Example Inventory 1 Updating and Revising an Inventory

1. Example of inventory updating and revision triggered by changes in emission factors

This example illustrates the inventory updating and revision for a single source class – open burning of domestic waste - which is triggered by the revision of the emission factor in the Toolkit methodology.

Let's consider a hypothetical inventory of country X. **The baseline inventory** is developed in 2005, based on data collected for the reference year 2003 and by using the Toolkit 2005 methodology. The baseline inventory estimates that approximately 60,000 tons of domestic waste from rural and urban areas is burned in 2003. The total annual releases of the baseline year are calculated based on the Toolkit 2005 methodology, by applying an emission factor for air of 300 µg TEQ/t of material burnt. The baseline releases to air from open burning of domestic waste are thus estimated at 18 g TEQ/year.

Baseline PCDD/PCDF released to air in 2003** (g TEQ/year)=* ***Quantity of waste burnt x EF$_{Air}$=

60'000 t/yr x 300 µg TEQ/t=

18 g TEQ/year

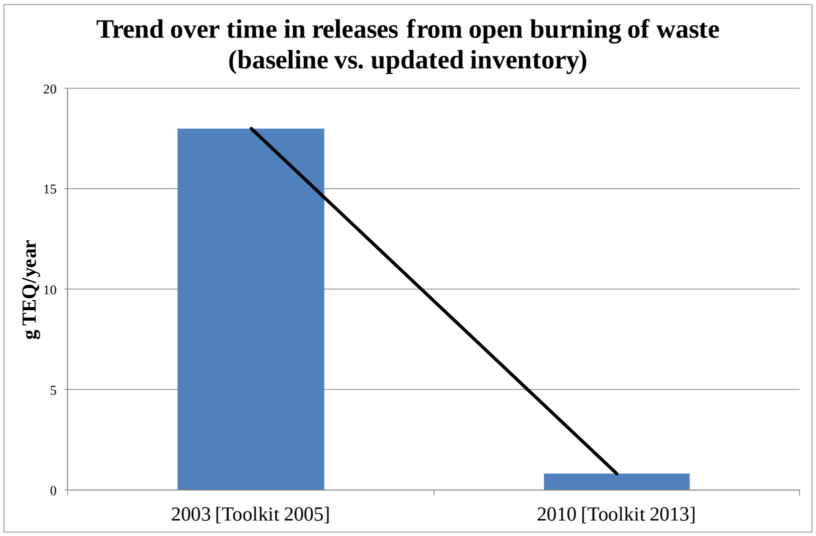
Country X implements measures to reduce releases from open burning as part of the action plan within the National Implementation Plan, and initiates an update of the PCDD/PCDF inventory to assess the success of these measures and report them as part of the national report under Article 15.

The updated inventory is developed in 2013, based on data collected for the reference year 2010 and the Toolkit methodology as revised in 2013. 2010 activity rates for this source were assessed at around 20,000 tons of domestic waste burned annually. The corresponding emission factor was revised since the first inventory and is much lower than the one used for the baseline inventory: EF$_{Air}$ is now 40 µg TEQ/t of material burned. The total annual releases are calculated based on the Toolkit 2013 methodology as below:

Updated PCDD/PCDF released to air in 2010** (g TEQ/year)=* ***Quantity of waste burnt x EF$_{Air}$=

20'000 t/yr x 40 µg TEQ/t=

0.8 g TEQ/year



The total releases to air from open burning of domestic waste are thus estimated at 0.8 g TEQ/year in 2010. This translates into a significant reduction in releases to air from this source class from 2003 to 2010 (-95% decrease) as illustrated below:

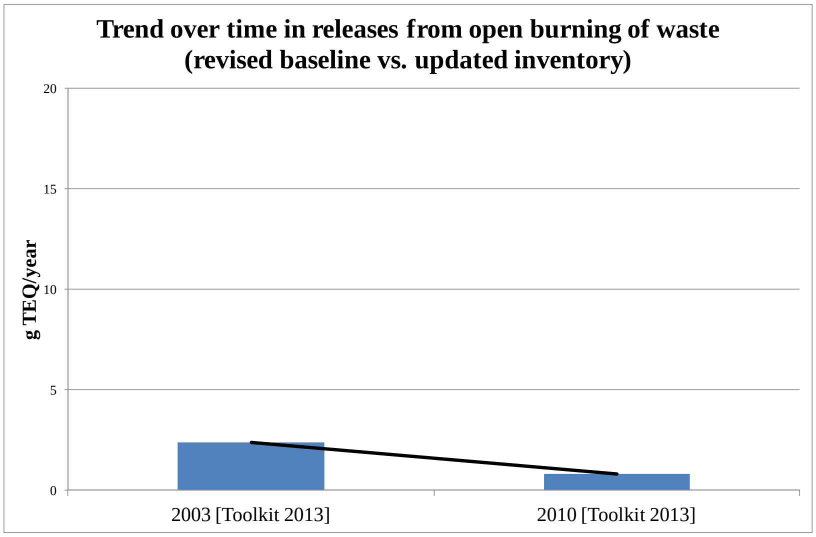
This assessment is not correct as it does not consider that along with the decrease in the activity level from 2003 to 2010, the emission factor has also been revised downwards. Since the basis for the calculation is not the same in the updated inventory as in the baseline **the estimations are not coherent** and the initial inventory will have to be reassessed to allow for correct trends over time to be calculated.

The revised baseline estimate will be the product of the baseline activity levels that were assessed for 2003 (60,000 tons of domestic waste burned per year) and the revised emission factors taken from the Toolkit 2013 methodology which was used in the updated inventory: 40 µg TEQ/t for air. The revised baseline levels of releases are thus 2.4 g TEQ/yr.

Revised PCDD/PCDF released to air in 2003 (g TEQ/year)= ***Quantity of waste burnt x EF$_{Air}$=***

60’000 t/yr x 40 µg TEQ/t=

2.4 g TEQ/year



The revision of the baseline inventory allowed country X to assess correct trends over time and see that indeed there was a decrease in releases from 2003 to 2010, but this amounted to only 66%.

2. Example of inventory updating and revision triggered by an additional source class

Let’s now consider another source category in this hypothetical inventory, where the revision of the baseline inventory is triggered by an additional class included in the revised Toolkit methodology.

The initial/baseline inventory was performed in 2005, based on 2003 data and the Toolkit 2005 methodology. In 2003, country X estimates that 4’000’000 tons of agricultural residues are burnt in poor conditions. An emission factor for air of 30 µg TEQ/t is applied according to the Toolkit 2005 methodology, and the overall emissions to air from this source class are estimated at 120 g TEQ/yr.

Baseline releases from agricultural residue burning in 2003 (g TEQ/year)=

Quantity of material burnt x EF$_{Air}$=

4’000’000 t/yr x 30 µg TEQ/t= 120 g TEQ/year

In 2013 country X updates the inventory based on 2010 data and by using the 2013 revised version of the Toolkit. The emission factor for agricultural residue burning in poor conditions is the same as in the 2005 methodology: 30 µg TEQ/t. **The updated inventory** assesses the activity rate as 2’000’000 t material burnt annually. In addition, the developer of the inventory discovers that a new class was added to this source category, which is of major relevance for the country: this is sugarcane burning.

The new emission factor for sugarcane burning included in the 2013 methodology is of 4 µg TEQ/t, while the activity rate for this source class is estimated at 2'000'000 tons residues burnt annually. The release estimates are calculated as below, by multiplying the activity rate with the respective emission factors:

***Updated releases from agricultural residue burning in 2010** (g TEQ/year)=*

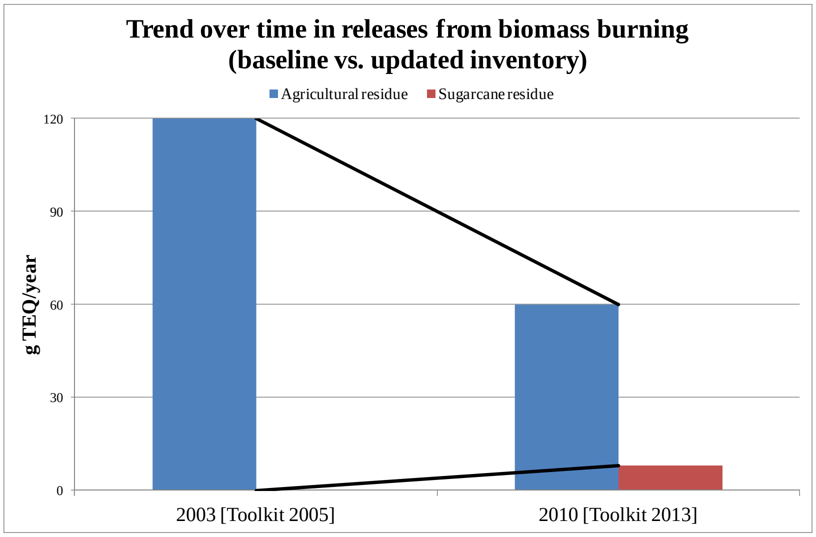
Quantity of material burnt x EF_{Air}=

2'000'000 t/yr x 30 µg TEQ/t= 60 g TEQ/year

***Updated releases from sugarcane burning in 2010** (g TEQ/year)=*

Quantity of material burnt x EF_{Air}=

2'000'000 t/yr x 4 µg TEQ/t= 8 g TEQ/year



Further to the updating of the inventory, the immediate conclusion would be a 50% reduction in air emissions from agricultural residue burning and a significant increase from 0 to 8 g TEQ in air emissions from sugarcane burning.

This conclusion is wrong, because the new class has to be assessed separately in the baseline inventory, similarly as in the updated inventory. At the time the baseline inventory was developed, emission factors were not yet specifically developed and available to assess releases from sugarcane burning, and this source class had to be assessed together with other types of agricultural residues. There is a need to go back to the previous inventory and revise the calculations therein to include this new class. Only after this revision, the comparison between the situation in 2003 and the one in 2010 can be done.

In **the revised baseline inventory**, activity rates for the two source classes (agricultural residue burning and sugarcane burning) need to be retrospectively estimated for the baseline year. In 2003, from the initially estimated 4'000'000 t agricultural residues burnt annually, only 3'000'000 t actually corresponded to this source class; the remaining 1'000'000 tons were actually sugarcane residues that were burnt in the open. Therefore, in the baseline year, emissions to air from agricultural residue burning were of 90 g TEQ/yr, while the emissions from sugarcane burning were of 4 g per year.

***Revised releases from agricultural residue burning in 2003** (g TEQ/year)=*

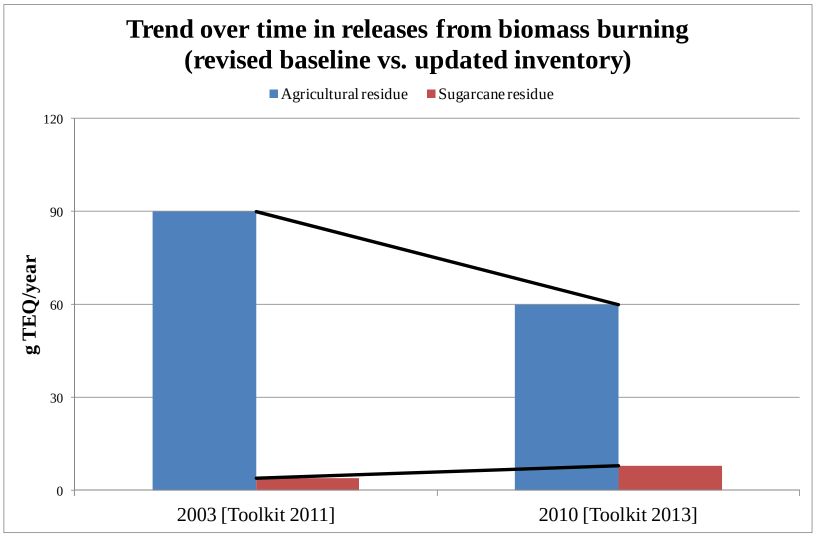
Quantity of material burnt x EF_{Air}=

3'000'000 t/yr x 30 µg TEQ/t= <u>90 g TEQ/year</u>

<u>Revised releases from sugarcane burning in 2003</u> (g TEQ/year)=

Quantity of material burnt x EF_{Air}***=***

1'000'000 t/yr x 4 µg TEQ/t= <u>4 g TEQ/year</u>



The revision of the baseline inventory shows that the actual reduction in air emissions from agricultural residue burning is of only 33%, while the increase in air emissions from sugarcane burning is only of 4 g TEQ:

3. Example of inventory updating and revision triggered by a missing source

This example illustrates a different type of situation, where the revision of the baseline inventory is not triggered by the changes in the methodology, but rather by better information becoming available at the country level during the inventory updating process.

We'll take the example of another source group: waste incineration.

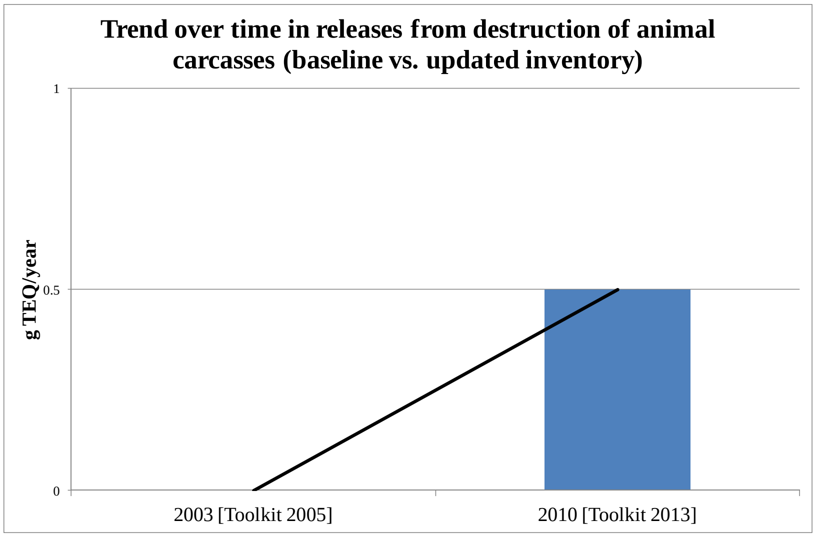
The baseline inventory of country X mentions that the incineration of animal carcasses is rarely applied in the country and information for this source category is not available. It is thus considered that releases from this source category are negligible in 2003.

With the **updating of the inventory** in 2013, country X discovers that one old facility exists that is specialized in thermal destruction of carcasses. The activity rate for 2010 (the reference year in the updated inventory) is estimated at 1'000 t carcasses destroyed. The emission factor applied is of 500 µg TEQ/t, corresponding to old facilities without air pollution control system. The overall emissions to air from this source category amount to 0,5 g TEQ/year.

<u>Updated PCDD/PCDF released to air in 2010</u> (g TEQ/year)= ***Quantity of carcasses x*** EF_{Air}***=***

1'000 t/yr x 500 µg TEQ/t=

<u>0.5 g TEQ/year</u>



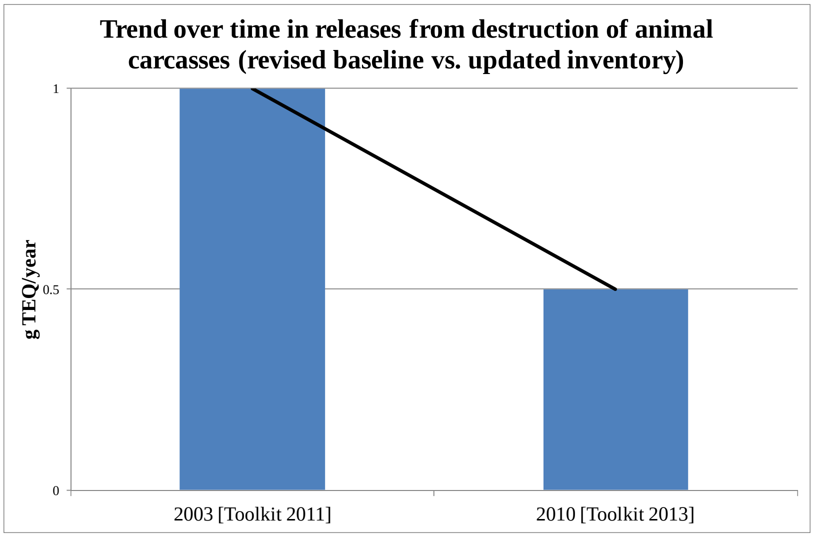
This would mean that an increase in emissions from this source took place from 2003 to 2010.

Nevertheless, the facility was operational in the baseline year as well, releasing dioxins and furans in the environment. A revision of the baseline inventory is thus necessary to ensure coherent trends over time. The revised baseline inventory estimates that the activity rate of this facility in 2003 was of 2'000 t of carcasses destroyed, double the amount in 2010. The corresponding emission level is of 1 g TEQ/yr.

Revised PCDD/PCDF released to air in 2003** (g TEQ/year)=* ***Quantity of carcasses x EF$_{Air}$=

2'000 t/yr x 500 µg TEQ/t=

1 g TEQ/year



The revision of the inventory enabled thus country X to observe an actual decrease in emissions from this category. If the revision was not performed, the incorrect conclusion would have been, on the opposite, an increase in emissions.

Example Inventory 2 Source Group 1 Waste Incineration

I. Example of baseline inventory using national waste combustion statistics as a major activity data source

This example illustrates the inventory process in the case where activity data are mainly obtained through national waste combustion statistics (questionnaires are partially used/targeted to obtain detailed information on incineration technologies in place). The example provides information on the baseline inventory process only, and is mainly focused to providing useful guidance on estimating activity rates.

Country X prepared its first inventory of dioxins and furans in 2006 to support the development of the action plan as required by Article 5 of the Convention. Activity data for the different sources of PCDD/PCDF were collected for the reference year 2004 (baseline year). The inventory is developed by applying the Toolkit 2005 methodology and the emission factors specified in that version of the Toolkit. Activity data was obtained from waste incineration national statistics.

According to waste statistics, in 2004 350,000 tons of wastes of more than 50 types were incinerated. Greatest incinerated volumes are communal-domestic wastes, wood wastes without pollution (‘clean’ wood wastes), polluted wood wastes, petrochemical sludge, wastes from paint production, waste petroleum oils, old tires, wastes from chipboard production, wastes from resins production, old sleepers impregnated with creosote, rags polluted with oils, old containers from pesticides, polluted paper and cardboard, liquid spirits, washing waters from chemical production and petroleum products storage, and hospital wastes.

For the quantification of PCDD/PCDF emissions, these major categories of combusted wastes were aggregated into different categories according to the Toolkit classification.

It was thus accounted that 60,000 tons of wastes are ‘Municipal solid wastes’, 50,000 tons ‘Hazardous wastes’, 5,000 tons ‘Medical wastes’, and 70,000 tons ‘Waste wood and waste biomass’. No incineration of sewage sludge, light fraction shredder wastes and animal carcasses was accounted for.

Among these waste types, 10,000 tons of old tyres were combusted in cement kilns; PCDD/PCDF emissions from this category were accounted for in Group 4 – Mineral products. 100000 tons of ‘clean’ wood wastes and 40,000 tons of biomass waste were incinerated in boilers for energy and heat production and accounted in Group 3. 15,000 tons of wastes could not be included into any category and PCDD/PCDF emissions from their incineration were not accounted for.

In addition, statistical data on wastes combusted in private households could not be obtained; an expert assessment of the total amount of such wastes used as an energy source for residential purposes was made, and emissions were accounted in Source Group 3.

The Environmental Protection Agency notifies that there are ten waste incineration plants in the country which mostly burn municipal wastes (or similar) and two plants which incinerate medical wastes. No statistical data could be found on the distribution of wastes according to the technology of combustion and level of abatement. To obtain such detailed data, questionnaires were sent to major waste incineration facilities, communal services and companies which produce the largest amounts of wastes.

It was found that most of the industrial waste and partially medical wastes are incinerated 'on-site', by the plant/hospital generating these wastes. As for municipal wastes, these are incinerated at special plants.

Through the analysis of the questionnaires it was found that waste incineration practices include simple types of incineration furnaces, mostly batch-type. It was thus concluded that most of the waste combustion installations are equipped with simple abatement devices (1-stage with afterburners, cyclones, scrubbers), which correspond to Class 2 of the Toolkit. Only a minor part of incineration facilities are equipped with 2-stages abatement systems including bagfilters; this corresponds to Class 3 of the Toolkit. Finally, some facilities do not have abatement at all (Class 1).

There is no special management of residues from waste burning and fly ash: these are collected and landfilled together with other industrial and municipal wastes.

According to these data, baseline estimates of PCDD/PCDF emission from this source group amounted to:

- Air emission: 54.9 g/TEQ,
- Emission to residues: 58.6 g/TEQ

II. General example of baseline inventory, updating and revision

Introduction

The purpose of this case study is to illustrate the process of inventory development, update and revision, including the various triggering factors that may come into play in this process. We will consider a hypothetical example of an inventory of country X, and describe the baseline inventory process, its update and revision, focusing on a single source group: Waste Incineration.

Baseline inventory

Country X prepares its first (baseline) inventory of dioxins and furans in 2006 to support the development of the action plan as required by Article 5 of the Convention and included in the National Implementation Plan pursuant to Article 7. Activity data for the different sources of dioxins and furans in country X are collected for the reference year 2004 (baseline year). The inventory is developed by applying the Toolkit 2005 methodology and the emission factors specified in that version of the Toolkit.

From the seven source categories included in this source group, only three are relevant for country X in the baseline year. These are presented below.

1a Municipal Solid Waste Incinerators

The preparer of the National Inventory sends a request to the national environmental permitting authority, asking for the number of MSW incinerators with active permits in 2004, their basic designs, design capacities and locations. The permitting authority reports that 30 MSW incinerators were permitted and active in country X during that year and provides the additional information requested for each incinerator. Based on their design capacities, it is estimated that ten MSW incinerators account for 90% of the total design capacity for MSW incineration in country X.

The inventory preparer sends a request to the national statistics office, asking for the quantity of MSW generated in each state or province in 2004, the fraction disposed by incineration, and, if available, the waste composition and characteristics (these data are publicly available). According to the statistical data, a total of 5,000,000 tons of MSW were incinerated in country X during 2004. To complement this information and to estimate activity levels with a higher degree of confidence, questionnaires are sent to the ten largest MSW incinerators. According to the statistical data and/or information provided by the permitting authority, the developer of the inventory determines that these ten MSW incinerators are located in only two provinces or states in country X. Site visits are scheduled to confirm and collect information on technologies in use and gain intelligence on actual practices of the facilities.

The waste incineration plants are assigned to four classes according to their technologies, by using the data obtained through questionnaires and complemented by site visits. The corresponding 2005 Toolkit emission factors are selected for these four source classes, and release estimates are obtained by each of the activity rates with their respective emission factors. The results are presented in the table below.

Source group	**Source category**	**Class**		**Activity rate (t/year)**	**Annual Release (g TEQ/a)**					
					Air	**Water**	**Land**	**Product**	**Residue**	
									Fly ash	**Bottom ash**
1 Waste Incineration	1a MSW	1	Low technology combustion, no APCS	-						
		2	Controlled combustion with minimal APCS	2,000,000	700				1,000	30
		3	Controlled combustion with good APCS	2,000,000	60				400	14
		4	High technology combustion, sophisticated APCS	1,000,000	0.5				15	1.5

1b Hazardous waste incineration

A request is sent to the national environmental permitting authority, asking for the number of HW incinerators with active permits in 2004, their basic designs, design capacities and locations. The permitting authority reports that 30 HW incinerators were permitted and active in country X during that year and provides the additional information requested for each incinerator.

A request is sent to the national statistics office, asking for the quantity of HW generated in each state or province in 2004 and the fraction disposed by incineration. According to the statistical data, a total of 200,000 tons of HW were incinerated in country X during 2004.

The HW incinerators are assigned to four classes according to their technologies. The corresponding 2005 Toolkit emission factors are selected for these four source classes, and release estimates are obtained by each of the activity rates with their respective emission factors. The results are presented in the table below.

Source group	**Source category**	**Class**		**Activity rate (t/year)**	**Annual Release (g TEQ/a)**					
					Air	**Water**	**Land**	**Product**	**Residue**	
									Fly ash	**Bottom ash**
1 Waste Incineration	1b Hazardous Waste	1	Low technology combustion, no APCS	50,000	1’750				450	
		2	Controlled combustion with minimal APCS	100,000	35				90	
		3	Controlled combustion with good APCS	-						
		4	High technology combustion, sophisticated APCS	50,000	0.0375				1.5	

1c Medical waste incineration

In the case of medical waste incineration, the developer of the inventory obtains useful information from the Ministry of Health, including the total number of hospitalized patients in 2004. By visiting a typical incineration facility located at a typical hospital in country X, information on the type and quantities of medical waste incinerated is obtained and averaged per patient. The data collected through this approach and extrapolated to the country level is used to estimate the total activity rate for the reference year. Information on technologies in place in these typical facilities was also used to classify medical waste incineration sources and assign corresponding emission factors from the 2005 Toolkit 2005.

Source group	**Source category**	**Class**		**Activity rate (t/year)**	**Annual Release (g TEQ/a)**					
					Air	**Water**	**Land**	**Product**	**Residue**	
									Fly ash	**Bottom ash**
1 Waste Incineration	1c Medical Waste	3	Controlled, batch type combustion, good APCS	800,000	420				736	

Updated inventory

Beginning in 2007, country X implements an action plan to reduce releases of unintentional POPs, as part of its National Implementation Plan. Measures are taken to reduce releases from waste incineration, in particular through phasing in BAT/BEP for waste incinerators, upgrading facilities and increasing recycling rates. In 2013, country X updates its inventory to assess the success of the measures implemented. Data are collected for the reference year 2010, and the inventory is established according to the Toolkit methodology as revised in 2013.[31]

As a first step in the updating process, the examination of the baseline inventory is a crucial step. It shows to the new developer of the inventory where information can be found, and which information gaps need to be filled using extrapolation and expert judgment. The same approach is thus taken in the updated inventory as in the baseline, based on statistical data for 2010 that is obtained from the same sources used for the 2004 inventory.

The Toolkit edition from 2005, which was used for the baseline inventory was revised and the Toolkit 2013 is used by the developer to update the inventory. In order to maintain consistency over time, the developer has to examine if the emission factors have been changed. The emission factors for the source group waste incineration are the same in both Toolkit versions.

1a Municipal Solid Waste Incinerators

According to the new data, the total amount of MSW incinerated in 2010 is 4,000,000 tons, a 20% decrease since 2004. This suggests that incentives to increase recycling rates in country X were successful in reducing the total amount of municipal waste sent to MSW incinerators. Through applying best available techniques for waste incinerators, all facilities have been significantly upgraded with improved technology since the development of the first inventory, and are assigned to the two classes with the lowest emission factors.

The results show, for instance, that further to the measures implemented under the action plan, releases to air from MSW incineration have dropped by 88% while total releases have fallen by 67%. This assessment was obtained through applying the same inventory approach and the same set of emission factors, therefore the results are readily comparable and the trends over time are consistent.

Source group	**Source category**	**Class**		**Activity rate (t/year)**	**Annual Release (g TEQ/a)**					
					Air	**Water**	**Land**	**Product**	**Residue**	
									Fly ash	**Bottom ash**
1 Waste Incineration	1a MSW	1	Low technology combustion, no APCS	-						
		2	Controlled combustion with minimal APCS	-						
		3	Controlled combustion with good APCS	3,000,000	90				600	21
		4	High technology combustion, sophisticated APCS	1,000,000	0.5				15	1.5

1b Hazardous waste incineration

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[31] NB: The dioxin emission factors for waste incineration were not revised/changed in the 2013 revised edition of the Toolkit. These are the same as in the Toolkit 2005.

The total annual destruction capacity for hazardous waste was estimated at 200,000 tons in 2010, remaining at constant levels since 2004. Facilities burning hazardous waste were equally upgraded through the introduction of best available techniques for incinerators:

Source group	**Source category**	**Class**		**Activity rate (t/year)**	**Annual Release (g TEQ/a)**					
					Air	**Water**	**Land**	**Product**	**Residue**	
									Fly ash	**Bottom ash**
1 Waste Incineration	1b Hazardous Waste	1	Low technology combustion, no APCS	-						
		2	Controlled combustion with minimal APCS	-						
		3	Controlled combustion with good APCS	150,000	1.5				67.5	
		4	High technology combustion, sophisticated APCS	50,000	0.0375				1.5	

The results thus show a massive decrease in releases from this category (more than 99%), as a result of upgrading the old facilities burning hazardous waste. This conclusion is based on results obtained through the same approach and same set of emission factors as in the baseline inventory.

1c Medical waste incineration

Medical waste incineration rates were also unchanged in 2010, with all facilities classified as class 3 of the Toolkit. The data were obtained as in the baseline inventory, through extrapolation of typical facility-specific information based on the number of patients registered in the baseline year. Therefore releases from this category remained at constant levels since 2004.

Source group	**Source category**	**Class**		**Activity rate (t/year)**	**Annual Release (g TEQ/a)**					
					Air	**Water**	**Land**	**Product**	**Residue**	
									Fly ash	**Bottom ash**
1 Waste Incineration	1c Medical Waste	3	Controlled, batch type combustion, good APCS	800,000	420				736	

1g Destruction of animal carcasses

In 2006, when the baseline inventory for 2004 was developed, no information was available to assess the rates of thermal destruction of animal carcasses in country X. This category was considered irrelevant for country X and excluded from the baseline inventory. In 2013, the developer of the inventory discovers that one old facility exists that is specialized in thermal destruction of carcasses. The activity rate for 2010 (the reference year in the updated inventory) is estimated at 1,000 t carcasses destroyed. The emission factor applied is 50 µg TEQ/t, corresponding to old facilities with limited air pollution control. The overall emissions to air from this source category amount to 0.05 g TEQ/year:

***PCDD/PCDF released to air in 2010* (g TEQ/year)=** **Quantity of carcasses x EF_{Air}=**

1,000 t/yr x 50 µg TEQ/t=

0.05 g TEQ/year

The immediate conclusion would be an increase in air emission from 0 to 0.05 g TEQ from 2004 to 2010. However, this particular source was equally present in country X in 2004 but not assessed in the baseline inventory because of lack of information. Consequently, the first inventory must be revised taking into account this new information. The results obtained for this source category in 2004 and 2010 can be compared only after the baseline release estimate has been revised.

Revision of the baseline inventory

The revision of the baseline inventory is necessary to ensure consistency of trends in releases over time. In this example, only the estimates for one source category pertaining to the waste incineration group need to be revised.

1g Destruction of animal carcasses

With the updating of the inventory in 2013, country X discovers new information about thermal destruction of animal carcasses which must be incorporated in the baseline inventory. This source was not accounted in the reference year 2004 due to lack of information. The developer of the inventory needs to assess retrospectively the activity rate of this source for the baseline year to enable the comparison of 2004 and 2010 release estimates.

The activity rates for the baseline year are re-estimated at 1’500 t, and revised release estimates calculated as below:

***PCDD/PCDF released to air in 2004* (g TEQ/year)=** **Quantity of carcasses x EF_{Air}=**

1’500 t/yr x 50 µg TEQ/t=

0.075 g TEQ/year

The results show thus a decrease by 33% in releases to air from this category. If the new information was not incorporated to revise the baseline release estimate, the resulting trend would have been, on the contrary, an increase in releases from this source.

Conclusion

This example shows that when updating the dioxin inventory, examination of the previous inventory is essential in order to identify quickly the approach used, find valuable information sources to estimate activity rates, use consistent expert judgment to fill information gaps, etc. It also shows that, besides changes in the Toolkit through its revision in 2013, new information that becomes available at the country level is equally important in triggering revision of baseline estimates of releases. If this revision is not performed, the results obtained for the different reference years cannot be compared and trends over time cannot calculated.

Example Inventory 3 Source Group 2 Ferrous and Non-Ferrous Metal Production

Introduction

The purpose of this case study is to illustrate the process of inventory development, update and revision, focusing on, metal industry. This case study provides a hypothetical example for a Country X, including practical details on updating of the inventory to assess the evolution of emissions further to implementing strict measures as specified in the action plan developed as part of the NIP. The case study also includes essential information on the process of revision of the baseline inventory, which is triggered by revision of emission factors in the Toolkit and discovery of new information on sources which existed in the baseline but were not accounted for due to lack of proper information at that time, allowing to refine the baseline estimates and obtain comparable results.

Baseline inventory

The baseline inventory of country X was conducted in 2006 using data collected for the 2004 reference year, according to the 2005 Toolkit methodology.

Using the following information sources, a list of relevant activity types and facility names was produced:

1. Listings of industrial activities in the Associations representing the sector,
2. Customs databases for imports of inputs for the foundry industry,
3. Industrial activities listed in trade guides for product offers,
4. Local authorities (Districts, Municipalities) and national government (Ministry for Environment).

Based on the questionnaire for Group 2 – Ferrous and Non-Ferrous Metal Production (Annex 3 of the Toolkit), an adapted questionnaire was developed and sent by e-mail or via fax in 2006, to the list of industries obtained. The heads of each company were requested to complete the necessary information and the activity data for reference year 2004.

Of the twelve categories of sources in this group, only four are relevant to the country in the 2004 baseline year, and are detailed below:

- 2c Iron and steel production and foundries,
- 2d Copper production,
- 2e Aluminum production,
- 2l Thermal wire reclamation.

In 2006 no information was available on activity levels and technologies for the metals smelting sector. To overcome this, the questionnaire was sent to all industries identified, a total of 11. All of them are engaged in secondary smelting of different materials with different qualities, as Country X has not developed primary production of metals from ores.

Of all industries, a sample of 5 was selected to be visited in order to verify the correct interpretation of the information requested in the questionnaire and the degree of accuracy of the information submitted by the responsible of the company.

The facilities visited were those with activities considered as more sensitive in the estimates of PCDD/PCDF emissions, either by the level of activity or the production and control technologies used. The companies selected covered between 80 and 85% of total ferrous and non ferrous production, so this helped to improve the confidence of the emissions estimates in this sector.

Open burning of stolen cables from power and telephone lines is an informal activity which frequently takes place in the country. The allowed recovery technology is the peeling of wire for subsequent entry into smelting furnaces, without PVC or other plastic materials. The informal activity is performed in poor conditions. The stolen wire amount in 2004 was obtained from the electricity transmission companies and from the telephone companies.

2c Iron and Steel Production and Foundries

In this subcategory a total of five facilities were identified, among which two produce a total of 120,000 tons of liquid steel a year, and three were iron foundries with a production of 30,000 tons per year. They were ordered into four classes taking into account the technologies used.

Source category	**Class**		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
				Air	**Water**	**Land**	**Product**	**Residue**	
Iron and steel plants	1	Dirty scrap, scrap preheating, limited controls	20,000	0.200				0.300	0.50
	2	Clean scrap/virgin iron, afterburner, fabric filter	-						
	3	Clean scrap/virgin iron, BOF furnaces	-						
	4	Blast furnaces with APC	100,000	0.001					0.00
Sub- Total			*120,000*	*0.20*	*0*	*0*	*0*	*0.300*	*0.50*
Foundries	1	Cold air cupola or rotary drum, no APCS	10,000	0.100					0.10
	2	Rotary drum - fabric filter	20,000	0.086				0.004	0.09
	3	Cold air cupola, fabric filter	-						
	4	Hot air cupola or induction furnace, fabric filter	-						
Sub- Total			*30,000*	*0.186*	*0*	*0*	*0*	*00*	*0.19*
Total		**Iron and steel production plants and foundries**	**150,000**	**0.388**	**0**	**0**	**0**	**0.304**	**0.69**

2d Copper Production

A total of three companies were identified as active in secondary smelting of copper, with a total production of 68,000 tons per year. Among these, 60,000 tons are produced in modern, well-operated plants, with a rapid quench system, bag filters and filter activated carbon. In this way, emissions are captured in the gas treatment system, while waste generated through the process is better controlled. The remaining 8,000 tons are produced in two basic technology plants without controls.

Class		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
			Air	**Water**	**Land**	**Product**	**Residue**	
1	Sec. Cu - Basic technology	8,000	6.400				5.040	11.44
2	Sec. Cu - Well controlled	-						
3	Sec. Cu - Optimized for PCDD/PCDF control	60,000	0.300				18.000	18.30
4	Smelting and casting of Cu/Cu alloys	-						
5	Prim. Cu, well-controlled, with some secondary feed materials	-						
6	Pure prim. Cu smelters with no secondary feed	-						
Total	**Copper production**	**68,000**	**6.700**	**0**	**0**	**0**	**23.0**	**29.8**

2e Aluminum Production

This sector involved a total of three plants for secondary aluminum production using scrap of varying quality. The emissions for the two classes are presented in the following table. It is worth mentioning that in the present case these values are rather low, without significant variations between the different classes.

Class		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
			Air	**Water**	**Land**	**Product**	**Residue**	
1	Processing scrap Al, minimal treatment of inputs, simple dust removal	5,000	0.750				1.000	1.75
2	Scrap treatment, well controlled, good APCS	-						
3	Scrap treatment, well-controlled, fabric filter, lime injection	15,000	0.075				1.500	1.58
4	Optimized proces for PCDD/PPCDF abatement	-						
5	Shavings/turnings drying (simple plants)	-						
6	Thermal de-oiling, rotary furnaces, afterburners, fabric filters	-						
7	Pure primary Al plants	-						
Total	**Aluminum production**	**20,000**	**0.825**	**0**	**0**	**0**	**2.5**	3.3

2l Thermal Wire Reclamation and e-waste recycling

To estimate emissions from wire burning, it was assumed that all stolen cables were burned in the open, so the country's copper smelters only receive bare wires. This will lead to an overestimation of the emissions which is however found acceptable due to lack of other information.

It is estimated that a total of 600 tons of cables were burned in the open in 2004. This is based on the length of stolen wire and weight per kilometer (kg/km), as provided by electricity transmission companies and phone companies. It was also assumed that the activities of electronic scrap recovery take place nationwide.

Class		Production (t/a)	Annual release (g TEQ/a)					Sub- Total (g TEQ/a)
			Air	Water	Land	Product	Residue	
1	Open burning of cable	600	3.000					3.00
2	Basic furnace with after burner, wet scrubber	-						
3	Burning electric motors, brake shoes, etc., afterburner	-						
Total	**Thermal wire reclamation**	**600**	**3.000**	**0**	**0**	**0**	**0**	**3.0**

Update of the inventory

As part of the National Implementation Plan, the Country X has implemented a set of measures to reduce the generation and release of unintentional POPs. The baseline inventory was updated in 2013 to assess whether the implementation of such measures was successful. The Toolkit as revised in 2013 was used as a basis for updating release estimates. The update served to assess both the changes in volumes and types of activity taking place in the country, as well as the effectiveness of measures implemented to reduce levels of emissions.

The measures implemented to reduce the PCDD/PCDF emissions from other source categories, in particular waste management, and the rising value of metals on the market, has led to an increase in waste recycling and increasing rates of metal scrap recovery, mainly ferrous.

In addition, during the baseline survey performed in 2006 to produce the baseline inventory, several gaps in information were detected. Therefore the Government decided to require registration of smelting activities through the Ministry of Environment. Through this government decision, companies are obliged to update their information every four years. Due to this initiative, necessary information was readily available for processing, and the time needed to update the inventory was significantly reduced. This also allowed to identify the leading smelting activity in Country X, which had not been detected in the first inventory.

2c Iron and Steel Production and Foundries

In 2010, the same five industries remain, with an increase of 33% in production, which are still insignificant compared to the total releases form Group 2.

Source	Class	Production	Annual release (g TEQ/a)	Sub- Total

Category			**(t/a)**	**Air**	**Water**	**Land**	**Product**	**Residue**	(g TEQ/a)
Iron and steel plants	1	Dirty scrap, scrap preheating, limited controls	25,000	0.250				0.375	0.625
	2	Clean scrap/virgin iron or dirty scrap, afterburner, fabric filter	-						
	3	Clean scrap/virgin iron or dirty scrap, EAF equipped with APCS, BOF furnaces	-						
	4	Blast furnaces with APCS	130,000	0.001					0.001
Sub-Total			*155,000*	*0.251*	*0*	*0*	*0*	*0.375*	*0.626*
Foundries	1	Cold air cupola or hot air cupola or rotary drum, no APCS	5,000	0.050					0.050
	2	Rotary drum - fabric filter or wet scribber	40,000	0.172				0.008	0.180
	3	Cold air cupola, fabric filter or wet scrubber	-						
	4	Hot air cupola or induction furnace, fabric filter or wet scrubber	-						
Sub-Total			*45,000*	*0.222*	*0*	*0*	*0*	*0.0*	*0.230*
Total		**Iron and steel production plants and foundries**	**200,000**	**0.47**	**0.00**	**0.00**	**0.00**	**0.38**	**0.86**

For the year 2012, a new steel facility will be installed which will process 160 ton/day. This will be a Class 3 electric arc furnace plant equipped with air pollution control systems designed for lower PCDD/PCDF emissions. The government is also interested in projections of future releases to know how these will impact in the overall PCDD/PCDF emissions. The Toolkit 2013 methodology was thus used to forecast the new emissions showing an increase of +0.058 g TEQ/a in waste and in air emissions. This represents a net increase of 13.5% in this sub-category when compared to the 2010 scenario.

2d Copper Production

Further to the baseline survey conducted in Country X, according to which copper production accounted for 83% of the total PCDD/PCDF emissions from source group 2, the authorities implemented a plan to improve emission control in the copper foundry sector focusing on two aspects: adequate waste disposal to mitigate the impact on the environment, and upgrading of the two plants producing 8,000 t/a with basic technology. As a result, 6,000 tons are now produced with good air pollution control, and were moved from Class 1 to Class 2.

Class	**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
		Air	**Water**	**Land**	**Product**	**Residue**	

1	Sec. Cu - Basic technology	2,000	1.600				1.260	2.860
2	Sec. Cu - Well controlled	6,000	0.300				3.780	4.080
3	Sec. Cu - Optimized for PCDD/PCDF control	60,000	0.300				18.000	18.300
4	Smelting and casting of Cu/Cu alloys	-						
5	Prim. Cu, well-controlled, with some secondary feed materials	-						
6	Pure prim. Cu smelters with no secondary feed	-						
Total	**Copper production**	**68,000**	**2.200**	**0**	**0**	**0**	**23.0**	**25.2**

2e Aluminum Production

In 2010, for the plants operated in Class 3 two aspects can be highlighted:

- the secondary aluminum production increased by 33% and
- 50% of solid residues were recycled internally, so waste emissions should be divided by two.

Class		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
			Air	**Water**	**Land**	**Product**	**Residue**	
1	Processing scrap Al, minimal treatment of inputs, simple dust removal	5,000	0.750				1.000	1.750
2	Scrap treatment, well-controlled, fabric filter, lime injection	20,000	0.100				8.000/2 = 4.000	4.100
3	Optimized proces for PCDD/PPCDF abatement	-						
4	Shavings/turnings drying (simple plants)	-						
5	Thermal de-oiling, rotary furnaces, afterburners, fabric filters	-						
6	Primary Al plants	-						
Total	**Aluminum production**	**25,000**	**0.850**	**0**	**0**	**0**	**5.0**	**5.9**

2f Lead Production

The information available for the 2010 reference year shows that lead battery components free of PVC are used for smelting in rotary kiln with fabric filter, corresponding to Class 2.

Class	**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
		Air	**Water**	**Land**	**Product**	**Residue**	

1	Sec. lead from scrap, PVC battery separators	-						
2	Sec. from PVC/Cl2 free scrap, some APCS	10,000	0.080				0.050	0.130
3	Sec. Lead, PVC/Cl2 free scrap in modern furnaces, with scrubber	-						
4	Pure primary lead production	-						
Total	**Lead production**	**10,000**	**0.080**	**0**	**0**	**0**	**0.05**	**0.13**

2l Thermal Wire Reclamation and e-waste recycling

In 2010, it is estimated that 400 tons of wire have been burned in the open. This is less than for the baseline year (2004), due to changes in above-ground wires to underground wires, which decreases the possibility of theft.

Class		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
			Air	**Water**	**Land**	**Product**	**Residue**	
1	Open burning of cable	400	4.800					4.800
2	Open burning of circuit boards							
3	Basic furnace with after burner, wet scrubber							
4	Burning electric motors, brake shoes, etc., afterburner							
Total	**Thermal wire reclamation and e-waste recycling**	**400**	**4.800**	**0**	**0**	**0**	**0**	**4.8**

Revision of the baseline inventory

In order to be able to compare the 2010 updated release estimates with the baseline inventory for 2004 to mark the progress in reducing PCDD/PCDF, the following aspects must be taken into account:

1) Classification of sources and emissions factors may vary due to revisions of the Toolkit.

2) Further activities were identified in 2010, for which data were not available in 2006.

The emission for 2004 need to be recalculated using the 2013 Toolkit to enable comparison.

The following table summarizes PCDD/PCDF emissions for a quick comparison between the 2004 and 2010 inventories.

Cat.	Class	Source categories	2004 recalculated					Production (t/a)	2010		
			Production (t/a)	Annual release (g TEQ/a)					Annual release (g TEQ/a)		
				Air	Residue	Total			Air	Residue	Total
c		**Iron and steel production plants and foundries**	**150,000**	**0.387**	**0.304**	**0.69**		**200,000**	**0.473**	**0.383**	**0.86**

		Iron and steel plants	*120,000*	*0.201*	*0.3*	*0.50*		*155,000*	*0.251*	*0.375*	*0.63*
	1	Dirty scrap, scrap preheating, limited controls	20,000	0.2	0.3	0.50		25,000	0.25	0.375	0.63
	4	Blast furnaces with APCS	100,000	0.001	-	0.001		130,000	0.0013	-	0.001
		Foundries	*30,000*	*0.186*	*0.004*	*0.19*		*45,000*	*0.222*	*0.008*	*0.23*
	1	Cold air cupola or hot air cupola or rotary drum, no APCS	10,000	0.1	-	0.10		5,000	0.05		0.05
	2	Rotary drum - fabric filter or wet scribber	20,000	0.086	0.004	0.09		40,000	0.172	0.008	0.18
d		**Copper production**	**68,000**	**6.7**	**23.04**	**29.7**		**68,000**	**2.2**	**23.04**	**25.2**
	1	Sec. Cu - Basic technology	8,000	6.4	5.04	11.4		2,000	1.6	1.26	2.9
	2	Sec. Cu - Well controlled	-	-	-	-		6,000	0.3	3.78	4.1
	3	Sec. Cu - Optimized for PCDD/PCDF control	60,000	0.3	18	18.3		60,000	0.3	18	18.3
e		**Aluminum production**	**20,000**	**0.825**	**7**	**7.8**		**25,000**	**0.85**	**5**	**5.9**
	1	Processing scrap Al, minimal treatment of inputs, simple dust removal	5,000	0.75	1	1.75		5,000	0.75	1	1.75
	2	Scrap treatment, well-controlled, fabric filter, lime injection	15,000	0.075	6	6.08		20,000	0.1	4	4.10
f		**Lead production**	**10,000**	**0.08**	**0.05**	**0.13**		**10,000**	**0.08**	**0.05**	**0.13**
	2	Sec. from PVC/Cl2 free scrap, some APCS	10,000	0.08	0.05	0.13		10,000	0.08	0.05	0.13
l		**Thermal wire reclamation and e-waste recycling**	**600**	**7.2**	**0**	**7.20**		**400**	**4.8**	**0**	**4.80**
	1	Open burning of cable	600	7.2		7.20		400	4.8		4.80
Ferrous and Non-Ferrous Metal Production			**647,200**	**15.2**	**30.4**	**45.6**		**806,800**	**8.4**	**28.5**	**36.9**

It is observed that although a 25% increase has been registered in the production of metals from 2004 to 2010, total emissions from this source group have decreased by 19% overall. The total air emissions from metal production have been mostly impacted, with a total decrease of 45%.

The following sections show the revised calculations of the baseline inventory for each category.

2c Iron and Steel Production and Foundries

For this category is not necessary to recalculate the baseline releases, as the difference between the estimated emissions for both inventories is only due to increased production levels. In this category a

33% increase in production is registered. As this increase is based on adoption of improved technologies, there is not a consequent appreciable increase in emissions.

2d Copper Production

For this category is not necessary to recalculate the baseline releases. The decrease of 4.5 g TEQ/a in air emissions from 2004 to 2010 (15%) is also due improved technology in 2010.

2e Aluminum Production

For this category, it is necessary to recalculate the baseline releases due to the revision of the waste emission factor (for class 3, this changed from 100 to 400 µg TEQ/t).

Class		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
			Air	**Water**	**Land**	**Product**	**Residue**	
1	Processing scrap Al, minimal treatment of inputs, simple dust removal	5,000	0.750				1.000	1.750
3	Scrap treatment, well-controlled, fabric filter, lime injection	15,000	0.075				6.000	6.075
4	Optimized process for PCDD/PPCDF abatement	-						
5	Shavings/turnings drying (simple plants)	-						
6	Thermal de-oiling, rotary furnaces, afterburners, fabric filters	-						
7	Primary Al plants	-						
Total	**Aluminum production**	**20.000**	**0.825**	**0**	**0**	**0**	**7.0**	**7.8**

Thus, in this category, a 33% increase in production produced an increase of 2 g TEQ/a in waste, which represents an increase of 26% compared to 2004 emissions in the secondary aluminum production.

2f Lead Production

For the year 2004, lead from battery components was melted in country X. However, this activity was not considered in the baseline inventory as it was not detected due to limitations in the survey. This new information should be included in the revised baseline inventory.

From the information available, it is estimated that in 2004, the activity took place at the same facility as in 2010, and with the same level of production, resulting in the same emissions than those estimated in 2010.

2l Thermal Wire Reclamation and e-waste recycling

Despite lower amounts of wire burnt in the open in 2010, by comparing to 2004 and 2010 release levels, PCDD/PCDF emissions are shown to increase. This is because the air emission factor for open burning of cable has been revised and is significantly higher in the Toolkit 2013 than in the 2005 edition. Therefore the baseline releases need to be recalculated using the revised emission factor.

Class		**Production (t/a)**	**Annual release (g TEQ/a)**					Sub- Total (g TEQ/a)
			Air	**Water**	**Land**	**Product**	**Residue**	
1	Open burning of cable	600	7.200					7.200
2	Open burning of circuit boards	-						
3	Basic furnace with after burner, wet scrubber	-						
4	Burning electric motors, brake shoes, etc., afterburner	-						
Total	**Thermal wire reclamation and e-waste recycling**	**600**	**7.200**	**0**	**0**	**0**	**0**	**7.2**

Thus, the decrease in releases from this source category is directly proportional to the decrease in the amount of burned wires, *i.e*. by 33%.

Conclusion

When updating the PCDD/PCDF inventory, it is necessary to review the baseline/previous inventories, due to a number of reasons:

- The Toolkit is regularly updated (emission sources and emission factors).
- The identification of additional sources in the updated inventory, for which information was not yet available at the time the previous inventories were conducted.
- The improvement of the estimates of activity rates in some complex categories, requiring a review of previous inventory estimates. This is not specifically addressed in this case study.

The process to update and, when necessary, revise the inventory is essential to guarantee the comparability among results and establishing trends over time. Data quality and confidence in inventory results can be improved by site visits using a limited number of significant facilities. It is worth to include those facilities which have the potential to contribute more to the inventory, *i.e*. large facilities contributing to a large part of the overall production of the sector.

Finally, the process of collecting information for the inventory updating helps to identify gaps and inconsistencies in available information. This offers the opportunity for a practical analysis and a chance to improve and implement better mechanisms for collecting reliable information that may decrease the time needed in future updates and improve the quality of past estimates through revision of previous inventories to fill such gaps.

Example Inventory 4 Source Group 3 Power Generation and Heating

Introduction

The purpose of this case study is to illustrate the process of inventory development, update and revision, focusing on a single source group: Power generation and heating. We will consider a hypothetical example of a PCDD/PCDF inventory in country X, and describe the baseline inventory process, its update and revision for this particular source group.

Baseline inventory

The total share of fuels in indigenous energy production in country X can be broken down as follows: 55% from hard coal, 37% from brown coal and the remaining 8% comes from gas, oil and hydro. Hard coal is thus the basic fossil fuel burned in households not only for heating, but also for cooking.

National activity statistics for the baseline reference year (2001) provide the following consumption figures:

- hard coal 174,338 TJ
- lignite 980 TJ
- high methane natural gas 110,658 TJ
- nitrified natural gas 16,953 TJ
- LPG 20,812 TJ
- light fuel oil 17,496 TJ

By grouping the fuels according to type (solid, liquid, gaseous) we obtain the following figures:

- coal 175,318 TJ
- oil 17,496 TJ
- natural gas 148,423 TJ

3e Household Heating and Cooking with Fossil Fuels

One of the main sources of PCDD/PCDF releases in country X comes from combustion processes in household boilers and furnaces, where commercial fuels are frequently co-combusted with household waste. The municipal and housing sector has a dominant share in PCDD/PCDF emissions, as the main fuel used in this sector is hard coal, with an annual consumption of 9 million tons.

The 2003 Toolkit applies an emission factor for burning of coal in residential heating systems of 70 µg I-TEQ/TJ corresponding to approximately 2 µg I-TEQ/t. The default emission factor was derived from mean values reported between 1.6 and 50 µg I-TEQ/t of coal burned. Several recent measurements indicate that the emission from the residential burning of coal in country X may be much higher.

These results indicate that the emission factor for residential burning of coal - even though the coal is not co-combusted with waste - may be significantly higher than the default emission factor of the

Standardized Toolkit. The default emission factor is still used as a medium estimate, but it is estimated that the real average emission factor is likely to be higher rather than lower, and a range of 35-1,000 µg I-TEQ/t will be applied.

The resulting annual releases to air are presented in the table below:

Source category	**Source Class**	**Activity rate TJ/year**	**EF_{Air} µg I-TEQ/t**		**Annual release to air (g TEQ/a)**	
			Medium (Toolkit 2003)	**Range**	**Medium**	**Range**
Domestic heating and cooking – fossil fuels	Coal fired stoves	219,484	70	30-1,000	15	6.6-200

Update of the inventory

In 2008, new emission factors are published in country X based on specific measurements of emissions from coal fired stoves. These country-specific factors are then used with higher confidence to update the inventory. Activity rates are comparable with those estimated for the baseline year, and are equally derived from national statistics, as in the baseline inventory.

Source category	**Source Class**	**Activity rate TJ/year**	**EF_{Air} µg I-TEQ/t Country-specific**	**Annual release to air (g TEQ/a)**
Domestic heating and cooking – fossil fuels	Coal fired stoves	200,000	115	23

The results show a slight increase in releases, although activity rates were maintained at relatively constant levels. This is clearly due to applying a different set of emission factors, which were derived to better reflect the national circumstances in country X.

Revision of the baseline inventory

The revision of the baseline inventory is thus necessary to ensure consistency of trends in releases over time. In this example, the revision is triggered by scientific findings and developments, allowing country X to re-calculate releases by using an own set of emission factors developed to better reflect national circumstances.

Source category	**Source Class**	**Activity rate TJ/year**	**EF_{Air} µg I-TEQ/t Country-specific**	**Annual release to air (g TEQ/a)**
Domestic heating and cooking – fossil fuels	Coal fired stoves	219,484	115	25.24

The revised baseline estimates show that indeed a decrease in releases from this major source has happened from 2001 till 2008.

Conclusion

This example shows that when applying own emission factors, through periodic refinement of the methodology to develop the PCDD/PCDF inventory, revisions of the previous inventories are equally needed. Besides changes in the Toolkit methodology through its revision in 2013, better information becoming available at the country level, including through direct measurements of emissions and development of more specific emission factors, is an equally important triggering factor to revise baseline estimates of releases. If the revision of the baseline is not performed, the results obtained for the different reference years are not readily comparable and trends over time cannot be estimated.

Example Inventory 5 Source Group 4 Mineral Products

Introduction

The purpose of this case study is to illustrate the process of inventory development, update and revision. We will consider a hypothetical example of an inventory of country X, and describe the inventory process focusing on the source group 4 Mineral Products.

Baseline inventory

Let's consider a hypothetical inventory of country X. **The baseline inventory** is developed in 2006, based on data collected for the reference year 2005 and by using the Toolkit 2005 methodology. The baseline inventory estimated that approximately 15,000 tons of bricks were manufactured each year based from statistical data obtained from the manufacturing industry. The technologies used in the manufacturing industry have no dust control systems in place and do NOT use contaminated fuels. The total annual releases for the baseline year were calculated based on the Toolkit 2005 methodology, by applying an emission factor for air of 0.2 µg TEQ/t of brick manufactured. The baseline releases to air from brick manufacturing were thus estimated at 0.003 g TEQ/year.

***Baseline PCDD/PCDF released to air in 2005* (g TEQ/year) = Quantity of bricks manufactured x EF_{Air}=**

= 15,000 t/yr x 0.2 µg TEQ/t = *0.003 g TEQ/year*

Update of the inventory

The updated inventory is developed in 2013, based on data collected for the reference year 2010 and the Toolkit methodology as revised in 2013. Activity rates for this source had been assessed at around 15,000 tons of bricks produced annually for the baseline year. The corresponding emission factor has been revised since the first inventory and is much lower than the one used for the baseline inventory: EF_{Air} is now 0.02 µg TEQ/t of brick produced using technologies that have no emission abatement technology in place and using non-contaminated fuels. This is in contrast to 0.2 µg TEQ/t that had previously been used for this technology. In addition in this category, there are new emission factors for Products (0.006 µg TEQ/t) and Residues (0.002 µg TEQ/t). The total annual release based on the Toolkit 2013 methodology is determined as below:

***PCDD/PCDF released to air in 2010* (g TEQ/year) = Quantity of bricks manufactured x EF_{Air}=**

= 15,000 t/yr x 0.02 µg TEQ/t = 0.0003 g TEQ/year

This is approximated to 0g TEQ/year in the excel tables.

***PCDD/PCDF to products in 2010* (g TEQ/year)= Quantity of bricks manufactured x $EF_{Product}$=**

= 15,000 t/yr x 0.006 µg TEQ/t = 0.00009 g TEQ/year

This is approximated to 0 g TEQ/year in the excel tables.

***PCDD/PCDF to residues in 2010* (g TEQ/year) = Quantity of bricks manufactured x $EF_{Residue}$=**

= 15,000 t/yr x 0.002 µg TEQ/t = 0.00003 g TEQ/year

This is approximated to 0gTEQ/year in the excel tables.

TOTAL RELEASES IN 2010 = sum of TEQs released to the different for the media = 0 g TEQ/year

Thus based on the 2013 Toolkit methodology, the updated release levels for this category for the baseline year 2010, changes from 0.003gTEQ/yr to 0g TEQ/yr.

Revised baseline inventory

Based on new statistical data available, it was now possible to estimate the total brick production in the country which will include bricks from commercial production and artisanal brick production as opposed to baseline year which only had data from the commercial manufacturing industries. This will give a better estimate of activity rate arising from this source category.

From statistical data 35,000 housing units are built per year and of these, approximately 16% are constructed using bricks. Assuming that each housing unit will use approximately 15,000 bricks and each weighing approximately 2.5kg, the resulting activity rate will be as follows:

Calculation of activity rate:

Total number of housing units built per year = 35,000
Total number of units built using bricks is 16% of total = 35,000 x 0.16
= 5,600 units
Bricks used per unit appx 15,000 and assuming 10% waste = 15,000 + (15,000 x 0.1)
= 16,500 bricks
Total number of bricks used for 5600 units = 16,500 x 5,600
= 92,400,000 bricks
Total tons of bricks produced/yr assuming 2.5kg per brick = 92,400,000 x 2.5/1000 tons
= 231,000 tons

In determining the activity rates based on construction data, there is a level of uncertainty that is inherent because of use of a uniform size of house unit, assumed identical sizes for both commercial and artisanal bricks and also not taking into consideration other buildings that are not residential units but use bricks for construction .

Calculation of release estimates:

Revised baseline PCDD/PCDF released to air (g TEQ/year) = Quantity of bricks manufactured x EF_{Air}***=***

= 231,000 t/yr x 0.02 µg TEQ/t = 0.005 g TEQ/year

Revised baseline PCDD/PCDF to products (g TEQ/year) = Quantity of bricks manufactured x $EF_{Product=}$

= 231,000 t/yr x 0.006 µg TEQ/t = 0.001 g TEQ/year

Revised baseline PCDD/PCDF to residues (g TEQ/year) = Quantity of bricks manufactured x $EF_{Residue}$***=***

= 231,000 t/yr x 0.002 µg TEQ/t = 0.00046 g TEQ/year

This is approximated to 0g TEQ/yr in the excel tables.

TOTAL RELEASES IN 2005 = 0.006 g TEQ/year

Based on the revised emission factors in the 2013 Toolkit, and improved activity rate data, this is a better estimate of the releases from this category for the baseline year 2005.

Conclusion

Revising the release levels from this category is advised, since the revised emission factor values in the 2013 Toolkit may affect the release levels by one order of magnitude as compared with those that had been determined using the previous emission factors. It important to establish activity rates in artisan brick production especially in situations where there are no statistics for production rates and there are indications that the estimated artisan production rates are significantly high as compared to commercial production. Construction/building statistics may assist in arriving at a reasonable estimate. It is also important to establish the types of fuels used, as the use of contaminated fuels influences the emission factor by one order of magnitude.

Example Inventory 6 Source Group 5 Transport

Introduction

The purpose of this case study is to illustrate the process of inventory development, update and revision, including the various triggering factors that may come into play in this process. We will consider a hypothetical example of an inventory of country X, and describe the baseline inventory process, its update and revision, focusing on source group 5 Transport.

Baseline inventory

Country X prepares its first inventory of dioxins and furans in 2006 to support the development of the action plan as required by Article 5 of the Convention and included in the National Implementation Plan pursuant to Article 7. Activity data for the different sources of PCDD/PCDF in country X were collected for the reference year 2004 (baseline year). The inventory is developed by applying the Toolkit 2005 methodology and the emission factors specified in that version of the Toolkit.

All four source categories included in this source group are relevant for country X in the baseline year. These are presented below.

According to the Toolkit 2005 methodology, activity rates for transport should be expressed as volumes of fuel used by category of fuel and transport. During the process of activity data collection, information on actual amounts of fuel used in the transport sector annually (gasoline, ethanol, diesel fuel, kerosene, residual oil, jet fuel etc.) at the national level was found from the national statistics office. According to these data, in 2004 in country X, 1,000,000 tons of gasoline, 500,000 tons of diesel fuel, 100,000 tons of heavy fuel (residual) oil, 50,000 tons of kerosene, 10,000 tons of LPG and 5,000,000 m^3 of CNG were used for transportation. The data provides details on quantities of fuel according to fuel type and sector (road transport, railway transport, mobile machinery in agriculture, construction, forest industry etc.).

However, no data on distribution of leaded and unleaded gasoline are publicly available; no data on distribution of fuel consumption according to the type of vehicles (4-stroke and 2-stroke) and its ecological class (without catalyst and with catalyst) are available.

To complement this information and be able to obtain estimates of fuel distribution with a higher degree of confidence, questionnaires have been sent to the main offices and consumers of fuel in the country: Ministry of Transport, Ministry of Trade, Police Agency, Railroad agency, Aviation Company. The objectives of the questionnaires were to obtain more detailed data on the vehicle fleet.

It was thus established that data are available on request on the number of registered vehicles per type of vehicle. Data on the year of production of the registered cars were also obtained, but no account of vehicles by ecological characteristics (with or without catalysts) was available.

According to these data obtained by the developer of the inventory, 100,000 tons of leaded gasoline were imported in 2004, but the distribution between 4-stroke and 2-stroke vehicles could not be obtained. Questionnaires showed that 2-stroke vehicles are more often fueled with leaded gasoline in comparison with 4-stroke vehicles; expert judgment was used to estimate the distribution of leaded gasoline between 4-stroke and 2-stroke vehicles; this was assumed to be 80%:20%. For the distribution of fuel per type of vehicle, proxies were estimated by using data on the number of registered cars according to the type and the specific fuel consumption per unit.

For the distribution of vehicles according to ecological characteristics, data on the age of vehicles were used. It was assumed that vehicles which comply with Euro 2 class and higher are equipped with catalysts. It was assumed that vehicles imported from the European Community comply with the highest Euro class which was in force at the time of the vehicle production. Further, questionnaires allowed to estimate the distribution of vehicles according to the year of production, and through this - between Euro classes.

The amount of gasoline consumed was then distributed between 4-stroke and 2-stroke engines according to number of vehicles in a category, and averaged specific consumption of fuel per vehicle type was of 95 and 5%.

All diesel fuel engines were assigned to category 5c – Diesel engines, including light and heavy duty vehicles, railway transport, construction, agricultural and other mobile machinery.

The corresponding 2005 Toolkit emission factors were applied to these four source classes, and release estimates obtained by multiplying the activity rates with the emission factors. The results are presented in the table below. No PCDD/PCDF emission factors were available for airplanes (kerosene, jet fuel etc.) and for vehicles fueled with LPG and CNG, therefore releases from these sources were not assessed.

The total PCDD/PCDF releases to air from the transport sector in 2004 were of 0.968 g TEQ. No emission to other media was accounted.

Baseline inventory (reference year: 2004)

5 - Transport		**Activity rate t/year**	**Air EF (µg TEQ/t)**	**Annual Release (g TEQ/a)**				
	Source categories			**Air**	**Water**	**Land**	**Product**	**Residue**
a	4-Stroke engines	1000000						
	Leaded fuel	80000	2.2	0.176				
	Unleaded fuel without catalyst	720000	0.1	0.072				
	Unleaded fuel with catalyst	100000	0.00	0				
b	2-Stroke engines	100000		-				
	Leaded fuel	20000	3.5	0.07				
	Unleaded fuel without catalyst	80000	2.5	0.2				
c	Diesel engines	500000	0.1	0.05				
d	Heavy oil fired engines	100000	4	0.4				
TOTAL for the source group				0.968				

Update of the inventory

Starting with 2007, country X implements an action plan to reduce releases of unintentional POPs, as part of its National Implementation Plan. Measures are taken to reduce releases from transport, in particular through phasing out leaded gasoline, upgrading of vehicle fleet (through implementation of stricter standards for vehicles, higher taxes for import of old cars, programs of old vehicle replacement etc.). In 2013, country X updates its inventory to assess the success of the measures implemented. Data are collected for the reference year 2010, and the inventory is established according to the Toolkit methodology as revised in 2013.

As a first step in the inventory updating process, the examination of the baseline inventory essential to show to the developer of the inventory where the information can be found, and which areas need extrapolation and expert judgment to fill gaps. The same approach is thus taken in the updated inventory as in the baseline, based on statistical data from the same sources, selective questionnaires sent to profile ministries, agencies and associations.

According to the new set of data, the total amount of fuel used for transport in 2010 was of 2’400’000 tons, registering a 50% increase since 2004. Leaded gasoline was phased out, and the share of fuel used for 2-stroke engines was reduced by 30%. A program on updating the car fleet was implemented; as a result, the share of 4-stroke vehicles with catalysts increased by 20%. Ethanol powered vehicles have replaced part of the gasoline powered vehicles; ethanol consumption is now estimated at 100’000 tons. This new information showed that 20% of vehicles still use inadequate catalyst or not at all, and were considered as not equipped with catalyst. Diesel fuel was partially replaced by biodiesel (35000 tons of biodiesel were used in 2010).

Available literature showed that ethanol powered vehicles have a lower emission factor than gasoline powered vehicles, and that biodiesel powered vehicles emit less PCDD/PCDF than diesel powered vehicles. Thus, the emission factor for ethanol vehicles equipped with catalyst is close to zero, and the emission factor for biodesel20 is 0.07 µg TEQ/t.

Results of the updated emission inventory (reference year: 2010) are shown below.

5 - Transport		**Activity rate, t/year**	**EF (µg TEQ/t)**	**Annual Release (g TEQ/a)**				
	Source categories			**Air**	**Water**	**Land**	**Product**	**Residue**
a	4-Stroke engines	1500000						
	Leaded fuel	0	2.2	0				
	Unleaded fuel without catalyst or with inadequate catalyst	1080000	0.1	0.108				
	Unleaded fuel with catalyst	320000	0.001	0.00032				

	Ethanol with catalyst	100000	0.0007	0.00007				
b	2-Stroke engines	120000						
	Leaded fuel	0	3.5	0				
	Unleaded fuel without catalyst	120000	2.5	0.3				
c	Diesel engines	700000						
	Regular diesel	665000	0.1	0.067				
	Biodiesel (20% biofuel)	35000	0.07	0.002				
d	Heavy oil fired engines	100000	2	0.2				
Total for the source group				0.677				

The total dioxin and furan emissions were of 0.677 g TEQ in 2010.

Revision of the baseline inventory

The revision of the baseline inventory is necessary to ensure the consistency in trends in releases over time. In this example, the estimates for two source category pertaining to the transport group need to be revised.

With the updating of the inventory in 2013, country X discovers new information on the consumption of leaded gasoline by 4- and 2-stroke engines, which needs to be incorporated in the baseline inventory. The developer of the inventory needs to retrospectively assess the activity rate for this source and for the baseline year to enable the comparison of 2004 and 2010 release estimates. The volume of leaded fuel burned in 4- and 2-stroke engines in 2004 was thus reassessed.

The activity rates for leaded fuel the baseline year are re-estimated at 150000 t for 4-stroke and 50000 t for 2-stroke vehicles, and introducing the revised emission factors for gasoline and ethanol vehicles with catalyst and for heavy oil, the revised baseline release estimates are shown in the table below:

Revised baseline inventory (reference year: 2004)

5 - Transport		**Activity rate (t/year)**	**EF (µg TEQ/t)**	**Annual Release (g TEQ/a)**				
Source categories				**Air**	**Water**	**Land**	**Product**	**Residue**
a	4-Stroke engines	1,000,000						
	Leaded fuel	150,000	2.2	0.33				
	Unleaded fuel without catalyst or with inadequate catalyst	720,000	0.1	0.072				

	Unleaded fuel with catalyst	100,000	0.001	0.0001				
b	2-Stroke engines	100,000						
	Leaded fuel*	50,000	3.5	0.175				
	Unleaded fuel without catalyst	80,000	2.5	0.2				
c	Diesel engines	500,000	0.1	0.05				
d	Heavy oil fired engines	100,000	2	0.2				
Total for the source group				1.027				

The corresponding total dioxin and furan emission revised for the 2004 baseline year was of 1.027 g TEQ.

The results show a decrease of 34% in total releases from group 5 - Transport. If the new information was not incorporated to revise the baseline release estimate, the resulting trend would not have been the same, with an emission reduction of only 9%. The results of the inventory show that despite of the increase in motor fuel consumption in a country X, incentives to phase out leaded gasoline, switching to ethanol and upgrading of the vehicle fleet were important measures to reduce the overall PCDD/PCDF emissions from the transport sector.

This assessment was obtained through applying the same inventory approach and the same set of emission factors, therefore the results are readily comparable and the trends over time are consistent.

Example inventory 7 Source Group 6 Open Burning Processes

Introduction

The hypothetical inventory example presented below aims to illustrate the process of inventory development, update and revision for source group 6: Open Burning Processes. It takes into consideration some of the triggering factors for updating and revision that are specific to this particular source group.

Baseline Inventory

In country X, open burning processes releasing PCDD/PCDF mainly include biomass burning to clean the fields and domestic waste burning. The baseline inventory of country X is developed in 2006 based on data collected for the reference year 2004. The developer of the inventory found only limited data on activity levels for this sector. Data on forest fires was collected for instance from the Ministry of Agriculture and Forestry. Nevertheless, expert judgment was an essential tool to calculate releases from open burning.

6a Biomass burning

According to the statistics provided by the Ministry of Agriculture and Forestry of country X, three major fire incidents have occurred in 2004, affecting a total of 20’000 hectares of forest. Data from a national forest inventory and analysis program and a number of studies estimating forest biomass in country X using remote sensing and satellite products show that forest biomass density across the country is on average 150 tons/ha. The baseline activity rate for this source class is thus estimated at 3’000’000 tons burnt annually.

Secondly, the extent of crop residue burning is very difficult to estimate. The actual amount varies dramatically from year to year, depending upon amounts of rainfall, cropping patterns and weather conditions during and after the harvest season. Some years, burning may take place over quite a long fall season, or even be delayed to the following spring. As such, it is very difficult to estimate the extent of burning in a given year, or to analyze trends.

Assumptions are thus needed to quantify the quantity of agricultural residues that are burnt annually. Two assumptions are made by the developer of the inventory, according to a similar study:

1) that the amount of agricultural residue able to be burned was equal to the total crop production, and
2) that 80% of residues were burned in the developing world and 50% of residues were burned in the developed world for any given year.

Based on these assumptions, activity rates for agricultural residue burning were estimated at 500’000 tons of material burnt in 2004. Dioxin and furan releases from these sources were calculated according to the Toolkit (2005) methodology and the corresponding results are presented below.

Source category	Source Class	Activity rate (t/year)	Annual release (g TEQ/a)					Total
			Air	Water	Land	Product	Residue	
Biomass	Forest fires	3’000’000	15		12			27

burning								
	Agricultural residue burning, poor combustion conditions	500,000	15		5			20

6b Waste burning and accidental fires

The only relevant source contributing to dioxin and furan releases from this category is domestic waste burning. Data on domestic waste burning are not readily available in country X. The developer of the inventory therefore needs to estimate activity rates for this sector based on assumptions and expert judgment. The average amount of waste produced in urban areas is of 0.7 kg per capita per day and of 0.5 kg per capita per day in rural areas. From the total amount of waste generated in urban areas, 70% are collected for reuse, incineration or disposal, leaving 30% that can be burned in backyard fires. From the total amount of waste generated in rural areas, it is considered that 20% are burnt in the open, since a greater fraction is used for composting.

The estimated amount of domestic waste burnt annually is of 60,000 tons in 2004. The total annual releases are calculated by multiplying this activity rate with the corresponding emission factor. The results are shown in the table below:

Source category	**Source Class**	**Activity rate (t/year)**	**Annual release (g TEQ/a)**					**Total**
			Air	**Water**	**Land**	**Product**	**Residue**	
Waste burning and accidental fires	Open burining of domestic waste	60,000	18		36			54

Update of the inventory

Country X implements measures to reduce releases from open burning as part of the action plan within its National Implementation Plan. The measures are based on providing incentives to avoid open burning and manage waste in a more appropriate manner: through education and awareness raising programmes, better infrastructure and enforcement. In 2013, country X initiates an update of the inventory to assess the success of these measures. The activity data used for updating release estimates are collected for the reference year 2010, while the inventory is developed according to the Toolkit methodology as revised in 2013.

6a Biomass burning

The 2010 activity data are estimated according to the same approach and using the same expert judgment and assumptions as in the baseline inventory. Only two fire incidents were registered in 2010, totaling 2’000’000 tons of forest material burnt annually.

Furthermore, in addition to agricultural residue burning, a new class of major relevance for country X is included in the inventory – sugarcane burning. This class is newly added in the 2013 version of the Toolkit, and new emission factors were developed and are now available for this very specific source. Agricultural residues and sugarcane residues burnt in 2010 are estimated according to the same assumptions as in the baseline inventory and amount to 300’000 tons and 100’000 tons material burnt respectively. The resulting release estimates are shown below:

Source category	**Source Class**	**Activity rate (t/year)**	**Annual release (g TEQ/a)**					**Total**
			Air	**Water**	**Land**	**Product**	**Residue**	
Biomass burning	Agricultural residue burning, poor combustion conditions	300,000	9		3			11
	Sugarcane burning	100’000	0.4		0.005			0.45
	Forest fires	2’000’000	2		0.3			2.3

The immediate conclusion after the updating of the inventory would be a drastic reduction in emissions to air from agricultural residue burning (-40%) and forest fires (-87%) and an increase from 0 to 2 g TEQ in emissions to air from sugarcane burning. This conclusion would not take into account the fact that the emission factors have equally been revised and are much lower in the 2013 edition of the Toolkit than in the 2005 edition. This has an impact on the resulting estimates of releases, contributing to lower emission values. In addition, the new class of sugarcane burning for which emission factors were not available in the 2005 edition of the Toolkit, will also have to be assessed separately in the baseline inventory, so that the same basis for calculation (and same emission factors) and the same scheme of classification of sources be used for both reference years.

6b Waste burning and accidental fires

2010 activity rates for open burning of domestic waste are calculated by extrapolating per capita waste production to population levels in urban and rural areas, and using the same assumptions concerning the fraction of waste that is burnt in the open in these areas. Approximately 70,000 tons of domestic waste are considered to be burnt annually. The total annual releases in 2010 are calculated as below, based on the Toolkit 2013 methodology:

Source category	**Source Class**	**Activity rate (t/year)**	**Annual release (g TEQ/a)**					**Total**
			Air	**Water**	**Land**	**Product**	**Residue**	
Waste burning and accidental fires	Open burning of domestic waste	70,000	2.8		0.07			2.9

Despite the increase in the quantity of domestic waste burnt in the open, releases are shown to be much lower than in the baseline year (-85%). This is due to the revision of the respective emission factor *e.g.,* for air, the emission factor was revised from 300 µg TEQ/t to 40 µg TEQ/t. To be able to assess the actual trend in releases over time, a revision of the baseline inventory is thus necessary use the same basis for calculation for both 2004 and 2010 estimates.

Revision of the baseline inventory

Two triggering factors come into play in this case prompting the need for revision: one is the revision of emission factors in the Toolkit, and the second one is the addition of new source classes to the Toolkit classification. To be able to compare release estimates in 2004 and 2010, the same methodology, the same basis for calculation (the same emission factors) need to be consistently used in the different inventories, along with the same source classification scheme.

There is a need to go back to the baseline release estimates for this source group and re-calculate those estimates according to the same methodology and approach as used in the updated inventory. The revised baseline estimate will be the product of the baseline activity levels and the revised emission factors taken from the Toolkit 2013 methodology.

6a Biomass burning

The baseline release estimates are re-calculated by applying the 2013 set of Toolkit emission factors and the classification of sources put forward in the 2013 version of the Toolkit. From the 400’000 tons of agricultural residues were considered to be burnt in the open in 2004 (the baseline year), 100’000 tons were actually sugarcane residues. As at the time the baseline inventory was developed there were no emission factors available for sugarcane burning, those residues were assessed together with the other agricultural crops. The releases are re-calculated by including this additional class and applying the emission factors proposed in the Toolkit 2013 methodology:

Source category	**Source Class**	**Activity rate (t/year)**	**Annual release (g TEQ/a)**					**Total**
			Air	**Water**	**Land**	**Product**	**Residue**	
Biomass burning	Agricultural residue burning, poor combustion conditions	300,000	9		3			11
	Sugarcane burning	100’000	0.4		0.005			0.4
	Forest fires	3’000’000	3		0.45			3.45

The comparison between the updated and revised inventory accurately shows that the releases from agricultural residue burning and sugarcane burning are at a constant level since 2004. Only the forest fire emissions are down by one third, corresponding to an equivalent decrease in activity rates.

6a Waste burning and accidental fires

The re-calculation of release estimates from this source category is simply done by multiplying the baseline activity levels with the revised emission factors taken from the 2013 methodology. As no new or corrected information has become available that would influence activity level estimates, these are the same as in the 2004 inventory: 60'000 tons of domestic waste burnt annually. The revised baseline release estimates are shown in the table below:

Source category	**Source Class**	**Activity rate (t/year)**	**Annual release (g TEQ/a)**					**Total**
			Air	**Water**	**Land**	**Product**	**Residue**	
Waste burning and accidental fires	Open burning of domestic waste	60,000	2.4		0.06			2.5

The results demonstrate that between 2004 and 2010 there was an actual increase in emissions from 2.5 to 2.9 g TEQ/year. If the baseline estimate was revised by using the same emission factors for the calculation, the conclusion of a reduction in releases from 2004 to 2010 would have been largely amiss.

Conclusion

The Toolkit emission factors for open burning were significantly revised since the 2005 edition, and new source classes added to the respective categories. These two factors will most likely trigger the need to revise baseline estimates in most cases. In addition, reviewing the approach that was used in the baseline inventory provides useful information on how to estimate activity rates for this source group. Data on open burning is very limited at the country level, and expert judgment will be needed to fill such gaps. Checking the assumptions made in the baseline inventory to estimate activity rates and applying the same assumptions in the updated inventory equally enables obtaining consistent results and coherent trends in releases over time.

Example Inventory 8 Source Group 7 Production and Use of Chemicals and Consumer Goods

Introduction

The purpose of this case study is to illustrate the process of inventory development, update and revision, focusing on the production and use of chemicals. This case study provides a hypothetical inventory example of a Country X, including practical details on updating and revision of the inventory to assess trends in releases over time.

Country X developed the baseline inventory of dioxins in 2004 to support the development of the action plan as required by Article 5 of the Stockholm Convention. Activity data for the different sources of dioxins were collected for the reference year 2004 (baseline year). Activity data were obtained from the statistic yearbook. The inventory is developed by applying the Toolkit 2005 methodology and the emission factors specified in the 2005 edition of the Toolkit.

In this sample inventory, the inventory development process for the chemical industry is detailed, and provides useful guidance on estimating PCDD/PCDF releases for this source group.

Baseline inventory for source category 7b

The baseline inventory of Country X was conducted in 2004 using data collected for the reference year 2004, according to the emission factors included in the Toolkit 2005 methodology.

Activity rates

For pentachlorophenol (PCP) and polychlorinated biphenyls (PCB), the production and use of PCP and PCB had been forbidden in Country X for many years, and thus no production of these chemicals occurred in the baseline year. For PCP-Na, the output was of 2,000 tons.

For chlorinated pesticides, 2,4,-dichlorophenoxy acetic acid (2,4-D) and 2,4,6-trichlorophenol were used as herbicides in Country X. The outputs of 2,4-D and 2,4,6-trichlorophenol in Country X in 2004 were of 16,000 and 800 tons respectively. No production of other chemicals listed in category 7b occurred in Country X in the baseline year 2004.

For chloranil, there were three plants in Country X in 2004. Plant A produced *p*-chloranil via chlorination of phenol. Plant B manufactured *p*-chloranil via hydroquinone, and Plant C produced *o*-chloranil via chlorination of phenol. The activity levels were of 300, 1,000, and 400 tons for Plants A, B, and C, respectively.

With regard to chlorobenzenes, the activity levels were of 6,000, 22,000 and 6,000 tons for p-dichlorobenzene, o-dichlorobenzene and 1,2,4-trichlorobenzene respectively.

In 2004, the production of alkali from the chlor-alkali industry in Country X was about 10.6 million tons. Among them, about 20,000 tons of alkali was produced using graphite anodes. The other alkali production in Country X was manufactured by membrane technology. No formation and emission of dioxins occurred during the production of chlorine/alkali by membrane technology.

The output of PVC was about 800,000 tons manufactured in modern plants (belonging to class 2 of EDC/VCM/PVC facilities) in Country X. About 4.53 million tons of PVC production belonged to class 3 (PVC only).

Estimation of dioxins from source 7b in Country X

Release estimates were made by assuming a linear relation between the intensity of the activity and the emission resulting from this activity.

Release to Air

For source 7b, the emission factors to air were only available for class 2 and 3 of the EDC/VCM/PVC in Toolkit 2005 methodology. Releases to air from source 7b were calculated by using the following equation:

Release of dioxins to air

$$= \sum_{i=1}^{n} \text{activity levels for class } i \times \text{emission factor to air for class } i$$

= 800 000 t × 0.4 µg TEQ/t (Modern plants, EDC/VCM or EDC/VCM/PVC) + 4 530 000 t × 0.0003 µg TEQ/t (PVC only)

= 0.32 g

Release to Water

For source 7b, the emission factors to water were only available for class 2 and 3 of the EDC/VCM/PVC in Toolkit 2005 methodology. Releases to water were calculated by using the following equation:

Release of dioxins to water

$$= \sum_{i=1}^{n} \text{activity levels for class } i \times \text{emission factor to water for class } i$$

= 800 000 t × 0.5 µg TEQ/t (Modern plants, EDC/VCM or EDC/VCM/PVC) + 4 530 000 t × 0.03 µg TEQ/t (PVC only)

= 0.536 g

Release to Land

Emission factors were not available for dioxin release into land in the Toolkit 2005 methodology. Thus, no release into the land was expected for source 7b according to the Toolkit 2005 methodology.

Release in Products

PCDD/PCDF releases in product were the dominant release route for source 7b. The emission of dioxins in product from source 7b was estimated to be 157.57 g according to the equation described below.

Release of dioxins in products

$$= \sum_{i=1}^{n} \text{activity levels for class } i \times \text{emission factor in products for class } i$$

= 2 000 t × 500 µg TEQ/t (PCP-Na) + 800 t × 700 µg TEQ/t (2,4,6-trichlorophenol)

+ 16 000 t × 700 µg TEQ/t (2,4-D) + 300 t × 400 000 µg TEQ/t (p-chloranil via chlorination of phenol) + 1 000 t × 100 µg TEQ/t (p-chloranil via hydroquinone) + 400 t × 60 000 µg TEQ/t (o-chloranil via chlorination of phenol) + 6 000 t × 39 µg TEQ/t (p-dichlorobenzene) + 800 000 t × 0.03 µg TEQ/t (Modern plants, EDC/VCM or EDC/VCM/PVC) + 4 530 000 t × 0.1 µg TEQ/t (PVC only)

= 157.57 g

Release in Residues

PCDD/PCDF releases in residues were significant in 2005. The emission factors of dioxins in residues from source 7b were available for production of chlorobenzenes, Chlorine/alkali, and ECD/VCM/PVC production according to the Toolkit 2005 methodology. Thus, the estimated release of PCDD/PCDF in residues from source 7b was of 46.91 g.

Release of dioxins in residues

$= \sum_{i=1}^{n} \text{activity levels for class } i \times \text{emission factor in residues for class } i$

= 6 000 t × 3 000 µg TEQ/t (1,2,4-trichlorobenzene) + 20 000 t × 1 000 µg TEQ/t (Chlor-alkali production using graphite anodes) + 800 000 t × 10 µg TEQ/t (Modern plants, EDC/VCM or EDC/VCM/PVC) + 4 530 000 t × 0.2 µg TEQ/t (PVC only)

= 46.91 g

The total dioxin release from source 7b by five different release routes was calculated to be 205.33 g. The emission inventory for source 7b is presented in the following table.

Total dioxin release = Release to Air + Release to Water + Release to Land + Release in Products + Release in Residues = 0.32 g + 0.536 g + 157.57 g + 46.91 g = 205.33 g

Baseline inventory (reference year 2004)

Class	Source category 7b	**Production t/a**	**Annual release**				
			g TEQ/a	**g TEQ/a**	**g TEQ/a**	**g TEQ/a**	**g TEQ/a**
	Production and Use of Chemicals		**Air**	**Water**	**Land**	**Product**	**Residue**
	Chemical industry		**0.321**	**0.536**		**157.571**	**46.906**
	PCP	2,000				**1.000**	
1	European, American production (chlorination of phenol with Cl2)	0				**0**	
2	Chinese production (thermolysis of HCH)	0				**0**	
3	PCP-Na	2,000				**1.000**	
	PCB	0				**0**	
1	Low chlorinated, e.g., Clophen A30, Aroclor 1242	0					
2	Medium chlorinated, e.g., Clophen A40, Aroclor 1248	0				**0**	
3	Medium chlorinated, e.g., Clophen A50, Aroclor 1254	0				**0**	
4	High chlorinated, e.g., Clophen A60, Aroclor 1260	0				**0**	
	Chlorinated Pesticides	16,800				**11.760**	

1	Pure 2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	0				**0**	
2	2,4,6-Trichlorophenol	800				**0.560**	
3	Dichlorprop	0				**0**	
4	2,4-Dichlorophenoxy acetic acid (2,4-D)	16,000				**11.200**	
5	2,4,6-Trichlorophenyl-4'-nitrophenyl ether (CNP = chloronitrofen)	*0*				*0*	
	Old technology	0				**0**	
	New technology					**0**	
	Chloranil	1,700				**144.100**	
1	*p*-chloranil *via* chlorination of phenol	300				**120.000**	
2	*p*-chloranil *via* hydrochinone	1,000				**0.100**	
3	Dyestuffs on chloranil basis (old process, Class 1)	0				**0**	
4	*o*-chloranil *via* chlorination of phenol	400				**24.000**	
	Chlorobenzenes	34,000				**0.234**	**18**
1	*p*-Dichlorobenzene	6,000				**0.234**	
2	*o*-Dichlorobenzene	22,000				**NA**	
3	1,2,4-Trichlorobenzene	6,000				**NA**	**18**
	Chlorine/chlor-alkali production	20,000					**20**
	Chlor-alkali production using graphite anodes	20,000					**20**
	ECD/VCM/PVC	5,330,000	**0.3**	**0.5**		**0.477**	**9**
1	Old technology, EDC/VCM, PVC	0		**0**			
2	Modern plants, EDC/VCM or EDC/VCM/PVC	800,000	**0.32**	**0.400**		**0.024**	**8**
3	PVC only	4,530,000	**0.0014**	**0.1359**		**0.453**	**0.9**
	Category 7b (Total per vector)		**0.321**	**0.536**		**157.571**	**46.906**
	Category 7b (Grand total)		**205.33**				

Update and revision of the inventory

The updated inventory of Country X was developed using data of activity levels collected for the reference year 2010, according to the updated emission factors in Toolkit 2013. The revised Toolkit includes important structural changes to the classification of sources in the chemical industry sector, new or revised emission factors for a number of sources, as well as additional source categories and classes.

The activity levels of chemicals production are the same as in the baseline year and the corresponding release estimates are summarized in the following table using the Toolkit 2013 and corresponding emission factors.

Updated inventory (reference year 2010)

Class	Source categories	**Production t/a**	**Annual release**				
			g TEQ/a	**g TEQ/a**	**g TEQ/a**	**g TEQ/a**	**g TEQ/a**
7b	**Chlorinated Inorganic Chemicals**		**0.0**	**0.0**	**0.0**	**0.0**	**20.0**
	Elemental chlorine production (per ton ECU)	**20'000**	**0**	**0**	**0**	**0**	**20**
1	Chlor-alkali production using graphite anodes	20'000					**20**
2	Chlor-alkali production using titanium electrodes						

2a	Low-End Technologies			0			0
2b	Mid-Range Technologies			0			0
2c	High-End Technologies			0			0
7c	**Chlorinated Aliphatic Chemicals**		0.5	0.4	0.0	0.0	0.4
	EDC/VCM and EDC/VCM/PVC (per ton EDC)	800'000	0.040	0.400	0.000	0.000	0.076
1	Low-End Technologies						
1a	With fixed-bed oxychlorination catalyst		0.000	0.000		0.000	0.000
1b	With fluidized-bed oxychlorination catalyst		0.000	0.000		0.000	0.000
2	Mid-Range Technologies						
2a	With fixed-bed oxychlorination catalyst		0.000	0.000		0.000	0.000
2b	With fluidized-bed oxychlorination catalyst		0.000	0.000		0.000	0.000
3	High-End Technologies						
3a	With fixed-bed oxychlorination catalyst	800'000	0.040	0.400			0.076
3b	With fluidized-bed oxychlorination catalyst		0.000	0.000			0.000
	PVC only (per ton PVC product)	4'530'000	0.453	0.014	0.000	0.000	0.281
1	Low-End Technologies		0.000	0.000			0.000
2	Mid-Range Technologies	4'530'000	0.453	0.014			0.281
3	High-End Technologies		0.000	0.000			0.000
7d	**Chlorinated Aromatic Chemicals (per ton product)**		0.0	0.0	0.0	455.4	0.0
	Chlorobenzenes	28'000	0.000	0.000	0.000	1.092	0.000
1	1,4-Dichlorobenzene	28'000				1.092	
	PCB	0	0.000	0.000	0.000	0.000	0.000
1	Low chlorinated, Clophen A30, Aroclor 1242					0.000	
2	Medium chlorinated, Clophen A40, Aroclor 1248					0.000	
3	Medium chlorinated, Clophen A50, Aroclor 1254					0.000	
4	High chlorinated, Clophen A60, Aroclor 1260					0.000	
	PCP and PCP-Na	2'000	0.000	0.000	0.000	25.000	0.000
1	PCP					0.000	
2	PCP-Na	2'000				25.000	
	2,4,5-T and 2,4,6- trichlorophenol	800	0.000	0.000	0.000	0.560	0.000
1	2,4,5-T					0.000	
2	2,4,6- trichlorophenol	800				0.560	
	Chloronitrofen (CNP)	0	0.000	0.000	0.000	0.000	0.000
1	Old technologies					0.000	
2	New technologies					0.000	
	Pentachloronitrobenzene (PCNB)	0	0.000	0.000	0.000	0.000	0.000
1	Low-End Technologies					0.000	
2	Mid-Range Technologies					0.000	
3	High-End Technologies					0.000	
	2,4-D and derivatives	16'000	0.000	0.000	0.000	2.720	0.000
1	Low-End Technologies					0.000	
2	Mid-Range Technologies	16'000				2.720	
3	High-End Technologies					0.000	
	Chlorinated Paraffins	0	0.000	0.000	0.000	0.000	0.000
1	Low-End Technologies						

2	Mid-Range Technologies					0.000	
3	High-End Technologies					0.000	
	P-Chloranil	**2'000**	0.000	0.000	0.000	1900.000	0.000
1	Direct chlorination of phenol	1'000				400.000	
2	Chlorination of hydroquinone with minimal purification					0.000	
3	Chlorination of hydroquinone with moderate purification	1'000				26.000	
4	Chlorination of hydroquinone with advanced purification					0.000	
	Phthalocyanine dyes and pigments	**0**	0.000	0.000	0.000	0.000	0.000
1	Phthalocyanine copper					0.000	
2	Phthalocyanine green					0.000	
	Dioxazine dyes and pigments	**0**	0.000	0.000	0.000	0.000	0.000
1	Blue 106					0.000	
2	Blue 108					0.000	
3	Violet 23					0.000	
	Triclosan	**0**	0.000	0.000	0.000	0.000	0.000
1	Low-End Technologies					0.000	0.000
2	Mid-Range Technologies					0.000	
3	High-End Technologies					0.000	
7e	**Other Chlorinated and Non-Chlorinated Chemical (per ton product)**		0.0	0.0	0.0	0.0	0.0
	TiCl4 and TiO2	**0**	0.000	0.000	0.000	0.000	0.000
1	Low-End Technologies			0.000		0.000	0.000
2	Mid-Range Technologies			0.000		0.000	0.000
	Caprolactam	0	0.000	0.000	0.000	0.000	0.000
1	Caprolactam		0.000	0.000			
Chemicals Industry (categories 7b through 7e)			**0.493**	**0.414**	**0.000**	**455.372**	**20.357**
Chemicals Industry (Grand total)			**476.635**				

Although the activity rates remained at constant rates since 2004, the difference between the baseline and updated releases is consequent: 476.63 - 205.33 = 271.3 g TEQ. In particular, releases in product are twice as high as baseline values. This is only due to the changes in the Toolkit emission factors, as the activity rates remained at constant levels since 2004. To ensure consistent results over time, the baseline release estimates need to be revised according to the Toolkit 2013 set of emission factors, ensuring that the difference between the 2010 and 2004 values is, as expected, null.

Conclusion

New data and information have been integrated in the revised 2013 edition of the Toolkit, and important changes have been made to emission factors and the classification of sources for the chemical industry. The updating of the inventory for this source group needs to be accompanied by the revision of the baseline values to enable assessment of consistent trends in releases over time.

Example Inventory 9 Source group 8 Miscellaneous

I. Source category 8b Crematoria

This example inventory aims to illustrate the process of inventory development, update and revision for source group 8: Miscellaneous, source category 8b: Crematoria. This case study provides a hypothetical example of a country X that compiles inventory data for crematoria as part of the action plan within the National Implementation Plan (NIP) according to the Stockholm Convention on Persistent Organic Pollutants (POPs).

Baseline inventory

The baseline inventory of country X was conducted in 2005 by using data collected for 2004 (reference year); the amount of PCDD/PCDF releases to air and residue were calculated following the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases, UNEP 2005. According to country X, cremation was mainly performed as a Buddhism tradition. Therefore, religion and death records were obtained from National Statistics in 2004, as well as the number and list of Buddhist temples that have cremation facilities. According to country X, 75.82% of deaths resulted in cremations. Questionnaires were sent to these temples to obtain more detailed information including the type and temperature of the burning chamber, as well as after burning chamber, duration of operation, dust abatement system, air pollution control system, type and amount of fuel, and number of cremations per year.

The crematoria were classified into 3 classes according to the technologies in use, based on the data obtained from questionnaires complemented by site visits as follows:

- Class 1 (no control) refers to the crematoria where the combustion temperature is below 850 °C, with uncontrolled combustion air flow or no flue gas cleaning system in place. The coffin is decorated with plastic material or made of treated wood;

- Class 2 (medium control) refers to the crematoria where the combustion temperature is above 850°C, with controlled combustion air flow and only dust removal in place. The coffin does not contain plastic material or treated wood;

- Class 3 (optimal control) refers to the crematoria where the combustion temperature is above 850°C with controlled combustion air flow and air pollution control system (APCS) in operation.

The data for Class 1, 2 and 3 are segregated, then the activity rate or production (t/a) of crematoria in each class is multiplied by a PCDD/PCDF emission factor to obtain the amount of PCDD/PCDF releases to air and residue as illustrated below:

	Source Categories	Activity (t/a)	Annual release (g I-TEQ/a)				
			Air	Water	Land	Product	Residue
	8 Miscellaneous						
	8b Crematoria						
1	No control	238,455	21.46				ND
2	Medium control	15,333	0.15				0.04
3	Optimal control	0	0.00				0.00

	Total for Crematoria	**253,788**	**21.61**	**0.00**	**0.00**	**0.00**	**0.04**

Updating of the inventory and revising the baseline

The measures included in the action plan targeting crematoria are based on best available techniques considering both environmental aspects (e.g. appropriate air pollution control systems) and technology (e.g. minimum temperature, residence time and oxygen content requirements). Further to implementing these measures, country X needs to assess whether PCDD/PCDF releases from this source decreased over time. The inventory is thus updated in 2011 to evaluate the changes in releases as a result of implementing best available techniques and best available practices. Data were collected for 2010 (reference year). During the process of updating the inventory it was found that 20 new crematoria with optimal control for PCDD/PCDF (class 3) release were installed in various regions in country X. Questionnaires were sent to both new and existing crematoria to obtain up-to-date information regarding their production or activity rates, temperature and duration of cremation process, fuel use, air pollution control system and evaluate/reclassify these facilities according to their current technology profile and activity levels. The same approach as in the baseline inventory was thus applied and resulted in 30% of the crematoria which were classified as class 1 in the baseline inventory being upgraded to class 2, and 5% of the crematoria which were classified as class 2 in the baseline being upgraded to class 3.

The results show that although the number of facilities increased in country X from 2004 to 2010, PCDD/PCDF releases decreased over the same period of time as a result of phasing in best available techniques for crematoria:

	Source Categories	**Activity (t/a)**	**Annual release (g I-TEQ/a)**				
			Air	**Water**	**Land**	**Product**	**Residue**
	8) Miscellaneous						
	8b) Crematories						
1	No control	99,000	8.91				ND
2	Medium control	152,000	1.52				0.38
3	Optimal control	50,000	0.02				0.12
	Total for Crematoria	**253,788**	**10.45**				**0.5**

Country X also plans an own PCDD/PCDF measurement campaign to collect and analyze samples from several facilities and refine the emission factors used in estimating releases. Once the emission data are generated and new emission factors derived, country X will revise the inventory by applying the same set of revised emission factors based on own measurements, to enable consistent evaluation of trends in releases over time.

Conclusion

When updating the PCDD/PCDF inventory, it is necessary to review the baseline or previous inventories to maintain consistency over time and ensure that the estimates obtained are comparable over time. Data quality is important; therefore, it is also essential to revise and update data obtained from national statistics, questionnaires and site visits. More specifically, it is important to note all factors such as the type of wood used in making the coffin, the preservatives used in treating the wood, plastic decorations added to the coffin, which would contribute to higher emissions of PCDD/PCDF to air and residue.

II. Source category 8d Dry cleaning

Introduction

Dioxin and furans emitted by the dry cleaning processes are found in the residues from distillation of the solvents and in filters. The emission factors for PCDD/PCDF found in the literature are usually expressed relative to the amount of residue from the solvent recycling process. Depending on the efficiency of stills, the bottoms range from a dry powder to a wet sludge that contains some solvent and the filtered material.

As shown in the Toolkit, a ton of residue from a dry cleaning machine may contain from 50 µg TEQ to 3000 µg TEQ of PCDD/PCDF depending on the nature of the cloths and tissues treated and the amount of contamination they contain.

To evaluate releases of PCDD/PCDF from the dry cleaning industry at a country level using the Toolkit method, one has to estimate the amount of residues generated and the relative nature of the tissues cleaned (heavy or contaminated textiles/normal textiles). In nearly all countries it is difficult to find such data to complete the inventory.

In case of lacking data, the following considerations may help in the estimation of these values:

- In a US EPA study, it was reported that an average dry cleaning machine (16 kg cloths per hour/1890 kg per month) generates an average of 183 kg of residues from the bottom of the still; an approximation of the amount of residues generated might be 1 kg/10 kg of textiles ;
- The ratio of heavy textiles to normal textiles treated in dry cleaning laundries is varying from country to country; an expert judgment is needed according to local practices;
- Last generation dry cleaning processes use less than 10 kg of solvent per ton of textiles;
- Residues of dry cleaning contain less than 1% of solvent (new dry cleaning processes).

Example 1

In country A, the total installed dry cleaning capacity is 2500 kg/h and the activity is 3600 t/year of which 60% are heavy textiles. The total amount of residues is estimated at 360 t/year and the PCDD/PCDF releases in residues are:

- From heavy textiles : 60% x 360 t/y x 3000 µg TEQ = 0.648 g TEQ
- From light textiles : 40% x 360 t/y x 50 µg TEQ = 0.0072 g TEQ

Releases in residues for dry cleaning category are 0.6552 g TEQ/year. Total releases for this category are 0.6552 g TEQ/year as there is no release through other media.

Example 2

In country B, there is not enough information concerning the production rate but we know there are at least 60 dry cleaning laundries in the country. We can assume the average production rate is 24,000 kg/year/laundry (1890 kg/month) and their release rate is 2.4 t/year. The ratio between the two categories of textiles treated is not really known but a local expert estimated that it would be about 1/1.

PCDD/PCDF releases in residues are:

- From heavy textiles : 50% x 60 x 2.4 x 3,000 = 0.216 g TEQ
- From light textiles : 50% x 60 x 2.4 x 50 = 0.0036 g TEQ

Total releases for dry cleaning category are 0.2196 g TEQ

Example 3

In country C, there is no data concerning the production rate and the residues generation for the dry cleaning category, but it is known, from official statistics, that the average annual imported quantities of solvent for use in dry cleaning (perchloroethylene, Stoddard solvent, other brand names) are stable at about 500 tons per year.[32] Assuming an average consumption of 10kg/ton of textiles[33] treated in dry cleaning processes, a production rate of about 50 000 t is estimated, which will generate about 500 tons of residue.

PCDD/PCDF releases in residues are:

- From heavy textiles: 50% x 500 t/y x 3,000 µg TEQ = 0.75 g TEQ
- From light textiles: 50% x 500 t/y x 50 µg TEQ = 0.0125 g TEQ

Total PCDD/PCDF releases from dry cleaning are of 0.7625 g TEQ.

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[32] In addition to dry cleaning, are other possible uses of these solvents are possible, such as metal degreasing. It is thus important to try to obtain an industry-based breakdown of the import data.

[33] The regulation in US and Canada sets a limit of solvent consumption for dry cleaning to 6.5 l/ton of cloths (10 kg/ton of cloths in the case of perchlorethylene).

Example Inventory 10 Source Group 9 Disposal and Landfill

Baseline inventory

Country A has prepared its PCDD/PCDF inventory for the reference year 2005. For source group 9, data on the amount of wastes deposited on landfills and waste dumps, sewage collection, treatment and disposal were obtained from the National Department of Statistics and from the National Survey on Basic Sanitation, complemented by data from agencies and companies responsible for waste and sewage collection, treatment and disposal.

Category 9a Landfills and Waste Dumps

To estimate leachate releases generated by organic decomposition of municipal solid waste, the total amount of wastes disposed of in sanitary landfills - 1,011,780 t/year - and in waste dumps – 809,424 t/year – was considered, resulting in a total of 1,821,204 t wastes disposed of per year. Reliable studies were conducted by researchers at the National University in Country A, indicating generation of leachate from 0.1 to 0.2 cubic meter per ton of waste disposed of. Considering the intermediate value of 0.15 m^3/t, the total volume of leachate generated in 2005 was of 273,181,000 liters.

Information for the calculation of leachate from hazardous waste releases does not exist. The surveyed companies reported that formation of leachate in landfills containing industrial hazardous waste is small, as special landfills are used for this type of waste, compliant with the legislation in force, with low amounts of degradable organic matter, and where rain is prevented from reaching the landfilled waste.

Municipal solid wastes are considered to contain 5% of hazardous wastes according to information given by the Federal Environment Agency. The total annual release was then calculated by multiplying the activity rates by the corresponding emission factors according to the Toolkit (2005). The results are shown in the following table:

Annual PCDD/PCDF releases for source category 9a (reference year 2005)

Category	Class	Activity Rate	Annual release (g TEQ/a)					Total
			Air	Water	Land	Product	Residue	
Landfills and waste dumps	Hazardous wastes	13,659,000 L/year leachate 91,060 t/year solid waste	-	0.003	-	-	4.6	**14.9**
	Non-hazardous wastes	259,521,600 L/year leachate 1,730,144 t/year solid waste	-	0.008	-	-	10.4	

Landfill mining and excavation

Landfill mining and excavation was not considered in the baseline inventory of Country A. Nonetheless a good example of emission from this source is given by Torres *et al*. (2012). It is the case of a company in Sao Paolo that produced acetylene/vinylchloride monomer (VCM), ethylenedichloride (EDC) and PVC since mid 1950s and deposited the related production wastes on a landfill. The VCM production via the acetylene method stopped in 1996. The corporate landfill has been used for approximately 40 years and was closed in 1996. Lime milk from the acetylene process was the main type of waste disposed of at this site, with approximately 1,400,000 tons of lime milk stored (Torres *et al*. 2012). In 1997, a company started to mine the lime waste from the site and put it on the construction market for neutralizing citrus pulp to produce citrus pulp pellets (CPP). The citrus pulp pellets were exported to Europe as feed for cattle, resulting in PCDD/PCDF contamination of milk and dairy products in several countries (Malisch 2000, Torres *et al*. 2012). After the PCDD/PCDF contamination was discovered, mining of the PCDD/PCDF contaminated lime for CPP ceased. To evaluate the extent and type of PCDD/PCDF contamination of the landfill, 323 samples were taken from the site and analyzed. Concentrations ranged between 0 to 81,000 ng TEQ/kg, averaging around 1000 ng TEQ/kg. The total TEQ amount at the site was estimated at 1.4 kg TEQ. Patterns in the higher contaminated samples (1000 ng – 81,000 ng TEQ/kg) were similar to the EDC catalysts described by Carroll *et al*. (2001). During the last ten years, securing measures were installed including the construction of a hydraulic barrier. The site was also capped (Torres *et al*. 2012). This example demonstrates how PCDD/PCDF from reservoirs can enter via landfill mining in the food chain, directly into cattle feed and human nutrition.

Category 9b Sewage and Sewage Treatment

The National Statistics Department detains information on the volume and type of disposal and treatment given to sewage collected in Country A. The volume of sewage collected and treated was of 668,000 m^3/day (243,820,000 m^3/year). The amount of sludge generated in several types of treatment processes was of 175 g/m^3 (calculated on the basis of 25 grams of dry sludge per person per day and a daily consumption of water of 0.143 m^3/person).

It was estimated that 10% of the sewage collected (24,382,000 m^3/year) contains industrial effluents with chlorine relevance; sewage treatment processes generate sludge, which is afterwards removed. The remaining 90% of the sewage collected (219,438,000 m^3/year) are treated in systems with (93%) and without (7%) sludge removal. Treatment systems without removal of sludge are of the wetland type.

No statistics were available to calculate the activity rates for remote environments or with input control, and they were not included in the inventory.

The results of the inventory are shown in the following table:

Annual PCDD/PCDF releases for source category 9b (reference year 2005)

Category	Class	Activity Rate	Condition	Annual release (g TEQ/a)					Total
				Air	Water	Land	Product	Residue	
Sewage and	Mixed domestic and	0.0	No sludge removal	-	0.0			0.0	**8.0**

sewage treatment	industrial inputs	Sewage: 24,382,000 m^3/year Sludge: 4,267 t/year	With sludge removal	-	0.012			4.27	
	Urban environments	Sewage: 15,360,660 m^3/year	No sludge removal	-	0.031			0.0	
		Sewage: 204,077,340 m^3/year Sludge: 35,714 t/year	With sludge removal	-	0.102			3.57	
	Remote environments or input control	N/A							

Category 9c Open Water Dumping

Water consumption in urban areas reached a total amount of 971,000 m^3/day in 2005, producing 873,900 m^3 sewage/day. By discounting the volume of sewage collected and treated (668,000 m^3/day), it was calculated that the amount dumped in open water (mainly rivers and ocean) was of 205,900 m^3/day or 75,153,500 m^3/year. The same consideration was made in relation to the presence of industrial effluents. Thus, the activity rate in class 1 will be 10% of total sewage volume discharged in open water, and the remaining 90% is assigned to class 2. No information was collected on class 3 (remote environments or input control).

Annual PCDD/PCDF releases for source category 9c (reference year 2005)

Category	Class	Activity Rate	Annual release (g TEQ/a)					Total
			Air	Water	Land	Product	Residue	
Open Water Dumping	Mixed domestic and industrial inputs	7,515,350 m^3/year	-	0.038	-	-	-	**0.051**
	Urban environments	67,638,150 m^3/year	-	0.014	-	-	-	
	Remote environments	N/A						

Category 9d Composting

Composting is not a relevant way of disposing of waste in Country A, and estimates of amounts of wastes converted to compost are uncertain. About 1% of municipal waste is considered to be converted in compost, that is, around 20,000 t/year. Considering the default value of 30% of water content given in the Toolkit (2005), the total amount of compost produced would be 14,000 t/year (dry basis). Assuming an all organic fraction in compost, annual releases of PCDD/PCDF are of 1.4 g TEQ/year.

Category 9e Waste Oil Treatment (Non-Thermal)

As there is no emission factor for this type of source, no further attempt was made to quantify PCDD/PCDF releases from this source.

Total Annual Releases from Source Group 9

The total annual releases of PCDD/PCDF from source group 9 in Country A, in the reference year 2005, amount to 24.4 g TEQ/year.

Updating of the inventory

Based upon the results of 2005 baseline inventory, Country A introduced a number of measures to reduce releases of PCDD/PCDF. In relation to source group 9, the main actions taken were:

a) To reduce by 50% the hazardous content of wastes deposited on landfills and dumps;

b) To introduce a recycling program to reduce the amount of landfilled waste per capita. In 2010 the reduction was of 5%;

c) To eliminate mixing of industrial inputs into sewage collection and treatment systems.

The update of the inventory is described below.

Category 9a Landfills and Waste Dumps

The same methodology as in the baseline inventory was employed to estimate releases generated by organic decomposition of municipal solid waste. According to the Toolkit 2013, emission factors for category 9a have been revised and the need to estimate the amount of leachate generated by waste decomposition has been eliminated; the emission factors are now based on the amount of solid wastes generated. Also, as a result of measures taken, hazardous wastes contained in domestic wastes reduced by half and there was a 5% reduction on domestic wastes.

The updated values are shown in the table below. The results show a decrease of 6.4 g TEQ/year, as compared with the baseline release estimates.

Annual PCDD/PCDF releases for source category 9a (reference year 2010)

Category	Class	Activity Rate	Annual release (g TEQ/a)					Total
			Air	Water	Land	Product	Residue	
Landfills and waste dumps	Hazardous wastes	45,530 t/year	-	0.2	-	-	NA	**8.5**
	Mixed wastes	-	-		-	-		
	Domestic wastes	1,643,637 t/year	-	0.08	-	-	8.2	

Category 9b Sewage and Sewage Treatment

The data from the National Statistics Department show that the sewage volume decreased by 10% due to the elimination of mixed industrial and domestic effluents in relation to 2005. The type of disposal and treatment remained the same as in 2005. Then the volume of sewage collected and treated was of 601,200 m^3/day (219,438,000 m^3/year). The amount of sludge generated in several types of treatment processes in use in Country A was thus similarly estimated as in 2005.

However, based on the measures included in the National Implementation Plan (NIP) of Country A, there is no mixing of industrial inputs with chlorine relevance. All sewage collected can be classified as class 2, 93% being treated in systems with sludge removal and 7% in systems without sludge removal.

No statistics were available to calculate the activity rates for remote environments or with input control, and they were not included in the inventory.

The total annual releases for 2010 show a reduction of 7.14 g TEQ/year as compared with the baseline situation.

Annual PCDD/PCDF releases for source category 9b (reference year 2010)

Category	Class	Activity Rate	Condition	Annual release (g TEQ/a)					Total
				Air	Water	Land	Product	Residue	
Sewage and sewage treatment	Mixed domestic and specific industrial inputs	0.0	No sludge removal	-	0.0			0.0	**0.7**
		0.0	With sludge removal	-	0.0			0.0	
	Urban and industrial inputs	Sewage: 13,824,594 m^3/year	No sludge removal	-	0.01			0.0	
		Sewage: 183,669,606 m^3/year Sludge: 32,142 t/year	With sludge removal	-	0.04			0.64	
	Domestic inputs	N/A	No sludge removal						
			With sludge removal						

Category 9c Open Water Dumping

Water consumption in urban areas registered a 10% reduction in relation to 2005 consumption, due to the separation of industrial effluents with chlorine relevance from domestic effluents, reaching a volume of 873,900 m^3/day, producing a total amount of sewage of 786,510 m^3/day. By discounting the volume of sewage collected and treated (601,200 m3/day), the amount dumped in open water (rivers and ocean) was estimated at 185,310 m^3/day or 67,638,150 m^3/year. This is entirely assigned to class 2. There is no information on class 3 (remote environments or input control). The total annual releases for category 9c in 2010 (0.014 g TEQ/year) are thus lower than 2005 releases (0.051 g TEQ/year).

Category 9d Composting

The situation in 2010 changed due to changes in the Toolkit 2013 emission factors. The amount of wastes converted to compost remained the same and is assigned to class 1 (compost of organic wastes separated from mixed wastes). The release decreased by 50%, with a total of 0.7 g TEQ/year of PCDD/PCDF.

Category 9e – Waste Oil Treatment (Non-Thermal)

No releases are calculated for this source category, similarly as in 2005.

Total Annual Releases on Source Group 9

The total annual releases of PCDD/PCDF from source group 9 in Country A, in the reference year 2010, amounts to 9.9 g TEQ/year, registering thus a decrease of 14.4 g TEQ/year as compared to the baseline.

Revision of the Baseline Inventory

The update of the inventory for the reference year 2010 was associated with changes in the Toolkit emission factors. Thus, to be able to calculate trends in releases over time based on a consistent set of emission factors, the baseline values must be recalculated by using the Toolkit 2013. The revision of the baseline inventory enabled the detection of a decreasing trend in releases from 2004 to 2010.

Category 9a Landfills and Waste Dumps

Annual PCDD/PCDF releases for source category 9a (revised for the reference year 2005)

Category	**Class**	**Activity Rate**	**Annual release (g TEQ/a)**					**Total**
			Air	**Water**	**Land**	**Product**	**Residue**	
Landfills and waste dumps	Hazardous wastes	91,060 t/year solid waste	-	0.5	-	-	NA	**9.2**
	Mixed wastes	0	-	-	-	-	-	
	Domestic wastes	1,730,144 t/year solid waste	-	0.1	-	-	8.7	

Category 9b Sewage and Sewage Treatment

Annual PCDD/PCDF releases for source category 9b (reference year 2005)

Category	**Class**	**Activity Rate**	**Condition**	**Annual release (g TEQ/a)**					**Total**
				Air	**Water**	**Land**	**Product**	**Residue**	

Sewage and sewage treatment	Mixed domestic and industrial inputs	N/A	No sludge removal	-	0.0			0.0	**0.9**
		Sewage: 24,382,000 m3/year Sludge: 4,267 t/year	With sludge removal	-	0.024			0.85	
	Urban and industrial inputs	Sewage: 15,360,660 m^3/year	No sludge removal	-	0.015			0.0	
		Sewage: 204,077,340 m^3/year Sludge: 35,714 t/year	With sludge removal	-	0.04			0.7	
	Domestic inputs	N/A	No sludge removal						
			With sludge removal						

For categories 9c Open Water Dumping, and 9e Waste Oil Treatment, no changes in emission factors have been made in the revised Toolkit, therefore there is no impact on the calculation of release estimates for these sources. The inventory does not need to be revised in such cases where both the emission factors and the activity rates remain unchanged as compared with the baseline.

For category 9d Composting, the releases are revised to account for the changes in emission factors. The revised PCDD/PCDF release estimates amount to 0.7 g TEQ/year.

Comparison of total releases for reference year 2010 to the revised baseline inventory

The total annual releases of PCDD/PCDF from source group 9 in Country A, in the reference year 2010, amounts to 10 g TEQ, and 12 g TEQ in the revised baseline inventory for reference year 2005, registering a reduction of 2 g TEQ, or around 15%. The results show the importance of the revision of baseline inventory, since without this step the conclusion after updating the inventory would have been a reduction of about 13 g TEQ, or around 60%.

Example inventory 11 Source Group 10 Contaminated Sites and Hotspots

This example inventory contains a series of practical examples and best practice cases of PCDD/PCDF inventories for the most relevant source categories, including, where available, quantitative PCDD/PCDF data.

10a Production Sites of Chlorine

I. Chlor-alkali production

Experience from China, Germany, Sweden and the USA proves that chlor-alkali processes can generate large quantities of PCDD/PCDF (Weber *et al*. 2008). Limited data are available on the total PCDD/PCDF production and release in chlor-alkali plants, but a detailed inventory has been prepared and published for Rheinfelden in Germany (Otto *et al.* 2006). Griesheim Elektron operated a chlor-alkali plant at this site starting with 1898 for 87 years. Toxic residues of the chlor-alkali process together with other industrial waste were disposed of in small gravel pits in the vicinity of the plant without safety measures. In 1989, widespread PCDD/PCDF contamination was discovered in soils (Otto *et al.* 2006). The analysis demonstrated that PCDF contamination was dominant, and samples revealed peak concentrations of 26,000 ng TEQ/kg in topsoil and up to 3,800,000 ng TEQ/kg in deep soil, comprising mainly of historic sludge deposits.

The approach for the inventory at Rheinfelden included:

- An investigation of the history of chlorine production and technologies used at the factory and a review of the methods and sites used for the disposal of residues.
- A preliminary screening of contamination: in a first phase, 100 locations where sampled with 303 core probes. Forty representative pooled samples were then analysed for PCDD/PCDF, heavy metals, total organics and other site-specific parameters.
- In the second phase it was discovered that heavily contaminated solid residues have been used as infill materials at many sites as the city developed in the 20th century. This resulted in widespread contamination with PCDD/PCDF, heavy metals and other contaminants. The entire inner city area (ca. 290 ha) was assessed. Soil samples from 1615 estates involving 3566 individual drillings were collected and screened. Finally, a soil contamination map of the entire city was developed, showing indicator heavy metals.

A PCDD/PCDF inventory was established based on monitoring data and related assessments, followed by remediation and containment of deposits and contaminated soils. The total amount of PCDD/PCDF residues deposited from the chlor-alkali plant was estimated at 8.5 kg I-TEQ (Otto *et al*. 2006). Furthermore, between 1970 and 1986 the factory also produced PCP and PCP-Na, and the residues associated with this production were estimated to contain an additional 7.7 kg I-TEQ (with a total 7 tons of PCDD/PCDF), thus a total PCDD/PCDF contamination of 16.2 kg I-TEQ (Otto *et al*. 2006).

II. Former Leblanc factory site

The only PCDD/PCDF inventory yet established for a Leblanc factory is at Lampertheim, Germany, for a plant which operated between 1840 and 1893. In the late 1980s, high levels of arsenic and lead were detected in soil in the vicinity of the site. Subsequent investigations in the 1990s also revealed high levels of PCDF (and PCDD to a lesser extent) (Balzer *et al*. 2007, 2008).

The assessment included historical investigation and archive research to retrieve information on the production site, as well as technical and scientific literature review on the Leblanc process and associated processes. Based on these investigations, a detailed soil analysis was undertaken, with more than 600 soil cores analysed for a range of organic and inorganic contaminants. Approximately 500 samples were also analysed for PCDD/PCDF, confirming that the entire surface and subsurface soil was highly contaminated with PCDD/PCDF and heavy metals. A PCDD/PCDF inventory was thus established based on the levels measured in samples and the volumes of deposited residues and contaminated soils. The total amount of PCDD/PCDF in soils and deposits was of 1-10 kg TEQ, while the total arsenic and lead contamination was of 12- 80 tons and 50-300 tons respectively (Balzer *et al*. 2007).

Since a range of chemical processes were employed in Leblanc plants, the individual steps and processes were evaluated with respect to their PCDD/PCDF formation potential. Four distinct operational steps with a high PCDD/PCDF formation potential have been identified for the Lampertheim factory (Balzer *et al.* 2008):

a) The direct manganese oxide method was used for chlorine production from HCl.

b) The production of calcium hypochlorite (bleaching powder) from elemental chlorine and $Ca(OH)_2$ in "chlorine chambers": in these processes, coal tar was used as a filler and protection material, resulting in PCDD/PCDF formation. At Lampertheim, highly contaminated residues with TEQ levels above 200 µg TEQ/kg and waste deposits with levels of 500 µg TEQ/kg were found in the vicinity of the former production area. The PCDD/PCDF pattern of these residues is similar to those characteristic of the chlor-alkali process.

c) Hydrochloric acid released from the Leblanc process ovens was condensed in coke towers for further processing. PCDD/PCDF contamination in soils where the piping system and the coke towers were located was above 10 µg TEQ/kg.

d) Finally, the production of sodium sulphate and sal soda in "sulphate ovens" and flame ovens, with residues from these thermal processes contaminated with up to 95 ng TEQ/kg.

A European survey of Leblanc factories revealed that at least 70 to 100 factories were operated during the 19th century mainly in Great Britain, France and Germany (Balzer *et al*. 2008). According to historical records, 413,000 tons of sal soda were produced in 1865 via the Leblanc process, with the main producers located in the United Kingdom (234,000 tons), France (108,000 tons) and Germany (66,000 tons). An inventory of former Leblanc sites has only been made in Germany, where 15 locations have been identified (Balzer *et al*. 2008). At least 30 Leblanc factories have also been operated in France, while in the United Kingdom approximately 30 to 40 Leblanc factories were operational during the mid-19th century.

10b Production Sites of Chlorinated Organics

I. Chlorophenol production

The Finnish Environment Institute has compiled an inventory and risk assessment of PCDD/PCDF contaminated sediments from releases of a polychlorophenol (PxCP) wood preservative Ky-5. Ky-5 was manufactured in the upper reaches of the Kymijoki river in South-Eastern Finland between 1940 and 1984 (Verta *et al*. 2009).

The product consisted mainly of 2,3,4,6-tetrachlorophenol (83%), pentachlorophenol (8%) and 2,4,6,-trichlorophenol (6%). PCDD/PCDF, especially the higher chlorinated dibenzofurans, were major impurities in the product and in residues. The company discharged residues into the river system resulting in highly contaminated sediments with a maximum PCDD/PCDF concentration above 400,000 µg/kg (Verta *et al*. 1999c).

Sediment cores from 220 sites were collected between 1997 and 2003. PCDD/PCDF were analysed from sub-samples of ten sediment cores, 35 surface sediment samples, 15 locations in the river and ten coastal sites from the Gulf of Finland (Isosaari *et al*. 2002, Verta *et al*. 2007).

Figure III.11.1 shows the concentration of PCDD/PCDFs in sediments. The total volume of contaminated sediments was estimated to be 5×10^6 m^3 and the hotspot volume amounted to approximately 90,000 m^3 of sediments with extremely high concentrations (max. 292,000 µg/kg or 1,060 µg I-TEQ/kg d.w.). These were located immediately downstream from the factory.

The total amount of Ky-5 chlorphenol-derived PCDD/PCDF was estimated to be approximately 5,960 kg (17.3 kg I-TEQ) in the river sediments and 1,770 kg (12.4 kg I-TEQ) in the Gulf of Finland (Fig. III.11.1; Verta *et al*. 2009). In addition to the PCDD/PCDF inventory, the Finnish Environment Institute calculated the yearly PCDD/PCDF fluxes within the river and into the Gulf of Finland and projections for the next decades (Verta *et al*. 2009).

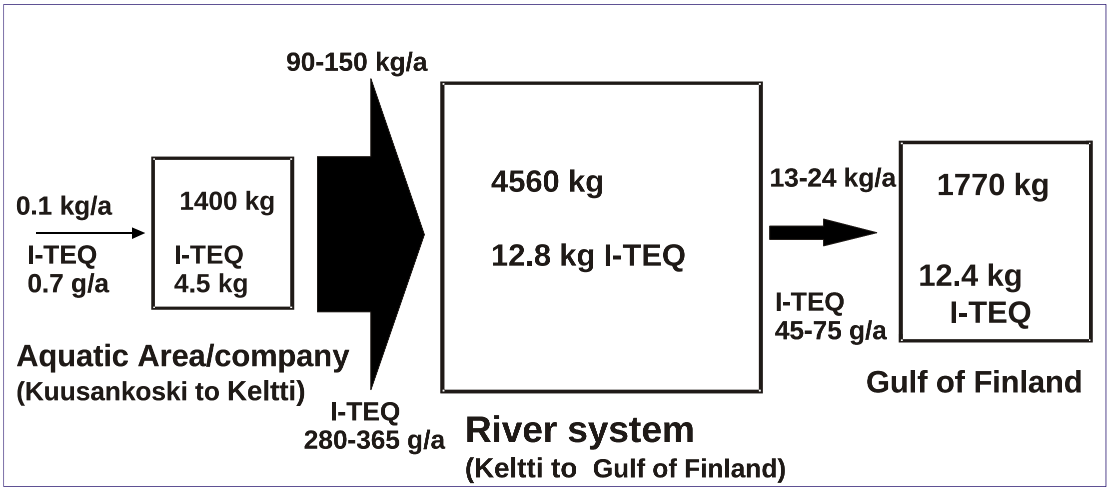

Figure III.11.1 2001 PCDD/PCDF inventory of the Kymijoki river and annual transport to the Gulf of Finland

II. Lindane production with recycling of HCH waste isomers

In some cases, lindane production has recycled (part of) HCH waste isomers due to economic reasons and to reduce dumping of HCH waste. In Germany, HCH waste isomers were recycled between 1953 and 1984 by thermal decomposition (250ºC-260ºC) to produce technical tri/tetrachlorbenzene. In this reaction step, a so-called 'decomposer residue' was produced, containing 1.4 to 2.7% PCDD/PCDF with I-TEQ in the high ppm range (90 to 230 ppm) (Vijgen *et al*. 2011). The final residues from the HCH recycling process were highly contaminated with PCDD/PCDF and resulted in the closure of the factory in 1984 (Vijgen *et al*. 2011, Götz *et al*. 2012).

The total amount of PCDD/PCDF landfilled from registered waste residues generated by thermal HCH decomposition was estimated between 53 and 102 tons for sum PCDD/PCDF, and between 333 and 854 kg I-TEQ contained in approximately 3,700 tons of wastes from HCH recycling (Götz *et al*. 2012). In addition, approximately 2,500 tons of un-recycled HCH waste isomers and 10,000 tons of other organochlorine wastes with lower PCDD/PCDF content were deposited in at least eight landfills (Bürgerschaft Hamburg 1985, University Bayreuth 1995). A detailed inventory of contaminated sites and deposits has been developed for the city of Hamburg and other landfills. PCDD/PCDF fingerprinting has been used for assigning contamination and proving that a site was contaminated with PCDD/PCDF (Sievers and Friesel 1989).

- For the production site, a PCDD/PCDF inventory in the soil has been compiled (Table III.11.1). The site has been secured with a 50 m deep cut-off wall, groundwater was pumped and residues were incinerated (Weber and Varbelow 2012).
- At the Georgswerder landfill in Hamburg, approximately 50% of the PCDD/PCDF load (157-403 kg I-TEQ) contained in 1,750 tons of HCH 'decomposer residues' and 4,000 tons or other organochlorine waste were deposited (Götz *et al*. 2012). The landfill has been secured and oily leachates containing PCDD/PCDF were incinerated.
- Another deposit in Hamburg has also received waste from this factory and has been assessed and inventoried (Sievers and Friesel 1989).
- Approximately 50% of the PCDD/PCDF wastes (included in the inventory) were disposed of at six landfills outside Hamburg along with approximately 70% of the wastes. Detailed data on the leachate and groundwater situation from these individual landfills are not available.

Recycling of HCH waste has been undertaken by several other lindane producers (Vijgen *et al*. 2011) and may still be in practice today in two former lindane factories in India (Jit *et al*. 2010). A similar approach to establishing an inventory might be useful for other sites.

Table III.11.1 PCDD/PCDF and other chlorinated organohalogen compounds in soil from storage, spills and leaks at the production site*

Contaminant	Amount of organohalogens
Total PCDD/PCDF (TEQ)	6 kg
HCH isomers	262 tons
Chlorobenzenes	551 tons
Chlorophenols	18 tons

EOX (calculated to Cl)	663 tons

*contained in a total volume of 559,000 m^3 soil

III. Other chemicals known or suspected to contain PCDD/PCDF or other unintentional POPs

While the levels of PCDD/PCDF in some products (*e.g*. pesticides) have been monitored, the levels in production residues are often unknown. To assess occupational safety during the excavation of the Bonfol chemical landfill in Switzerland, a PCDD/PCDF inventory of the deposited waste was compiled. The Basel Chemical Industry[34] (BCI) has produced and used a range of chlorinated aromatic compounds not known to be highly contaminated with PCDD/PCDF or precursors (*e.g*. 2,4-D, 2,4,5-T or PCP). Between 1961 and 1976, the industry disposed of 114,000 tons of chemical wastes in the Bonfol landfill, an old clay quarry. Because the landfill contaminated groundwater, BCI was forced to fully remediate the site by excavating and incinerating chemical wastes.

For the inventory, the chemicals listed by the German Environmental Agency (UBA) as containing or potentially containing PCDD/PCDF were used as one information source (UBA 1985). This list was supplemented by additional literature on substances containing PCDD/PCDF and PCB (Forter 2005, 2006) including:

- Three lists containing approximately 5,000 substances which were produced during 1960-2003, by BCI. The information included data on educts, production intermediates and products.
- Other unpublished internal documents from chemical companies including information on production and synthesis methods, capacity calculations and internal analysis reports.
- Newsletters and reports or other publications by companies, chemical associations and further publications.
- Analytical results available from samples taken from around disposal sites used by BCI members operating in Switzerland, France, Germany and the USA.
- The amended lists and additional information were then discussed with chemists, chemical engineers and laboratory experts at Roche, Sandoz, Geigy, Ciba and Ciba-Geigy.

It was established that at least 38 substances produced and used from the 1950s to 1970s by BCI contained, or potentially contained PCDD/PCDF. These substances were used in the production of several hundred final products. PCDD/PCDF wastes were estimated for four of these products: the production of trichlorophenol by Roche and the production of dioxazin pigments and paints, Mitin LA and triclosan by Geigy or Ciba-Geigy (Forter 2005, 2006) (Table III.11.2).

The majority of PCDD/PCDF and PCB impurities from educts and those formed during the production of trichlorophenol, triclosan, Mitin LA and Oxazin/Dioxazin pigments and paints ultimately ended up, by a process of filtration and distillation of the chlorinated solvents, in the residues and were ultimately disposed of at the Bonfol chemical landfill between 1965 and 1975. Considering the PCDD/PCDF quantities resulting from these four production processes, and taking into account that BCI was a heavy user of chlorinated solvents, it was shown that total TEQ levels of several tens of kilogram were present

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[34] http://www.bci-info.ch/

in the Bonfol landfill (Forter 2005, 2006). The total quantity of PCDD/PCDF and PCB was estimated to be as much as one ton (Forter 2005, 2006).

Table III.11.2 Order of magnitude estimates of the PCDD/PCDF wastes from BCI production during 1964-1975

Production/ use of	Period of time	Estimated total PCDD/PCDF amount (kg)	Estimated PCDD/PCDF I-TEQ (kg)
Trichlorophenol	End 1960s	Unknown	> 0.1
Oxazin & Dioxazin pigments and dyes	1965–1975	Several 100	1 to several kg
Triclosan	1966–1975	Several 10 to several 100	0.1 to 1
Mitin LA	1974–1975	Unknown	0.01 to several 0.01
Total		**Several 100**	**1 to several kg**

IV. Unintentionally produced HCB wastes from solvent production

Wastes from the production of chlorinated solvents at the former Kalush Chemical and Metallurgical Industrial Complex were buried near Kalush City, Ukraine. The solvents produced included carbon tetrachloride, tetrachloroethene and dichloroethene (ethylene dichloride EDC) for PVC manufacturing. Solvent production started in 1973 with an estimated production capacity of approximately 30,000 tons per year. Approximately 540 tons of hazardous “HCB waste” with unintentionally produced HCB as a primary contaminant was produced annually, suggesting an emission factor of 18 kg “HCB waste”/t solvent produced for this factory (Weber *et al*. 2011). The total amount of “HCB waste” deposited was estimated to be approximately 11,000 tons (UNEP, OCHA and EU Commission 2010). Since the HCB content of the waste is around 20%, the total amount of HCB deposited at this site can be estimated to be around 2,200 tons (Jacoff *et al*. 1986). Sampling of “HCB waste” also found PeCB at levels approximately an order of magnitude lower than HCB. The total quantity of PeCB waste contained in the total 11,000 tons of “HCB waste” can be estimated to be approximately 200 tons.

Other cases of stored or deposited HCB waste show that the inventories for solvent production facilities which did not have adequate destruction capacity in the 1950s to 1990s are of the same order of magnitude:

- The manufacture of chlorinated solvents by Orica between 1963 and 1991 produced more than 10,000 tons of concentrated “HCB waste” (Independent Review Panel 2006) (www.oricabotanytransformation.com). About 1,000 tons of this waste was generated by the production of ethylene dichloride (EDC) for manufacturing PVC.
- 80,000 drums of “HCB waste” were disposed of from Spolchemie (Chabaiovice,Czech Republic) near the Elbe river (Heinisch *et al.* 2006). Subsequent leaching of the waste into the Elbe river resulted in high concentrations of HCB accumulating in downstream sediments and PeCB levels of approximately 15% of those of HCB (Heinisch *et al.* 2006).

V. Lindane production

In the production of lindane (gamma-HCH), approximately 85% of the waste isomers are formed in the chlorination step of benzene as unintentional POPs (Vijgen *et al.* 2011). The active gamma-isomer was commonly separated, and the remaining 85 to 90% waste isomers, consisting mainly of alpha-HCH and some beta, delta and epsilon-HCH, were dumped. A global inventory of these wastes was compiled based on information collected for over 20 years of production, including HCH production capacities and estimated amounts of wastes generated (Vijgen *et al*. 2011). 1.6 – 1.9 million tons of disposed HCH waste were thus estimated in the former producing countries (Albania, Austria, Argentina, Brazil, China, Croatia, Czech Republic, France, Germany (including former German Democratic Republic), Hungary, India, Italy, Japan, Macedonia (former Yugoslavia), Nigeria, Poland, Romania, Slovakia, South Africa, Spain, Switzerland, Turkey, The Netherlands, UK, USA, and the former USSR). This inventory is considered to underestimate the scale of the problem because of the incomplete reporting and the likely existence of unidentified productions sites and waste deposits.

In a second inventory approach, the total quantity of HCH waste was estimated by using the proportion of waste isomers produced per tonne of lindane used (Vijgen *et al*. 2011). Global historical lindane use for agricultural purposes was estimated to have been between 1950 and 2000 of 450,000 t, with the largest share (63%) in Europe (Vijgen *et al*. 2011). Additional use of lindane on livestock, in forestry, in human pharmaceuticals and for other purposes has also been considered and is estimated to add another 150,000 t (Vijgen 2006a,b), bringing the total global figure to 600,000 t. According to Bodenstein (1972), the total HCH isomer waste was about 8 tons per ton of Lindane produced. Other experts have estimated about 10 tons per ton of Lindane produced (Krum 1982) and 10-12 tons per ton of Lindane produced (Treger 2004). Using the range of these approximations (8 to 12 tons), the total global amount of HCH waste is estimated between 4.8 and 7.2 million tons, constituting the largest international POPs stockpile.

10c Application Sites of PCDD/PCDF Containing Pesticides and Chemicals

The total amount of PCDD/PCDF releases from former pesticide use and related contaminated areas has been investigated and assessed in Japan (Masunaga 2001, Seike *et al*. 2007, Weber and Masunaga 2005). Two herbicides, PCP and CNP, applied from 1950s to 1980s, contained elevated concentrations of PCDD/PCDF. In the case of CNP, the average PCDD/PCDF content in formulations produced pre-1982 was estimated to be 6 g/kg and 3.60 mg TEQ/kg active ingredient (N= 39 samples). After 1982 the PCDD/PCDF content of CNP decreased to 0.71 g/kg and 0.022 mg WHO-TEQ/kg active ingredient (N= 23 samples) (Masunaga *et al*. 2001, Seike *et al*. 2003). High PCDD/PCDF levels were found in PCP produced in the early 1960s, but also for some PCP produced at the end of the 1970s. The average dioxin content in PCP (N= 14 samples) was 3.3 g PCDD/PCDF per kilogram and 1.5 mg TEQ/kg active ingredient (Masunaga *et al.* 2001, Seike *et al.* 2003). Other pesticide formulations contained comparatively low concentrations of PCDD/PCDF (Masunaga *et al.* 2001).

The total dioxin releases from the application of pesticides on rice fields and agricultural areas in Japan during 1955-1995 was estimated based on the arithmetic average concentration of PCDD/PCDF in historical pesticides and the amount of pesticides used. The total emission from PCP use was estimated to be 540 tons of PCDD/PCDF or 250 kg TEQ. The total emission from CNP use was estimated to be 380 tons of PCDD/PCDF or 210 kg TEQ (Figure III.11.2; Weber *et al*. 2008). These loads contribute a large proportion of today's PCDD/PCDF contamination in Japanese soil and sediments (Masunaga *et al.* 2004, Sakai *et al.* 2007). The PCDD/PCDF pattern in human milk samples from Japan has even nowadays a significant input from former PCP use (Tawara *et al.* 2006, Weber *et al.* 2008).

A historical PCDD/PCDF inventory application and PCDD/PCDF transport to rivers and ocean sediments has been established for the Tokyo Bay basin (Masunaga 2004, Weber and Masunaga 2005). For this task, the dioxin load of the Tokyo Bay basin was estimated from the annual quantities of agrochemical shipments to Tokyo, Saitama, Chiba and Kanagawa prefectures, the percentage area belonging to the basin, and the dioxin contamination of the agrochemicals. The PCDD/PCDF load of the Tokyo Bay basin due to PCP use was estimated to be approximately 31,000 kg PCDD/PCDFs and 14 kg TEQ. The contribution from CNP was estimated to be 9,300 kg PCDD/PCDF and 5 kg TEQ. The total amount of PCDD/PCDFs deposited in sediments was estimated from sediment core data (Masunaga 2004). A comparison between the total PCDD/PCDF emissions and the sediment load in Tokyo Bay shows that only a few percentages of PCDD/PCDF applied to paddy fields as agrochemical impurities have been deposited in the Tokyo Bay. Due to the persistency of these compounds, the remaining PCDD/PCDF still exist in terrestrial soil and river sediments, representing an input source into the future. According to the concentration of PCDD/PCDF in Tokyo Bay sediments, the flux from PCP use remained constant over the past 20 years. This indicates that PCDD/PCDF transport processes in the environment may last for decades and most likely centuries.

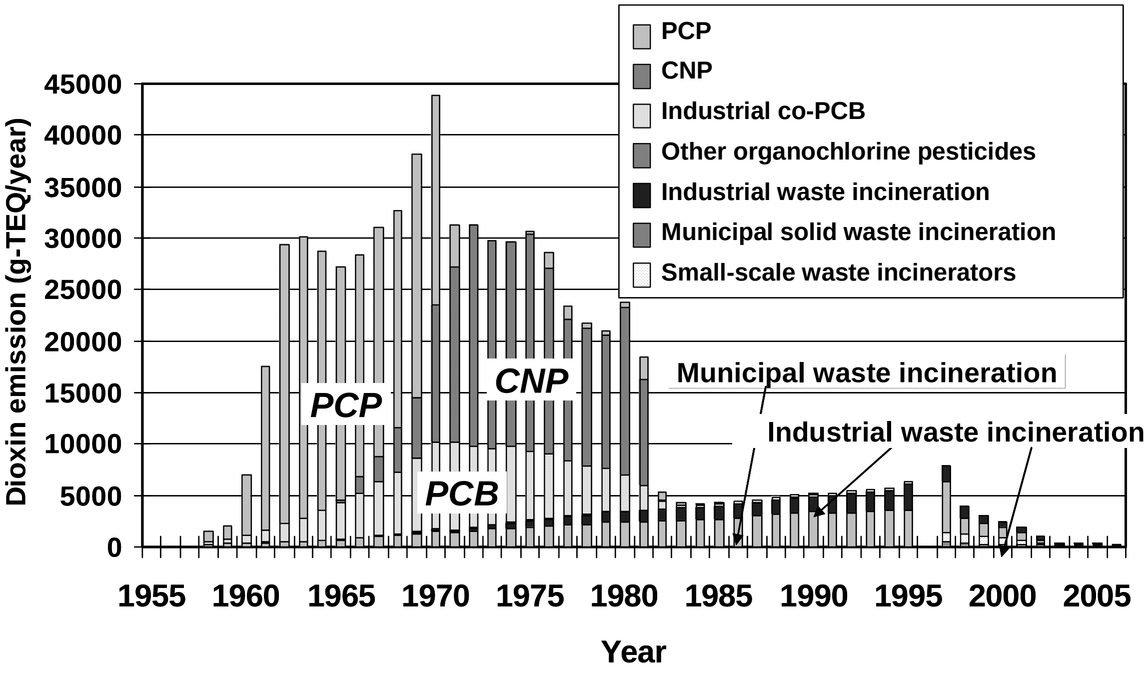

Figure III.11.2 Historic Japanese PCDD/PCDF (TEQ) release inventory to the environment

10f Use of PCB

I. Inventory of PCB contaminated sites in Belarus

The inventory of PCB contaminated sites in Belarus included:

1) PCB-containing equipment

The first inventory of PCB-containing equipment in Belarus was developed in 2004. More than 2,000 enterprises were covered in the inventory process. The methodology is described in Kukharchyk and Kakareka (2008). About 40 companies were identified as owners of PCB-containing transformers and 750 companies as owners of PCB-containing capacitors (Government of Belarus 2006). All of these sites were treated as potential hotspots. A database was created, containing detailed information on the facilities and the PCB-containing equipment, including facility name and address, types and number of equipment, trademarks, volumes of PCB, dates of manufacture, condition of the equipment, levels of operation, descriptions of installations or storage locations. The total volume of PCB in PCB-containing equipment in Belarus was estimated at 1,500 tons. 55% of the total amount of PCB is contained in power transformers and 44% in power capacitors. A substantial part of PCB-containing equipment has been removed from service long time ago: around 25% of capacitors and 9% of transformers with a total volume of 230 tons PCB have been taken out of operation. In the past, no measures have been taken to ensure storing of PCB-containing equipment in an environmentally sound manner. The condition of power capacitors and transformers was evaluated in many cases as unsatisfactory, due to the destruction of their frames.

The sites where PCB leakages occur were also revealed. Special attention was given to open sites where the probability of PCB leakage was very high. Documented accidents were also taken into account. Special field investigations of selected sites were organized with the aim to indicate damage characteristics, features of PCB leakages, etc.

Based on the results of the investigation, PCB release factors were developed: for PCB-containing transformers – 0.3 kg/t dielectric fluid, for capacitors – 2 kg/t (EMEP/EEA 2009). It was found that approximately 1.5 tons of PCB are annually discharged into the environment from leaking power transformers and capacitors.

The potential discharges of PCDD/PCDF were calculated taking into account the total PCB leakage from PCB-containing equipment and the content of PCDD/PCDF in low chlorinated dielectrics fluids (in capacitors) and high chlorinated fluids (in transformers).

The PCB database is updated every year, including information on the total number of PCB-containing equipment and equipment taken out of service (Government of Belarus 2006).

Several projects investigating PCB-contaminated sites and soil pollution were implemented during 2005-2011 in Belarus, including on-site inspection, identification of damaged equipment, detection of leakages, soil sampling and analysis. More than 80 open sites and several dozens of closed sites where PCB-containing equipment is still in operation or in storage were investigated. As a result, the list of PCB contaminated sites was developed including facility name, address, location, type of sources, and PCB content in soil. About 60 sites were found to have polluted soil. PCB content in soil is found at levels up to milligrams or sometime grams per kilogram (Kukharchyk *et al.* 2008, 2011). The highest concentrations of PCB (up to 105 g/kg) were found in the soil near destroyed capacitors and transformers. In most cases, PCB content in soils was heterogeneous; usually there are several small hotspots within one site. The size of hotspots is different; most of them are less than 1 m^2, but sometimes reach up to 50 m^2. The largest polluted site has an area of more than 1000 m^2 and included several individual hotspots. Generally, the number of hotspots and their size depends on the area where

PCB-containing equipment is installed or stored, as well as on the quantity of PCB-containing equipment, the time of its operation or storage, the share of damaged equipment, incidents such as explosion of capacitors and PCB spraying. The highest level of pollution was found in the upper soils (top 10 cm). However, in some cases, high levels of PCB pollution were also found at depths of 1 m and more.

2) PCB-containing paint/varnish production

A significant source of PCB release into the environment was the use for paint and varnish production (Kukharchyk *et al*. 2008). Historical data on the annual volume of PCB in use at the Lakokraska factory in the city of Lida, Belarus were collected. It was established that during 1968-1998, about 5,000 tons of Sovol was used. The paint/varnish production process was analysed and possible ways of Sovol discharges into environment were assessed. Taking into account technological discharges of raw material, it was established that approximately 130 tons of Sovol were released into the environment (mainly in soil) on the site of the plant.

PCB content in soil was found at levels up to 96.6 mg/kg. The spatial distribution of PCB is homogenous in comparison with the places where PCB-containing equipment is installed or stored. Penta- and hexachlorobiphenyls are dominating among PCB compounds, with 53% and 28% respectively, clearly indicating that the source of PCB discharge is Sovol.

II. Inventory of PCB contaminated sites impacting rivers and fish

The Swiss Federal Office for Environment in cooperation with the Swiss EMPA developed a methodology for inventorying PCB-impacted water bodies and classification according to the dioxin-like PCB content in fish. The inventory approach includes tracking of PCB point sources resulting in levels of dioxin-like PCB in fish above the regulation limits for fish consumption.

Monitoring data of 1,300 fish samples analysed over two decades were evaluated. For three rivers, dioxin-like toxicity levels above legislation limits were found (BAFU 2010). An inventory of impacted river sections was then established (Zennegg *et al*. 2010). Fish were contaminated within sections of 20 to 40 km of river. In a second step, river sections with elevated PCB levels in fish were screened for point sources by passive sampling.

A former disposal site (La Pila) was identified as the point source responsible for PCB contamination in the Saane river. The landfill was used for domestic and industrial waste (from 1952 to 1975). The amount of PCB was estimated to be more than 20 tons within approximately 195,000 m^3 waste (Zennegg 2010). Flooding events and rain washed out these PCB and enabled their migration into the river.

On the basis of PCB levels measured in fish, water bodies were classified into three categories (Zennegg 2010): the first category was defined as water bodies with PCB background contamination corresponding to levels below 4 pg WHO-TEQ/g fw (50% of the maximum level of 8 pg WHO-TEQ/g fw); the second category contains water bodies with diffuse to higher PCB load and levels of 4 to 8 pg WHO-TEQ/g fw in fish; the third category was defined as water bodies with high PCB contamination, where most fish species exceed the permitted maximum level.

10g Use of Chlorine for Production of Metals and Inorganic Chemicals

The pulp and paper sludge from bleaching with elemental chlorine has been highly contaminated with PCDD/PCDF and other chlorinated compounds. The application of such sludges on land or through their dumping have resulted in hotspots or contaminated land. Paper sludge residues from a German paper mill were deposited on an area of 7,000 m^2 during the 1970's (Rotard *et al*. 1990). The area was developed into a residential area in the 1980s. For the assessment, the area was divided into 12 sectors of about 500 to 1,000 square meters each. From each sector, 20 to 35 soil samples were taken from a depth of 0.3 m, then mixed thoroughly to give a representative sector sample. Some samples were taken at a depth of 4 meters by ram core sampling. The area was found interspersed with paper sludge lumps on the surface and at depths of 1.8 meters. Soil samples showed contamination of up to 149 ng/kg I-TEQ. The sludge lumps contained PCDD/PCDF levels between 573 to 5,165 ng/kg I-TEQ (Rotard *et al*. 1990).

10h Waste Incinerators

If incinerators are operated according to BAT and the wastes managed according to BEP, PCDD/PCDF contaminated sites or hotspots should not be generated except for the deposit of fly ash and air pollution control residues which can still have relatively high levels of contamination. Experience has shown that incinerators which are not well-operated and controlled can produce high levels of PCDD/PCDF emissions to all media and result in contaminated sites or hotspots.

Emissions from a chemical waste incinerator at the Coalite Chemicals plant in Bolsover (UK), which was used for the incineration of chlorinated phenol wastes, resulted in elevated PCDD/PCDF levels in cow’s milk from the surrounding area (Holmes *et al*. 1994, 1998) and other foodstuff including game birds (Malisch *et al*. 1999). This case demonstrates that hazardous waste incinerators that process high proportions of products from the organochlorine industry, especially PCDD/PCDF precursors (PCB, chlorophenols, chlorobenzenes and other chlorinated aromatics), can result in high emissions of PCDD/PCDFs with considerable impacts on the local environment (Holmes *et al*. 1994, 1998). The Coalite plant also generated high levels of contamination in river sediments. Investigations by the UK National Rivers Authority found that the river sediments contained 20,269,000 ng/kg PCDD/PCDF (45,300 ng/kg TEQ) immediately downstream of the company's outfall, while the upstream levels were of only 2,030 ng/kg (9 ng/kg TEQ). The impact of the site was discernable 11 kilometres downstream on the Rother river, where sediments contained 110,000 ng/kg PCDD/PCDF (ENDS 1994).

Further, the largest release vector for PCDD/PCDF from BAT/BEP incinerators are residues and ashes from flue gas treatment, which can contaminate the environment if they are not appropriately managed. One example is the Byker municipal waste incinerator in Newcastle (UK) where ashes (generally a mixture of fly and bottom ash) were used to construct footpaths and added to the garden soils, resulting in elevated PCDD/PCDF levels in food (eggs and vegetables) (Pless-Mulloli *et al*. 2001, Watson 2001).

10i Recycling of e-waste

The low-tech recycling of e-waste utilizing open burning in China, India, and many other Asian and African countries has resulted in contaminated sites from these activities. Such low-tech e-waste recycling sites exist predominantly in developing and transition countries and PCDD/PCDF emissions from the open burning of PVC and partly flame retarded and PCB-containing e-waste can be very high. A wide range of PCDD/PCDF and other dioxin-like compounds including brominated and mixed halogenated dioxins, furans, biphenyls and other mixed brominated-chlorinated aromatics have been detected at open burning sites in Guiju, China (Yu *et al*. 2008, Zennegg *et al*. 2009, Leung *et al*. 2007, Li *et al*. 2007, Wong *et al*. 2007). Preliminary inventory investigations of PCDD/PCDF and dioxin-like compounds revealed contamination levels of soils above international limit values (Yu *et al*. 2008). A combination of instrumental- and bioassay-based assessments was used for adequately estimating dioxin-like toxicity. Levels up to 100 µg TEQ/kg soil have been measured at open burning sites (Yu *et al*. 2008), with brominated-chlorinated PXDD/PXDF as a main contributor (Zennegg *et al.* 2009). In the Guiyu area, where e-waste burning has been practiced for more then a decade, the contamination levels in the soils are in the kg TEQ range. These sites are also highly contaminated with heavy metals resulting in ground water pollution (Chan *et al*. 2007). All these aspects need to be considered when developing pollutant inventories for these sites.

10j Accidental Fires

On December 22, 1992, a fire destroyed a warehouse containing cable drums at JSC "Irkutskcable" (Shelekhov, Irkutsk region). The fire destroyed an area of 20,000 m^2 around the ignition point, including adjacent warehouses containing plastic resin and paper, as well as a drying and impregnation shop. The fire lasted for 10 days, with the height of the smoke column reaching 100 m in the early stage. According to draft assessments, 600 tons of PVC plastics and 100 tons of PVC film were destroyed in the fire (Kiselev and Khudolej 1997). For technical reasons, fire masks were not used. Acute poisoning has been confirmed for 69 firefighters; 43 of them were recognized as disabled. As a result of incomplete combustion, PCDD/PCDF were released. The soot formed during the decomposition of PVC cables contained up to 200 ng PCDD/PCDF per gram. It should be noted, however, that the uncertainty of the results is high due to the limited volume of samples analyzed.

10k Dredging of Sediments and Contaminated Flood Plains

The Elbe river has been impacted during almost a century by POPs (PCDD/PCDF, HCHs, DDT etc.) and other pollutants such as Organo-tin from industrial discharges, including organochlorine production and other industries using chlorine in the Bitterfeld region of Germany. The sediments and floodplains were shown to be contaminated with PCDD/PCDF approximately 350 km downstream - as far as Hamburg and even the North Sea (Götz *et al*. 2007). The sources of pollution have been assessed and an inventory developed, showing that approximately 60 km^2 of lowland area downstream of the Spittelwasser creek are heavily contaminated by PCDD/PCDF, HCH and DDT. The pollutant reservoir includes 20,000 m^3 of highly contaminated PCDD/PCDF sediments (Förstner and Salomonis 2010). PCDD/PCDF levels in the floodplains soils reached up to 2,100 ng I-TEQ/kg. In addition to inventory activities, the options for the different zones along the river (river shore, inner dyke, outer dyke) have been assessed taking into account the EU food limits for managing cattle and feedstuff in the floodplains (Schulz *et al*. 2005, Kamphues *et al*. 2011). While milk from grazing cows and meat from permanent grazing animals is above the EU food limits and can not be produced, certain techniques have been developed for harvesting the grass/hay so that it can be used for feeding. Recommendations for farmers using contaminated grassland for feed and food production were developed (Kamphues *et al*. 2011)) and can be regarded as a pilot case for inventory and managing other floodplanes contaminated with PCDD/PCDF or PCB and the related pollutant reservoirs upstream (Förstner and Salomon 2010).

10l Dumps of Wastes/Residues from Source Groups 1-9

Teshima Island (Japan)

More than 500,000 tons of mixed industrial wastes were illegally dumped into a 30 ha gravel pit site on Teshima Island in Japan from 1970 until 1988 (Takeda 2007). Major components included shredder residues from end-of-life vehicles and electric appliances, paper mill sludges, slags, dewatered industrial sludge, incineration residues. A detailed assessment and inventory of the wastes, surrounding soil, groundwater and surface water was conducted. It revealed that wastes and soil were contaminated with notable quantities of heavy metals and chlorinated organic compounds, including an estimated 1.5 kg TEQ PCDD/PCDF (Takeda 2007). Water soluble pollutants contaminated groundwater with a risk of releases to the sea and shore. A remediation plan was established to excavate the waste and the contaminated soil and transport this material to a neighbouring island where an incinerator and a melting plant was built (Takeda 2007). The cost of the remediation work was estimated at 428 million US$, while the operation of the dumpsite had generated approximately 3 million US$ revenue (Takeda 2007).

Love Canal (United States)

The example at the Love Canal site in the Niagara County also shows successful site remediation and cleanup procedure.[35] The site encompasses a hazardous waste landfill where chemical waste products were disposed of from 1942 to 1952 by an Electrochemical Company. It first came into national prominence in the late 1970s, when it was discovered that contaminated leachate had migrated to the surface of the canal and to nearby residential basements. Contaminants also migrated to nearby creeks via the sewage system. Scientific studies did not conclusively prove that these chemicals were responsible for residents' illnesses, and scientists were divided on the issue, even though eleven known or suspected carcinogens had been identified, one of the most prevalent being benzene. Polychlorinated dibenzodioxins were also found, with levels measured in water samples of 53 ppb.

In October 1978, containment measures were undertaken, including the construction of a tile drain and leachate collection system, placement of a clay cap over 16 acres of the canal, creation of an on-site leachate treatment facility and installation of a fence around the area. Approximately 1,000 families have been relocated from the area.

In 1984, 40 acres were covered by a synthetic liner and clay cap and surrounded by a barrier drainage system. A long-term monitoring study was implemented to evaluate the effectiveness of the leachate collection system and assess the contaminant migration in soil and groundwater. In September 2004, the EPA removed the Love Canal site from the National Priorities List (NPL). All cleanup work had been

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[35] http://www.epa.gov/history/topics/lovecanal/index.html

completed, and follow-up monitoring conducted over the past 15 years confirms that the cleanup goals have been reached. The site will continue to be monitored and remains eligible for cleanup work in the event that a change in site conditions should warrant such an action.

The discovery of toxic waste dumps such as the Love Canal led to the adoption of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in the United States. CERCLA is commonly referred to as the "Superfund" because of the fund established to help the cleanup in residential locations (http://www.epa.gov/superfund/). The Superfund cleanup process involves steps to assess sites, placing them on the National Priorities List (NPL), and establish and implement appropriate cleanup plans. Over the past years, tens of thousands of hazardous waste sites and other polluted sites were located and analyzed. Currently, 13,742 sites are listed, among which 1,723 sites belong to the NPL. The inventory contains 225 sites polluted by PCDD/PCDF, among which 210 NPL sites, and 488 sites polluted by PCB, including 431 NPL sites.

10m Kaolin or Ball Clay Sites

Several kaolin and ball clay deposits have been found to be contaminated with PCDD/PCDF in different regions in the word (Hori *et al*. 2011). The Dutch governmental institute RIKILT analysed 28 samples of “pregnancy clays” (20 from Africa and 8 bought in The Netherlands) for the presence of PCDD/PCDF as part of a first inventory of contaminated clays in some African countries (Uganda, Kenya, Tanzania, Nigeria, Mali, Ivory Coast and Zimbabwe). In some regions, such as Africa and South America, clay minerals and soils are consumed by pregnant women as a cure for morning sickness and possibly a source of minerals such as iron. Clay for this use is available for sale in many parts of the world. Consumption can be as high as 300 gram per day, but average daily intake seems to be around 30-80 gram (Hoogenboom *et al*. 2011). The study assessed whether the clays were contaminated and carried a potential risk for the newborns. Four of these samples showed relatively high levels of PCDD/PCDF: 66 ng TEQ/kg product (Mabele, Cameroon), 66 ng TEQ/kg product (Mabele, Democratic Republic of Congo), 75 ng TEQ/kg product (Kaolin, Côte d’Ivoire) and 103 ng TEQ/kg product (Mabele, country of origin unknown). In addition, a sample from Nigeria (Nzu) had a level of 24 ng TEQ/kg product and a sample from Cameroon (Mabele) had a level of 4.5 ng TEQ/kg product. Levels in other samples were much lower (Hoogenboom *et al*. 2011). Only PCDDs contributed to these TEQ levels, but the congener patterns were not the same for all clay samples.

The WHO/UNEP coordinated study on human milk included a number of African countries. The clay data have been compared with human milk data to evaluate whether the consumption of clay may add to the dioxin exposure. The highest PCDD/PCDF levels in African samples where observed in Côte d’Ivoire (11.1 pg TEQ/g fat) and the Democratic Republic of Congo (11.1 pg TEQ/g fat) whilst the other samples were in the range of 1.5 to 3.9 pg TEQ/g fat (Malisch *et al*. 2011). The PCDD/PCDF pattern of the clay and human milk samples, along with the relatively high levels measured in Congo and the Ivory Coast suggest that the use of clay during pregnancy contributes to these high PCDD/PCDF levels in human milk. Due to vulnerability to PCDD/PCDF in the fetal development phase and for the newborn, the use of contaminated clays should be prevented. Inventories of clays used for human consumption or as animal feed additive should be carried out as a matter of urgency.