregarded as NNMVOC, HM and POPs are fully covered by data from the EMEP/CEIP Centre.

With regard to soil-borne emissions, emissions for 23 substances (8 HM, 15 organics) could be retrieved. However, large limitations in the country coverage exist. This may be the result of variations in industrial activities from one country to another. It may also be due to incomplete reporting for some countries. Table 9 provides an overview of the country coverage per substance.

Table 9. Coverage of soil-borne industrial releases from E-PRTR (year 2010) [a]

Substance	Country coverage		Substance	Country coverage	
Heavy metals			Benzo(g,h,i)perylene	1	NO
Arsenic and compounds (as As)	4	CZ, DE, FR, UK	Dichloromethane (DCM)	1	CZ
Cadmium and compounds (as Cd)	3	FR, PL, SK	Fluoranthene	1	NO
Chromium and compounds (as Cr)	6	CZ, DE, FR, PL, SK, UK	Halogenated organic compounds (as AOX)	2	DE, SK
Copper and compounds (as Cu)	7	CZ, DE, ES, FR, PL, SK, UK	Hexabromobiphenyl	1	FR
Lead and compounds (as Pb)	7	CZ, DE, ES, FR, PL, SK, UK	Naphthalene	1	SK
Mercury and compounds (as Hg)	4	FR, PL, SK, UK	Octylphenols and Octylphenol ethoxylates	1	NO
Nickel and compounds (as Ni)	7	CZ, DE, ES, FR, PL, SK, UK	Phenols	1	SK
Zinc and compounds (as Zn)	6	DE, ES, FR, PL, SK, UK	Polychlorinated biphenyls (PCBs)	2	CZ, FR
Organics			Polycyclic aromatic hydrocarbons (PAHs)	2	FR, SK
1,1,1-trichloroethane	1	NO	Tetrachloroethylene (PER)	1	NO
1,2-dichloroethane (DCE)	1	FR	Trichlorobenzenes (TCBs) (all	1	NO

			isomers)
Anthracene	1	SK	

[a] Substances with a coverage above 20 EU countries highlighted in light grey.

Few of the items reported in Table 5 are groups of substances that do not allow assessment in the current format of the USEtox model. A strategy should be developed in future research activities, in order to link the group of substances to the adequate characterisation factor.

3.2.2 Application of sewage sludge to agricultural soil

A number of countries allow the use of sewage sludge as soil amendment (after specific treatment as its direct use is banned in most EU countries). This can be a substantial source of releases of organics and HM.

Data on use of sewage sludge applied to agricultural land in 2010 (2009 for CY, EE, FI, HU, LT, LV, NL, PT, RO, SI, SK) were retrieved from EUROSTAT (2012). These were coupled with typical concentrations of seven heavy metals (Zn, Cu, Pb, Ni, Cr, Hg, Cd) at country level that are provided in a report by the EU Commission (2010). These HM concentration profiles were collected for the reference year 2005/2006. It is assumed that they are still valid for the year 2010. Profiles are missing for a number of countries; they were assumed similar to the profile of other countries that share similar regulations with regard to concentration thresholds of heavy metals in sewage sludge applied to agricultural land (data on thresholds also in EC 2010). Germany’s profile was thus taken representative for Austria (same ranges of threshold and same policy towards banning the use of sewage sludge on land); Danish profile was assumed identical to Slovenia (Denmark has the most stringent regulations in the EU and Slovenia has overall the lowest thresholds among the reported countries); Cyprus’s profiles were taken representative of Greece and Luxembourg (thresholds are among the highest, and the poor state of the sludge policy in LU is confirmed in the report); Ireland is modelled as Spain (same regulations); Romania is modelled as Poland (closest regulations). These assumptions represent 9.2% of the total sewage sludge applied in the EU-27+3 countries.

Up-to-date concentrations of organics in sewage sludge applied to land is more difficult to obtain and most available data are reported per group of substances (e,g, AOX). Only dioxins were thus included based on EC-JRC (2001). The used concentration is assumed the same in all countries; the original data referred to measurements in few countries, i.e. DE, DK, SE, UK, and referred to early-mid 90s investigations.

Main limitations of the current inventory are related to: a) gaps in the average concentration of HM in sewage sludge (missing countries); b) missing differentiation of sludge concentrations within a country (concentrations in sludge applied to land will depend on the type of treatments undergone by the sludge upstream); c) limited coverage of substances and rather old data used (organics and heavy metals). Heavy metals could be complemented and/or updated. Only dioxins could be included with original data from mid-90s.

3.2.3 Use of manure on agricultural soil

The use of manure as fertilizer on agricultural land can be a substantial source of HM, in particular because of mineral additives in feedstock for animals. Pig manure and slurry is thus typically associated with high levels of zinc and copper (Amlinger et al. 2004). Amlinger et al. (2004) report concentration ranges from different national surveys conducted in Europe for a number of heavy metals. The country-specific figures coupled with national use of manure and slurry should be retrieved to quantify the emissions of HM via this route. Data on animal live stock may be obtained from FAOSTAT (FAO 2013) and matched to the metals associated to the production of manure per type of living animal per year (e.g. mule, goat, or sheep) as reported by Delahaye et al. (2003).

The use of manure applied to agricultural land is documented at a country level by the FAOSTAT database (FAOSTAT 2012). The soil manure figures are reported as ton N content for nine different animal types (see Table 10). To match the available chemical composition data expressed per dry matter (dm) weight, the content of nitrogen needs to be evaluated. Data for solid manure retrieved from Chambers et al. (2001) on the management of livestock manures on land in the UK were used for that purpose; these data could be differentiated according to the nine types of livestock considered. Heavy metals concentrations were extracted from Amlinger et al. (2004), who reported ranges of mean concentrations for 12 countries among the EU-27+3(AT, BE, DK, FI, FR, DE, IT, LU, NL, NO, CH, UK). Without further specifications, averages of the ranges provided were taken. Uncertainties may stem from this approach. Table 10 provides the background data per type of livestock.

Table 10. Nitrogen content and heavy metal concentrations in solid manure

Animal types	Nitrogen content (ton-N/ton-dm)	Concentrations (mg/kg-dm)							
		Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
Buffaloes	2,40E-02	0,49	30,5	46,5	0,21	25,5	11,5	228	1,22
Chickens	5,33E-02	1,52	8,7	99	0,085	19,05	16,2	469	0,69
Dairy cattle	2,40E-02	0,49	30,5	46,5	0,21	25,5	11,5	228	1,22
Ducks	2,60E-02	1,52	8,7	99	0,085	19,05	16,2	469	0,69
Goats	2,40E-02	0,345	33,15	33,5	0,17	11,4	15,7	155,5	1,82
Non-dairy cattle	2,40E-02	0,49	30,5	46,5	0,21	25,5	11,5	228	1,22
Pigs	2,80E-02	0,715	12,225	508	0,04	16,35	10,85	1091,5	*0,675*
Sheep	2,40E-02	0,345	33,15	33,5	0,17	11,4	15,7	155,5	1,82
Turkeys/broilers	5,00E-02	1,52	8,7	99	0,085	19,05	16,2	469	0,69

3.2.4 Pesticide use

3.2.4.1 Pesticide usage statistics and active ingredient breakdown

To obtain an accurate assessment of pesticides, emission data need to be disaggregated on a single-substance basis, i.e. broken down into active ingredients (AI). However, this information is rarely available because of commercial interests between the chemical producing companies.

The main data source used in the current work was a report by the EU Commission on "the use of plant protection products in the European Union" over a 10-year time frame, i.e. 1992 – 2003 (EU Commission 2007). The report contains detailed information on pesticide usage disaggregated in EU countries (EU-27+3 minus Bulgaria and Romania) and major types of crops (cereals, maize, oilseed, potatoes, sugar beet, citrus, wine grapes, fruit trees, and vegetables; other types of crops are reported in a section "Others", which, for the reported countries, appears to have a limited pesticide consumption). Across the different sections of the report, the following data can be extracted:

1. The top-5 amounts of active ingredients used for each country and for each type of crop (year 2003):

2. The top-5 chemical class with their associated average dosage (e.g. in kg-AI/ha) for each country and for each type of crop (year 2003);
3. The top-5 chemical class with their associated average dosage for each type of crop and for each of the 3 major classes of pesticides, namely fungicides, insecticides, herbicides (year assumed to be 2003)

The data from (2) and (3) are very similar and most dosages reported in (2) can be found in (3), which support the assumptions that the data from (3) are for the year 2003. However, in data set (2), information on other pesticide classes, e.g. plant growth regulators, are also reported. Therefore, the 2 data sets can be considered as partially complementary.

Several gaps occur in the data set (1) because of confidentiality issues related to specific active ingredients, e.g. glyphosate. These active ingredients are flagged “confidential” in the report and despite being in the top-5 used active ingredients, no quantification is actually provided. To fill in these gaps, the dosage of the chemical class to which the unreported active ingredient belongs was combined with the harvested area of the considered type of crop to reach a quantification of the AI application. The assumption behind such gap-filling procedure is that the AI is representative for its chemical class, i.e. it is the major AI used within its chemical class for the considered type of crop in the considered country. When two AI belonging to the same chemical class were reported in the top-5 AI, either one of the two was not confidential, which enabled to subtract its amount to the total computed from the dosage of the chemical class (most of the cases) or the two AI were allocated equal amounts unless information on the ranking was known (e.g. if quantities applied for nr. 3 and nr. 5 are known, the unknown quantity of nr. 4 needs to fall within the range defined by available figures for nr. 3 and nr. 5 active ingredients in a top-5 list). In some specific cases, the amounts derived from the dosage per chemical classes did not match the amount reported for the AI within this chemical class, which resulted in inconsistencies; these were treated on a case-by-case basis and are reported in the country-specific documentation below. The number of such inconsistencies is however limited in the overall country/crop systems. The results of this gap-filling procedure were individually checked by evaluating whether or not the top-5 ranking was respected. In nearly all occurrences, this was the case. Specific minor assumptions have been performed where needed – these are reported in the country-specific tables below.

The outcome after the gap-filling procedure is the applied quantity of five active ingredients in 2003 for each country/crop system (25 countries times 7-8 crop types per country, depending on agriculture uses). Knowing the harvested areas per types of crops in 2003 and 2010, extrapolation was performed using the same AI dosage in 2010 as in 2003. The assumption behind such computation is that i) the same active ingredients have been in use in 2003 and 2010 and ii) that their dosages remained the same.

3.2.4.2 Fate modelling from technosphere to biosphere

Agricultural soil is usually regarded as technosphere with regard to pesticide application because the spreading is intentional and serves the purpose of increasing crop production. Only the fraction of pesticides reaching the biosphere should thus be included in an emission inventory prior to impact assessment. Once applied, pesticides are either taken up by the plants or end up in different compartments (e.g. air via wind drift, surface water via run-off, etc). The PestLCI model was designed to predict the different fractions of applied pesticides that would be released to air, surface water and groundwater (Birkved and Hauschild 2007; Dijkman et al. 2012). It thus models the fate of pesticides from the technosphere to the biosphere. In the current work, the same assumption as made by Laurent et al. (2011b) was considered to estimate the fractions of pesticides reaching the biosphere. Fractions of 0.1% and 5.0% were used for emissions to surface water and air, respectively. In principle, these fractions are dependent on the substance property and the conditions specific to the location where the substance is applied (land and climate properties, application technology, and crop type). In the absence of sufficient data and because of the broadness of the scope here (no single products but overall continental agricultural activities), no differentiation was however considered in this work. In future refinements, their considerations may be undertaken by applying a spatially-differentiated inventory model. Regionalization of all data would, thus, be required.

3.3 Emissions at a world level: criteria for extrapolation

Alternative extrapolation strategies were applied for the extrapolation from EU27+3, USA, Canada, Japan, and Australia to the world. Two parallel extrapolation-bases were selected, a GDP-based and a CO_2-based extrapolation strategy. For each of the extrapolation strategies, two further differentiations were made, according to the way the EU27+3 data and the world data were extracted.

The national PRTRs (Pollutant Release and Transfer Registers) of the United States, Canada, Japan, and Australia (respectively, US-EPA, 2012; Environment Canada, 2012; NITE, 2012; AG-DEH) constituted the relevant data sources for the extrapolation, and were the most comprehensive internationally. Data was extrapolated for the compartments air, freshwater, industrial soil and natural soil (including landfill).

The inventory for EU27+3 was compiled by combination with all the other inventories based on an automated search using CAS numbers. When no CAS number was available, each substance was searched by name in the different database and added consequently. In all cases where no match was found (e.g. misspelled name, or different acronym), substances were searched based on their names and acronyms in the different registers.

For some substances, a greater coverage was available in other registries than the EU27+3 one. In general, the US-EPA provided the biggest coverage. For the Japanese database it was possible to integrate, into the calculations, the percentage of facilities (e.g. a specific chemical factory in the Hoshu region) that reported emissions for each substance. For those substances for which a value was not available for EU27+3 the total for other countries was used (together with the extrapolation factors, i.e. GDP and CO_2). The EU27+3 inventory was also composed, as a matter of control, solely based on the USA, Canada, Japan, and Australia data.

Both in the extraction and extrapolation phases, the issue of emissions available in the form of compounds (e.g. copper and compounds) had to be faced. Values for the world were extrapolated following the available data for USA, Canada, Australia, Japan, and the EU27+3. The extracted, adapted and extrapolated dataset was used as a basis for the calculation of the impact of emissions in the EU27+3 and in the whole world for the USEtox-based toxic impact categories, i.e. freshwater eco-toxicity, human toxicity (cancer, non-cancer, total effects). The impacts were calculated based on the air, freshwater, industrial soil and natural soil sub-compartments.

Data was gathered for a total of 670 substances and their relative emissions in air, freshwater, industrial soil and natural soil.

3.3.1 Extrapolation of EU values to worldbased on GDP

The world data was extrapolated first including the EU27+3 data (plus USA, Canada, Japan, and Australia) and then without the inclusion of the EU27+3 data. As for the extrapolation of data at a world level, firstly, a spatial extrapolation strategy based on GDP was applied for the extrapolation of values for single countries to the world level. Sleeswijk et al. (2008) showed a good correlation between emissions reported in inventories and GDP, thus a GDP-based extrapolation was followed. As reported in the next section, the

inventory defined for EU27+3 was matched with the available countries from the rest of the world and extrapolated inventory values were obtained based on the GDP for EU27+3. The World Bank (2012) reported the GDP of single countries for which data was available and the total GDP of the entire world.
world emission values were extrapolated using as extrapolation factors the global GDP (World Bank 2012) values of the world and those of the countries for which emission data was available (i.e. USA, Canada, Japan, Australia), according to the formula:

emission_world_GDP =
(sum_emission_usa_canada_japan_australia * GDP_world) /
(GDP_usa+GDP_canada+GDP_japan+GDP_australia) .

In order to test the viability of the strategy, data for EU27+3 was fully extrapolated, hypothesising the case of no data available for the EU27+3. The following formula was used:

emission_europe_extrapolated_GDP =
(emission_usa_canada_japan_australia * GDP_europe) /
(GDP_usa+GDP_canada+GDP_japan+GDP_australia) .

The extrapolated emissions for the EU27+3 were compared to the available data where possible (e.g. no comparison was possible for landfill). Some differences appeared to be highly significant for certain emissions. Thus, it was decided to include the available data for the EU27+3 in the extrapolation of world data, using the formula:

emission_world_GDP =
(sum_emission_eu_usa_canada_japan_australia * GDP_world) /
(GDP_EU30+GDP_usa+GDP_canada+GDP_japan+GDP_australia) .

The full set of calculations was implemented in MS Excel and may be expanded or updated in case of availability of more accurate data in future research activities.

3.3.2 Extrapolation of EU values to world based on CO_2 emissions

A similar pathway was followed for the extrapolation of EU27+3 data and world data based on CO_2 emissions. In principle, CO_2 emissions could be questioned as proxy of the overall environmental impact of products, and specifically a proxy of the magnitude of toxicity-related impact categories (Laurent et al 2012). Nonethless, the amount of CO_2 emission from a country may represent a better proxy of the overall industrial development (e.g. energy-consumption related) than the GDP figures only. In parallel, the inventory defined and described in the previous sections for EU27+3 was combined with the emissions reported in the USA, Canada, Japan, and Australia. An extrapolated inventory was calculated based on the total CO_2 emission for EU27+3 as reported by the World Bank for the year 2009 (World Bank, 2012), the total CO_2 emissions of the single countries for which data was available, and the total CO_2 emissions of the entire world. The limitation of data availability for the year 2009 was assumed not to be significant for the calculation of the final extrapolated values, as the difference of reported CO_2 emissions was considered to be similar to that of 2010. Thus, the results were assumed to be the same for the year 2010.

The world emissions were calculated, as in the previous GDP-based case, firstly without taking into consideration the EU27+3 data, as in the following:

emission_world_CO_2 =
(sum_emission_usa_canada_japan_australia * CO_2_emission_world) /
(CO_2_EMISSION_usa+CO_2_EMISSION_canada+CO_2_EMISSION_japan+CO_2_EMISSION_australia).

As a control, the EU27+3 inventory was also fully extrapolated, as if no data would be available at a EU27+3 level:

emission_europe_extrapolated_CO_2 =
(emission_usa_canada_japan_australia * CO_2_EMISSION_europe) /
(CO_2_EMISSION_usa+CO_2_EMISSION_canada+CO_2_EMISSION_japan+CO_2_EMISSION_australia).

Finally, a new world data inventory was calculated for the world based on the EU27+3 emissions:

emission_world_CO_2 =
(sum_emission_eu_usa_canada_japan_australia * CO_2_EMISSION_world) /(CO_2_EMISSION_EU30+CO_2_EMISSION_usa+CO_2_EMISSION_canada+CO_2_EMISSION_japan+CO_2_EMISSION_australia)

4 Results

4.1 Characterisation of inventory based on USEtox. Comparison to earlier normalization works

For all those substances for which a correspondent characterisation factor was identified, the relative impact was calculated; for the EU27+3 based only on reported data (EU 1, in the following tables); for the EU27+3 based on reported data and extrapolated data (EU 2); for the world based on EU 2, plus USA, Canada, Japan and Australia (WORLD 1); and finally for the world based only on USA, Canada, Japan, and Australia (WORLD 2). In all cases the matching was based on an automated search and selection based on the CAS number where available. In the case of metals, the match was based on the name of the substance. At this stage, the combined association, e.g. in compounds or multiple group of substances (e.g. beryllium and compounds), was not taken into consideration. The characterisation was done using the USEtox impact categories human toxicity and freshwater ecotoxicity (Rosenbaum et al. 2008), including interim characterisation factors.

Table 11 provides the normalisation references using the USEtox-based impact category freshwater eco toxicity for both the CO_2-based and GDP-based extrapolation strategies. Results are reported per year using the notation suggested by Heijungs (2005).
For the CO_2-based strategy, the normalisation references differ in the case of EU 1 – WORLD 1 by one order of magnitude. The WORLD 2 normalisation reference has a ratio of 2.45 compared to the EU 2.
The GDP-based normalisation reference for freshwater ecotoxicity shows higher values for EU 1-CO_2-based and EU 1-GDP-based (i.e. 33%), a less than 1% higher value for EU 2-CO_2-based compared to EU 2-GDP-based, and lower values (i.e. average of 38% less) compared to the WORLD based on CO_2 emissions.

Table 11. Normalization references for USEtox™ freshwater eco toxicity for EU27+3 and the world. The reference year is 2010

	Geographical scope	Unit	USEtox™-based impact categories Freshwater eco toxicity
CO_2-based extrapolation			
	EU 1[a]	[PAF*m3*day/year]	5,35E+11
	EU 2[b]	[PAF*m3*day/year]	2,08E+12
	WORLD 1[c]	[PAF*m3*day/year]	8,60E+12
	WORLD 2[d]	[PAF*m3*day/year]	4,59E+12
GDP-based extrapolation			
	EU 1[a]	[PAF*m3*day/year]	8,05E+11
	EU 2[b]	[PAF*m3*day/year]	2,09E+12
	WORLD 1[c]	[PAF*m3*day/year]	4,90E+12
	WORLD 2[d]	[PAF*m3*day/year]	3,05E+12

[a] Based on the EU27+3 inventory fully extrapolated from USA, Canada, Japan, Australia. [b] Based on the inventory of data gathered from EU27+3 sources where available or extrapolated from USA, Canada, Japan, Australia. [c] Based on the data of the WORLD inventory extrapolated from EU 2, USA, Canada, Japan, Australia. [d] Based on the data of the WORLD inventory extrapolated from USA, Canada, Japan, Australia.

Table 12 provides normalisation references for human toxicity obtained by extrapolation based on CO_2 and GDP respectively. The normalisation factors are in the same order of magniture for all cases. An exception is the WORLD 2-CO_2-based, which is significantly higher for all impact categories than the WORLD 2-GDP-based. This last case shows significantly lower emissions even compared to those of the EU 2 case, suggesting that the use of the GDP extrapolation tends to underestimate emissions on a world level when the EU emissions are not taken into account.

Table 12. Normalization references for USEtox™ human toxicity (cancer effects, non-cancer effects) for EU27+3 and the world. The reference year is 2010

	Geographical scope	Unit	USEtox™-based impact categories		
CO_2-based extrapolation			**Human toxicity, cancer effects**	**Human toxicity, non-cancer effects**	**Human toxicity,total effects**
	EU 1[a]	[cases/year]	1,01E+03	2,77E+04	2,87E+04
	EU 2[b]	[cases/year]	9,34E+04	4,86E+06	4,96E+06
	WORLD 1[c]	[cases/year]	2,69E+05	1,36E+07	7,61E+06
	WORLD 2[d]	[cases/year]	1,41E+05	6,83E+06	6,97E+06
GDP-based extrapolation					
	EU 1[a]	[cases/year]	1,23E+03	4,08E+04	4,21E+04
	EU 2[b]	[cases/year]	9,46E+04	4,86E+06	4,96E+06
	WORLD 1[c]	[cases/year]	1,53E+05	7,72E+06	4,31E+06
	WORLD 2[d]	[cases/year]	4,47E+03	1,45E+05	1,49E+05

[a] Based on the EU27+3 inventory fully extrapolated from USA, Canada, Japan, Australia. [b] Based on the inventory of data gathered from EU27+3 sources where available or extrapolated from USA, Canada, Japan, Australia. [c] Based on the data of the WORLD inventory extrapolated from EU 2, USA, Canada, Japan, Australia. [d] Based on the data of the WORLD inventory extrapolated from USA, Canada, Japan, Australia.

A comparison of the top contributing substances for each impact category did not highlight substantial changes in the top contributors beyond a different order of contribution between the two classes of data. In all cases a limited set of substances are the main contributers to the total impact. The top-contributing substances for human toxicity and ecotoxicity are reported in Table 13.

Table 13. Top-contributing emissions following the two different extrapolation strategies based on USEtox™-based impact categories. Overall contribution for each of the impact categories is provided with a cut-off value of 1%. The order is alphabetical.

CO_2-based extrapolation	**Overal contribution to Human Human Toxicity**	**Overall contribution Freshwater Ecotoxicity**	**GDP-based extrapolation**	**Overal contribution to Human Human Toxicity**	**Overall contribution Freshwater Ecotoxicity**
Acetochlor	-	8%	Acetochlor	-	8%
Acrolein	-	3%	Acrolein	-	4%
Acrylamide	1%	-	Acrylamide	2%	-
Arsenic (III)	2%	-	Arsenic (III)	1%	-
Arsenic (V)	2%	1%	Arsenic (V)	1%	-
Carbon disulfide	8%	-	Carbon disulfide	8%	-
Copper	-	13%	Copper	-	13%
Chromium (VI)	18%	8%	Chromium (VI)	18%	-
Dieldrin	5%	-	Dieldrin	4%	-
Endrin	-	1%	Endrin	-	1%
Folpet	-	6%	Folpet	-	6%
Formaldehyde	1%	1%	Formaldehyde	1%	-
Isoproturon	-	10%	Isoproturon	-	10%
Lead	3%	-	Lead	2%	-
Mercury	23%	3%	Mercury	20%	3%
Nickel	-	2%	Nickel	1%	2%
Polychlorinated biphenyl	6%	-	Polychlorinated biphenyl	7%	-
Vanadium	7%	19%	Vanadium	10%	19%
Zinc	19%	14%	Zinc	20%	14%

The list provides a full coverage of impacts with a cut-off value of 1% contribution. Emissions to sub-compartments were considered based on the available data. In the case of emissions to air, emissions were split evenly among urban and rural sub-compartments, due to the lack of more specific data. Therefore, the emissions to air were considered unspecified.

The only difference among the two sets of results obtained using the CO_2 and GDP strategies seems to be the different contribution to the total of single substances. The top substances in terms of contribution to the total final normalization reference are the same.

Results show a prevalence of contribution to impacts due to metals such as, hexavalent chromium (or chromium VI), arsenic pentoxide (or arsenic V) and trichloride (or arsenic III), copper, lead, mercury, nickel, vanadium, and zinc. Mercury contributes in both cases the greatest share to human health impacts (respectively for about 23% and 20% of the overall contribution) to both cancer and non-cancer impacts.

In the case of freshwater ecotoxicity, the top contributor for CO_2-based and for GDP-based extrapolation was Vanadium (i.e. 19%), followed by zinc and copper in both cases.

Other top contributors are pesticides applied to agricultural soil. These include, acetochlor, acrolein, endrin, and dieldrin.

4.2 Comparison with previous normalisation works

In Laurent et al. (2011a), a comparison of the top-contributing substances in earlier normalization works was done. Different assumptions were used by the authors both in the building of the inventories as well as in the chosen LCIA model.

Table 14. Top contributing substances in the literature for human toxicity and eco toxicity for EU, under different assumptions, cut-off 1%.

Laurent et al. (2011b)	Laurent et al. (2011a)	Lautier et al. (2010)	Sleeswijk et al. (2008)
Acrolein	1,30butadiene	Arsenic	Aldicarb
Antimony	Acetone	Atrazine	Arsenic
Arsenic	Acrolein	Benzene	Atrazine
Cadmium	Benzo(alpha) pyrene	Benzo(alpha)pyrene	Barium
Chlorothalonil	Benzaldehyde	Cadmium	Cadmium
Chlorpyrifos	Benzene	Chromium	Chlorine
Chromium	Butanol	Copper	Chloropicrin
Chromium VI	Chlorpyrifos	Decabromophenyl ether	Chlorpyrifos
Copper	Copper	Dioxins	Copper
Cyfluthrin	Cypermethrin	Lead	Cypermehtrin
Cypermethrin	Dioxins	Nickel	Lead
Folpet	Ethene	Phenol, pentachloro-	Manganese
Formaldehyde	Dormaldehyde	Zinc	Mercury
Furane	Hexanes		Laurydimethylamine-N-oxide
Isoproturon	Iron		Nickel
Lead	Lead		Selenium
Mercury	Mercury		Terbufos
Zinc	Parathon-methyl		Vanadium
	PAH [a]		Zinc
	Strontium		

Thallium
Vinyl chloride
VOC
Zinc

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[a] PAH polycyclic aromatic hydrocarbons (inventoried as benzo[a] pyrene or B[a]P)

Results seem to overlap for metals and some other substances (e.g. formaldehyde), but show discrepancies in terms of the impact of pesticides.

The datasets which were consulted for USA, Canada, Japan, and Australia did not provide much information on pesticides use. In the overall results, the presence of substances which have been banned or whose use has decreased in recent years may be due to the type of the spatial extrapolations from regions where legislation is different and due to the extrapolation in time from years where emission patterns and/or legislation were different. This can explain the presence in the list of the insecticide and rodenticide, and persistent organic pollutant, Endrin (about 1% of total contribution to impact in all cases), and of the insecticide Dieldrin (7% ca.), whose use has been banned from the EU since 1979 (directive 79/117/EC). Similar conlcusions may be drawn for Polychlorinated biphenyl (7% ca.) still present after the ban of 1996 (Directive 96/59/EC). Another reason for the high scores of such substances is the reporting of their presence in high numbers in landfills in the USA.

The recent project by the European Commission on Life cycle indicators for resources, products, and waste (EC, 2012), further explored normalisation references for the year 2004, 2005, 2006. The project distinguished between apparent consumption, imported emissions, and exported emissions for EU-27. For human toxicity the top contributors to cancer effects were metals (e.g. chromium, mercury), and dioxins (e.g. 2,3,7,8-tetrachlorodibenzo-p-dioxin) for all categories considered (i.e. apparent consumption, import, export). In the case of non-cancer effects, zinc and mercury account for about 60% of the overall impact.

In the case of freshwater ecotoxicity the main flows responsible for the domestic consumption in the EU-27 are alpha-cypermethrin, cyhalothrin, and endosulfan (for 74% of the total). In the case of imported emissions, the main contributors were copper and vanadium (for about 70% of the total), as well as zinc, copper, and vanadium for exported emissions (i.e. 44%).

5 Conclusions, data need and missing links

This report provides normalization references for the year 2010 for Europe and the world. The use of two alternative extrapolation strategies allowed for comparison of results and testing of assumptions. The current results seem to be in line with the literature, with metals in water and pesticides in natural soil as top contributors.

The use of a GDP-based strategy may be supported by the fact that many of the pollutants are associated with economic growth and economic activities of regions of the world. Empirical evidence has been available since the early nineties and concepts such as the Environmental Kuznets curve (see Stern 2004) may give an appealing justification for the use of GDP as a proxy for filling data gaps and for the extrapolation of local/regional data to a the entire world. In the context of normalization in LCA, GDP has proven to have a good correlation with emission of certain toxic substances, but not as strong for e.g. pesticides (e.g. Sleeswijk et al. 2008). As an alternative, a CO_2-based strategy was conducted, which may be more suitable for certain sectors and substances. However, the comparison of the two strategies did not highlight differences in the top-substances that contributed to the totals, while the share of contribution was different among them.

Problems in the availability of data arose in gathering of information for other regions than EU27+3. In the case of Australia, metals were more systematically reported, while the criteria for the reporting of other substances were not as clear. In the case of Japan, data was reported without providing CAS numbers, making the matching of data difficult.

As outlook, international efforts such as the Global Emission Initiative (GEIA, 2012) may, in the future, allow for a more systematic matching of data across countries and increase the reporting rate. The analysis of the inventory put together for the USA (TRI, USEPA 2012) confirms the findings of Lim et al. (2010; 2011) for the inventory of 2006. The works highlighted how metals were in 2006 the top contributing substances to the toxic impacts in the USA, with mercury, arsenic, lead, copper and vanadium having the highest contribution to human- and eco- toxicity.

Mattila et al. (2011) highlighted how LCIA models set different priorities in the control of emission and analysis. The characterization of emissions based on IMPACT 2002+, ReCiPe or USEtox determine a significant difference in results. As anticipated by the authors, a careful selection of the right LCIA model is advisable. The use of USEtox impact categories, as in this contribution, put high priority on metals emission to air and water, confirming the findings of Mattila et al. (2011). The assumptions used on the composition of inventories (e.g. EU 1, WORLD 1) or extrapolation strategies (i.e. CO_2-based, GDP-based) seemed not to have any influence on the results. This can also explain the variation in top contributing substances that was highlighted in Table 14.

Among metals, several inventories have been put together over the years according to different assumptions. Pacyna et al. (2006a) put together a detailed inventory of mercury for the year 2000 and project future emissions of mercury for the year 2020 (Pacyna et al. 2006b). A total of 1990 tonnes is reported by the authors for the year 2000 (Pacyna et al. 2006b), with a projection of a potential decrease by 20% to 80% according to different scenarios for the year 2020. The update for the year 2005 (Pacyna et al. 2010), reported emissions in the range of 1930 tonnes. The authors admit large level of uncertainties in the data projection for the future (Pacyna et al. 2010), largely due to a lack of actual measurement data.

The extrapolation conducted in this contribution sets the global emission of mercury for the year 2010 at around 2600 tonnes, suggesting an increase in emissions compared to that reported for 2000 and 2005. The effective reduction of mercury, however, is the subject of an international agreement reached in January 2013 (Mason et al. 2012). Future work should be oriented at quantifying more accurate emission inventories for the top contributors, which arise from different characterisation methods. This would lower the potential bias in the normalisation process (Heijungs et al. 2007).

For the case of pesticides, most of the information was gathered at the European level, with total quantities for 140 active ingredients for 2010, representing ca. 160 kt of pesticide used. An additional amount of 47.6 kt of pesticides was also reported as not belonging to the top-5 active ingredients (AI). No information on the AI is available; however, dosages for many chemical classes belonging to the category “Others” are known per crop type and per country. The category “Others” contains all AI not in country-specific top-5 AI lists. Therefore, it may happen that an AI reported in a top-5 list for a given country falls under the category “Others” in another country. As a result, the aggregated category “Others” also includes AI emissions, which are already reported separately (but de facto underestimated).

The study confirmed the difficulty in finding suitable data on pesticide use at EU and world level. More work is needed to refine the category “Others” and to go back to the relative active ingredients. Data for the UK (http://pusstats.fera.defra.gov.uk/), and Scotland (http://www.sasa.gov.uk/pesticides/pesticide-usage/pesticide-usage-survey-reports) was collected and differences in the order of magnitude of the quantity of pesticides used was found. A more in-depth analysis should be conducted to evaluate if ad–hoc extrapolation factors (e.g. crop production area, assumed to be related to pesticide use) are needed for a better coverage of pesticides. Limited or no data could be found for the rest of the world. As suggested by

Sleeswijk et al. (2008), FAO (2012) provides data on the consumption of different pesticide groups for a reasonably large number of European countries and for the rest of the world. Although, these groups of data cannot be used as emission estimates for individual pesticides, they may be useful for checking the validity of alternative estimation factors. Statistical strength of correlation between e.g. GDP and other solutions could be checked. Data from 2000 could also be compared with available data for 2010 and extrapolation strategies developed accordingly.

A refinement of the category "Others" may be attempted in future work based on the knowledge of the chemical classes involved for each country/crop system. Representatives of AI could thus be assigned with the help of an expert. A cross-check needs to be performed between the obtained amount of pesticides and the amounts reported by different organizations (e.g. FAOSTAT, EUROSTAT for sales). This cross-check can be done at the level of target classes, i.e. fungicides, insecticides, herbicides, or growth regulators. The aim is to quantify the coverage of pesticide use in the current work as well as identify possible inconsistencies.

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7 Appendix I – Overview of NMVOC sector breakdown with associated species profile treatment, background methodology available in Laurent et al 2013

Sectors	NFR09 codes	SNAP97 codes	Species profile allocation [a]	2010 EU-27+3 emissions [b]
1 A 1 Energy industries (Combustion in power plants & Energy Production)	1 A 1 a Public electricity and heat production	S1	Combination	0,9%
	1 A 1 b Petroleum refining	S1	Oil combustion	0,1%
	1 A 1 c Manufacture of solid fuels and other energy industries	S1	Coking plant	0,1%
1 A 2 Manufacturing Industries and Construction (Combustion in industry including Mobile):	1 A 2 a Stationary combustion in manufacturing industries and construction: Iron and steel	S3	Combination	0,1%
	1 A 2 b Stationary Combustion in manufacturing industries and construction: Non-ferrous metals	S3	Combination	0,0%
	1 A 2 c Stationary combustion in manufacturing industries and construction: Chemicals	S3	Combination	0,1%
	1 A 2 d Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	S3	Combination	0,1%
	1 A 2 e Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	S3	Combination	0,1%
	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other.	S3	Combination	0,8%
	1 A 2 f ii Mobile Combustion in manufacturing industries and construction	S8	Combination	0,6%
1 A 3 a,c,d,e Non-road transport	1 A 3 a i (i) International aviation (LTO)	S8	Aircraft commercial and public	0,1%
	1 A 3 a ii (i) Civil aviation (Domestic, LTO)	S8	Aircraft commercial and public	0,0%
1 A 3 b Road Transport;	1 A 3 b i Road transport: Passenger cars	S7	Combination	7,2%
	1 A 3 b ii Road transport:Light duty vehicles	S7	Combination	0,8%
	1 A 3 b iii Road transport:, Heavy duty vehicles	S7	Combination	1,6%
	1 A 3 b iv Road transport: Mopeds & motorcycles	S7	Combination	4,1%

	1 A 3 b v Road transport: Gasoline evaporation	S7	Benzine evaporation	2,1%
	1 A 3 b vi Road transport: Automobile tyre and brake wear	S7	No emissions	0,0%
	1 A 3 b vii Road transport: Automobile road abrasion	S7	No emissions	0,0%
1 A 3 a,c,d,e Non-road transport	1 A 3 c Railways	S8	Vehicles diesel highway	0,2%
	1 A 3 d ii National navigation (Shipping)	S8	Combination	1,7%
	1 A 3 a ii (ii) Civil aviation (Domestic, Cruise)	S11	Aircraft commercial and public	0,0%
	1 A 3 a i (ii) International aviation (Cruise)	S11	Aircraft commercial and public	0,2%
	1 A 3 d i (i) International maritime navigation	S11	Combination	1,0%
	1 A 3 d i (ii) International inland waterways	S11	Combination	0,0%
	1 A 3 e Pipeline compressors	S1	Gas distribution	0,0%
1 A 4 Other sectors (Commercial, residential , agriculture and fishing stationary and mobile combustion)	1 A 4 a i Commercial / institutional: Stationary	S2	Combination	0,6%
	1 A 4 a ii Commercial / institutional: Mobile	S8	Combination	0,2%
	1 A 4 b i Residential: Stationary plants	S2	Combination	12,9%
	1 A 4 b ii Residential: Household and gardening (mobile)	S8	Combination	0,6%
	1 A 4 c i Agriculture/Forestry/Fishing: Stationary	S2	Combination	0,6%
	1 A 4 c ii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	S8	Combination	1,3%
	1 A 5 a Other stationary (including military)	S2	Combination	0,0%
1 A 5 Other	1 A 5 b Other, Mobile (including military, land based and recreational boats)	S8	Combination	0,1%
	1 B 1 a Fugitive emission from solid fuels: Coal mining and handling	S5	Coal combustion	0,4%
1 B Fugitive emissions (Fugitive emissions from fuels);	1 B 1 b Fugitive emission from solid fuels: Solid fuel transformation	S4	Coal combustion	0,1%
	1 B 1 c Other fugitive emissions from solid fuels	S5	Coal combustion	0,1%
	1 B 2 a i Exploration, production, transport	S5	Refinery processing	1,1%
	1 B 2 a iv Refining / storage	S4	Refinery processing	3,1%
	1 B 2 a v Distribution of oil products	S5	Refinery processing	2,0%
	1 B 2 b Natural gas	S5	Gas distribution	1,5%

	1 B 2 c Venting and flaring	S8	Combination	0,4%
	1 B 3 Other fugitive emissions from geothermal energy production , peat and other energy extraction not included in 1 B 2	S11	Coal combustion	0,0%
	1A 4 c iii Agriculture/Forestry/Fishing: National fishing	S8	Combination	0,1%
2 Industrial Processes;	2 A 1 Cement production	S4	Coking plant	0,0%
	2 A 2 Lime production	S4	Coking plant	0,0%
	2 A 3 Limestone and dolomite use	S4	Coking plant	0,0%
	2 A 4 Soda ash production and use	S4	Coking plant	0,0%
	2 A 5 Asphalt roofing	S4	Combination	0,1%
	2 A 6 Road paving with asphalt	S4	Combination	0,7%
	2 A 7 a Quarrying and mining of minerals other than coal	S5	Coking plant	0,0%
	2 A 7 b Construction and demolition	S4	Coking plant	0,0%
	2A 7 c Storage, handling and transport of mineral products	S4	No emissions	0,0%
	2 A 7 d Other Mineral products	S4	Coking plant	0,0%
	2 B 1 Ammonia production	S4	Chemical production	0,0%
	2 B 2 Nitric acid production	S4	Chemical production	0,0%
	2 B 3 Adipic acid production	S4	Chemical production	0,0%
	2 B 4 Carbide production	S4	Chemical production	0,0%
	2 B 5 a Other chemical industry	S4	Chemical production	1,7%
	2 B 5 b Storage, handling and transport of chemical products	S4	Chemical production	0,0%
	2 C 1 Iron and steel production	S4	Metal foundry	0,3%
	2 C 2 Ferroalloys production	S4	Metal foundry	0,0%
	2 C 3 Aluminum production	S4	Metal foundry	0,0%
	2 C 5 a Copper production	S4	Metal foundry	0,0%
	2 C 5 b Lead production	S4	Metal foundry	0,0%
	2 C 5 c Nickel production	S4	Metal foundry	0,0%
	2 C 5 d Zinc production	S4	Metal foundry	0,0%
	2 C 5 e Other metal production	S4	Metal foundry	0,0%
	2 C 5 f Storage, handling and transport of metal products	S4	Metal foundry	0,0%
	2 D 1 Pulp and paper	S4	Paper manufacturing	0,3%
	2 D 2 Food and drink	S4	Bread manufacturing, Beer brewery, Wine manufacturing, Fermentation of bread, beer and wine	3,5%
	2 D 3 Wood processing	S4	Wood pressboard	0,1%

	2 E Production of POPs	S4	Chemical production	0,0%
	2 F Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	S4	Chemical production	0,0%
	2 G Other production, consumption, storage, transportation or handling of bulk products	S6	Chemical production	0,2%
3 Solvent and other product use;	3 A 1 Decorative coating application	S6	Paint application for constructions and buildings and domestic use	6,4%
	3 A 2 Industrial coating application	S6	Paint application	7,4%
	3 A 3 Other coating application	S6	Paint application for constructions and buildings and domestic use	0,9%
	3 B 1 Degreasing	S6	Metal degreasing	2,2%
	3 B 2 Dry cleaning	S6	Dry cleaning	0,4%
	3 C Chemical products	S6	Combination	5,0%
	3 D 1 Printing	S6	Printing industry	3,5%
	3 D 2 Domestic solvent use including fungicides	S6	Domestic solvent use	9,9%
	3 D 3 Other product use	S6	Combination	6,7%
4 B Animal husbandry and manure management	4 B 1 a Cattle dairy	S10	Hobbs et al. 2004	0,2%
	4 B 1 b Cattle non-dairy	S10	Hobbs et al. 2004	0,1%
	4 B 13 Other	S10	Hobbs et al. 2004	0,0%
	4 B 2 Buffalo	S10	Hobbs et al. 2004	0,0%
	4 B 3 Sheep	S10	Hobbs et al. 2004	0,0%
	4 B 4 Goats	S10	Hobbs et al. 2004	0,0%
	4 B 6 Horses	S10	Hobbs et al. 2004	0,0%
	4 B 7 Mules and asses	S10	Hobbs et al. 2004	0,4%
	4 B 8 Swine	S10	Hobbs et al. 2004	0,2%
	4 B 9 a Laying hens	S10	Hobbs et al. 2004	0,1%
	4 B 9 b Broilers	S10	Hobbs et al. 2004	0,0%
	4 B 9 c Turkeys	S10	Hobbs et al. 2004	0,0%
	4 B 9 d Other poultry	S10	Hobbs et al. 2004	0,0%
4 D Plant production and agricultural soils	4 D 1 a Synthetic N-fertilizers	S10	CORINAIR 2009 (sect. 4 D)	0,3%
	4 D 2 a Farm-level agricultural operations including storage, handling and transport of agricultural products	S10	CORINAIR 2009 (sect. 4 D)	0,0%
	4 D 2 b Off-farm storage, handling and transport of bulk agricultural products	S10	No emissions	0,0%
	4 D 2 c N-excretion on pasture range and paddock unspecified	S10	No emissions	0,0%

4 F,G Field burning and other agriculture	4 F Field burning of agricultural wastes	S10	Lemieux et al. 2004; EUROSTAT 2012	0,8%
	4 G Agriculture other(c)	S10	Disregarded [c]	0,1%
6 Waste;	6 A Solid waste disposal on land	S9	Based on Allen et al. 1997	0,7%
	6 B Waste-water handling	S9	Based on Ethirajan et al. 2012	0,1%
	6 C a Clinical wasteincineration (d)	S9	US EPA 1990	0,0%
	6 C b Industrial waste incineration (d)	S9	US EPA 1990	0,1%
	6 C c Municipal waste incineration (d)	S9	US EPA 1990	0,0%
	6 C d Cremation	S9	US EPA 1990	0,0%
	6 C e Small scale waste burning	S9	Lemieux et al. 2004; EUROSTAT 2012	0,2%
	6 D Other waste(e)	S9	Based on Ethirajan et al. 2012	0,0%
7 A Other (included in National Total for Entire Territory)	7 A Other (included in national total for entire territory)	S5	Reported as Other VOCs (no information available)	0,0%

[a] For sectors NFR09 1to NFR09 3, speciation profiles refer to those documented in Theloke et al. 2007. For sector NFR09 4 and NFR09 6, speciation profiles refer to the indicated literature sources used.

[b] Blue cells show sectors for which NMVOC emissions contribute to more than 1% of total in EU-27+3 in the year 2010.

[c] Sector “4 G Agriculture other” refers to pesticides released to air; the inventory element related to pesticides already account for this contribution, hence it was disregarded to avoid double counting.