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Update and improvement of estimated air emissions of mercury, dioxin and HCB in Sweden - a pre-study

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Content

Sammanfattning

För att uppnå en mer korrekt uppskattning av Sveriges utsläpp av kvicksilver, dioxin och hexaklorbensen (HCB) bör en genomgång och uppdatering av Sveriges inventering av dessa ämnen genomföras.

När det gäller kvicksilver täcker dagens inventering de dominerande källorna. En genomgång av den svenska inventeringen bör därför koncentreras på att validera eller, om nödvändigt, uppdatera de emissionsfaktorer som för närvarande används. Den aktuella pågående forskning som bedrivs inom området ger stora möjligheter att hitta ny och intressant information för en kommande uppdatering av den svenska inventeringen avseende kvicksilver.

En mer omfattande studie av svenska emissioner av framförallt HCB, men också dioxiner är av intresse för att erhålla en mer exakt bild av dagens totala utsläpp av dessa ämnen. De största emissionskällorna av dioxiner i Sverige idag tycks vara metallindustrin och okontrollerad förbränning som t.ex. vid deponibränder. Även genomgång av andra okontrollerade småskaliga förbränningskällor (förbränning av trädgårdsavfall och småskalig vedeldning) borde prioriteras vid en ny emissionsinventering. De idag viktigaste emissionskällorna för HCB utgörs till stora delar av sekundära järn- och stålverk, okontrollerad småskalig förbränning, som deponibränder, eldning av trädgårdsavfall och småskalig biobränsleförbränning, samt vissa kemiska industrier. Generellt finns det fortfarande relativt få svenska studier och data gällande emissioner av HCB.

Summary

In order to achieve a more accurate estimate of the Swedish emissions of mercury, dioxins and hexachlorobenzene (HCB) to air, a survey and update of the Swedish inventory is of great need.

For mercury most sources are covered in the Swedish inventory, and further work should concentrate primarily on validating and, if needed, to update the emission factors used. The ongoing research focussing on mercury emissions and ambient concentrations provides a great opportunity to find new information useful for an update of the Swedish inventory on mercury.

A more comprehensive estimate of the Swedish emissions of HCB and dioxins is necessary in order to obtain a more exact picture of the total emissions. The largest emission sources of dioxin in Sweden seem to be the metal industries and uncontrolled combustion, e.g. landfill fires. Other uncontrolled small scale combustion (backyard burning and residential heating) should be considered as prioritised in a new comprehensive emission inventory. The most important sources of emission of HCB to air today are probably the secondary iron and steel mills, uncontrolled small-scale combustion, such as landfills fires, backyard burning and residential heating, and some chemical industries. Generally, there are still a relatively limited number of studies and data concerning the emissions of HCB.

1 Background and objective

In 2002 - 2003 the emissions to air of particles, metals, dioxin and PAH-4 were estimated for Sweden (Kindbom et al, 2004). This was the first time that a complete estimate of emissions of mercury (Hg) and dioxin was attempted and subsequently reported to the CLRTAP.

During 2003 - 2004 a number of studies on emissions from navigation were made. Among the substances studied were mercury, dioxin and HCB (Cooper and Gustafsson, 2005). In 2005, commissioned by the Swedish Government, the Swedish Environment Protection Agency published a survey of sources for emissions of unintentionally formed substances such as dioxins, PCB and HCB (Swedish EPA, report 5462).

So far, navigation is the only source of HCB emissions reported for Sweden. Hence there is great need to study the possibility to improve the Swedish international reporting of especially HCB, but also for mercury and dioxin, substances given high priority by Swedish EPA in the international work on air pollution abatement.

1.1 Objective

The objective of this pre-study is to make a prioritisation and recommendations for further work, based on an assessment of the present state of the emission inventories of mercury and dioxin in Sweden, accompanied by a literature survey of relevant and useful new findings and knowledge.

The pre-study is also aiming at examining the possibility to carry out a more comprehensive estimate of the Swedish emissions of HCB, presently only including HCB from navigation.

1.2 Scope of the work

The pre-study comprises a survey and assessment of the quality of the present estimates of emissions of mercury, dioxin and HCB, as well as a literature study and a compilation of new findings and knowledge regarding emissions and emissions inventory methodology for those substances. This results in an identification of sources which should be prioritised for further study. The judgements and prioritisation is based on the relative importance of the source, as well as the availability of new and relevant information, which is one of the prerequisites for revisions and improvements of emission inventories.

1.2.1 Outline of work items

1.2.1.1 Mercury and Dioxin

1) A study of literature from recent years is performed in order to identify for which sources new information relevant for Swedish conditions is available, which could be used for improvements of the present estimates.
2) Study the Key Source analysis regarding mercury and dioxin from submission 2006 to identify the most important sources.
3) A survey of the reported emissions of mercury and dioxin from submission 2006. The quality of reported data for each individual reporting code is assessed based on known or assumed quality in activity data, emission factors and/or emissions.
4) An assessment of the completeness in the reporting is performed by an identification of sources where emissions of mercury and/or dioxin occur or could occur, but are not included in the inventory.
5) Based on the result from the work items listed above, a comprehensive assessment and prioritisation is made of which emission sources should be included in further work, in order to improve accuracy and quality of the national estimates of mercury and dioxin.

1.2.1.2 HCB

1) A literature study is performed in order to identify the most important sources for HCB emissions, and to find information relevant for Swedish conditions and useful for estimating these emissions. This information is compiled and used for concluding which sources that should be prioritized in further work aiming at a more accurate national estimate of the HCB emissions to air in Sweden.

2 Literature study

2.1 Mercury

Environmental mercury levels have increased considerably since the beginning of the industrial age. The most significant releases of mercury pollution are emissions to air, but mercury is also released from various sources directly to water and land. The majority of air emissions are in the form of gaseous elemental mercury, which can be transported globally to regions far from the emission source. The remaining emissions are in the various forms of gaseous inorganic ionic mercury or bound to emitted particles. Once deposited, the mercury form can change to methylmercury, which has the capacity to bioaccumulate in organisms and to enrich in concentration along food chains.

2.1.1 Anthropogenic sources

Some of the more important anthropogenic processes for mercury emissions are coal-fired power and heat plants, cement production, mining and other metallurgic activities involving extraction and processing of mineral materials (i.e. iron and steel production). Other sources important to mention are those originating due to intentional use of mercury as gold and silver mining, chlorine-alkali production, manufacturing of products containing mercury as thermometers and other instruments, dental amalgam fillings, waste treatment and incineration of products containing mercury, landfills and cremation.

Several actions implemented in Europe and North America has reduced the use and release of mercury. Nevertheless, environmental concern due to mercury emissions and concentrations are still of high priority. In October 2005 a workshop on heavy metals and persistent organic pollutants took place in Rovaniemi, Finland. The workshop was organised by the UNECE Task Force on Emission Inventories and Projection (TFEIP) and the EU 6th Framework Programme, research project ESPREME. This EU-funded project is aiming at developing methods and tools to support the European environmental policy making for reducing the impact of heavy metals (in particular mercury, cadmium, chrome, nickel, lead and arsenic).

The ongoing research focussing on mercury emissions and ambient concentrations gives a great opportunity to find new information useful for an update of the Swedish inventory on mercury.

2.2 Dioxin

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofuranes (PCDF) are two similar groups of substances consisting of benzene rings joined by oxygen atoms and commonly named dioxins. There are in total 75 PCDD and 135 PCDF congeners. Dioxins are chemically stable and are together with other persistent organic pollutants (POPs) subject to the Stockholm Convention, a global agreement to protect human health and the environment from POPs. When evaluating the occurrence of dioxins, information of their toxic effects is often required, since the toxicity differs greatly between the various congeners. Thus, dioxin concentrations are often presented as combined values, toxic equivalents (TEQ) (Hedman, 2005)

2.2.1 Production and reformation of dioxins

Dioxins have never been produced intentionally, but are generated in small amounts when organic material is burned in the presence of chlorine, either as chloride ions or as organochlorine compounds. In Europe > 30% of the total dioxin emissions originates from residential combustion (Figure 1, BiPRO, 2006). Other important sources for dioxin emissions are open burning of waste, wood preservation, the iron and steel industry, power production, non-ferrous metal industry and the chemical industry (Figure 1, BiPRO, 2006).

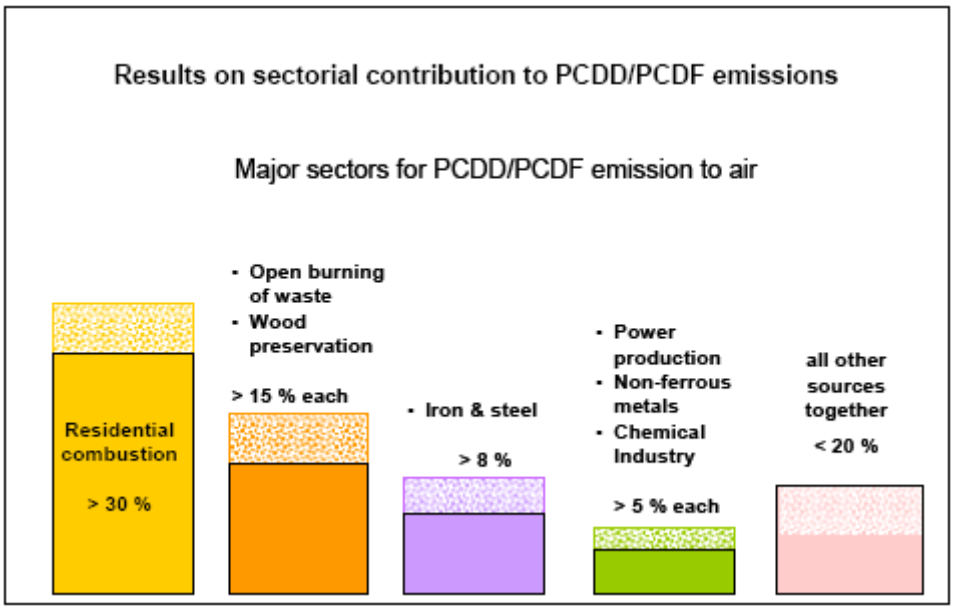

Figure 1. Results on sectoral contribution to PCDD/PCDF emissions. (From BiPRO, 2006).

According to recent and not yet published US EPA data (2005, DRAFT), the leading source of dioxin emissions in the U.S. in 1987 and 1995 was municipal waste combustion. Due to reductions in dioxin emissions from municipal waste combustion the most important source in 2000 was burning of domestic refuse in backyard burn barrels. Another important source in the U.S. is medical waste incineration.

2.2.2 The emission sources of dioxins in Sweden

In the Scandinavian perspective, Sweden seems to cover most of the important sources and sectors for emissions of dioxins to air. Also the values are in the same order of magnitude compared to those reported by Denmark and Finland, (EMEP 2006). Dioxin emissions from medical waste incineration, a source eventually of significance for Sweden, are presently not included in the Swedish inventory.

2.2.2.1 Combustion

The emission to air from waste incineration has earlier been considered as a major source of dioxin in Sweden. However, during recent years, emissions from waste incineration facilities have been reduced considerably due to improvements in the combustion processes and by cleaning of flue gases. Today the sum of dioxin emissions from other combustion processes exceeds the emissions from waste incineration (NV report 5462).

Emissions of dioxins originating from small scale biomass combustion (residential heating) are considered as one of the most important sources, in Sweden as well as in other countries (BiPRO, 2006). Differences in use of fuel and boiler type, leads to large differences in amounts of dioxin emitted (Hedman, 2005, MK2005:01).

The information regarding uncontrolled backyard burning of household and garden waste in Sweden, is very scarce. There is lack of emission data from studies and knowledge concerning the amount of burnt waste is also incomplete. A study made by Umeå University (MK2005:01) show that there are large differences in emissions of dioxins from backyard burning experiments, depending on the kind of waste and the method used for combustion of the waste. Backyard burning is considered as a potential and probably important dioxin emission source (MK2005:01).

The annual emission of dioxins to air from landfills fires may be a significant source of dioxins in Sweden. However, there are only a few studies available, which make it important to verify or update the emission factors used for the estimations of dioxin emissions to air.

2.2.2.2 Metal industries

Metal industries are today considered as one of the more important sources of dioxins in Sweden. In some recent Swedish studies there are new relevant data of the dioxins emissions from pellets mills, iron and steel mills, foundries and primary and secondary non-iron metal industries (MK2005:01, NV report 5462).

Due to improvements in process technology, the dioxin release from iron and steel mills has been reduced by 70% during the last 20 years.

2.2.2.3 Chemical industries

The emissions of dioxins from the chemical industries in Sweden are relatively small. In recent reports, new emission data from industries such as refineries and inorganic and organic chemical industries (including cement production) are presented (MK2005:01, NV report 5462).

2.2.2.4 Pulp and paper industry

Most of the available Swedish data from the pulp and paper industry is relatively old and thus not relevant to use for updating the emission factors for estimating dioxin emissions from this sector. The large number of improvements performed by the pulp and paper industry during the 1990s resulted in a significant reduction of the formation and release of dioxins to air, water and products. Forestry is today not an important source of dioxin emissions to air (NV report 5462). The efforts made to reduce the dioxin emissions from the pulp and paper industry are assumed to also have resulted in reduced HCB emissions (NV report 5462).

2.2.2.5 Navigation/Shipping

Today's emission of dioxins from the shipping is probably very small compared to national totals estimated in 1995. The summed dioxin emissions from international and national navigation accounts for 1 - 2% of the national total for 2002 (Cooper, 2005). For 2004, national navigation accounted for less than 0.2% of the national totals.

2.2.2.6 Road traffic

Emissions from land-based diesel engines in Sweden (road and military vehicles, off-road machinery and locomotives) are for the emission year 2004 estimated to contribute 0.18 - 0.42 g TEQ (Cooper, 2005). The uncertainty is however significant due to limited number of measurements and measurement uncertainties (Cooper, 2005). In total road transportation accounts for between 1 and 2% of the dioxin national totals.

2.2.2.7 Impregnated wood

In Sweden there is still a large amount of pentachlorophenol (PCP) impregnated wood that may contain considerable amounts of dioxins. It is possible that this kind of old impregnated wood may still contain approximately 30 kg dioxins (NV report 5462; MK 2005:1). To prevent these amounts of dioxin to be emitted it is important to find ways to take care of this PCP impregnated wood.

2.3 HCB

2.3.1 Use of HCB

Hexachlorobenzene (CAS No. 118-74-1), or perchlorobenzene, is a chlorinated hydrocarbon with the molecular formula C_6Cl_6, that has been used in Sweden in small quantities as a fungicide. This use of HCB has been prohibited since 1980.

Other former applications of HCB have been as chemical intermediates in the synthesis of other organic chemicals, as a wood-preserving agent, in production of pyrotechnics in the military, and in the production of nitroso and styrene rubber. Today, the use of HCB has been replaced by other chemicals (MK2005:1; Jones, 2005).

2.3.2 By-product emission and incomplete combustion of HCB

Although HCB production has decreased in most countries, it is still being generated inadvertently as a by-product and/or impurity in several chemical processes, such as manufacturing of chlorinated solvents and pesticides, and in manufacturing of other substances that contain chlorine.

HCB may also be emitted from incinerators as a result of incomplete thermal decomposition of HCB-contaminated industrial waste, and different chlorinated organics. Small amounts of HCB may also be released from industrial processes, where both carbon and chlorine are present at high temperatures. Therefore, both combustion and some metal processes emit small amounts of HCB (Jones, 2005).

2.3.3 The emission sources of HCB in Sweden

Among EU member states, 13 are reporting emissions of HCB for at least one sector. The parties are reporting emissions from the sectors 1 A "Stationary combustion", 2 A, 2 B and 2 C "Industrial processes", 3 "Solvents and other product use", 4 "Agriculture" and 6 "Waste" (EMEP, 2006). Stationary combustion (1 A) and waste (6) seems to be the largest sectors, followed by agriculture. The agricultural sector should not be representative as an emission source in Sweden, since the use of HCB in Sweden has been prohibited as a pesticide for more than 20 years.

Between 1975 and 1990 the total Swedish estimated HCB emission decreased with 96%, from 3800 to 161 kg/year. Globally, in the middle of 1980s, pesticide use and waste incineration were the two largest sources of HCB emission to the environment (Jones 2005). In this chapter, the most important Swedish emission sources of HCB are presented.

2.3.3.1 Combustion

The amount of HCB that enters the atmosphere from waste incineration facilities in Sweden has been estimated to 1 - 30 kg/year during the mid 1980s. Due to improvements in the combustion processes, today's values are expected to be considerably lower (NV report 5462).

Just as for dioxins, uncontrolled combustion seems to be one of the more important sources of the HCB emission to air. Concerning the small scale biomass combustion, the variance in emissions of HCB seems to be relatively high depending on the type of boiler and fuel used. Also for the backyard burning, there are

large differences in emission of HCB from backyard burning experiments, depending on the type of waste and the manner of combustion (MK2005:01).

In the study performed by Umeå University (MK2005:01), emission factors for large and small scale biomass combustion, backyard burning and landfills fires have been estimated.

The emission data of HCB is very brief or out of date and insecure concerning emissions from hazardous waste, landfills burning and fossil fuels. Landfills fires are considered as a potential source of HCB emissions to air.

2.3.3.2 Metal industries

The total amount of HCB air emissions from secondary iron and steel producers has been estimated to 30 000 g/year (NV report 5462). In Kim et al (2004) furnaces from sintering are considered as a significant source of HCB emissions. The importance of the metal industry as a source for HCB emissions is supported by Luscombe and Costner (2001). The HCB emissions from copper smelting and secondary production of aluminium, based on information from EMEP (MSC-E), are by Luscombe and Costner (2001) considered to be $3.9 * 10^4$ µg/ton and $5 * 10^6$ µg/ton, respectively.

2.3.3.3 Chemical industries

HCB and dioxins may be generated inadvertently as a by-product during manufacturing of pesticides and chlorinated solvents. In Sweden, there is nowadays no production of pesticides and therefore any pesticide-related HCB and dioxin emissions are solely related to the use of these products.

There is also a decreasing trend of emissions of HCB to air from the production of PVC, due to improvements of the technical processes during production. The production of hydrochloric acid is another source that may contribute to the total emissions of HCB in Sweden.

There are no relevant data available concerning HCB and dioxin emissions from the oil refining, chlorine-alkali or cement industry.

2.3.3.4 Pulp and paper

Information on HCB emissions from the forest industries in Sweden is scarce. Chlorine gas was earlier used in significant quantities for bleaching, leading to formation and emissions to air of HCB and also dioxins. Since 1994, chlorine gas is no longer used as a bleach agent in the pulp and paper industry. Hence, the emissions of HCB are now considered to be minor from this kind of processes. However, the paper industry is very energy demanding and HCB may be generated during combustion processes. The emissions of HCB from these processes are assumed to be in the same order as for the incineration facilities in Sweden (NV report 5462).

2.3.3.5 Navigation/Shipping

Results presented by Cooper (2005) show that emissions of HCB from ships using Swedish fuels are small compared to national totals estimated in 1995 (MSC-E, 1995). Fuels with higher organic chlorine contents are generating higher release of HCB and dioxins (Cooper, 2005).

2.3.3.6 Road traffic

There are presently no Swedish data of HCB emissions from petrol vehicles. Only emission factors for diesel vehicles are currently available (Cooper, 2005). As only a minor part of the Swedish passenger cars are diesel cars (5%, data for 2004, SIKA, www.sika-institute.se), the lack of information concerning HCB emissions from petrol cars makes HCB emissions from road traffic hard to estimate.

3 Characterisation of estimated emissions of mercury and dioxin

3.1 Key sources

The key sources for mercury and dioxin emissions for 2004, as calculated from the reported data to the CLRTAP in submission 2006, are presented in Table 1 and Table 2. In the table, the sources are ranked from the largest relative contribution to the national total, and those included in the table together comprise 95% of the estimated national emissions.

Emissions from "Metal Production" (NFR 2C) and "Public Electricity and Heat Production" (NFR 1A1a) are the two most important sources for mercury emissions in 2004, contributing together to almost 50% of the national total (Table 1). In comparison to 1990, the mercury emission from "Public Electricity and Heat Production" has been reduced by 95%. In 1990 "Public Electricity and Heat Production" alone emitted 3.7 Mg, more than 75% of the national total.

Table 1. Key sources for mercury emissions 2004, submission 2006.

NFR Source category	2004(Mg)	% of National Total	Cumulated
2 C METAL PRODUCTION	0.22	27%	27%
1 A 1 a Public Electricity and Heat Production	0.18	22%	49%
2 B 5 Other (Please specify in a covering note)	0.14	18%	67%
6 C WASTE INCINERATION	0.11	14%	81%
1 A 2 f Other	0.05	6%	87%
1 A 4 b i Residential plants	0.02	3%	90%
2 D 1 Pulp and Paper	0.02	2%	92%
1 A 2 d Pulp, Paper and Print	0.02	2%	94%
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	0.01	2%	96%

Emissions from "Public Electricity and Heat Production" (NFR 1A1a) is the most important source for dioxin emissions in 2004, contributing to around 45% of the national total emissions of dioxin (Table 2). "Metal Production" (NFR 2C) is the second most important source, contributing to 16% of the national totals. In comparison to 1990 the dioxin emissions from "Metal Production" has been greatly reduced. In 1990 "Metal Production" was the most important source of dioxin emissions in Sweden, with emissions of 18 g, more than 30% of the national totals. The contribution of dioxin from "Public Electricity and Heat Production" to the national total in 1990 was, as in 2004, just below 16 g.

Table 2. Key sources for dioxin emissions 2004, submission 2006.

NFR Source category	2004 (g I-Teq)	% of National Total	Cumulated
1 A 1 a Public Electricity and Heat Production	15.95	45%	45%
2 C METAL PRODUCTION	5.68	16%	61%
1 A 2 d Pulp, Paper and Print	4.39	12%	74%
1 A 2 f Other	3.59	10%	84%
1 A 4 b i Residential plants	1.93	5%	90%
2 A 7 Other including Non Fuel Mining & Construction	1.1	3%	93%
6 C WASTE INCINERATION	0.61	2%	94%
1 A 3 b i R.T., Passenger cars	0.57	2%	96%

4 Quality assessment of reported emissions, completeness and missing sources

In the Swedish reporting some activities do not occur and consequently these sources are reported as "Not Occurring" (NO). These NFR activities are listed in Table 3.

Table 3. NFR sectors with activities reported NO (Not Occurring) in the Swedish inventory.

NFR sectors
1 A 5 a Other, Stationary (including Military)
1 B 2 b Natural gas
1 A 3 d i (ii) International inland waterways (Included in NEC totals only)
1 B 1 a Coal Mining and Handling
1 B 2 a i Exploration Production, Transport
1 B 2 b Natural gas
2 B 1 Ammonia Production
2 B 3 Adipic Acid Production
2 G OTHER
4 B 2 Buffalo
4 B 5 Camels and Llamas
4 B 7 Mules and Asses
4 C RICE CULTIVATION
4 F FIELD BURNING OF AGRICULTURAL WASTES
X (11 08 Volcanoes)
7 OTHER

In the following chapters (4.1 and 4.2) the estimated emissions or reported notation keys for mercury and dioxin from submission 2006 are presented. In chapter 5 the prioritized sources for further work are listed.

4.1 Mercury

4.1.1 Stationary combustion

When comparing the Swedish inventory on mercury with those of other European countries, it seems like the most important sources in the "Stationary combustion" sector are covered.

There is need for a review of the emission factor presently used. Since the content of mercury in coal varies with origin and for biomass with fuel type (e.g. pellets and wood), this review is mainly to be concentrated on those fuels.

Table 4 Estimated emissions of mercury from stationary combustion in 2004, submission 2006.

NFR code	Hg, Mg
1 A 1 a Public Electricity and Heat Production	1.75E-01
1 A 1 b Petroleum refining	7.26E-03
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	1.45E-02
1 A 2 a Iron and Steel	1.24E-02
1 A 2 b Non-ferrous Metals	5.19E-04
1 A 2 c Chemicals	1.03E-03
1 A 2 d Pulp, Paper and Print	1.61E-02
1 A 2 e Food Processing, Beverages and Tobacco	8.43E-04
1 A 2 f ii Other	4.79E-02
1 A 3 e i Pipeline compressors	NA
1 A 4 a Commercial / Institutional	1.89E-03
1 A 4 b i Residential plants	2.26E-02
1 A 4 c i Stationary	5.49E-04
1 B 1 c Other, Fugitive Emissions from Solid Fuels	5.71E-03
1 B 2 a vi Other	NA
1 B 2 c Venting and flaring	NA

4.1.2 Combustion in mobile sources

Several other countries report mercury emissions from "Combustion in mobile sources". In the Swedish reporting the notation key NA (Not applicable) is used for most of the NFR codes. Only for National Navigation (1 A 3 d ii) and National Fishing (1 A 4 c iii) emission factors are used for estimations of mercury emissions. A study, recently published by US EPA (Hoyer et al., 2006), reveals that gasoline and diesel motor vehicles do contribute to environmental mercury. Hence, emission of mercury from NFR codes 1 A 3 b i, 1 A 3 b ii, 1 A 3 b iii, 1 A 3 b iv, 1 A 3 e ii, 1 A 4 b ii and 1 A 4 c ii (Table 5) should not be reported as NA (Not applicable). If possible, emission factors suitable for Swedish conditions should be used for estimations of mercury emissions from NFR codes 1 A 3 b i, 1 A 3 b ii, 1 A 3 b iii, 1 A 3 b iv, 1 A 3 e ii, 1 A 4 b ii and 1 A 4 c ii. If such emission factors are not accessible, the notation key NE (Not estimated) is preferred.

Table 5 Estimated emissions of mercury from combustion of fuels in mobile sources in 2004, submission 2006.

NFR code	Hg, Mg
1 A 2 f i Other mobile in industry	NA
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)	NA
1 A 3 a ii (ii) Civil Aviation (Domestic, Cruise)	NA
1 A 3 b i R.T., Passenger cars	NA
1 A 3 b ii R.T., Light duty vehicles	NA
1 A 3 b iii R.T., Heavy duty vehicles	NA
1 A 3 b iv R.T., Mopeds & Motorcycles	NA
1 A 3 c Railways	NA
1 A 3 d ii National Navigation	2.22E-04
1 A 3 e ii Other mobile sources and machinery	NA
1 A 4 b ii Household and gardening (mobile)	NA
1 A 4 c ii Off-road Vehicles and Other Machinery	NA
1 A 4 c iii National Fishing	3.35E-06
1 A 5 b Other, Mobile (Including military)	NA

4.1.3 Other sources in the Energy sector

Mercury emissions from coke production ("Solid fuel transformation", 1 B 1 b) are today reported as NE (Not estimated). Development of an emission factor for estimating the mercury emissions from coke production is of importance.

Table 6 Estimated emissions of mercury from other sources in the energy sector in 2004, submission 2006.

NFR code	Hg, Mg
1 A 3 b v R.T., Gasoline evaporation	NA
1 A 3 b vi R.T., Automobile tyre and brake wear	NA
1 A 3 b vii R.T., Automobile road abrasion	NA
1 B 1 b Solid fuel transformation	NE
1 B 1 c Other, Fugitive Emissions from Solid Fuels	5.71E-03
1 B 2 a iv Refining / Storage	NA
1 B 2 a v Distribution of oil products	NA
1 B 2 a vi Other	NA
1 B 2 c Venting and flaring	NA

4.1.4 Industrial processes

Most of the information concerning mercury emissions from Industrial processes comes from the facilities environmental reports and are also reported as found in these reports. Of the NFR codes reported NA (Not applicable), it is worth to note that many other countries report mercury emissions from Cement production (2 A 1) while it in the Swedish inventory is reported NA. In Sweden all metal emissions from Cement production are considered to originate from the combustion of fuels and hence the metals are reported in NFR sector 1 (1A2f).

For the NFR codes 2 B 5 and 2 C 5 the reported mercury emissions may not be totally complete since emissions or sources may be missing due to lack of data from some facilities.

Table 7 Estimated emissions of mercury from industrial processes in 2004, submission 2006.

NFR code	Hg, Mg
2 A 1 Cement Production	NA
2 A 2 Lime Production	NA
2 A 3 Limestone and Dolomite Use	NA
2 A 4 Soda Ash Production and use	NA
2 A 5 Asphalt Roofing	NA
2 A 6 Road Paving with Asphalt	NA
2 A 7 Iron ore mining and dressing	1.19E-04
2 A 7 Non-iron ore mining and dressing	9.00E-04
2 A 7 ii Construction and demolition	NE
2 A 7 iii Glass production	9.30E-04
2 A 7 iii Batteries manufacturing	NA
2 A 7 iii Glass and mineral wool production	1.00E-05
2 B 2 Nitric Acid Production	NA
2 B 4 Carbide Production	NA
2 B 5 Sulphuric acid production	8.70E-02
2 B 5 Other inorganic chemical products	5.53E-02
2 B 5 Other organic chemical products	NE
2 B 5 Base chemicals for plastic industry	NE
2 B 5 Other non-specified	NE
2 B i Storage and handling of industrial bulk products	NE
2 C 1 Iron and Steel Production	1.55E-01
2 C 2 Ferroalloys Production	NA
2 C 3 Aluminium Production	NA
2 C 5 Other	6.31E-02
2 D 1 Pulp and Paper	1.73E-02
2 D 2 Food and Drink	NA
2 D i Wood processing	NE
2 D ii Other production including storage and handling of bulk products other than in 2B5i	NE

4.1.5 Solvent and other product use

In the sector Solvent and other product use, presently only emissions of NMVOC and particles (from tobacco smoking and use of fireworks) are included. In 3 D also products containing heavy metals and Persistent Organic Pollutants (POPs) are to be reported. These products, e.g. mercury containing products as thermometers, fluorescent lamps, instruments and tubes, are currently not included in the Swedish reporting.

Table 8 Estimated emissions of mercury from solvent and other product use in 2004, submission 2006.

NFR code	Hg, Mg
3 A Paint application	NA
3 B Degreasing and dry cleaning	NA
3 C Chemical products, manufacture and processing	NA
3 D i Printing	NA
3 D ii Preservation of wood	NA
3 D iii Domestic solvent use	NA
3 D iv Other, Leather industry	NA
3 D iv Other, Textile finishing	NA
3 D iv Other, Tobacco smoking and fireworks	NE

4.1.6 Agriculture

In the sector "Agriculture" no significant mercury emissions are likely to occur.

Table 9 Estimated emissions of mercury from agricultural activities in 2004, submission 2006.

NFR code	Hg, Mg
4 B 1 a Dairy	NA
4 B 1 b Non-Dairy	NA
4 B 13 Other	NA
4 B 3 Sheep	NA
4 B 4 Goats	NA
4 B 6 Horses	NA
4 B 8 Swine	NA
4 B 9 Poultry	NA
4 D 1 i Synthetic N-fertilizers	NA
4 D 1 ii Animal waste applied to soil	NA
4 D 1 iii Other	NA
4 D 2 N-excretion on pasture range and paddock	NA
4 D i Farm-level agricultural operations including storage and handling of agricultural products	NA
4 D ii Off-farm storage and handling of bulk agricultural products	NA
4 G Other	NA

4.1.7 Land use, land-use change and forestry

In the sector "Land use, land-use change and forestry" no significant mercury emissions are likely to occur.

Table 10 Estimated emissions of mercury from land use, land use change and forestry in 2004, submission 2006.

NFR code	Hg, Mg
5 B Forest and grassland conversion	NA
5 E Other	NA

4.1.8 Waste

In the sector "Waste" emissions of mercury is reported for NFR 6 C (Waste incineration) and 6 D (Other waste). The dominating source for mercury emissions in 6 C are crematories, but emissions from combustion of hazardous waste is also reported. Concerning incineration of medical waste, no national activity data exists for this source category.

In 6 D emissions from landfill fires are reported. The emission factors presently used are based on a limited number of measurements and need to be verified or updated.

Table 11 Estimated emissions of mercury from waste handling in 2004, submission 2006.

NFR code	Hg, Mg
6 A Solid waste disposal on land	NA
6 B Waste-water handling	NA
6 C Waste incineration	1.14E-01
6 D Other waste	6.54E-04

4.2 Dioxin

4.2.1 Stationary combustion

The sector "Stationary combustion" constitutes the largest total emission source of dioxins in Sweden. It seems that the most important sources in this sector are covered. A recent study shows large differences in emissions due to differences in fuels and types of boilers (MK 2005:1).

Table 12 Estimated emissions dioxin from stationary combustion in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
1 A 1 a Public Electricity and Heat Production	1.60E+01
1 A 1 b Petroleum refining	2.33E-01
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	NE
1 A 2 a Iron and Steel	NA
1 A 2 b Non-ferrous Metals	1.65E-02
1 A 2 c Chemicals	9.04E-02
1 A 2 d Pulp, Paper and Print	4.39E+00
1 A 2 e Food Processing, Beverages and Tobacco	4.57E-02
1 A 2 f ii Other	3.59E+00
1 A 3 e i Pipeline compressors	NA
1 A 4 a Commercial / Institutional	2.30E-01
1 A 4 b i Residential plants	1.93E+00
1 A 4 c i Stationary	1.84E-02
1 B 1 c Other, Fugitive Emissions from Solid Fuels	NA
1 B 2 a vi Other	NA
1 B 2 c Venting and flaring	NE

4.2.2 Combustion of fuels in mobile sources

The sector "Combustion of fuels in mobile sources" does not contribute significantly to the total emissions of dioxins in Sweden.

Table 13 Estimated emissions dioxin from combustion of fuels in mobile sources in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
1 A 2 f i Other mobile in industry	NE
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)	NA
1 A 3 a ii (ii) Civil Aviation (Domestic, Cruise)	NA
1 A 3 b i R.T., Passenger cars	5.75E-01
1 A 3 b ii R.T., Light duty vehicles	IE
1 A 3 b iii R.T., Heavy duty vehicles	IE
1 A 3 b iv R.T., Mopeds & Motorcycles	IE
1 A 3 c Railways	NA
1 A 3 d ii National Navigation	4.50E-02
1 A 3 e ii Other mobile sources and machinery	NA
1 A 4 b ii Household and gardening (mobile)	NA
1 A 4 c ii Off-road Vehicles and Other Machinery	NA
1 A 4 c iii National Fishing	9.81E-03
1 A 5 b Other, Mobile (Including military)	NA

4.2.3 Other sources in the Energy sector

Regarding to the formation processes of dioxins, these sources in the "Energy sector" are not contributing significantly to the total emissions of dioxins in Sweden.

Table 14 Estimated emissions of dioxin from Other sources in the Energy sector in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
1 A 3 b v R.T., Gasoline evaporation	NA
1 A 3 b vi R.T., Automobile tyre and brake wear	NA
1 A 3 b vii R.T., Automobile road abrasion	NA
1 B 1 b Solid fuel transformation	NE
1 B 1 c Other, Fugitive Emissions from Solid Fuels	NA
1 B 2 a iv Refining / Storage	NA
1 B 2 a v Distribution of oil products	NA
1 B 2 a vi Other	NA
1 B 2 c Venting and flaring	NE

4.2.4 Industrial processes

Generally, it seems like the most important sources in the sector "Industrial processes" are covered in the Swedish inventory. In recent studies, estimated emissions of dioxins from cement production (0.3 g I-TEQ) and secondary non-iron metal industries (aluminium and copper) (4 g I-TEQ) are presented (MK 2005:1, NV report 5462). In Sweden dioxin emissions from Cement production are considered to originate from the combustion of fuels and hence dioxin is reported in NFR sector 1.

For the NFR code 2 B 5 the reported emissions may not be totally complete since some emissions or sources may be missing due to lack of data from some facilities. For NFR code 2 C 5 (including secondary aluminium and copper industries) dioxin from secondary aluminium production is currently not reported.

Table 15 Estimated emissions of dioxin from industrial processes in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
2 A 1 Cement Production	NA
2 A 2 Lime Production	NA
2 A 3 Limestone and Dolomite Use	NA
2 A 4 Soda Ash Production and use	NA
2 A 5 Asphalt Roofing	NE
2 A 6 Road Paving with Asphalt	NE
2 A 7 Iron ore mining and dressing	1.10E+00
2 A 7 Non-iron ore mining and dressing	NE
2 A 7 ii Construction and demolition	NA
2 A 7 iii Glass production	NA
2 A 7 iii Batteries manufacturing	NA
2 A 7 iii Glass and mineral wool production	NA
2 B 2 Nitric Acid Production	NA
2 B 4 Carbide Production	NA
2 B 5 Sulphuric acid production	NE
2 B 5 Other inorganic chemical products	7.47E-02
2 B 5 Other organic chemical products	2.40E-03
2 B 5 Base chemicals for plastic industry	1.20E-02
2 B 5 Other non-specified	NE
2 B i Storage and handling of industrial bulk products	NE
2 C 1 Iron and Steel Production	3.93E+00
2 C 2 Ferroalloys Production	NA
2 C 3 Aluminium Production	NA
2 C 5 Other	1.75E+00
2 D 1 Pulp and Paper	5.19E-01
2 D 2 Food and Drink	NA
2 D i Wood processing	NE
2 D ii Other production including storage and handling of bulk products other than in 2B5i	NE

4.2.5 Solvent and other product use

There is currently no data concerning the dioxin emission from "Solvent and other product use" reported in the Swedish inventory. In the Swedish inventory particles from tobacco smoking are reported in sector "Solvent and other product use". The activity data used for estimating particles from tobacco smoking can also be used for estimations of dioxin emissions using emission factors presented by Fowler and Bates (2000).

Table 16 Estimated emissions of dioxin from solvents and other product use in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
3 A Paint application	NA
3 B Degreasing and dry cleaning	NA
3 C Chemical products, manufacture and processing	NA
3 D i Printing	NA
3 D ii Preservation of wood	NA
3 D iii Domestic solvent use	NA
3 D iv Other, Leather industry	NA
3 D iv Other, Textile finishing	NA
3 D iv Other, Tobacco smoking and fireworks	NA

4.2.6 Agriculture

There is no Swedish data available concerning emission of dioxins from agriculture.

Table 17 Estimated emissions of dioxin from agricultural activities in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
4 B 1 a Dairy	NA
4 B 1 b Non-Dairy	NA
4 B 13 Other	NA
4 B 3 Sheep	NA
4 B 4 Goats	NA
4 B 6 Horses	NA
4 B 8 Swine	NA
4 B 9 Poultry	NA
4 D 1 i Synthetic N-fertilizers	NA
4 D 1 ii Animal waste applied to soil	NA
4 D 1 iii Other	NA
4 D 2 N-excretion on pasture range and paddock	NA
4 D i Farm-level agricultural operations including storage and handling of agricultural products	NA
4 D ii Off-farm storage and handling of bulk agricultural products	NA
4 G Other	NA

4.2.7 Land use, land-use change and forestry

There is no Swedish data available about the "Land use and the forestry" sector.

Table 18 Estimated emissions of dioxin from land use, land use change and forestry in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
5 B Forest and grassland conversion	NA
5 E Other	NA

4.2.8 Waste

Due to technical improvements of the combustion processes as well as on the cleaning of flue gases, resulting in reduced emissions of dioxin, waste incineration is today less important as dioxin source than many of the other combustion processes. For instance, landfills fires have been pointed out as an important emission source of dioxins. Also backyard burning of household waste may contribute substantially to dioxin emission but are today not included in the sector 6D (MK 2005:1, NV report 5462).

Table 19 Estimated emissions of dioxin from waste handling in 2004, submission 2006.

NFR code	Dioxin, g I-Teq
6 A Solid waste disposal on land	NA
6 B Waste-water handling	NA
6 C Waste incineration	6.15E-01
6 D Other waste	1.10E-01

5 Prioritised emission sources for further work

5.1 Mercury

In Table 20 the prioritised sources for further work on mercury are listed. The largest sources for mercury emissions, as shown by the key source analysis, are Metal Production (2 C) and Public Electricity and Heat Production (Stationary production, 1 A 1 a). Hence, the largest effort is to be to put on those two areas. Also mercury emissions originating from waste incineration are of significance and are thus important to cover. In the NFR sector "Solvent and other product use" products containing heavy metals are to be reported. Currently this source of mercury emissions is not included in the Swedish reporting and an estimation of the significance of this source is important for completeness.

Table 20. Prioritised emission sources for further work on mercury for the Swedish inventory

NFR sector	Order of priority	Activity
Industrial processes	1	Survey of sources and mercury emissions in 2 B 5 and 2 C.
Stationary combustion	2	Survey of emission factors currently used. Concentrating on emissions from combustion of coal and biomass.
Waste	3	Survey of emission factors for mercury from landfill fires If possible, find activity and emission data from incineration of medical waste.
Solvent and other product use	4	Include products containing mercury in NFR 3 D. Include mercury emissions from the use of fireworks.
Other sources in the Energy sector	5	Survey of emission factors for mercury from "Solid fuel transformation" (1 B 1 b).
Combustion in mobile sources	6	Emission factors for mercury from mobile sources (1 A 3 b i, 1 A 3 b ii, 1 A 3 b iii, 1 A 3 b iv, 1 A 3 e ii, 1 A 4 b ii and 1 A 4 c ii).

5.2 Dioxin

In Table 21 the prioritised sources for further work on dioxin are listed. The largest sources for the emissions of dioxin reported to CLRTAP are, as for mercury, stationary combustion and metal production. The emissions from large combustion plants are considered to be well covered and reliable, and most efforts are to be put on estimations of the emissions from "Residential plants" (NFR 1 A 1 a). Also prioritised for further work on dioxin emissions is a survey of the emissions originating from the chemical industry (NFR 2 B 5) and from the metal industry (2 C). Furthermore, dioxin from the sector "Other waste" (NFR 6 D), including back yard burning of waste and landfill fires, are of significance and should be included in a more extensive study of the Swedish dioxin emissions.

Table 21. Prioritised emission sources for further work on dioxin for the Swedish inventory

NFR sector	Order of priority	Activity
Stationary combustion	1	Validation and/or updating of emission factors for NFR code 1 A 4 b i "Residential plants"
Industrial processes	2	Survey of sources on facility level and data on dioxin emissions in 2 B 5 and 2 C.
Waste	3	Validation and/or update of emission factors from landfills fires and backyard burning of household and garden waste.

5.3 HCB

Generally, the most important sources for the formation and release of dioxin in Sweden have also to be considered to be of importance for the Swedish HCB emissions. Just as for dioxins, uncontrolled combustion processes also seem important. In a recent study (MK2005:01), emission factors for large and small-scale biomass combustion, backyard burning and landfill fires, are presented. Also the metal and chemical industry can be of significance for the HCB emissions, but for these areas the information is scarce. In Table 22 the prioritised sources for further work on HCB are listed.

Table 22 Prioritised emission sources for further work on HCB for the Swedish inventory

NFR sector	Order of priority	Activity
Stationary combustion	1	Finding emission factors suitable for Swedish conditions
Waste	2	Finding emission factors suitable for Swedish conditions for landfill fires and backyard burning of household and garden waste.

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