Unintentional formation and emission of the persistent organic pollutants HCB and PCBs in the Nordic countries

Documentation of existing information regarding sources and emissions to air, water and soil, with focus on reporting obligations according to the Stockholm Convention, the UNECE POP protocol, and PRTR registers

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Nordic co-operation

Nordic cooperation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and three autonomous areas: the Faroe Islands, Greenland, and Åland.

Nordic cooperation has firm traditions in politics, the economy, and culture. It plays an important role in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe.

Nordic cooperation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

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Abbreviations

AFBC:	Atmospheric Fluidized Bed Combustion
APCD:	Air Pollution Control Devices
ASR:	Auto Shredder Residues
BAT:	Best Available Technique
BEP:	Best Environmental Practice
BIPRO:	Beratungsgesellschaft für Integrierte Problemlösungen
BREF:	Best available techniques REference documents
CAMI:	Chlor-Alkali Manufacturing industry
CLMI:	Cement and Lime Manufacturing Industries
CRF:	Common Reporting Format
DRE:	Destruction and Removal Efficiency
EAF:	Electric Arc Furnaces
ELV:	End-of-Life Vehicle's
E-PRTR:	European Pollutant Release and Transfer Register
FMPI:	Ferrous Metals Processing Industry
GMI:	Glass Manufacturing Industry
HCB:	HexaChloroBenzene
IIR:	Informative Inventory Report
IPPC:	Integrated Pollution Prevention and Control
IS:	Iron and Steel
LCP:	Large Combustion Plants
LRTAP:	Long-Range Transboundary Air Pollution
LVOC:	Large Volume Organic Chemicals
MOGR:	Mineral Oil and Gas Refineries
MSW:	Municipal Solid Waste
MSWI:	Municipal Solid Waste Incineration
MTWR:	Management of Tailings and Waste-Rock in mining activities
NFMI:	Non Ferrous Metals Industries
NRF:	Nomenclature Reporting Format
NIP:	National Implementation Plan
OFC:	Organic Fine Chemicals
PCB:	PolyChlorinated Biphenyls
ΣPCB6:	PCB-28, PCB-52, PCB-101, PCB-138, PCB-153 and PCB-180
ΣPCB7:	PCB-28, PCB-52, PCB-101, PCB-118, PCB-138, PCB-153 and PCB-180
PCDD:	PolyChlorinated Dibenzo-p-Dioxin
PCDF:	PolyChlorinated Dibenzofuran
POP:	Persistent Organic Pollutant
PPI:	Pulp and Paper Industries
PRTR:	Pollutant Release and Transfer Register
RDF:	Refused Derived Fuel
SABI:	Slaughterhouses and Animal By-products Industries
SIC:	Speciality Inorganic Chemicals
SR:	Shredder Residues
Ti:	Textile Industry
TSFI:	Techniques in the Smitheries and Foundries Industry
UNECE:	United Nations Economic Commission for Europe
UPOP:	Unintentional Persistent Organic Pollutant
WI:	Waste Incineration
WTI:	Waste Treatment Industry
WWTP:	Waste Water Treatment Plant

Preamble

All Nordic countries are parties to the Stockholm Convention on Persistent Organic Pollutants (the Stockholm Convention) and the Persistent Organic Pollutants Protocol (the POP Protocol) under the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP). According to the Stockholm Convention, parties to the convention have to reduce, with the aim of eliminating, the unintentional formation and emission of hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs). Emissions of these substances to air, water and soil must be assessed and reported.

The overall goal of the project is to compile existing information on emissions from unintentional formation of HCB and PCBs to air, water and soil, which is relevant for the Nordic countries in order to be able to report on such emissions in accordance with the reporting obligations under the Stockholm Convention, the POP Protocol, the PRTR Protocol and the EU PRTR regulation.

It should be noted that there may exist further relevant information regarding national sources to HCB and PCBs that has not been available to the authors within the time available for the elaboration of this project, and which has therefore not been included in the present report.

The project is financed by the Nordic Council of Ministers and coordinated by the Nordic Chemicals Group. The work has been performed by the National Environmental Research Institute (NERI), Aarhus University, Denmark. The project has been overseen by a Steering Group consisting of members from the environmental administrations of the participating Nordic countries of Denmark, Finland, Norway and Sweden.

Steering group:

- Mona Westergaard, Chair, Danish Environmental Protection Agency
- Kristina Saarinen, Finnish Environment Institute
- Christel Benestad, Norwegian Pollution Control Authority
- Niklas Johansson, Swedish Environmental Protection Agency
- Marianne Thomsen, project leader from NERI

The content of this report does not necessarily reflect the opinion of the Nordic countries or the Nordic Council of Ministers.

Executive summary

The background of this project was the need for an overview of existing knowledge regarding sources of unintentional emissions of HCB and PCBs, relevant for the Nordic countries, with the purpose of enabling these countries to fulfil their reporting obligations under the Stockholm Convention on Persistent Organic Pollutants (POPs), the Persistent Organic Pollutants Protocol (the POP Protocol) under the UNECE LRTAP Convention, and finally the European Pollutant Release and Transfer Register (E-PRTR) according to regulation (Regulation (EC) No 166/2006), which implements the UNECE PRTR Protocol. These international agreements require reporting of unintentional emissions/releases of dioxin, HCB and PCBs to air, water and soil. However, until now actual reporting on unintentional emissions has mainly taken place for dioxin to air, and countries have not been able to report on unintentional emissions/releases of HCB and PCBs to air, water and soil, due to the difficulties in assessing these emissions/releases.

The aim of the project has been to improve the basis for reporting on the mentioned emissions/releases. It has been done by studying and assessing the existing knowledge regarding sources to unintentional formation and emission/release of HCB and PCB, including available information on source-specific activity data and emission factors. The project takes into account the latest research in the area and also identifies areas where there are gaps in knowledge. Focus has been on the review of existing knowledge on the potential sources rather than on delivering an inventory of emissions.

A general problem has been the lack of available data and emission factors that are directly applicable to the conditions in the Nordic countries. Some knowledge exists regarding unintentional emissions of HCB and PCBs to air in general, but there are considerable uncertainties and widespread lack of knowledge in relation to emissions from sources prevailing in the Nordic countries. This is even more pronounced in relation to emissions to water and soil, where knowledge is very limited. It has therefore not been possible in a meaningful way to assess any such potential releases to water and soil.

The study has pointed to a number of likely sources in the Nordic countries and possible emission magnitudes, and has thereby brought the countries a step closer to being able to report on emissions. However, it has also revealed that with the knowledge available ultimo 2007, a complete assessment of unintentional emissions of HCB and PCB is not possible.

The study shows that the relative importance of sources varies between the countries. No attempt has been made to compare emissions

between countries; focus has been on identifying the most relevant sources for each country.

For the purpose of identifying sources, activities listed in the E-PRTR Regulation and the Source Categories listed in Annex C of the Stockholm Convention were used. A division into point sources and diffuse sources according to the approach presented by BiPRO (Beratungsgesellschaft für integrierte Problemlösungen) and the E-PRTR Regulation was adopted.

The PRTR activities that represent point sources have been grouped into 9 activity sectors:

- 1. Energy
- 2. Production and processing of metals (metal industry)
- 3. Mineral industry
- 4. Chemical industry
- 5. Waste and waste water management
- 6. Paper and wood production and processing
- 7. Intensive livestock production and aquaculture
- 8. Animal and vegetable products from the food and beverage sector
- 9. Other activities

In addition to the point sources listed above, diffuse sources, such as mobile sources (especially road transport), agriculture, diffuse stationary combustion/residential combustion including domestic heating as well as shipping, have been included.

It has not been possible within the scope of this study to conduct an in-depth quality assurance and assessment of data sources at national or plant-specific process level.

Since focus is on the review of existing knowledge on the potential sources of unintentional formation and emission of HCB and PCBs rather than delivering an inventory, European level datasets comprising potential sources were preferred, since they represent national activity data. However, where national activity data have already been reported as part of the obligations under the UNECE Convention, these data have been used. This information has, where possible, been supplemented with national data and expert knowledge.

Potential sources of unintentional formation and emission of HCB and PCBs may be verified by information and data for sources related to activities at the national level. In cases where country-specific data on processes or activities as well as relevant emission factors have been available, indicative emission levels have been estimated. However, as neither uncertainty analysis nor in-depth quality assessment of the sources has been performed, and the data available are themselves subject to uncertainty, the results of calculations presented must be seen as solely indicative.

Emissions to air

General aspects regarding available information on unintentional sources of emissions to air

Emissions to air are potentially formed unintentionally during e.g. combustion and other thermal processes within energy production, industrial processes or waste management processes. Furthermore, emissions may stem from diffuse sources such as road transport and residential combustion.

Due to the multitude of industrial production processes and specialized industries, there may be sources to PCB and HCB emission that have so far not been identified. Furthermore, data on production processes, for example within the chemical industry, are plant specific or scarce and difficult to obtain (SPIN database, and PRODCOM, 2007); therefore, the list of potential sources identified may be incomplete.

Potentially contaminated building materials and associated near-field exposure impacting on indoor air quality and human health have not been addressed in any detail.

Available information on fires at landfill sites and other accidental fires is incomplete, and therefore only partly allowed for an estimation of HCB or PCBs emissions from these sources (Annex 6). This source category may potentially be of importance for the total emission of HCB and PCBs, depending on the chlorine and organic matter content of the material deposited at the landfills in question. Emissions from crematoria were included for PCB, but are indicated to be of minor importance.

Results

General

Overall, the indicative air emission estimates suggest that combustion processes may be a main source of unintentional emission of HCB and PCBs. Regarding HCB, it seems that emissions from residential combustion of wood, a diffuse source, and combustion of waste, especially hazardous waste, are more important than combustion processes within the industry and point source within the energy sector. The picture is more differentiated regarding PCB emissions, but energy production from coal, mobile sources (road transport) and petroleum refineries seem to be general main sources.

Denmark

HCB: Residential combustion may represent one of the main sources of unintentional emissions of HCB. Combustion of waste, which in Denmark is always combined with energy production, may be another. However, a recent study on trends in dioxin emissions from combustion of

waste indicates that this may no longer be the case. Combustion of hazardous waste and the chemical industry are also likely sources. Road transport, seem to be of little importance. Metal and mineral industries, being very small in Denmark, seem to be insignificant sources.

PCBs: Energy production based on combustion of coal seems to be the main source to unintentional emission of PCB, but road transport may also be of importance. Petroleum refineries, the mineral industry, waste treatment at shredder plants and energy production from waste may also be sources of some significance, while residential combustion and energy production of wood are likely to be minor sources.

Finland

HCB: The study points to combustion of hazardous waste, residential combustion of wood and the chemicals industry as being the main sources. However, in a recent national study in Finland, the chemical industry was estimated to contribute with up to 81 % of the total emissions in 2004 (Saarinen et al., 2007). This is not consistent with the results of this study, which underlines the uncertainties involved. The Finnish estimation is likely to be more correct. The metal industry and energy production based on combustion of wood are indicated to be sources of some importance. Energy production of waste, combustion of municipal waste and road transport are suggested to be of minor importance.

PCBs: Energy production based on combustion of coal and combustion of waste seem to constitute the main sources of PCB. Road transport, energy production based on combustion of wood, metal industry and petroleum refineries are indicated to be sources of some importance. Residential combustion, the mineral industry and energy production from municipal waste seems to represent sources of lesser importance.

Norway

HCB: Emissions from residential combustion of wood and combustion of hazardous waste seem to be the main sources in Norway. The metal industry is indicated to be a source of some importance. Energy production from waste, combustion of municipal waste and road transport are indicated to be sources of lesser importance.

PCBs: Road transport and petroleum refineries seem to be the main sources to PCB emissions. The mineral industry, combustion of hazardous waste and the metal industry are indicated to sources of some importance. Residential combustion and energy production seem to represent minor sources.

Sweden

HCB: Residential combustion of wood and combustion of hazardous waste seem to comprise the main sources of emission of HCB in Sweden. Other sources that may be important are the metal industry, combustion

of municipal waste and energy production from waste. Energy production from wood and road transport, seem to be lesser sources.

PCBs: Road transport and petroleum refineries seem to be the main sources to PCB emissions. Emissions from the metal industry, energy production of wood and coal, combustion of hazardous waste and the mineral industry may also be of importance. Residential combustion of wood, energy production from waste and combustion of municipal waste are indicated to be source of lesser importance in Sweden.

These findings are summarized in the tables below:

HCB emissions to air: Probable sources of importance

Country	Main source	Medium source	Lesser source
Denmark	Residential combustion (wood) Energy production (waste)*	Energy production (combustion of hazardous waste) Chemical industry	Mobile sources (road transport)
Finland	Combustion of hazardous waste** Residential combustion (wood) Chemical industry	Metal industry Energy production (wood)	Energy production (waste) Combustion of municipal waste Mobile sources (road transport)
Norway	Residential combustion (wood) Combustion of hazardous waste	Metal industry	Energy production (waste) Combustion of municipal waste Mobile sources (road transport)
Sweden	Residential combustion (wood) Combustion of hazardous waste	Metal industry Combustion of municipal waste Energy production (waste)	Energy production (wood) Mobile sources (road transport)

*Recent studies on dioxin indicate otherwise, see ref lab (2007).

**The data on emissions from the sources are very uncertain, see also section 3.3.1

PCB emissions to air: Probable sources of importance

Country	Main source	Medium source	Lesser source
Denmark	Energy production (coal) Mobile sources (road transport)	Petroleum refineries Mineral industry Waste treatment (shredder) Energy production (waste)	Residential combustion (wood) Energy production (wood)
Finland	Energy production (coal) Combustion of hazardous waste	Mobile sources (road transport) Energy production (wood) Metal industry Petroleum refineries	Residential combustion (wood) Mineral industry Energy production (municipal waste)
Norway	Mobile sources (road transport) Petroleum refineries	Mineral industry Combustion of hazardous waste Metal industry	Residential combustion (wood) Energy production (coal) Energy production (waste) Energy production (wood)
Sweden	Mobile sources (road transport) Petroleum refineries	Metal industry Energy production (wood) Energy production (coal) Combustion of hazardous waste Mineral industry	Residential combustion (wood) Energy production (waste) Combustion of municipal waste

Gaps in knowledge

A main gap is the lack of emissions factors for unintentional emissions to air of HCB and PCB for the types of plants operating in the Nordic Countries.

Water and soil

General aspects regarding available information on unintentional sources of release to water and soil

Available data for releases to water and soil are more scattered and incomplete than the data for air emissions, and until recently there was a general lack of harmonized reporting systems and statistics. It has not been possible to conduct an in-depth assessment of the potential sources of releases to water and soil within the framework of this study. This also includes secondary sources, for example redistribution from contaminated sites. It has therefore, as mentioned earlier, not been possible to meaningfully undertake an assessment of the magnitude of such releases.

The available data and information on release of HCB and PCBs to water and soil suggest that potential sources comprise by-products and waste such as solid and liquid residues, solid waste, oils and wastewater. Especially industrial sources and waste management processes seem to be of importance, depending on final disposal and recovery. Examples include industrial wastewater, waste incineration and waste from energy production. Since the amount of waste produced is increasing, this may be an important source. However, activities centring on avoiding problematic content in waste and the reuse and recycling of waste are on the rise in the Nordic countries, and therefore this need not be the case these countries.

On the basis of the available information, the most important sources seem to be:

Solid residues and waste

Releases from solid residue, e.g. fly ash from combustion processes deposited at landfill sites, especially depend on whether post-combustion of residues has taken place to further increase the destruction efficiency, and on the potential source intensity of the solid residues. Where the residues are not deposited as landfill, their future potential release will depend on the final reuse category, for example use of fly ash in cement or asphalt production.

Accidental emissions from release of percolates from landfill and sludge used as fertiliser may be other potential sources. Sludge as a source will depend on the degree to which influent organic matter in in-

dustrial wastewater contributes to the final sludge production. However, strict quality requirements apply to sludge in the Nordic countries.

Accidental leakage

Accidental leakage, or release, of e.g. percolates from old landfill sites or residue oils may result in release to soil and water, despite technological developments and measures to protect the underlying soil and groundwater.

Wastewater

Industrial wastewater from wet scrubbing processes may include problematic suspended solids to varying degree, depending on which pre-treatment is undertaken prior to discharge to surface waters or to municipal sewer systems, where this is permitted. The cleaning efficiency of industrial wastewater and the organic load in wastewater that enters centralized wastewater treatment plants is not well known. However, based on available data from separate industrial wastewater effluents in Denmark, there seems to be no or little need for concern regarding HCB and PCBs in the effluent wastewater from industrial point sources.

Overall trends in potential sources – air, soil and water

Technology, practices, rules and regulations are improving, and this may influence the relative importance of different sources in the future, reducing the emissions and releases from known sources.

Relevant for all the Nordic countries are several EU regulations concerning waste and reuse of end-of-life vehicles as well as other products, e.g. electric and electronic products. These regulations may be drivers behind the trends for the emissions and release of HCB and PCBs to air, soil and water.

More and better data, inter alia on emission/release factors, would be needed to make an optimal assessment of the trends for future emissions and releases, but based on the available knowledge the following relatively new sources might increase in importance:

- landfill as a temporary deposit site for e.g. aerobic mineralization of sludge mixed with private garden waste for production of e.g. compost
- end-of-life tyres for use in industrial production processes, e.g. asphalt production
- co-combustion in cement kilns
- fugitive emissions and/or accidental leakage to underlying soil from deposited slag and other solid residues from combustion processes and incineration of hazardous waste

Sammenfatning

Baggrunden for dette projekt har været behovet for en oversigt over den eksisterende viden vedrørende kilder til utilsigtede udledninger af HCB og PCB, som kan være relevante for de nordiske lande, med det formål at gøre landene i stand til at efterleve deres rapporteringsforpligtelser under den globale Stockholm konvention om persistente organiske forurenende stoffer, protokollen om persistente organiske forurenende stoffer (POP-protokollen) som hører under Konventionen om Langtrækkende Grænseoverskridende Luftforurening (CLRTAP) i regi af FN's økonomiske kommission for Europa (UNECE), og endelig det europæiske register over udledning og overførsel af forurenende stoffer (PRTR) ifølge forordning EF nr. 166/2006, som implementerer UNECE's PRTR protokol. Under disse internationale aftaler indgår der rapporteringsforpligtelser for utilsigtede emissioner/udslip af dioxin, HCB og PCB'er til luft, vand og jord. Dog er der primært sket rapportering hvad angår utilsigtede emissioner af dioxin til luft, idet vidensgrundlaget ikke har tilladt en rapportering af utilsigtede udslip af HCB og PCB til luft til vand og jord, på grund af vanskelighederne ved at estimere disse emissioner/udslip.

Målet med projektet har været at forbedre basis for rapportering af de nævnte emissioner/udledninger. Det er blevet gjort ved at gennemgå og vurdere den eksisterende viden om kilder til utilsigtet dannelse om emission/udledning af HCB og PCB, herunder tilgængelig information om kilde-specifikke aktivitetsdata og emissionsfaktorer. Projektet tager hensyn til den nyeste viden og identificerer områder, hvor der er huller i vores viden. Der har været fokus på en gennemgang af eksisterende viden om potentielle kilder, fremfor på at forsøge at udarbejde en oversigt over estimerede emissioner.

Et generelt problem har været manglen på tilgængelige data, samt emissionsfaktorer der er direkte anvendelige i de nordiske lande. Der eksisterer en vis viden om utilsigtede emissioner af HCB og PCB til luft generelt, men der er betydelige usikkerheder og en udbredt mangel på viden om emissioner fra de faktiske kilder i de nordiske lande. Dette er endnu mere udtalt for emissioner til vand og jord, hvor viden er meget begrænset. Det har derfor ikke været muligt at vurdere omfanget af potentielle udslip til vand og jord.

Rapporten peger på et antal sandsynlige kilder til emissioner i de nordiske lande og deres mulige størrelsesorden, og landene er derfor kommet et skridt nærmere til at kunne rapportere deres emissioner. Med den viden der er tilgængelig ultimo 2007 vil det ikke være muligt at udarbejde en fuldstændig opgørelse af utilsigtede emissioner af HCB og PCB.

Rapporten viser, at den relative betydning af kilderne varierer mellem landene. Det har ikke været forsøgt at sammenligne emissioner mellem landene, fokus har været på at identificere de mest relevante kilder for hvert land.

Med det formål at identificere kilder, er der anvendt de aktiviteter, som er opført i E-PRTR forordningen, samt de kildekategorier, der fremgår af Stockholmkonventionens bilag C. Der er anvendt en tilgang til opdeling i punktkilder og diffuse kilder, som er anvendt af BiPRO (Beratungsgesellschaft für integrierte Problemlösungen) og i E-PRTR forordningen.

De PRTR aktiviteter, som repræsenterer punktkilder er blevet opdelt i 9 aktivitetssektorer.

- 1. Energi
- 2. Produktion og forarbejdning af metaller (metalindustri)
- 3. Mineralindustri
- 4. Kemisk industri
- 5. Affald og spildevandsforvaltning
- 6. Papir- og træproduktion og processering
- 7. Intensiv dyreproduktion og aquakultur
- 8. Dyre- og vegetabiliske produkter fra føde- og drikkevaresektoren
- 9. Andre aktiviteter

Udover de punktkilder, der er opført ovenfor, er der inkluderet diffuse kilder såsom mobile kilder (primært vejtrafik), landbrug, forbrændingsanlæg i husholdninger og skibsfart. Det har ikke været muligt inden for rammerne at dette studie at gennemføre en dybdegående kvalitetssikring af datakilder på nationalt niveau eller anlægsniveau.

Siden der er fokus på en gennemgang af eksisterende viden om de potentielle kilder til utilsigtet dannelse og emission af HCB og PCB, frem for at forsøge at udarbejde en oversigt over emissionerne, er det foretrukket at benytte materiale med data over potentielle kilder på europæisk niveau, siden det repræsenterer samlede nationale aktivitetsdata. Undtaget herfra er dog tilfælde, hvor nationale data er blevet rapporteret som led i forpligtelserne under UNECE, hvor disse er anvendt i stedet. Disse oplysninger er, hvor muligt, blevet suppleret med nationale data og ekspertviden.

Potentielle kilder til utilsigtet dannelse og emission af HCB og PCB kan til tider blive verificeret af information og data for kilder relateret til aktiviteter på nationalt niveau. I tilfælde hvor landespecifikke data om processer eller aktiviteter, såvel som relevante emissionsfaktorer, har været til rådighed, er der blevet foretaget en estimering af indikative emissionsniveauer. Det skal understreges, at de estimeringer, der er foretaget må anses alene som indikative, da hverken følsomhedsanalyser eller

dybdegående kvalitetssikring af kilder er blevet foretaget, og data i sig selv er behæftet med usikkerhed.

Emissioner til luften

Generelle aspekter vedrørende tilgængelig information om utilsigtede kilder til emissioner til luften

Emissioner til luften kan dannes utilsigtet ved fx forbrænding og andre termiske processer indenfor energiproduktion, industriprocesser eller affaldshåndteringsprocesser. Emissioner kan også stamme fra diffuse kilder som vejtransport og energiproduktion i husholdninger – primært til boligopvarmning.

På grund af de mange forskellige industrielle produktionsprocesser og specialiserede industrier, kan der være kilder, som hidtil ikke er blevet identificeret. Desuden er data fra produktionsprocesser, for eksempel indenfor den kemiske industri, specifikke for det enkelte anlæg eller ganske få, og vanskelige at få adgang til (SPIN databasen og PRODCOM, 2007). Derfor kan listen over identificerede potentielle kilder være ukomplet.

Der er ikke set nærmere på potentielt forurenede byggematerialer og tilhørende forurening i nærområdet, som kan påvirke luftkvalitet og dermed indendørs luftkvalitet og menneskers sundhed.

Information om brande på lossepladser og andre utilsigtede brande er ukomplet, hvilket påvirker estimeringen af emissioner fra disse kilder, som angivet i bilag 6. Kilderne fra denne kategori kan være af betydning for estimeringen af den totale emission af HCB og PCB, men det afhænger af indholdet af klorholdigt materiale og organisk materiale, som er deponeret på lossepladserne m.m. Emissioner fra krematorier er inkluderet hvad angår PCB, men vurderes at være af mindre betydning.

Resultater

Generelle

Overordnet set indikerer emissionsestimererne, at forbrændingsprocesser kan være den relativt største kilde til utilsigtede emissioner af HCB og PCB'er. Hvad angår HCB, ser det ud til, at emissioner fra forbrændingsanlæg i husholdninger baseret på biomasse, en diffus kilde, og forbrænding af affald, især farligt affald, er vigtigere end forbrændingsprocesser i industrien og energisektoren (store anlæg). Billedet er mere komplekst hvad angår PCB emissioner, men energiproduktion fra kul, mobile kilder (vejtransport) og raffinaderier ser ud til generelt at være de relativt største kilder.

Danmark

HCB: Forbrændingsanlæg i private husholdninger ser ud til at være kilde til en af de relativt største andele af emissioner af HCB i Danmark. Forbrænding af affald, som i Danmark altid er kombineret med samproduktion af energi, kan udgøre en anden. Dog viser et nyligt studie om udviklingen i dioxinemissioner i Danmark fra affaldsforbrændingsanlæg, at det sandsynligvis ikke er tilfældet længere. Forbrænding af farligt affald og kemisk industri er også sandsynlige kilder. Vejtransport ser ud til at være af begrænset betydning, mens metal og mineral industrierne ser ud til at være ubetydelige kilder.

PCB: Energiproduktion baseret på forbrænding af kul ser ud til at være kilde til den overvejende del af emissioner af PCB, men vejtrafik kan også være af betydning. Raffinaderier, mineral industrien, affaldsbehandling fra shredderanlæg og energiproduktion fra affald kan også ud til at være af betydning, hvorimod forbrændingsanlæg i private husholdninger og energiproduktion baseret på træ (store anlæg), ser ud til at være mindre kilder.

Finland

HCB: Studiet peger på forbrænding af farligt affald, forbrændingsanlæg i husholdninger (træ) og kemikalieindustrien som de tre relativt største kilder, med forbrænding af farligt affald som den største. Et nyligt nationalt studie estimerer i modstrid hermed, at den kemiske industri bidrager med op til 81 % af de totale emissioner i 2004 (Saarinen et al., 2007). At de to studier ikke er konsistente understreger usikkerhederne på området, og det finske studie må antages at være mere korrekt. Metalindustrien og energiproduktion baseret på træ tyder også på at være kilder af nogen betydning. Energiproduktion fra affald, forbrænding af husholdningsaffald og vejtransport ser ud til at være af mindre betydning.

PCB: Energi produktion baseret på forbrænding af kul og forbrænding af affald ser ud til at være kilder til den overvejende del af PCB udledninger i Finland. Vejtransporten, energiproduktion baseret på forbrænding af træ, metalindustrien og raffinaderier ser også ud til at være af betydning. Forbrændingsanlæg i private husholdninger, mineral industrien og energiproduktion fra husholdningsaffald ser ud til at være af mindre betydning.

Norge

HCB: Emissioner fra forbrændingsanlæg i private husholdninger og forbrænding af farligt affald ser ud til være kilder til den overvejende del af emissioner i Norge. Metal industrien ser også ud til at være af betydning. Energiproduktion fra affald, forbrændingsanlæg i private husholdninger og vejtransport ser ud til at være kilder af mindre betydning.

PCB: Vejtransport og raffinaderier ser ud til at være kilder til den overvejende del af PCB emissionerne. Mineralindustrien, forbrænding af

farligt affald og metalindustrien er sandsynligvis også kilder af en vis betydning. Energiproduktion i husholdninger samt energi produktion på store anlæg ses som mindre betydelige kilder.

Sverige

HCB: Forbrændingsanlæg i private husholdninger og forbrændingen af farligt affald ser ud til at udgøre kilderne til den overvejende del af emissioner af HCB i Sverige. Andre kilder, der kan være af betydning er metalindustrien, forbrænding af husholdningsaffald og energiproduktion baseret på affald. Energiproduktion fra træ og vejtransport ser ud til at være kilder af mindre betydning.

PCB: Vejtransport og raffinaderier ser ud til at være kilder til den overvejende del af PCB emissionerne i Sverige. Emissioner fra metalindustrien, energiproduktion på basis af træ og kul, forbrænding af farligt affald og mineralindustrien kan også være af betydning. Forbrændingsanlæg i private husholdninger, energiproduktion baseret på affald og forbrænding af husholdningsaffald er sandsynligvis kilder som er af mindre betydning i Sverige.

De væsentligste fund kan opsummeres i tabellerne nedenfor:

HCB emissioner til luften: Sandsynlige kilder af betydning

Land	Relativt største kilde	Relativt mellemste kilde	Relativt mindste kilde
Danmark	Forbrændingsanlæg i husholdninger (træ) Energiproduktion (affald)*	Energiproduktion (farligt affald) Kemisk industri	Mobile kilder (vejtransport)
Finland	Forbrænding af farligt affald** Forbrændingsanlæg i husholdninger (træ) Kemisk industri	Metalindustri Energiproduktion (træ)	Energiproduktion (affald) Forbrænding af husholdningsaffald Mobile kilder (vejtransport)
Norge	Forbrændingsanlæg i husholdninger (træ) Forbrænding af farligt affald	Metal industri	Energiproduktion (affald) Forbrænding af husholdningsaffald Mobile kilder (vejtransport)
Sverige	Forbrændingsanlæg i husholdninger (træ) Forbrænding af farligt affald	Metalindustri Forbrænding af husholdningsaffald Energiproduktion (affald)	Energiproduktion (træ) Mobile kilder (vejtransport)

*Nylige studier af udviklingen i de uitsigtede emissioner af dioxin tyder på, at dette ikke længere er tilfældet, se ref lab (2007)

**Data forbundet med forøget usikkerhed, se afsnit 3.3.1

PCB emissioner til luft. Sandsynlige kilder af betydning

Land	Relativt største kilde	Relativt mellemste kilde	Relativt mindste kilde
Danmark	Energiproduktion (kul) Mobile kilder (vejtransport)	Raffinaderier Mineralindustri Affaldsbehandling (shredder) Energiproduktion (affald)	Forbrændingsanlæg i husholdninger (træ) Energiproduktion (træ)
Finland	Energiproduktion (kul) Forbrænding af farligt affald	Mobile kilder (vejtransport) Energiproduktion (træ) Metalindustri Raffinaderier	Forbrændingsanlæg i husholdninger Mineralindustri Energiproduktion (husholdningsaffald)
Norge	Mobile kilder (vejtransport) Raffinaderier	Mineralindustri Forbrænding af farligt affald Metalindustri	Forbrændingsanlæg i husholdninger (træ) Energiproduktion (kul) Energiproduktion (affald) Energiproduktion (træ)
Sverige	Mobile kilder (vejtransport) Raffinaderier	Metalindustri Energiproduktion (træ) Energiproduktion (kul) Forbrænding af farligt affald Mineralindustri	Forbrændingsanlæg i husholdninger (træ) Energiproduktion (affald) Forbrænding af husholdningsaffald

Mangler i den eksisterende viden om utilsigtede emissioner af HCB og PCB til luft

Der er en væsentlig mangel på viden hvad angår emissionsfaktorer for utilsigtede udledninger af HCB og PCB til luft på den type af anlæg, som opererer i de nordiske lande i dag.

Vand og jord

Generelle aspekter vedrørende tilgængelig information om utilsigtede kilder til udledninger til vand og jord

Tilgængelige data for udledninger til vand og jord er mere spredte og ukomplette end data for emissioner til luften, og indtil for nylig var der en generel mangel på harmoniserede rapporteringssystemer og statistikker. Der har ikke været muligt at gennemføre en dybdegående undersøgelse af de potentielle kilder til vand og jord inden for rammerne af dette studie. Dette gælder også sekundære kilder, for eksempel udledninger fra forurenede områder. Det har derfor som nævnt ikke været muligt på en meningsfuld måde at gennemføre en vurdering af størrelsesordenen af sådanne udledninger.

De tilgængelige data og den tilgængelige information om udledninger af HCB og PCB til vand og jord tyder på, at potentielle kilder kan være biprodukter og affald, såsom faste og flydende restprodukter, fast affald, olie og spildevand. Især industrielle kilder og affaldsbehandlingsprocesser ser ud til at være relevante, afhængig af en endelig deponering og genanvendelse. Eksempler inkluderer industrielt spildevand og restpro-

dukter fra affaldsforbrænding og energiproduktion. Siden mængden af produceret affald generelt er for opadgående, kan dette være en potentielt betydningsfuld kilde. På den anden side, da der er en stigende indsats i de nordiske lande for at undgå problematisk indhold i affald, og mere fokus på genanvendelse og genbrug af affald, behøver det ikke at være tilfældet.

På basis af den tilgængelige information, ser de væsentligste kilder ud til at være:

Faste restprodukter og affald

Udledninger fra faste restprodukter, fx flyveaske fra forbrændingsprocesser deponeret på lossepladser, afhænger især af, hvorvidt efterbrænding af restprodukter har fundet sted for at forbedre destruktions effektiviteten, og på den potentielle kildeintensitet af det faste restprodukt. Hvor restprodukterne ikke er deponeret på losseplads, vil deres potentielle fremtidige udledningspotentiale afhænge af den endelige anvendelseskategori, for eksempel brug af flyveaske i cement eller asfaltproduktion.

Udledninger som følge af uheld med perkolat fra lossepladser og slam brugt som gødning kan være andre potentielle kilder. Potentialet for slam som kilde vil afhænge af den grad, hvormed organisk materiale tilført med industrispildevand bidrager til den samlede slamproduktion. Der er dog strenge kvalitetskrav til slam i de nordiske lande.

Lækager som følge af uheld

Lækager eller udledninger som skyldes uheld med fx perkolat fra gamle lossepladser eller restolier kan medføre udledninger til jord og vand, til trods for teknologiske udviklinger og tiltag for at beskytte jord og grundvand.

Spildevand

Industrielt spildevand fra vådvaskningsprocesser kan indeholde problematiske stoffer i varierende grad. Det afhænger af, hvilken forudgående behandling, der er foretaget inden spildevandet udledes til overfladevandet eller - hvor dette er tilladt - til kommunale rensningsanlæg. Renseeffektiviteten for industrispildevand, og det organiske indhold i spildevand, der kommer til centrale spildevandsanlæg, er ikke velkendt. Dog tyder tilgængelige data fra Danmark på, at der ikke er grund til bekymring vedrørende HCB og PCB i det spildevand, der udledes fra industrielle punktkilder.

Overordnede tendenser i potentielle kilder – luft, vand og jord

Teknologi, praksis, regler og reguleringer forbedres stadig, og dette kan have indflydelse på den relative betydning af forskellige kilder til utilsigtede udledninger af HCB og PCB i fremtiden.

Adskillige EU forordninger vedrørende affald og genbrug af udtjente køretøjer såvel som andre produkter, fx elektriske og elektroniske produkter, er relevante for alle de nordiske lande. Disse forordninger kan være med til at drive udviklingen i forbindelse med emissioner og udledninger.

Flere og bedre data, blandt andet om emissions- og udledningsfaktorer, er nødvendige for at foretage en optimal opgørelse af tendenserne for fremtidige emissioner og udledninger, men baseret på den eksisterende viden, kan de følgende relativt nye kilder potentielt stige i vigtighed:

- lossepladser som midlertidigt deponi for fx aerob mineralisering af slam blandet med privat haveaffald for produktion af fx kompost
- udtjente dæk til brug i industrielle processer, fx asfaltproduktion
- sam-forbrænding i cementovne
- flygtige emissioner og/eller utilsigtet lækage til underliggende jord fra deponeret slagge og andre faste restprodukter fra forbrændingsprocesser og forbrænding af farligt affald.

1. Introduction

This project, under the Nordic Council of Ministers, Nordic Chemicals Group, provides an overview of existing information regarding sources and unintentional emissions of hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs) to soil, water and air. Focus is on reporting obligations according to the Stockholm Convention, the UNECE POP Protocol and the PRTR registers under the UNECE PRTR Protocol and the EU PRTR regulation. This potentially contributes to attainment of the objectives of the Stockholm Convention and other POP-related EU and international regulation in the long run, and thereby to a better environment in the Nordic countries, the Arctic and globally.

These international agreements require reporting of unintentional emissions/releases of dioxin, HCB and PCBs to air, water and soil. However, until now actual reporting on unintentional emissions has mainly taken place for dioxin to air, and countries have not been able to report on unintentional emissions/releases of HCB and PCBs to air, water and soil, due to the difficulties in assessing these emissions/releases. A toolkit (guidelines) for unintentional formation and emission of dioxins/furans has been elaborated under the Stockholm Convention. However, no such toolkit has been prepared for HCB and PCBs, because of the limited knowledge of the unintentional formation and emission of these substances. This limitation in knowledge also applies to the Nordic countries.

No attempt has been made to compare emissions between countries; focus has been on identifying the most relevant sources for each country. Furthermore, any assessment of potential consequences for the environment or health of the indicative emissions/releases is outside the scope of this study.

PCBs cover a group of 209 different PCB congeners which can be divided into two groups according to their toxicological properties. One group, consisting of 12 congeners, shows toxicological properties similar to dioxins and is therefore termed 'dioxin-like PCBs' or 'co-planar PCB', with reference to their conformation. The general human exposure to dioxins and these dioxin-like PCBs in Europe is still close to the TDI (Tolerable Daily Intake) set by the EU (SCF, 2001). In fact, more than 10% of the Swedish population is estimated to overstep this TDI. The other PCBs, referred to as 'non dioxin-like PCBs' do not primarily interact by means of a similar mode of action as the dioxins. This does not mean that these PCBs lack toxicological properties. On the contrary, they have been shown to be able to generate a variety of other toxic effects. Both groups of PCB are usually found in the environment. PCB was formerly used widely in a number of industrial and commercial applications.

It is estimated that more than 1 million tonnes of technical PCB mixtures have been produced worldwide since their first commercial use in the late 1920s.

Although the manufacture, processing and distribution of PCBs have been prohibited in almost all industrial countries since the late 1980s, their entry into the environment still occurs, especially due to improper disposal practices or leaks in electrical equipment and hydraulic systems still in use. A number of industrial and other high-temperature processes have been shown to generate PCBs via *de novo* synthesis.

Data on the occurrence of PCBs in the environment have been reported in many different ways: e.g. as PCB congener 153 only; as the sum of three PCB congeners (PCB 138, 153 and 180); as the sum of six PCB congeners (PCB 28, 52, 101, 138, 153, 180), often referred to as indicator PCB; or as the sum of seven (sum of six indicator PCB plus PCB congener 118). This lack of consistency hampers a comparison of occurrence data.

For the sake of simplicity, in the present investigation the term PCB has been used for all possible combinations. This of course introduces a certain amount of uncertainty to the analysis, but this uncertainty is regarded as considerably smaller than a number of other uncertainties present in this compilation.

PCBs, as a group, are chemically stable/inert, heat resistant and non-flammable, and have particularly useful dielectric properties. PCBs were utilized in a wide variety of open, nominally closed and closed systems. Open use included the addition of PCBs in plasticizers, carbonless copy paper, lubricating oils, inks, laminating and impregnating agents, paints, adhesives, waxes, additives to cement and plaster, casting agents, dedusting agents, sealing liquids, fire retardants, immersion oils and pesticide extenders (de Voogt and Brinkman, 1989). Nominally closed and closed usage applications included hydraulic and heat transfer fluids, small capacitors in cars and household electrical appliances, vacuum pumps, as well as transformers and large capacitors. Electrical companies were the largest users of PCBs worldwide. PCBs can enter the environment via a number of different pathways, e.g. direct emission from equipment still in use or in storage, emission from PCB-contaminated waste or from contaminated sites, disposal areas, etc. In the past products containing PCBs may have constituted a source for release from landfill to water and air (BiPRO, 2006; DEFRA, 2006). Today equipment containing PCBs is disposed of by chemical incineration (Directive 2000/76/EC).

Due to their very low biodegradability in the environment and their tendency to bioaccumulate, and biomagnify, PCBs belong to the so-called persistent organic pollutants (POPs). In spite of their low vapour pressure, and partly as a result of their hydrophobicity, PCBs volatilize from water surfaces. Many of the individual PCB compounds exhibit toxic

properties. PCBs rarely cause acute toxic effects, but most of the effects observed are the result of repetitive or chronic exposure. There is growing evidence linking PCBs and other persistent halogenated aromatic hydrocarbons to reproductive and immunotoxic effects in wildlife. Effects on the liver, skin, immune system, reproductive system, gastrointestinal tract and thyroid gland of laboratory rats have been observed, and PCBs are classified as probable human cancer promoters.

HCB has been widely used as a pesticide to protect the seeds of onions and sorghum, wheat and other grains against fungus. HCB has been used as an intermediate or additive in various manufacturing processes, including the production of synthetic rubber, pyrotechnics and ammunition, dyes and pentachlorophenol. Today HCB is emitted primarily as by-products in industrial and combustion processes, but is also found in certain pesticides or chlorinated solvents (US EPA, 2000). HCB may also be found in ferric chloride used in precipitation processes during water or wastewater treatment (Danish Crown, 2006; DEPA, 200a and b, US EPA, 2000).

In addition to the above-mentioned sources, both PCBs and HCB are known to be formed through the same processes that create PolyChlorinated Dibenzo-p-Dioxins (PCDDs) and PolyChlorinated Dibenzofurans (PCDFs).

The current project is limited to a study of Annex C compounds of the Stockholm Convention, of which the PCDDs and dibenzofurans have already been investigated elsewhere. Focus is on the unintentional formation and emission of the persistent organic pollutants (UPOPs) HCB and PCBs, from anthropogenic sources.

Ongoing and past actions and measures taken to monitor and reduce or eliminate the unintentional emission of HCB and PCBs are described as part of the National Implementation Plans (NIPs). All the Nordic countries have submitted their NIPs to the conference of parties in accordance with Article 7 of the Stockholm Convention (<http://www.pops.int/documents/implementation/nips/>).

All countries have, at some level, adopted several BAT and BEP approaches with the purpose of limiting the emission of the above-mentioned pollutants; e.g. technological developments driving the industry to apply best available techniques and to adopt processes that prevent emissions, as well as through waste management regulations. As observed in Table 1, the Nordic countries regulation of PCBs is far ahead of the requirements of the Convention, which calls for a phase-out by 2025 and final disposal by 2028.

Table 1 National restrictions by law and in accordance with the requirements of the Stockholm Convention, Annex A

Restrictions by law	Substance	Historical use	Last use / Phasing out	Ban of Export-Import*
Denmark	PCB	Transformer oils, capacitors, "open" use like paints, fillers, self-copying paper	1977 open use; 1986 ban on sale of PCB and products containing PCB; 1995 PCB-containing capacitors and transformers > 1 kg total weight; 2000 ban on use and storage of equipment containing PCB with a total weight >1kg	1986
	HCB	Industrial use	1992 ban of use as active ingredient in pesticides; 2003 total ban	
Finland	PCB	Transformer oils, capacitors and sealants of prefabricated homes	1970s; prohibition of manufacturing, marketing and use, 1990	1990/2002
	HCB	Pesticide	1976; prohibition of manufacturing, 2002; marketing, 2004; use, 1996	
Norway	PCB	Capacitors and transformers, insulating windows, in small capacitors in fluorescent light fixtures, in high voltage equipment, in capacitors in old radios and in old construction materials (as paints, sealed joints etc)	Production and use banned in 1980; Use of bigger transformers and condensators phased out in 1994–1995, prohibited in 1995.	
	HCB	Pesticide	1979, use or place on the market all plant protection products containing hexachlorobenzene prohibited	
Sweden	PCB	Power capacitors, switching gear and transformer dielectric fluid Anti-skid flooring sealants Insulation glass units Small capacitors Hydraulic fluids Carbonless copying paper Chloro caoutchouk paint Anti-fouling paint	1973 open use banned 1978 'new' uses in closed applications banned 1988: stepwise reduction of use in closed systems 1995: all use banned 2013: contaminated sealants and flooring resins in buildings to be removed	
	HCB	Voronit; fungicide for treatment of seed (first registered 1964)	Production and use banned in 1980	

*Prohibited by adoption of the Basel Convention

Decontamination and/or disposal of all PCB-containing equipment should be completed before 2010 according to the EU PCB Directive and before 2028 according to the Stockholm Convention. Small capacitors and transformers may be used until the end of their useful economic life, with the WEEE Statutory Order requiring that components containing PCB in scrap electrical and electronic equipment must be removed from the products and destroyed. As such, the Nordic countries are ahead of the

target years for phasing out PCB/HCB-containing products. An overview of the destruction of historic PCB-containing products and sources of emissions and waste treatment activities before 1998 may be found in the Inventory of Worldwide PCB Destruction Capacity (UNEP/SBC, 1998).

The Stockholm Convention requires parties to take measures to reduce or eliminate emissions of POPs from intentional production and use (Article 3), unintentional production (Article 5) and stockpiles and wastes (Article 6). Concepts of Best Available Techniques (BAT) and Best Environmental Practices (BEP) are to be further elaborated by the Conference of the Parties. Article 5 and 6 of the Stockholm Convention relate to the nature of the potential sources for emissions of HCB and PCBs.

In accordance with Article 6 of the Stockholm Convention, 'Measures to reduce or eliminate emissions from stockpiles and wastes', the parties to the convention are to cooperate closely with the appropriate bodies of the Basel Convention on the Control of 'Transboundary Movements of Hazardous Wastes and their Disposal' (Basel, 2005). Furthermore, countries are obliged to submit emission inventories as a measure of the reduced emissions of the unintentional POPs listed in Annex C of the convention; i.e. dioxins, PCBs and HCB.

Annex C, part V of the Stockholm Convention includes elements to be considered under prevention of the unintentional production and emission of PCBs and HCB. Furthermore, a revised version of the guidelines on BAT and BEP was released in December 2006 (Guidelines on BAT and Guidance on BEP, 2006), including, in addition to a description of processes that are UPOP sources, a description of control treatment processes and handling of residual product and waste characterization, sorting, recycling, etc. to secure that no UPOP re-enters the product cycle. Furthermore, the aim is that emissions upon final disposal or destruction of PCB- or chlorine-containing residual products are prevented and/or decreased to a maximum level by means of BEP and BAT approaches (Basel, 2007a and b). The threshold for emission of HCB and PCBs caused by unintentional formation processes at facility level is given in Table 2; the concentration in solid residues being classified as hazardous waste if the general definition of 50 mg POP/kg waste is exceeded (Basel, 2005).

Both the Stockholm Convention and the LRTAP Protocol on long-range atmospheric transport are important tools in the process of reducing, with the final aim of eliminating, POPs as well as UPOPs. Potential sources of emissions of PCBs and HCB relate to UPOPs, i.e. Annex C of the Stockholm Convention, comprising unintentional formation and releases as impurities during various processes including industrial processes and nearly all types of combustion processes such as waste incineration, combustion of fuels and small scale burning of wood. From 2007, industry is obliged to report emissions of HCB and PCB at facility level to the E-PRTR. Existing sources that may result in unintentional

formation and emissions of HCB and PCB, as listed in the Annex C of the Stockholm Convention, are as follows:

Industrial source categories according to Annex C of the Stockholm Convention, Part II, 'having the potential for comparatively high formation and release of these chemicals to the environment':

- Waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge
- Cement kilns firing hazardous waste
- Production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching
- The following thermal processes in the metallurgical industry:
 - (i) Secondary copper production
 - (ii) Sinter plants in the iron and steel industry
 - (iii) Secondary aluminium production
 - (iv) Secondary zinc production

Source categories according to Annex C of the Stockholm Convention, Part III, 'that may also unintentionally form and release' UOPs:

- Open burning of waste, including burning of landfill sites
- Thermal processes in the metallurgical industry not mentioned in Part II
- Residential combustion sources
- Fossil fuel-fired utility and industrial boilers
- Firing installations for wood and other biomass fuels
- Specific chemical production processes releasing unintentionally formed persistent organic pollutants, especially production of chlorophenols and chloranil
- Crematoria
- Motor vehicles, particularly those burning leaded gasoline
- Destruction of animal carcasses
- Textile and leather dyeing (with chloranil) and finishing (with alkaline extraction)
- Shredder plants for the treatment of end of life vehicles
- Smouldering of copper cables
- Waste oil refineries

The lists of potential sources presented above are to some extent covered by the E-PRTR reporting format, which is presented at the beginning of Chapter 2. However, this format is designed for industry reporting obligations at facility level, e.g. transport is not included. The source categories listed in Part III of the Stockholm Convention are covered by sources originating from industrial activities or diffuse sources as defined in the E-PRTR guidelines.

Chapter 2 presents an investigation existing information regarding activities that may fit into the individual types of industrial categories as defined in Annex 2 of the E-PRTR regulation (Table 2). In addition to the industrial point sources, diffuse sources have been included as defined in the E-PRTR protocol and described in more details by BiPRO (Beratungsgesellschaft für integrierte Problemlösungen). Potential sources for the Nordic countries, and identification of the country specific relevance of these, are presented in the Chapter 2.

In Chapter 3, the identified sources contributing to unintentional emissions of HCB and/or PCBs to air, soil or water, respectively, will be presented and estimated where possible together with existing data gaps. If emission factors are available, these are provided and indicative emission levels have been estimated in cases where activity data were available. In view of the limited resources within this project, European level datasets on potential sources were preferred as representing national activity data. National data and expert knowledge was included to secure correctness of the indicative nature of the data presented in this study where possible. All data presented in this study are to be seen as indicative measures as no uncertainty analysis or in depth quality assessment of the sources have been performed.

Chapter 4 presents the main conclusions regarding sources, data gaps and uncertainties and suggestions for further investigations in specific areas of this review regarding information on sources of release of HCB and PCBs to soil, water and air.

2. Identification of sources

For the identification of sources of unintentional emissions of HCB and PCBs, the reporting guidelines under the Protocol on Pollutant Releases and Transfer Registers (PRTR) are used. The Protocol on Pollutant Release and Transfer Registers (PRTR) was adopted on 21 May 2003 during the fifth 'Environment for Europe' Ministerial Conference in Kiev (Regulation (EC) No 850/2004). The protocol, which applies to 36 European countries and the European Union, is the first legally binding international instrument on pollutant release and transfer registers. PRTRs are inventories of pollution released to all media by industrial sites and other sources. As such, the PRTRs implementing the PRTR Protocol will in the long run contain two types of data: facility-level data and data for so-called diffuse sources. A description of diffuse sources, e.g. road transport and domestic heating, where such data is available are presented in section 2.2., while potential sources to be reported in future at facility level are described as potential point sources in section 2.1. In general terms, data for the two types of sources must be integrated into an overall picture of emissions to air, water and land and off-site transfers of waste and of pollutants, here UPOPs, in wastewater (E-PRTR Regulation (EC) No 166/2006).

2.1 Point sources

Point sources are defined as facility-level emissions from facilities carrying out specific activities listed in Table 2 and defined in the E-PRTR Regulation (EC) No 166/2006 and guidelines for implementation of the E-PRTR at the European level (European Commission, 2006). The defined facility activities cover the industrial source categories listed in Annex C, Part II and III, of the Stockholm Convention, also provided in Chapter 1 of this study, as well sources within the Energy sector. Details concerning reporting obligations may be found in the E-PRTR guidelines (European Commission, 2006) and Article 7 of the Stockholm Convention.

Potential sources of HCB and PCBs release to air, water and land are marked by dots and crosses in Table 2. The dots are taken from the guidance document for reporting to the E-PRTR and represent indicative sector-specific sources to PCBs and HCB emissions to air and water (European Commission, 2006). The crosses have been added as a result of the present work and do not infer any judgement as to expected size of the potential source. This is in accordance to the E-PRTR regulation in which it is stated that if a facility is/was 'engaged in' an activity listed in Table

2, and the activity occurred at the facility at any time during the reporting year, then the releases, disposals and transfers of UPOPs must be considered regardless of the extent or the primary purpose of the facility; including fugitive and diffuse releases of facilities.

Air

HCB and PCB may be unintentionally formed during production processes as well as combustion processes in various industrial sectors (power production, waste incineration, metallurgical industry, cement production, domestic burning, etc.). *De novo* synthesis is especially important if certain catalysts (e.g. copper and lead) or chlorine precursors are present in the feed material and therefore a detailed knowledge of industrial production processes as well as combustion processes and feed material is needed to identify sources of emissions of HCB and PCBs. Available knowledge regarding activities and processes leading to unintentional production and emission of HCB and PCBs from different types of industrial facilities is presented below. The information has been extracted from the scientific literature as well as existing BAT and BEP guidelines, as well as reports relating to sources of PCB and HCB emission.

Water

The direct emission of UPOPs via effluents is regarded as insignificant or of minor importance as the relevant industries are assumed to be connected to the municipal sewer system or the wastewater is assumed to be effectively treated prior to release. It is expected that PCBs and HCB may potentially be sorbed to dust in the wastewater as well as other flue-gas cleaning and combustion residues. Thus, the centralized wastewater treatment plants may have been subjected to an increased influent load of organic matter and potentially PCB and HCB sorbed to dust from wet-scrubbing processes.

Land

Releases to land apply only to pollutants in waste which is subject to the disposal operations 'land treatment' or 'deep injection' as defined in Article 6 of the E-PRTR Regulation (EC Regulation No 166/2006). Land treatment may result from the use of sludge as fertilizer in agricultural soils, whereas deep injection would result from 'injection of pumpable discards into wells, salt domes or naturally occurring repositories' (Guidance Document for European PRTR implementation, 2006).

Off-site transfer of waste, i.e. movement of waste fractions beyond the boundaries of a facility, destined for disposal or recovery is not included in this survey. As such, the project does not include any attempt to quantify off-site transfer of waste in any detail. Information on potential sources of unintentional emission of HCB and PCBs are mentioned in relation to recovery and disposal (R and D) treatment processes.

Table 2 General overview of sources to emissions of PCBs and HCB to air, water and land

	Environmental matrix	Air		Water		Land	
		HCB	PCB	HCB	PCB	HCB	PCB
	Pollutant name						
	E-PRTR threshold for releases [kg/yr] (European PRTR Regulation 166/2006/EC, Annex 2)	10	0.1	1	0.1	1	0.1
1	Energy sector						
	(a) Mineral oil and gas refineries		x				
	(b) Installations for gasification and liquefaction	x	x				
	(c) Thermal power stations and other combustion installations	x	x				
	(d) Coke ovens						
	(e) Coal rolling mills						
	(f) Installations for the manufacture of coal products and solid smokeless fuel						
2	Production and processing of metals						
	(a) Metal ore (including sulphide ore) roasting or sintering installations						
	(b) Installations for the production of pig iron or steel (primary or secondary melting) including continuous casting						
	(c) Installations for the processing of ferrous metals						
	(d) Ferrous metal foundries						
	(e) Installations for the production of non-ferrous crude metals from ore, concentrates or secondary raw materials by metallurgical, chemical or electrolytic processes and for the smelting, including the alloying, of non-ferrous metals, including recovered products (refining, foundry casting, etc.)						
	(f) Installations for surface treatment of metals and plastic materials using an electrolytic or chemical process						
3	Mineral industry						
	(a) Underground mining and related operations						
	(b) Opencast mining and quarrying						
	(c) Installations for the production of cement clinker in rotary kilns, lime in rotary kilns, cement clinker or lime in other furnaces	x					
	(d) Installations for the production of asbestos and the manufacture of asbestos-based products						
	(e) Installations for the manufacture of glass, including glass fibre						
	(f) Installations for melting mineral substances, including the production of mineral fibres						
	(g) Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain	x	x				
4	Chemical industry						
	(a) Chemical installations for the production on an industrial scale of basic organic chemicals						
	(b) Chemical installations for the production on an industrial scale of basic inorganic chemicals						
	(c) Chemical installations for the production on an industrial scale of phosphorous-, nitrogen- or potassium-based fertilizers (simple or compound fertilizers)						
	(d) Chemical installations for the production on an industrial scale of basic plant health products and of biocides						
	(f) Installations for the production on an industrial scale of explosives and pyrotechnic products						

To be continued

		Environmental matrix	Air		Water		Land	
			HCB	PCB	HCB	PCB	HCB	PCB
5		Waste and wastewater management						
	(a)	Installations for the disposal or recovery of hazardous waste		x				
	(b)	Installations for the incineration of non-hazardous waste in the scope of Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste (2)		x				
	(c)	Installations for the disposal of non-hazardous waste		x				
	(d)	Landfills (excluding landfills for inert waste and landfills, which have been definitely closed before the 16.7.2001 or for which the after-care phase required by the competent authorities according to Article 13 of Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (3) has expired)		x			x	x
	(e)	Installations for the disposal or recycling of animal carcasses and animal waste						
	(f)	Urban waste-water treatment plants		x				
	(g)	Independently operated industrial waste-water treatment plants which serve one or more activities of this annex	x	x				
6		Paper and wood production and processing						
	(a)	Industrial plants for the production of pulp from timber or similar fibrous materials						
	(b)	Industrial plants for the production of paper and board and other primary wood products (such as chipboard, fibreboard and plywood)				x		
	(c)	Industrial plants for the preservation of wood and wood products with chemicals						
7		Intensive livestock production and aquaculture						
	(a)	Installations for the intensive rearing of poultry or pigs						
	(b)	Intensive aquaculture						
8		Animal and vegetable products from the food and beverage sector						
	(a)	Slaughterhouses		x				
	(b)	Treatment and processing intended for the production of food and beverage products from animal raw materials (other than milk) and vegetable raw materials						
	(c)	Treatment and processing of milk						
9		Other activities						
	(a)	Plants for the pre-treatment (operations such as washing, bleaching, mercerization) or dyeing of fibres or textiles						
	(b)	Plants for the tanning of hides and skins						
	(c)	Installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, water-proofing, sizing, painting, cleaning or impregnating						
	(d)	Installations for the production of carbon (hard-burnt coal) or electrographite by means of incineration or graphitization						
	(e)	Installations for the building of, and painting or removal of paint from ships						x

Possible production processes which may result in potential emissions of HCB and/or PCBs have been reviewed with reference to the existing literature, reports and databases. Emission factors for potential sources to unintentional emissions of PCBs and HCB have been extracted from the literature and guidance documents, such as:

- The Corinair Guidebook (EMEP, 2006)
- The IPPC (Integrated Pollution Prevention and Control) BREFs (Best available techniques REFERENCE documents)
- Draft guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention
- The technical guidelines on the environmentally sound management of wastes prepared under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
- The scientific literature

Activity data for potential sources of unintentional emissions of PCBs and HCB have been extracted from official national statistics as well as Nordic or European databases. Selected data sources are listed below:

- National Inventory Reports from the EIONET website
- CRF tables from the UNFCCC website
- European Association of Mining Industries at <http://www.euromines.org/>
- International Solid waste association at <http://www.iswa.org/web/guest/home>
- European asphalt pavement association at <http://www.eapa.org/>
- Nordic Waste Info at www.nordic-waste.info
- Statistics Norway
- Statistic Finland
- Statistics Sweden
- Statistics Denmark
- EUROSTAT

Below a short description including the relevance of the E-PRTR activities for the Nordic countries is presented with reference to literature and references on specific processes which may lead to emission of PCBs and HCB. Processes identified in accordance with the categories as given in Table 2 have been verified by data on specific activities and/or emission factors. Activity data representative for potential sources are presented in Chapter 2, emission estimates and emission factors are presented in Chapter 3 and supporting material in Annex 1 to 6. The resources available for this project do not allow for in-depth quality assurance and assessment of data sources at national or plant-specific process levels. As such, focus is on the compilation and review of existing knowledge on the potential sources of unintentional emissions of HCB and PCBs, rather than delivering an inventory of unintentional emissions of these substances.

2.1.1 The Energy Sector

Oil refineries (PRTR code 1a)

The reference document on BAT for Mineral Oil and Gas Refineries (IPPC BREF MOGR, 2003) describes the dioxin emission to air as well as to wastewater during wet scrubbing processes. Electrostatic precipitator and activated carbon filters are among the flue-gas cleaning techniques mentioned as BAT prior to emission of the flue gas. PCBs are mentioned as potential contaminants in waste lubricants (IPPC BREF MOGR, 2003), but no emission factors are provided.

According to available information from the U.S. Geological Survey Mineral Information, Finland and Sweden have no production of crude petroleum (see Annex 1, Table 1.6), but do have refining processing activities as listed in Table 3. According to Table 3 the activity data for Norway and Sweden are approximately a factor of two above the activity data for Finland and Denmark. Petroleum refining is reported to be a potential source of unintentional PCB emission (BiPRO, 2006).

Table 3 Activity data on amounts of petroleum refinery products produced within in the Nordic countries [tonnes]

	2001	2002	2003	2004	2005	Reference
Denmark	9 820 800	7 890 058	8 143 080	8 156 720	8 320 400	1
Finland	5 772 175	7 474 856	7 495 998	8 325 447	10 747 774	1
Norway	17 595 600	17 732 000	18 004 800	14 066 114	15 408 290	1
Sweden	21 005 600	21 278 400	21 414 800	21 687 600	21 960 400	1
Sweden*	19 592 850	19 313 700	19 661 650	20 611 900	19 920 000	2

References:

1: US Geological survey, <http://minerals.usgs.gov/minerals/pubs/country/europe.html>

2: National expert knowledge

Given the available data, air emissions from the petroleum industry represent an important source of PCB air emissions in the Nordic countries. Petroleum industry wastes may include significant concentrations of PCB (e.g. Frank J. Castaldi, P.E., 2004).

Alternative and secondary fuels for energy production (PRTR code 1b)

New approaches for producing energy from different types of wastes and residues are likely in the future. As such, the PRTR sub-category 1.b may very well take on greater importance in years to come. However, these activities are currently still in the pilot phase and therefore only scarce information on these processes is available at present (Belgiorno et al, 2003; Ratafia-Brown et al, 2002). Gasification is particularly suitable for treatment of industrial wastes, but a number of problems exist with municipal solid wastes (MSW) due to their heterogeneity. Energy from gasification of different types of waste may contribute to emission of soluble pollutants in wastewater in wet scrubber and gas cooling processes as well contaminants in solid residues. The presence of HCB/PCBs in these

by-products and residues depends entirely on the feed material, e.g. paper mill waste, mixed plastic waste, forest industry waste and agricultural residues, and the subsystems employed to deal with releases into the environment (Belgiorno et al., 2003; Kikuchi et al., 2007; Pegg et al., 2007).

Gasification of coal and oil currently takes place to a certain degree, while the conversion of biomass to energy as well as gasification as an alternative to thermal treatment of waste are both fairly new. For MSW and refuse-derived fuel (RDF), pyrolysis and gasification stand-alone applications, in Europe, are still in the premature stages. However, large-scale pyrolysis and gasification applications, combined with combustion, are already in place in Sweden and Finland (Malkow, 2004). New approaches to using e.g. pyrolysis of waste and organic materials to produce solid, liquid and gaseous fuels for energy may increase; e.g. driven by new technologies and waste strategies at national and EU level, based on selection, recycling and energy recovery (Hedman et al., 2005; Baggio et al., 2008).

Further knowledge on these new technologies and potential unintentional emissions of HCB and PCBs from waste-to-energy production processes in the Nordic countries is required.

As far as the authors are aware, no statistics on the use of secondary fuels for energy production are available at this stage of development and therefore this source can only be assessed as an emerging, and expected, growing industry.

Large combustion plants (PRTR code 1 c)

Information from the IPPC reference document on BAT for large combustion plants (IPPC BREF LCP, 2006) includes an emission factor of 11 mg/Nm³ for PCB emissions to air from biomass-fired atmospheric fluidized bed combustion (AFBC) plants with a capacity of 100–300 MW_{th}. The emissions from large combustion plants are divided into capacity ranges of 50–100 and 100–300 MW_{th}, respectively, and no PCB emissions are reported for the low-range capacity combustion plants. To the knowledge of the authors this type of plant no longer operates in any of the Nordic countries. No emission for HCB is included in the BAT document (IPPC BREF LCP, 2006). However, available information concerning sources of unintentional emissions of HCB and PCBs and their correlation to dioxin emissions does not support that there will be no HCB emission from either of the two size categories of large combustion plants, or that PCBs will only be emitted from the high-range capacity combustion plants (Kenichi et al., 2002).

The document (IPPC BREF LCP, 2006) indicates that co-combustion of sewage sludge does not increase the flue-gas concentration of PCBs; in fact, the PCB concentration seems to be lowest in the flue gas with sewage sludge co-combustion – 8.25 ng/m³ – versus 9.8 ng/m³ without sewage sludge co-combustion. An explanation may be that the factor governing the

UPOP concentration in flue gas is determined by the level of application of air pollution control devices (APCD) and other combustion process parameters (e.g. Andrijewski, M. et al., 2004). The energy sector may contribute to the unintentional emission of HCB and PCBs to air, depending on the feed material used for energy production, when comparing plants of the same size and with similar technological characteristics.

Even if PCBs are present as contaminants in secondary fuels but destroyed in the combustion chamber, they may be reformed or *de novo* synthesized. *De novo* synthesis of PCBs is possible due to the presence of non-chlorinated precursors where there is an associated supply of inorganic chlorine substances in the secondary fuels, such as demolition wood or refuse-derived fuel (RDF). HCB and PCB emissions may, as in the case of dioxin emissions, be reduced by means of injection of an activated carbon into the flue gas.

Emissions of dioxins and furans from coal-fired plants are low due to their specific combustion characteristics and the sulphur content of the fuel, which inhibits the formation of these compounds; this may also be true for the formation of PCBs (Leclerc et al., 2006). This does not change with co-combustion, even with a secondary fuel with high chlorine content (IPPC BREF LCP, 2006; Leclerc et al., 2006). Technological developments may even further decrease the *de novo* formation of UPOPs (Pandelova et al., 2006; Ishikawa et al., 2007).

A recent study has shown that the dioxin emissions from 17 different combustion categories are approximately linearly correlated with the copper and chlorine content of the feed material, whereas the dioxin emissions are linearly inverse in relation to the average content of sulphur in the feed material (Thomas and McCreight, 2007). Kim et al. (2004) have shown that PCB and dioxin represent 7% and 9% respectively of the HCB stack emission. The study by Kenichi et al. supports the correlation of HCB and PCB, respectively, to measured dioxin emissions in the flue gas of industrial waste incinerators. The above-mentioned investigations include different types of waste which are of relevance for PRTR category 5a-c as well (see section 5 Waste and wastewater management in Table 2).

It is outside the scope of this study to address the facility-specific activity data and therefore the emission estimates from the Energy sector are based on fuel consumption from the most recent submission to the UNFCCC (see Annex 1). PCB and HCB emissions from the Energy sector are based on available information on fuel consumption reported by the individual countries; extracted from national inventory reports of the CRF (Common Reporting Format) tables. The use of alternative fuels is not included in the screening level air emission estimates included in this study.

For all the Nordic countries, unintentional emissions of HCB and PCB from combustion are likely to be of importance. The higher activity data

for energy production from combustion of municipal solid waste for Sweden and Denmark may result in the unintentional emission from energy production contributing to a greater degree to the total PCB and HCB emission in these countries compared with Finland and Norway. The lower consumption of coal for Norway and Sweden compared with Denmark and Finland may be explained by the alternative energy sources available in the former in terms of hydro and nuclear power.

Table 4 Fuel consumption for Energy production for 2005, divided into the fuel types municipal solid waste, coal and wood [tonnes]

Source sector*	Fuel type		
1. Energy Industries			
a. Public Electricity and Heat Production	Coal	Wood**	MSW
Denmark	5 904 545	1 358 527	3 316 932
Finland	3 053 373	6 995 210	361 290
Norway	47 000	151 000	697 000
Sweden	426 902	7 659 748	3 250 000
2. Manufacturing Industries and Construction	Coal	Wood*	MSW
Denmark	306 480	309 362	184 000
Finland	1 132 549	13 802 605	NO
Norway	110 200	548 700	94 000
Sweden	414 223	4 820 756	NO

NO: Not occurring

*IPCC nomenclature

**may include wood waste (national expert knowledge)

References:

National expert knowledge and Inventory Reports submitted in 2007 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php

Details of available emission factors are provided in Annex 1, while emission estimates are provided in Chapter 3.

According to Bailey (2001), coal combustion is the third-largest global source of HCB emission. Still, fossil fuel combustion is suggested to produce a much lower level of UPOPs compared to waste-derived fuels (Sloss and Smith 1993; Sloss 2001; Dyke 2004), due to the inhibiting effect of sulphur on the *do novo* synthesis of HCB and PCBs. Sulphur is suggested to inhibit the formation of chlorinated UPOPs by two mechanisms: the presence of SO₂ depletes molecular chlorine through a gas-phase reaction and SO₂ reacts with copper (CuO and CuO₂) to produce CuSO₄. Thereby the presence of sulphate is suggested to deplete molecular chlorine as well and the presence of copper as a catalyst for *de novo* synthesis of HCB and PCBs (Raghunathan and Gullett, 1996). The sulphur-to-chlorine ratio in coal is around of 5 to 1, which is much greater than that found in municipal solid waste, thus preventing the formation of chlorinated aromatics which arise in the combustion waste-derived fuels where chlorine dominates over sulphur (Mobbs, 2005). The chloride content of individual fuel types is given in Annex 4.

The above parameters refer to non-optimally operated combustion systems. In properly operated combustion systems, volatiles are subject to high temperatures for sufficient time, with adequate oxygen and mixing, to enable uniform and complete combustion. When those conditions are not present, PCBs and HCB (similar to dioxins) may be formed by *de novo* synthesis or survive the combustion process (Van Remmen 1998; UNEP 2003) and result in unintentional emissions to air. According to e.g. Zevenhoven and Kilpinen (2001), *de novo* formation is determined by:

- The cooling rate of the flue gas, especially around 300°C
- The amount of fly ash
- The presence of trace elements, especially Cu and Pb
- The carbon and chlorine content of the fly ash
- The presence of free oxygen

Solid residues, in terms of ashes and slag are a by-product of the combustion processes (e.g. Dyke, 2002) and may potentially release PCBs and HCB. The reported concentration in residue products from combustion based on coal only and sewage sludge co-combustion is 0.02 µg/kg residue product (IPPC BREF LCP, 2006).

In Table 5, an example of off-site transfer of residue products from combustions processes within the energy sector is provided.

Table 5 Extracts from reuse categories in the Danish waste statistics, with focus on residues from combustion with energy production [1,000 tonnes]

Year	1995	1996	1998	2000	2002	2003	2004	2005
Fly ash and slag from coal combustion plants, inclusive bioash	1 276	1 213	859	770	802	1 090	851	783
Fly ash and slag from other sources except for combustion	3	2	2	1	60	54	60	59
Flue-gas cleaning products	288	416	400	406	388	323	329	270

Reference: Danish waste statistics 2005 (DEPA, 2006b)

The Danish waste statistics, in addition to the figures shown in Table 5, report fly ash disposed of to landfill (DEPA, 2006b). Definitions of waste, residue products or when waste becomes a new product and the relationship to reuse, recovery and recycling processes are not within the scope of this study. Still, life-cycle analysis of end-of-pipe products or waste is of importance for determining mass flows and potential releases to soil and water as well as the risk of UPOPs re-entering the product cycles. According to a quality report for statistics on generation and recovery and disposal of waste in Sweden, ashes, slag and mineral waste from combustion processes are either disposed of at landfill or used as construction material in e.g. roads (Swedish Environmental Protection Agency, 2006). Off-site transfer from the Energy sector may contribute to

the diffuse source category '*Roofing and road paving with asphalt*' as described in section 2.2.1.

Technological improvements in combustion and incineration processes towards higher DRE suggest a decrease in potential emissions to air. Information regarding potential releases with solid residues and waste streams, and with dust in wastewater, is limited (e.g. BiPRO, 2006). In general, point source releases in effluent are of minor importance due to the limited solubility of the UOPs. UPOP-contaminated dust in the water used in wet scrubbing of flue gas may be a potential source of HCB and PCB release via separate effluent from industry.

To the extent of the knowledge of the authors, consideration of industrial plants categorized under the PRTR subcategories, *Coke ovens (PRTR code 1d)*, *Coal rolling mills (PRTR code 1e)* and *Installations for the manufacture of coal products and solid smokeless fuel (PRTR code 1f)*, is not relevant as these activities either do not occur or are not relevant in relation to unintentional sources of HCB and PCBs in the Nordic countries.

2.1.2 The Metal Industry

Potential sources of emission vary widely depending on the type of processes and technological aspects of the production processes involved. Therefore there is no straightforward way of calculating or assigning emission factors to the different production processes within the metal industry. Detailed data based on available knowledge produced during this project are given in Annex 2. Data may be incomplete due to the limited knowledge of the authors regarding the specific industries present in the other Nordic countries and the timeframe of the project.

Activity data for the production of ferrous and non-ferrous metals have been extracted from the European Association of Mining Industries, the US Geological Survey and national expert knowledge and statistics (see Annex 2, Table 2.1). A description of relevant sources is given below.

Iron and steel production (PRTR 2b)

For steel production a very important factor is whether the steel is produced from primary metals or from scrap metal (secondary metal production), with the latter giving rise to much higher dioxin emissions and therefore presumably also HCB/PCB emissions. PCBs can be formed in trace amounts from chlorinated precursors in thermal processes such as scrap metal recycling. The iron and steel industry is a highly material- and energy-intensive industry. More than half of the mass input becomes output in the form of off-gases and solid wastes/by-products. As a result, significant emissions are associated with the iron and steel industrial sector.

The types of plant involved in the main processing steps in pig iron and steel production are coke plants, sinter plants, blast furnaces, basic-oxygen furnaces and electric arc furnaces (EAFs). To the knowledge of

the authors only sinter plants and EAFs are in operation in the Nordic countries. Knowledge of potential sources from these two plant types are given below. For the remaining plant types no emissions of HCB or PCB are included in the IPPC BREF document (IPPC IS, 2001).

Sintering plants

High concentrations of a full range of PCB congeners/homologues have been measured in the atmosphere close to sintering strands (Alcock et al., 1999) and local soil pollution as well as groundwater pollution are other matters of concern for the iron and steel industry (IPPC, IS, 2001).

The IPPC BREF note on iron and steel production (IPPC IS, 2001) provides an emission factor of 1–13 mg/ t liquid (LS) produced, with 2,100 m³ off-gas/t sinter.

Sinter plants produce residues or by-products in the range of 0.9–15 kg dust / t LS and 0.3 t sludge /t LS. Moreover, use of hexachloroethane for removing magnesium from the melt may result in high HCB concentrations in the off-gas and dust contamination. However, the use of hexachloroethane is no longer applied in the EU (Guidelines on BAT and Guidance on BEP, 2006).

Emissions to water may occur from sinter plants using rinsing water techniques, cooling waters, which are usually recycled, and wastewater from gas treatment.

Electric arc furnaces (EAF)

For electric arc furnaces the emission in the primary gas is in the range of 1,500–45,000 µg PCB/t LS and 3,000–37,000 µg chlorobenzenes/t LS; the latter includes all chlorobenzenes except for monobenzene. The treatment processes within the metal industry also produce secondary emissions, including dust that also contributes to the HCB and/or PCB emissions if present in the primary gas.

Collected dust from off-gases is largely disposed of at landfill, but this depends on national laws governing legal requirements with regard to reuse. At modern EAF off-gas systems it is possible, with a fabric filter, to reach a clean gas dust concentration of less than 7 mg/Nm³. In addition, processing of slag includes cooling by water; with the slag being reused and thereafter disposed of as landfill.

Table 6 Activity data on production processes of relevance for potential sources to HCB and PCB emissions [tonnes]

Plant type	2001	2002	2003	2004	2005	Reference
Sinter plants						
Denmark	NO	NO	NO	NO	NO	3
Finland	2 650 000	2 573 693	2 815 000	2 782 000	2 857 000	1
Norway	60 000	80 000	90 000	90 000	90 000	1
Sweden	3 725 100	3 815 100	3 816 100	3 992 000	3 844 000	3
Electric arc furnaces						
Denmark	746 000	392 000	NO	NO	NO	1
Finland	3 938 000	4 003 000	4 766 000	4 833 000	4 738 000	2
Norway	635 000	694 000	698 000	695 000	690 000	1
Sweden	1 870 100	1 941 000	1 819 000	1 874 000	1 802 000	3

NO: Not Occurring

References:

1: US Geological survey; <http://minerals.usgs.gov/minerals/pubs/country/europe.html>; Finland: Association of Finnish Steel and Metal Producers

2: Association of Finnish Steel and Metal Producers

3: National expert knowledge

Denmark has no sintering plants, Finland has one, whereas Norway and Sweden have higher activity data regarding sintering and are therefore likely to have more sinter plants. Denmark has one electric arc furnace (EAF) and Finland two, while Sweden had around 11 EAFs in 1997 (IPPC BREF ISI, 2001). Finland has more EAFs in foundries, but only one in operation in iron and steel production plants. Denmark's only iron and steel production plant closed down in 2002 as can be observed from the figures in Table 6. Only sinter plants and EAFs are reported to be sources of emissions of HCB and PCB within the iron and steel production plants; therefore only these activities are included.

Of the Nordic countries, the majority of activity regarding iron and steel production occurs in Sweden and Finland, and only to a minor extent in Norway. For Denmark, there are no potential sources of unintentional emissions of HCB and PCBs from iron and steel production.

Ferrous metal industry (PRTR 2c and d)

Processing in the ferrous metal industry includes elemental chlorine, but very little information about the production of unintentional POPs is addressed in the IPPC reference document on the best available techniques (IPPC, BREF FMPI, 2001). Denmark has no ferrous metal foundries and the degree to which Norway, Sweden and Finland have plants for the processing of ferrous metals is unclear. The only sources included in this study are the sinter and EAF operating plants in relation to the processing of pig iron and steel, as well as coke production as provided in Table 7.

Potential sources to emissions may also occur from further processing of alloys, including e.g. wrought iron and scrap iron. Potential soil contamination from ferrous foundry raw materials arises from external storage of the scrap on soil. Contaminants of concern are oils that may in-

clude PCBs from capacitors; mainly shredded scrap with risk of washing out to the groundwater and nearby surface water (IPPC BREF SFI, 2005).

Activity data for coke production within the iron and steel industry are only relevant for Finland and Sweden and relate only to the emission of PCB (BiPRO, 2006).

Table 7 Activity data on coke production figures as potential sources to PCB emissions [tonnes]

Coke production	2001	2002	2003	2004	2005	Reference
Denmark	NO	NO	NO	NO	NO	1
Finland	909 000	912 000	895 217	903 723	893 628	2
Norway	NO	NO	NO	NO	NO	1
Sweden	1 184 900	1 073 300	1 059 700	1 179 000	1 188 000	3

References:

1: US Geological survey; <http://minerals.usgs.gov/minerals/pubs/country/europe.html>

2: Association of Finnish Steel and Metal Producers

3: National expert knowledge

As observed from Table 7, the activity in coke production corresponds to the high activity in iron and steel production, coke production being associated with ferrous metal processing.

Potential emissions from production processes at foundries for the production of non-ferrous metals are described below. Production statistics used as activity data for the screening level estimation of emissions of HCB and PCBs from these industrial activities are given in Table 2.1 in Annex 2.

Non-ferrous metal industry (PRTR code 2e)

Potential emissions associated with the production of non-ferrous metals are related to the use of secondary raw materials including chlorine and therefore the potential for formation and release of UOPs via the off-gases from the various furnaces and transfers. APCD to capture dust in the off-gas and/or afterburning techniques to increase the DRE of UOPs in the off-gas will reduce any unintentional emissions (IPPC, BREF on NFMI, 2001).

The presence of precursors, especially Pb and Cu, for the formation of PCBs and HCB during pyro-metallurgical processes to produce non-ferrous metals is a potential source of air emissions. Off-gas, i.e. gas produced during process stages such as sintering or roasting, smelting and casting, may include *de novo* produced chlorinated aromatics such as PCBs and HCB, therefore capturing and cleaning is needed to reduce potential emissions. Some non-ferrous metals, e.g. copper and lead, are reported to catalyse *de novo* synthesis. Therefore, a clean gas and quality control of the scrap used as feed material for non-ferrous metal production will decrease the risk of *de novo* formation of UOPs due to precursor impurities in the off-gas. Treatment methods such as electrostatic filters, scrubbing and afterburning will reduce potential releases from

residues such as furnace linings, sludge, filter dust and slag (IPPC, BREF on NFMI, 2001). As such, emission factors may vary accordingly.

Primary non-ferrous metal production is not associated with major dioxin emissions to air and therefore is expected to be of no concern for *de novo* production of HCB and PCBs.

Secondary aluminium

Secondary aluminium producers recycle aluminium from aluminium-containing scrap. The production process includes therefore pre-treatment cleaning processes, which are based on mechanical, pyro-metallurgical and hydrometallurgical techniques that lead in varying degrees to dioxin emissions. Therefore secondary aluminium production also results in the formation and release of HCB and PCBs. Finland reports a off-gas reduction efficiency of 51 % for HCB with a concentration of 5.78 $\mu\text{g}/\text{m}^3$ before filtering and 2.66 $\mu\text{g}/\text{m}^3$ after the filter (Saarinen et al, 2007).

Magnesium production

Production of magnesium from magnesium chloride by electrolysis may result in the generation of dioxins/furans and HCB. The only Nordic country producing magnesium is Norway and this production ceased in 2001, when the Norwegian transnational company, Norsk Hydro, moved its magnesium production (www.hydromagnesium.com) from Norway to China. This indicates that this source is no longer relevant for the Nordic countries and corresponds to the fact that magnesium production was reported only for Norway, and only in the years 2001 and 2002 (European Association of Mining Industries).

Copper production

The sources of potential emissions of dioxin, and by assumption therefore PCBs and HCB, from the copper production processes are scrap treatment and smelting according to the IPPC BREF document (IPPC, BREF, NFMI, 2001). Secondary smelting processes in copper production may use computer scrap and printed circuit boards as copper source. Therefore the pre-treatment of scrap by both the scrap industry and by some smelters influences the emission potential. Secondary smelters are more prone to fugitive emissions during charging and tapping cycles. Secondary copper smelting and refining are included in the Finnish HCB air emission inventory (Saarinen et al., 2007) and are on the list of major sources according to the Stockholm Convention.

Precious metals

The recovery of precious metals from secondary raw materials is particularly important and many of these materials are classified as wastes from other industries. Advanced processing techniques are used to contain these materials and the small scale of production allows these techniques

to be used effectively to minimize and abate potential emissions (IPPC, BREF, NFMI, 2001).

Finland, Sweden and Norway are involved in production of other metals, but for these processes no information regarding PCB or HCB emissions are available (e.g. BiPRO, 2006; Saarinen et al, 2007; IPPC, BREF NFMI, 2001).

Table 8 Activity data for the non-ferrous metal industry [tonnes]

Production processes	2001	2002	2003	2004	2005	Reference
Secondary Aluminium						
Denmark	18 000	18 000	18 000	20 000	20 000	1
Finland	34 252	28 014	23 652	24 629	20 242	4
Norway	223 900	271 000	256 800	348 700	362 400	1
Sweden	25 000	28 000	30 000	29 000	30 000	1
Primary zinc						
Denmark	NO	NO	NO	NO	NO	1,3
Finland	43 125	47 716	51 684	49 890	49 403	5
Norway	129 300	137 300	143 500	140 900	133 300	1
Sweden	156 334	148 600	185 900	197 000	214 600	1
Total copper production						
Denmark	NO	NO	NO	NO	NO	1
Finland	405 170	391 283	395 884	390 289	392 865	1,2,4
Norway	26 700	30 500	35 900	35 600	38 500	1
Sweden	208 000	223 000	215 000	236 000	222 000	1
Precious metals						
Denmark	NO	NO	NO	NO	NO	1,3,5
Finland	28	35	40	39	38	4
Norway	1	1	1	1	1	5
*Sweden	311	325	304	297	4	3

NO: Not Occurring

*the data for precious metals includes silver and gold for all years except 2005, for which year no data on silver production was reported. The figures for silver production data may be overestimated.

References:

- 1: US Geological survey; <http://minerals.usgs.gov/minerals/pubs/country/europe.html>
- 2: VAHTI (data system of the Finnish Environmental Institute)
- 3: European Association of Mining Industries; <http://www.euromines.org/>
- 4: Teknologiateollisuus, Year books 2004 and 2007; www.teknologiateollisuus.fi
- 5: National expert knowledge

The activity data in the above table summarizes figures for specific production processes depending on the origin of the feed material for the production. Detailed information on primary, secondary and other special production and production processes are given in Annex 2, Table 2.1.

Magnesium production, which was a major source of HCB emission, no longer occurs in the Nordic countries. Secondary production processes, which may be based on new and end-of-life scrap, are more potent sources of UPOP emissions compared with primary production processes. However, changes in the production cycles and improved quality of recycled material indicate a decreasing level of the presence of precursor impurities in recycled metal shredder and scrap material.

Aluminium and copper production are major contributors to potential emissions from the non-ferrous metal industry.

Copper production is at a higher level in Finland and Sweden compared to Norway. Finland, which has the highest copper production of the Nordic countries, also has highly specialized production processes for different types of feed material (see Annex 2, Table 2.1).

Aluminium production is a major source for Norway, but the source potency in terms of potential HCB emissions is highest from copper production. For PCB the potential emission intensity is comparable (see Annex 2, Table 2.2 and 2.3).

Precious metals include silver and gold. The associated production processes are judged of little importance for the non-ferrous source sector, as the figures for Sweden seems to relate to production capacities and not actual production levels.

Increased emissions from foundries using recycled metals and scrap in multi-melting furnaces may occur, depending on the quality of the input material (Alcock et al., 1999). However, most industrial processes have been updated and new BAT approaches have been implemented to decrease the unintentional emission of HCB and PCB as well as to increase the Destruction and Removal Efficiency (DRE) within all sub-processes, reducing both emission and contamination levels in residue products. The CORINAIR Emission Inventory Guidebook (EMEP, 2006) recommends emission factors for fragmentizing operation facilities (*PRTR code 2c and f*) of 0.25 g/t recycled ferrous scrap. However, data on export-import in terms of masses are scattered and very uncertain and no estimates of this activity have been included in this study.

Table 9 Ferrous and non-ferrous scrap material flow from the recycling industry in Denmark [tonnes].

Year	1995	1996	1998	2000	2002	2003	2004	2005
Denmark*	100 6000	933 000	971 000	1 089 000	718 000	857 000	634 000	475 000

*No differentiation between ferrous and non-ferrous metal scrap

Reference: DEPA, 2007

Increased minimization of the environmental impacts of metal recycling driven by the EU (Directive 2002/96/EC) and national waste strategies via new technologies are not addressed any further in this study. Emissions from thermal treatment processes in the pre-processing of metal scrap occur during an integrated process, separating plastics and halogens from the metals scrap; a methodology based on an integrated energy and materials recovery and recycling approach. There are methodologies for WEEE recycling and processes designed for the purpose of meeting the new EU WEEE recycling targets. Of interest in relation to UOPs in this study is the treatment of halogen-containing compounds in complex fractions of WEEE waste such as scrapped circuit boards in such a way that valuable metals can be recovered with no UPOP emission. In principle, end-of-life electric and electronic equipment and end-of-life vehicles both are sources of emissions of UOPs due to thermal processes included in

the separation of halogens, plastics and metals prior to reuse of the metal scrap. Shredder plants for the treatment of end-of-life vehicles are included in the list of sources of UPOPs in the Stockholm Convention, Annex C, Part III and further described in section 2.5.

2.1.3 The Mineral Industry

Cement production (PRTR code 3c)

Cement production may represent a source of unintentional emission of HCB/PCB; to some extent dependent on the feed material utilized. However, the DRE is 99–99.9999%, so despite the activity, expressed as the amount of cement produced, is high, the emission factor (to air) is expected to be very low (Karstensen, 2004, 2006 and 2007). A factor influencing the potential unintentional emission is the type of feed material used; e.g. the use of combustion residues such as electrostatic precipitator (ESP) fly ash from combustion of milled coal (Goodarzi, 2006) or other recycling material containing chloride. Still, cement-producing facilities have high quality requirements applying to feed material (Ito et al., 2007; Kikichi et al, 2007) and specified limits for the chloride content of feed material of 0.1 percent dry weight (CemMiljø A/S).

The emission of HCB and PCBs from cement-producing facilities may increase with increasing chlorine content of the feed material if the production process does not include cleaning and filtering activities for the reduction of dioxin emissions (Institut for Miljøvurdering, 2004). Filtering will increase the concentration of HCB and PCBs in solid and liquid residues if present or produced in the production process (cf. section on incineration of municipal solid waste).

The average exhaust-gas volume is 2300 Nm³/ton of clinker. The primary fuels used in the cement industry are coal, petroleum coke, heavy oil and – to a lesser extent – natural gas. The effect on the emissions of PCDD/PCDF, PCB and HCB of increasing the total thermal substitution rates with alternative fuels and raw materials (solvents, animal meal, bleaching earth, rubber, waste oil, paper and film plastics, fly ash and waste wood) is negligible. A recent study indicated no effect from increased substitution and showed concentrations of PCBs and HCB < 4 ng/m³ (Karstensen, 2007 in press) or 0.4 µg PCB TEQ/Nm³ (Karstensen, 2006; Cement Kilns BAT note, 2006). As part of the general BEP principles it is expected that co-combustion of hazardous waste in cement kilns will increase with time (IPPC, 2007). The worst-case emission scenario from the cement industry in the four Nordic countries has been calculated by assuming that the additional constituents besides clinker in cement corresponds to 10% of the total cement production given in tonnes; activity data are given in Annex 2.

A study by Abad et al. (2004) does not confirm a proportional relationship between emissions from the cement industry and material used

for co-combustion (secondary fuel) in addition to fossil fuels as primary fuel. The influence on co-combustion of secondary fuels, ranging from meat meal to used tyres and hazardous waste, was measured and reviewed, and insignificant increases in the emission values that remained below the limit according to the European Union Directive of 0.1 ng I-TEQ/Nm³ were shown, with values ranging from 0.001 to 0.042 ng I-TEQ/Nm³ - however, only PCDD/Fs were included, not PCBs. Ranges in emission factors for the emission of PCB and HCB to air from co-combustion processes in the cement kiln are provided in Table 2.2 of Annex 2.

Table 10 Activity data for potential source within the mineral industry [tonnes]

Year	2001	2002	2003	2004	2005	Reference
Cement production						
Denmark	2 660 972	2 698 459	2 546 295	2 861 471	2 706 371	5
Finland	1 324 705	1 194 676	1 185 886	1 295 058	1 347 007	2
Norway	1 870 000	1 850 000	1 860 000	1 870 000	1 900 000	1
Sweden	2 640 600	2 642 000	2 491 000	2 604 700	2 730 700	3
Lime production						
Denmark	105 498	134 647	99 270	90 376	85 078	6
Finland	2 042 200	2 259 900	1 919 000	1 900 300	1 852 400	4
Norway	100 000	100 000	100 000	100 000	100 000	1
Sweden	550 000	580 000	590 000	590 000	600 000	1

References:

- 1: US Geological survey; <http://minerals.usgs.gov/minerals/pubs/country/europe.html>
- 2: VAHTI (data system of the Finnish Environmental Institute)
- 3: National expert knowledge
- 4: Kemia Kemi, 6/2006 p. 67 & 6/2003 p. 58
- 5: Figures from the Danish producer, Aalborg Portland Cement
- 9: Statistics Denmark

Production of cement is at the same level in Denmark and Sweden, while Norway and Finland have slightly lower activity for cement production.

Lime production activity is very high in Finland compared to the remaining Nordic countries. Regarding the figures for lime production from US Geological Survey, these overestimate the Danish figures, while the Finnish production data is significantly underestimated (see Table 2.1 in Annex 2). Despite the uncertainty associated with the activity data, lime production is considered of minor importance to the overall picture for the mineral industry sector, due to the low potency of emissions from this activity (see reported emission factors in Annex 2, Table 2.2 and 2.3).

Glass and glass fibre production (PRTR codes 3e and f)

The furnaces encountered within the glass industry, and within each individual sector, vary considerably in size, throughput, melting technique, design, age, raw material utilized, and the abatement techniques applied. Therefore, considerable variation is apparent in the emissions reported. Chloride may occur as an impurity in input material, and for some production types NaCl is used as a raw material as well. In processes including

organic additives as raw materials for pre-processing into blends transferred for melting in furnaces, HCB and PCBs may be *de novo* synthesized. However, as with any other industrial combustion process, facilities manufacturing glass products are able to decrease emissions by utilizing bag-house filters, electrostatic precipitators (ESPs) or using aqueous media (e.g. a wet scrubber) (IPPC, Reference document on BAT, GL, 2001; Australian Government, 2004).

Low but measurable concentrations of PCB have been detected in a Swedish study on ash samples from a small ceramic facility, while the HCB content of the ash was 53 µg/kg ash (Naturvårdsverket, 2005).

Where wet scrubbing and quick cooling of flue gas for the reduction of dioxin emissions are performed, the wastewater may be a source of release to water, depending on national laws, taxes and off-site treatment procedures (IPPC, BREF, GMI, 2001).

The numbers of installations in the Nordic countries producing mineral wool (*PRTR code 3f*) are 4, 5, and 5 in Denmark, Finland and Sweden, respectively (the 1996 production level per country being 7 – 9% of the total EU production, IPPC, BREF, GMI, 2001). For domestic glass there is 1 installation in Denmark, with 15 in Sweden and at least 4 in Finland. Still, the largest sector is production of container glass. The number of furnaces reported in relation to container glass is 1 installation in each country, and 3, 2 and 2 furnaces in Denmark, Finland and Sweden, respectively; Norway is not included.

Emissions to air may be a problem if e.g. dust is contaminated with UPOPs. Initiatives have been implemented to reduce waste generation and to recycle in-house and post-consumer waste.

Release to the water environment is relatively low, but is not specified according to contamination type.

Ceramics (PRTR code 3g)

In the reference document for BAT in the Ceramics Manufacturing Industry (IPPC BREF CMI, 2007), emissions of chlorinated organic compounds are not mentioned. Clays containing trace levels of chloride or water containing chloride are possible sources in the manufacturing process from which the occurrence of HCl may result in the firing process in the flue gases of the kiln. In addition to the organic content of the raw material, thermal process technologies involving fuels like oil, coal and alternative/secondary fuels, which may contain chlorine as well, are part of the production process. Therefore, it seems possible that PCBs and HCB may be emitted during production of e.g. roofing tiles and bricks (*PRTR code 3g*). In addition, contamination of process water may occur during the operation of wet off-gas scrubbers. The water added directly to ceramic body mixes subsequently evaporates into the air during the drying and firing stages (IPPC BREF CMI, 2007). Process water from wet scrubbing contains dust that may

increase the risk of release in effluent water; this is a general phenomenon for flue-gas or off-gas cleaning processes.

To the knowledge of the authors, asbestos (*PRTR code 3d*) is not produced in any of the Nordic countries and is judged of minor importance, if any, regarding unintentional emission of HCB and PCBs. Likewise, no activities categorized under *PRTR code a* and *b* could be identified as either occurring or relevant sources of UPOPs.

2.1.4 The Chemical Industry

As described in the introduction, and as implicit given by the title of this project, HCB and PCBs are not used, produced or imported in any of the Nordic Countries. Still, halogenation is one of the most important and versatile processes in chemistry. Its industrial application is dominated by chlorination, due to the different reactivity and the higher prices attached to bromine, iodine and fluorine.

Organic chemicals industry (PRTR code 4a)

The IPPC reference document on BAT for the production of organic fine chemicals (IPPC BREF OFC, 2006) focuses on the batch manufacture of organic chemicals in multipurpose plants and addresses the manufacture of a wide range of organic chemicals, but evidently not PCB and HCB. Still, chlorinated solvents prepared using modern techniques of purification include HCB impurity levels in the low $\mu\text{g/kg}$ (parts per billion) range (< 20 for trichloroethylene and < 10 for perchloroethylene). The IPPC reference document includes a sub-chapter on co-incineration of halogenated waste solvents together with exhaust gases from production processes at combustion temperatures of $1100\text{ }^{\circ}\text{C}$ and with residence times of 2 seconds or higher. Temperature control to prevent *de novo* formation of PAH, PCB and dioxins, and subsequent flue-gas treatment resulted in emission levels of $0.006\text{ }\mu\text{g PCB/m}^3$ clean gas, the waste solvent input being low weight aliphatic alcohols and methylene chloride (for details, cf. Table 4.47 in IPPC BREF OFC, 2006).

Large Volume Organic Chemicals Industry (PRTR code 4a)

The reference document on BAT within the Large Volume Organic Chemicals (LVOC) Industry gives an emission factor for PCBs of 0.1 ng I-TEQ/Nm^3 for good operation conditions in process vent (IPPC BREF LVOC, 2003). Furthermore, the document states that ‘polychlorinated dibenzodioxins (dioxins), polychlorinated dibenzofurans (furans) and polychlorinated biphenyls (PCBs) may be generated as pollutants from certain production processes that use chlorine’. Dioxins can also be emitted from incinerators treating a chlorinated or non-chlorinated feedstock if improper operating conditions are used’. HCB is mentioned as a water effluent contaminant; a wastewater effluent concentration level of HCB and PeCB

(Pentachlorobenzene) of 1 µg/l is reported as BAT for effluent where the final treatment is biological treatment (IPPC BREF LVOC, 2003). Effluent concentrations in wastewater from the chemical sector as well as waste gas emissions depend on the degree of technology implemented for the reduction of these emissions (cf. IPPC BREF CWW, 2003).

According to the Corinair Emission Inventory Guidebook (EEA, 2006), default emission factors to use when estimating the emission of HCB from the production and use of chlorinated organic solvent are in the range of 2 to 10 g/t for production of the solvents tetrachloromethane, trichloroethylene and tetrachloroethylene (Duiser and Veldt 1989). A default emission factor for unspecified chlorinated solvent production and use is 2 mg/t (EEA, 2006).

Production of fertilizers (PRTR 4c)

Some chlorine-containing pesticides may contain impurities of HCB as this compound is formed as a by-product during the production of e.g. Lindane, Dacthal (DCPA), Pentachlorophenol, Atrazine, Simazine, Picloram, Pentachloronitrobenzene (PCNB, quintozone), Chlorothalonil, Endosulfan and Clopyralid (see Annex 3).

Information from Cheminova's homepage indicates that chlorpyrifos is produced in Denmark under the trade name Cyren®/Nufos® (chlorpyrifos)¹. It is not known to the authors whether chlorinated pesticides are produced in Finland or Norway. No pesticides are produced in Sweden (Naturvårdsverket, 2005).

The use of pesticides known to include HCB impurities, and therefore representing a potential source to unintentional HCB emission, is prohibited in Denmark (DEPA, 2007). Of the above mentioned HCB-containing pesticides, chlorpyrifos is included in the Finnish sales statistics from 2006². None of the HCB-containing pesticides are in use in Sweden (Naturvårdsverket, 2005). Activity data on the production of pesticides are not available, but use-data for Finland are included as a diffuse source (see Table 18) and in Annex 3.

Inorganic chemicals industry (PRTR code b)

The IPPC reference document on production of special inorganic chemicals (IPPC BREF SIC, 2007) includes one activity that may result in unintentional emission of PCB, i.e. the utilization of industrial waste, and especially petrochemical residues, for power generation. This type of increased optimization of the use of biological energy resources, e.g. waste-to-energy approach, is based on highly developed technological processes, such as dry flue-gas treatment, to eliminate any wastewater contamination, and multiple-step combustion chambers to increase the

¹ http://www.cheminova.dk/dk/produkter_02/cyren/20021010_01.htm

² http://www.evira.fi/attachments/kasvintuotanto_ja_rehut/kasvinsuojeluaineet/tilastot/2006/myynti_rk_2006.pdf

reduction and destruction efficiency at the same time as energy production (IPPC BREF SIC, 2007).

Denmark has no chlor-alkali plants for the production of chlorine, sodium or potassium hydroxide, while Sweden, Norway and Finland produce chlorine with decreasing capacity from 2000 and forward according to European statistics (IPPC BREF CAMI, 2001).

No information about the emission potential is given in the IPPC BREF document for the Chlor-Alkali Manufacturing Industry and this activity has not been included in the emission estimates. However, chlorine is used for synthesis of e.g. organic chlorinated solvents, and this production is included in the inventory as mentioned below (IPPC BREF CAMI, 2001).

The Finnish HCB inventory includes the production of potassium sulphate as the most important source of unintentional emissions of HCB in Finland (Saarinen et al., 2007). No attempt has been made to investigate the specific production processes other than the ones that are included in the BAT reference documents (BREFs) under the IPPC Directive and according to point source sectors as defined in Table 3. An overview of sources of UOPs in Sweden may be found in the report from Naturvårdsverket published in 2005, although data gaps are present. The available information is provided below.

Table 11 Activity data for solvent production within the Chemical industry [tonnes]

Year	1999	2000	2001	2002	2003	2004	2005	Reference
Organic Chemicals production								
Chlorinated solvent production								
Denmark	63	9	0	4,068	804	NR	NR	1
Finland	0	0	0	0	0	0	0	2
Norway	NR	NR	NR	NR	NR	NR	NR	
Sweden	NR	NR	NR	NR	NR	NR	NR	
Inorganic Chemicals production								
Potassium sulphate								
Denmark	NR	NR	NR	NR	NR	NR	NR	
Finland	NR	NR	178 685	195 841	172 771	196 163	NR	2
Norway	NR	NR	NR	NR	NR	NR	NR	
Sweden	NR	NR	NR	NR	NR	NR	NR	

NR: Not Reported

References:

1: Statistics Denmark

2: Saarinen et al., 2007

Data on production and uses in the Nordic countries is very limited and scattered data and data gaps clearly exist (e.g. Naturvårdsverket, 2005). Therefore estimated emissions from the chemical industry are not consistent and comparable between countries and may not be representative of the current situation. Available emissions factors for HCB are given in Annex 3 and estimated emissions in Chapter 3. As a result of the clean production action (Clean Production Action, 2006) it is suspected that

production volumes are on the decrease. Information on Swedish production of vinyl chloride exists, but no activity data was available (Naturvårdsverket, 2005).

2.1.5 Waste and waste management

The IPPC reference document on BAT for the waste treatment industries (IPPC BREF WTI, 2006) is of relevance for industrial activities related to recovery and disposal of hazardous and non-hazardous waste. As such the information included regarding processes and sources of HCB and PCB off-site transfers of waste concerns all sectors, with the metal industry being a major contributor (see section 2.1.2 and below). Potential emissions relating to the waste industries are emissions and consumption from: common waste treatment processes/activities, biological treatment processes, physico-chemical treatment processes, waste treatments applied mainly to recover materials from waste, waste treatments aimed to produce a material to be used as fuel. In general, regulatory drivers for lowering the amount of waste produced, and increasing the return and investment regarding technologies for the recovery of materials and energy (e.g. *PRTR code 1b*; waste to energy technologies) from waste may result in an increased number of dedicated plants and i.e. treatment technologies for specific types of waste as described below. At the present stage such activities are largely unquantifiable.

Installations for disposal or recovery of hazardous waste
(PRTR code 5a) Waste oil refining /treatment plants

The reference document includes emissions of PCB from re-refining of oils (R9, as defined in Directive 75/442/EEC which refers to the IPPC Directive, changed according to the Commission Decision 96/350/EC). According to the IPPC BAT on waste incineration, re-refining waste oil installations operating in the EU show stack gas emissions of PCB at the level of 0.8 kg/year, effluent concentration of PCB in wastewater below 0.001 mg/L and PCB captured in solid particulates from filters (IPPC BAT on WTI, 2006)

According to Statistics Denmark, activity data for the production and use of waste oils including PCBs, polychlorinated terphenyls (PCT) or polybrominated biphenyls (PBBs) are around 11 tonnes produced and used waste oil, respectively. Waste oils are assumed to be included in the statistics on hazardous waste. No effort has been made to obtain information on the number of waste oil refining plants, if any, in the Nordic countries. According to the information from the Danish waste statistics, imported waste for energy production purposes may include fractions of waste oils.

PCB air emission factor from off-gas thermal destruction plants from waste oil treatment plants is 1 ng/Nm^3 according to the BAT document on waste treatment technologies (IPPC BAT on WTI, 2006)

Shredder plants for the treatment of end of life vehicles

Most vehicles and vessels contain large amounts of hazardous materials, such as asbestos (in particular if built before the 1980s), oils and oil sludge, PCBs (polychlorinated biphenyls), and heavy metals in paints and equipment. Before adoption of the part of the Basel convention dealing with hazardous waste, ship dismantling represented one of the major streams of hazardous waste from industrialized countries to the developing world. In 2004 a study for the Commission (DG TREN) estimated that oil sludge from end-of-life ships alone will total between 400,000 and 1.3 million tonnes per year by 2015. Of the hazardous waste in dismantling facilities every year, asbestos will amount to 1,000–3,000 tonnes, TBT 170–540 tonnes and environmentally harmful paints 6,000–20,000 tonnes (PRTR code xx). The WEEE directive was adopted in Denmark in 2005 (Statutory Order on Waste, no. 619 of 27 June 2000).

PCB tests of disposed shredder residues (SR) generated by several Californian facilities average total levels ranging from 16 to 82 ppm (Schwarzenegger and Gorsen, 2006); the 50 ppm limit triggering requirements for hazardous waste management of SR and e.g. if the SR are to be landfilled or managed at special facilities (cf. Table 2). Reported release factors for PCB from shredder plants into waste is 0.3 mg/t which means that it is not to be classified as hazardous waste and may well be deposited as landfill in Denmark and pre-processed prior to further reuse in e.g. cement production processes. The emission factor for PCB emissions from shredder plant processes to air is reported to be 5.2 mg/t (Bi-PRO, 2006). Comparison of the release factor into waste streams and emission factors to air, respectively, suggests that emission to air is the major pathway for UOPs.

Recovery and disposal of auto shredder residue or auto fluff

According to Nourreddine (2007), about 75% of the total weight of end-of-life vehicles (ELVs) is recycled in EU countries. The remaining 25%, auto shredder residues (ASR) or auto fluff, is disposed as landfill. The quantities of shredder fluff are likely to increase in coming years. This is because of the growing number of cars being scrapped, coupled with the increase in the amount of plastics used in cars.

The goal of the European ELV Directive is for max. 15% of the vehicle's weight to be disposed of at landfill sites, decreasing to 5% by 2015. The draft directive states that a further 10% can be incinerated (Nourreddine, 2007). Therefore, ASR is treated for the purpose of material recycling and energy recovery. In Denmark, special focus is on the change from landfill to reuse of foundry and shredder waste (DEPA, 2006); i.e.

pre-processing and reuse as input material in the metals industry. Most of the Danish metal shredder residue is exported.

Recycling of scrap and shredder

Residues characterized as recycling material or non-hazardous waste may be exported and imported for further processing and reuse (Regulation (EC) No. 1013/2006 of the European Parliament and of the Council)³. This makes it even more difficult to give an estimate of potential sources and emissions relating to solid residues. Within the recycling industry, there are companies which specialize in the pre-treatment of e.g. metal shredder residues to meet the quality requirements for re-entering metal production processes.

Incineration of hazardous waste (PRTR code 5a)

The IPPC Reference Document on BAT for the manufacture of organic fine chemicals gives emission levels of 0.002 to 0.02 $\mu\text{g}/\text{m}^3$ for co-incineration of halogenated waste solvents together with exhaust gases from production processes (IPPC, OFC, 2006).

In comparison the maximum emission from co-combustion processes with use of different types of hazardous waste in the cement production is 0.004 $\mu\text{g}/\text{m}^3$.

Feed material for combustion processes

Investigation of thermal treatment of ASR and RDF (Gendebien et al., 2003), respectively, have shown that combustion of ASR results in the production of more and higher chlorinated PCBs in the primary combustion phase compared to combustion using RDF as input material. This might be attributed to the effect of the abundance of chlorine, Cu and Fe metal in the input material on the unintentional formation of PCB as a by-product. The PCB formed in the primary combustion chamber was largely decomposed by the secondary combustion, and almost all PCB was removed by filtering and the activated carbon adsorption. The rates were 99.1% and 99.9% with the incineration of RDF or ASR, respectively (Ishikawa et al, 2007).

Incineration of non-hazardous waste (PRTR code 5b)

Burning of organic matter in the presence of chlorine is one of the main causes of formation of a range of organic pollutants, including dioxins, PCBs and HCB. The high temperatures that arise in a waste incinerator, for example, result in the pollutants in the material breaking down. However, when the flue gases are cooled, conditions arise which result in *de novo* formation of these substances. Not only the process parameters of incineration but also the chlorine content and waste composition influence the potential for *de novo* formation of UPOPs (e.g. Jacquinot et al.,

³ http://trade.ec.europa.eu/doclib/docs/2007/july/tradoc_135378.pdf

2000; Zevenhoven and Kilpinen, 2001). The contribution to PCB emissions depends largely on the type of wastes and incineration technology utilized. Incineration of PCBs and chlorine-containing wastes has the highest PCB emission factors.

Studies of non-optimal combustion conditions during waste incineration (Blumenstock et al., 2000) have shown that POP emission favours unintentional formation of lower chlorinated dioxins, furans and PAHs, while the formation of HCB, PCBs and the higher chlorinated dioxins seems unaffected or even to decrease under non-optimal combustion. Therefore, the emission of PCBs seems to be unaffected by non-optimal conditions, e.g. lower temperatures, during waste incineration to the same degree as higher chlorinated dioxins. The IPPC reference document on BAT for waste incineration provides an emission factor value ranging from $< 1 \mu\text{g}/\text{Nm}^3$ to $< 2 \text{ ng}/\text{Nm}^3$ (IPPC, WI, 2006). As data on incineration stack gases per year are not available, the emission factors presented and explained in Annex 3 have been used.

Besides the waste amounts in absolute numbers, the content of the waste in terms of precursors, such as plastics and certain metals, are of importance for the size of the emission factor. There are many ways of presenting waste categories and fractions within and between sectors, evident from an examination of the national waste statistics for the Nordic countries, and at EU level (see references to Table 4.1 in Annex 4). The newest approach is described in the new EU guidelines for reporting waste statistics. The categorization of waste into different categories is therefore not strictly harmonized between the countries and accordingly differences are apparent in the waste statistics categories (Statistics Denmark, Finland, Norway and Sweden). Some statistics are based on final disposal categories and statistics within sectors, some for households only and some include cross-sectoral waste fractions summed up into e.g. hazardous waste. At the same time, similar to the new E-PRTR register and underlying regulations, a relatively new way of registering waste statistics may influence national waste statistics in the future (Regulation No 1379/2007/EC). Furthermore, in the statistics published at sector level, e.g. the Swedish waste management report (RVF, 2006), the figures may differ from figures produced under reporting obligations to the EU (Swedish EPA, 2006). No in-depth comparative analysis of reports and differences in the reporting of waste statistics has been performed.

Another aspect worthy of note is that waste characteristics continually change due to e.g. increased sorting, recycling and reuse of various materials. This may have influenced the composition of MSW sent to combustion in terms of e.g. lower chlorine content. These aspects together with technological developments and optimization of the combustion processes mean that the reported emissions factors probably are exaggerated.

Aggregated figures for the waste categories reported in Table 4.1 in Annex 4 are shown in Table 12. Waste categories have been grouped into municipal waste and 'hazardous waste'; the latter group including all other reported waste categories besides domestic or municipal waste.

Table 12 2004/2005 activity data for incineration; feed material divided into 'hazardous' and municipal waste, respectively [tonnes]

	'Hazardous' waste	Municipal waste	Reference
Denmark	86 490	1 468 500	1
Finland	271 829	239 924	2
Norway	574 246	226 843	3
Sweden	1 440 640	1 944 290	4

References:

1: DEPA, 2007

2: Finnish waste statistics and expert judgement

3: Norwegian waste statistics and expert judgement

4: Statistics Sweden

Details regarding waste categorization are provided in Annex 4. The waste amounts reported as 'hazardous' waste in Table 12 do not refer to the definition according to the Basel Convention (releases into solid residues > 50 mg/kg for both PCB and HCB), but mostly to industrial waste and wastes other than household waste (see Annex 4, Table 4.1 and e.g. DEPA, 2006).

According to European and national waste strategies corresponding Recovery and Disposal codes for different waste types have been developed; e.g. Regulation (EC) No 1379/2007 (COM, 2007c). The methodologies for reporting waste amounts according to type as well as the number of subcategories within each type of waste differ between sector reports, national statistics and EU reporting Recovery and Disposal categories (see e.g. COM, 2006 and 2007b and c). It has not been possible to perform an in-depth analysis of the reasons behind the inconsistencies between the different reporting formats. Details regarding the raw data behind the figures given in Table 12 may be found in Annex 4, and possible explanations for the high variation in waste amounts between countries are given in Chapter 3.

Input material or feed material

The cornerstones of the EU strategy to manage waste are to prevent waste in the first place, recycle waste, turn waste into a CO₂-neutral energy source and optimize the final disposal of waste, including its transport. In this respect the fraction of plastics in waste for combustion is to be minimized. In the EU, municipal waste is by far the largest source of plastic waste with plastic comprising more than 60% of the total. An overview of the chlorine content of different types of plastics is provided in Kikichi et al., 2007, while an overview of the chlorine content in different waste types is given in Annex 5. PVC is a source of chlorine in the waste, but

under optimal combustion conditions is not necessarily a source to the emission of PCBs (e.g. Jacquinot et al., 2000).

Reported PCB levels in different types of waste are as follows: 0.2 to 0.4 mg PCB / kg dry weight municipal waste, up to 60% dry weight hazardous waste and 0.01 to 0.13 mg PCB / kg dry sewage waste (IPPC BRF WI, 2006). None of the waste categories reported in Annex 4, or i.e. in Table 12, are expected to be contaminated to a higher level than the maximum of 0.13 mg/PCB / kg dry weight waste. Other chlorine release, or even small amounts of PCB-containing waste, may arise from different types of refuse derived fuel (Gendebien et al., 2003). Depositing of organic and burnable waste at landfill sites is declining, and thereby this source of accidental leakage into the underlying soil and groundwater is reduced. Final disposal of the waste may occur in the form of combustion residues as described below.

The PCB concentration levels in sewage sludge from different sewage treatment plants are between 0.08 and 0.187 mg/kg dry matter, the limit for co-combustion being 0.2 mg/kg dry weight (IPPC BREF LCP, 2006). The amounts of sewage sludge disposed for combustion are included in the category municipal waste in Table 12. The amounts are however small and have been replaced by composting; in Denmark high quality sewage sludge is processed by storage at landfill sites combined with garden waste.

Output or Residual material from combustion

Regarding final disposal, the Basel Convention includes characterization categories of waste of which some are specifically related to the handling of PCB- and/or HCB-contaminated end-products and wastes. Specific waste characterization categories of Annex 1 (-to be controlled) and II (-requiring special consideration) of the Basel Convention of relevance for an HCB and PCB emission inventory are: Annex I category *Y10: Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)* and Annex II category *Y46: Wastes collected from households* and *Y47 Residues arising from the incineration of household wastes*.

Table 13 Reported residues from combustion [tonnes]

Year		2002	2003	2004	2005	2006	Reference
Sweden	Slag, from MSW combustion	395 500	446 500	485 000	550 850	598 545	1
Denmark	Slag, from combustion in total	543 254		564 313	595 272		2
Sweden	Flue-gas cleaning residues, from MSW combustion	109 900	149 300	138 000	160 920	176 298	1
Denmark	Flue-gas cleaning residues, from combustion in total	581 000	691 000	615 000	642 000	NR	2

References:

1: Svensk Affaldshåndtering 2007

2: Affaldsstatistik 2005, DEPA, 2006

From Table 13, a significant increase in the amounts of residue from combustion may be observed. This is an expected general trend for the Nordic countries due to the common goals of the national waste strategies of decreasing the amount of organic, CO₂-neutral, amounts of waste deposited as landfill.

According to guidance document of best available technologies under the Stockholm Convention, the amounts of combustion residues produced from MSW are as follows: 200 kg slag or bottom ash per tonne MSW, 3 kg boiler ash per tonne MSW, 10 kg filter ash or fly ash per tonne MSW. The amount of residues collected by ESP or FF combined with wet and dry scrubbing are 12 and 30 kg per tonne MSW, respectively (Vehlow et al, 2006; BATBEP guidelines, 2006).

Based on the MSW figures in Table 12, the combustion residues have been calculated and listed in Table 14. Estimated combustion residue amounts in Table 14 may be compared to the reported amounts in Table 13 for evaluation of uncertainties.

Table 14 Estimated amounts of combustion residues, in tonnes, produced in 2004/2005 [tonnes].

	MSW	Slag	Flue-gas cleaning residues
Denmark	1 468 500	256 988	10 280
Finland	239 924	41 987	1 679
Norway	226 843	39 698	1 588
Sweden	1 944 290	340 251	13 610

The amounts of slag and flue-gas cleaning residues produced respectively are 15–20% and 3–5% of the MSW input material according to the Danish and Swedish waste statistics (DEPA, 2006; RTF, 2006). The figures in Table 14 underestimate the reported residues in Table 13, a possible explanation for which being waste imported for the purpose of producing energy. There may be uncertainty with regard to the estimated amount of MSW with combustion as a final disposal category; e.g. the MSW data for Sweden may very well be underestimated (RTF, 2006).

Combustion residues from MSW incineration (Waste category Y47, Annex I of the Basel Convention)

PCBs and HCB are formed especially in municipal solid waste incineration. It is expected that the PCB level in bottom ashes from well-operated plants incinerating municipal solid waste is kept below 10 ng/g. The most frequent filter installed in waste incineration plants is the electrostatic precipitator (ESP). Fabric filters (FF) are mainly used if dry or semi-dry scrubbing is applied. According to a review by Vehlow et al., 2006 there are no significant differences between PCB concentrations in the combustion residue materials collected in ESP and FF. Concentration ranges from 1990 onward are from <1 to 110 ng/g. This means that for well-operated waste incineration plants a concentration in combustion residues below the upper limit of PCB concentrations of 50 µg/kg is realistic (Vehlow et al., 2006). Examples of annual PCB releases into combustion residues for 2004/2005 are given in Table 15.

Table 15 Estimated PCB content in combustion residues [kg/yr]

	slag	Flue-gas cleaning residues
Denmark	12 849	103
Finland	2 099	17
Norway	1 985	16
Sweden	1 7013	136

These figures are highly uncertain. Estimates are based on the combustion residues in Table 14, which are significantly underestimated. On the other hand, maximum measured PCB concentrations in combustion residues (Vehlow et al., 2006) have been used for deriving the release into waste figures in Table 15.

In the waste statistics from 2005, the Danish EPA states that the prohibition of combusting electric and electronic waste, non-reusable PVC and impregnated wood waste is argued to result in a significant reduction of heavy metals in the slag, whereas the influence on the amounts of UPOPs in the residue is not mentioned.

Taking into account the uncertainty, and that the estimated figures are indicative examples for deriving releases into waste streams and/or residue products, the figures still indicate a PCB release above 500 kg/yr, classifying this material stream as very important (BiPRO, 2006).

Based on the above estimated PCB content of slag, re-combustion at high temperatures should be performed to secure a high DRE % prior to recycling. In Denmark the 2008 goal of reusing 85% of the slag was reached in 2005 (Danish Government, 2005; DEPA, 2006).

Landfill (PRTR code 5d)

Drivers for changes in the composition of waste disposed of at landfill sites are e.g. the Waste Landfill Directive (1999) that bans the land filling

of tyres by 2006; the End of Life Vehicle Directive (2000) that stipulates the separate collection of tyres from vehicle dismantlers and encourages the recycling of tyres (Aylon et al., 2007). The current main routes for the management of waste tyres in Europe are landfill (40%), energy recovery (20%), material recycling (18%), rethreading (11%) and export (11%) (European Tyre Recycling Association, <http://www.etra-eu.org/>). Non-metallic parts from sorting of electric and electronic scrap (e.g. Maag and Lassen, 2000) and shredder plants (*PRTR code 2f or 5a*) are to be treated as hazardous waste, not to be incinerated but sent to landfill.

Other drivers are the national waste strategies and associated goals for recycling and reuse of residual products such as e.g. sewage sludge, municipal waste and hazardous waste. Problematic waste like PVC is to be recycled or deposited as landfill.

Potential sources from landfill sites depend on the waste types and mixtures present. Another important factor for this source is the use of sealant, the presence of a gas collection system. Sealant may inhibit the emission from landfills, but still the municipal wastes determine the maximum methane conversion factor and increased methane emissions increase the potential for PCB emissions. Figures in the Corinair guide-book range from 0.19 to 0.3 $\mu\text{g PCB}/\text{m}^3 \text{CH}_4$ (EEA, 2006). In the USA PCB emission inventory an emission factor for PCB emission to air from landfill is 4.3 kg/t PCB containing waste. The level of PCB emission from landfill highly depends on the type of PCB wastes and, to a lesser extent, on the content of PCB in the wastes. An investigation by Persson et al. (2005) showed that emission flux of PCBs from landfill which contains 10–18 tonnes PCBs in polysulphide sealant is only about 1 g Σ PCB/yr.

National waste strategies for the Nordic countries all comply with the EU waste strategy of increasing reuse and recycling, with disposal at landfill only as a final solution. Landfill will be used as a temporary storage and treatment system prior to final disposal for incineration, composting or reuse in production processes within the energy or industry sectors.

In Denmark a new database for registering activity and quality parameters for landfill sites has been developed (www.erisda.dk). However, this database is still in a developmental phase and may be used in the future for estimating fugitive emissions as well as default runoff parameters according to expected future guidelines on this theme. Future landfill sites are expected to form an integrated part of the sorting, reuse and recycling strategy and therefore maybe more correctly defined as temporary storage systems for pre-processing of material for reuse or recycling in the energy and industrial sectors.

Solid residues from e.g. the energy sector, industrial activities, e.g. slag for asphalt production, and combustion residues that are disposed of at landfill sites may result in leakages from these sites, even though contamination levels may be low.

Leakages from landfill and resulting soil and water contamination may be of lesser concern than emission to air, as HCB is relatively immobile in soil and modern landfills are designed to capture leachates (DEFRA, 2006). PCBs as well as HCB may eventually leach into the groundwater from contaminated soils, e.g. at old landfill sites, but the magnitude of such sources is highly uncertain.

Increased recycling and decreased solid residues for disposal at landfills
UNEP reports that 30% of the European dust from cement kilns is disposed of as landfill⁴, which implies the importance of high DRE percentages for the prevention of continuous recycling of UOPs into the production cycle.

Asphalt production at European level also includes high material recycling rates and the need for high DRE of UOPs in the recycling industries delivering the feed materials for reuse in energy and industry sectors. The production of asphalt is not included in the Finnish IIR (Saarinen et al., 2007). Industrial facilities for producing asphalt (SNAP code: 030313 Asphalt concrete plants and PRTR code 3; 40611: Road paving with asphalt and PRTR code 3f; 060310: Asphalt blowing) may be of relevance for future PCB and HCB inventories; and may also be of relevance for releases to soil.

Wastewater treatment plants (PRTR code 5f)

Sewage treatment processes

The emission of PCB from anaerobic digestion plants is reported at a level of 0.00073 g/tonne of waste (IPPC, BAT for WT, 2006). For plants including anaerobic treatment, fugitive emissions may contain PCBs of 730 µg/tonne waste. Overall, the emissions of HCB and PCBs to surface waters are expected to be very low. This is due to the technological upgrading of WWTPs and the stricter quality requirements in the industry.

Sewage sludge

PCBs and HCB may be present in sewage sludge due to their persistent nature, and may occur in significant quantities. The PCB concentration level in sewage sludge from different sewage treatment plants are reported to be between 0.08 and 0.187 mg/kg dry matter (IPPC BREF LCP, 2006). The IPPC Reference Document on Waste Treatment, sewage sludge from physico-chemical treatment of wastewaters (IPPC, BAT on WT, 2006) realistically includes PCBs (sum of 6) at a concentration level of maximum 0.12 mg/kg. This is in agreement with measurements of PCBs in Danish sewage sludge including both HCB and PCB at the levels of 0.005–0.12 and 0.0078–0.017 mg/kg dry weight, respectively (<http://www.aaa.dk/aaa/basis-2004-slam-spildevand.pdf>). The Danish sewage waste from municipal wastewater treatment plants includes on

⁴ http://www.chem.unep.ch/pops/pcb_activities/PCB_proceeding/pcb_proceeding.htm

average a 40% contribution from industries (Thomsen and Lyck, 2005), which may result in higher variation in the PCB and HCB content. Sewage sludge increasingly is composted at storage basins at landfill sites in combination with garden waste. Depending on the quality of the end-product, the compost is either combusted, used in e.g. park areas or as compost for private use. Some of the composted material may also be used as fertiliser in the agricultural sector (Directive 86/278EEC). Not all the PCBs spread on land will volatilize but the potential for emission to air is greater than that from landfill. The emission estimate for sludge comprises only 1% of the total and is highly uncertain. The fraction of sludge that, due to quality requirements, is combusted (cf. Table 3.1, Annex 3) may contribute to the PCB emission from waste incineration and refuse-derived fuel production due to the PCB content of the waste (UK IIR, 2006).

Industrial wastewater treatment plants (PRTR code 5g)

HCB has been detected in treated wastewater from non-ferrous metal manufacturing in the USA and it seems likely that discharges to water from the metal, mineral and chemical industry may occur. In general, it is expected that stricter quality requirements for effective detoxification and treatment processes prior to direct outlet or coupling to the municipal sewer systems have minimized releases to water.

In Denmark, around 40% of industrial wastewater is received and treated at centralized municipal wastewater treatment plants (Thomsen and Lyck, 2005). There is only few measurement reporting results above the limit of detection for effluent from separate industries in Denmark. Therefore, wastewater effluent is considered of little or no importance regarding the release of PCB and HCB to surface waters for all the Nordic countries due to improved wastewater treatment technologies and quality requirements for pollutants in the effluent water according to the Water Framework Directive. Still, data are scattered and e.g. Nerpin et al. (2005) report PCB as a general contaminant of industrial and household effluents, identified as raised PCB concentrations in sediments close to industrial wastewater point sources. Below the origin of some potential sources to PCB and HCB in urban waste water, and as results thereof in sludge, is listed:

Origin of some potential releases into sewers

Point sources:

- Industrial process wastewater from wet flue gas cleaning and other water containing liquid combustion wastes
- Leachate water from landfill sites
- Water-containing liquid waste from oil regeneration
- Atmospheric deposition from waste incineration

Diffuse sources:

- Background inputs to the sewer from normal dietary sources
- Background inputs by atmospheric deposition due to contemporary remobilisation/volatilisation from soil and cycling in the environment
- Atmospheric deposition from domestic combustion of coal
- The extent of biodegradation of organic contaminants during sludge treatment

It is judged that the above mentioned sources are of minor importance, even though information indicates that there is still existing diffuse sources contributing to the influent concentration of PCB other than surface run-off into the sewer system (e.g. Almqvist and Hanæus, 2006).

According to a Swedish survey (Naturvårdsverket, 2005), large volumes of air are supplied to the aeration tanks at WWTPs, and from here PCBs especially are emitted, along with small quantities of dioxins and HCB. Release with wastewater effluents as well as trace levels of PCB and HCB in sludge is further discussed in Chapter 2.2 and 3.

2.1.6 Paper and wood production and processing

Industrial plants for the production of pulp (PRTR code 6a)

According to the guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants (Guidelines on BAT and Guidance on BEP, 2006), HCB and PCBs are not formed during pulp bleaching.

Paper production from use of recycled fibre processes (PRTR code 6b)

Due to the success of the promotion of recycling paper systems in Europe, a corresponding increase in recycling fibre processes (RCF) within the paper industry can be observed; one main category, de-inking, being a source of the emission of PCB. Processes with mechanical and chemical unit processes, i.e. with de-inking, comprise products such as newsprint, tissue, printing and copy paper, magazine paper, some grades of cardboard or market de-inked pulp. The reported content of PCB in RCF sludge, based on German and Dutch studies, is 95 and <300 µg/kg dry solid RCF sludge (IPPC, BREF PPI, 2001). It has not been possible to derive activity data of relevance for the process specific sector source of PCB emission.

Wood preservation using pentachlorophenol (PRTR code 6c)

Pentachlorophenol (PCP), by its chemical structure, is a close surrogate of HCB. PCP is derived from HCB by substituting one of HCBs six chloro-substituents with a hydroxyl group. Given its chemical similarity to HCB and that its manufacturing ingredients contain the precursors for

chlorinated aromatic compounds, the manufacture of PCP often results in the incidental manufacture of both HCB and dioxins/furans. Hence, dioxins/furans and HCB are present in PCP formulations used for wood preservation and may be released, disposed of or transferred for recycling. Production of PCP is included in the emissions from the Chemical Industry, while impregnated wood may be a source of diffuse emission as well as UPOP emission when used as feed material for combustion (cf. Table 4.1, Annex 4).

2.1.7 Animal and vegetable products from the food and beverage sector

The chlorine in the salt in carcasses means there is a potential for dioxin formation. Therefore the incineration of animal carcasses and animal meal are performed with the risk of PCB formation depending of the technique used to operate the incinerator (*PRTR code 5e or 8a*). The production of fish oil includes a purification step that results in the production of solid carbon filter material that is disposed of as hazardous waste for incineration (IPPC BREF SABI, 2005).

The emission of PCB from waterproof floorings in slaughterhouses during washing/cleaning of the water may realistically result in PCB-contaminated wastewater effluents to surface waters.

2.1.8 Other

Textile Industry (PRTR code 9a)

The use of organic solvents in the textile industry may result in emissions from thermal processes and specific activities such as dry-cleaning of textiles. In addition, the reference document on BAT in the textile industry (IPPC BREF TI, 2003) recommends to 'avoid emissions of dioxins and furans arising from organically bound chlorine from pesticides potentially contained in the sludge' in relation to sludge disposal from wastewater treatment of wool scouring effluent.

Installation for the building and painting or paint removal from ships (PRTR code 9e)

This source is relevant, but not judged of importance in the long term or at present. No efforts towards quantification of this industrial process have taken place. There are many companies that have specialized competencies in the treatment of different types waste prior to recycling or final disposal by means of deposition at landfill or combustion.

2.2 Diffuse sources

According to the E-PRTR Regulation, diffuse sources are ‘the many smaller or scattered sources from which pollutants may be released to land, air or water, whose combined impact on those media may be significant and for which it is impractical to collect reports from each individual source’.

A list of diffuse source⁵ categories as well as the associated definitions may be found in the European PRTR Regulation, Art 2 (12). A description of each source category may be found on the BiPRO webpage on diffuse sources which was created as part of the as part of the E-PRTR webpage⁶. The BiPRO E-PRTR webpage presents available data with respect to emissions from diffuse sources⁷ at country level, for specific pollutants, divided into releases to water, soil and air. And, as may be observed, the available data are extremely limited in the case of PCBs and HCB. A description of available knowledge according to the description provided of each diffuse source by BiPRO is given below. It should be mentioned here that the main focus has been on potential industrial sources as these are judged of major importance in relation to diffuse sources. Still, some of the scattered sources may be of concern with regard to the local environment despite being of little importance in relation to the total emission. Information on emission estimates from diffuse sources is given in Chapter 3 together with the large industrial point sources.

2.2.1 Sources to air emissions

Mobile sources

Mobile combustion is, according to the E-PRTR regulation defined as a diffuse source. Mobile combustion in the Nordic countries has been approached based on fuel consumption. A short description of the sources is given below. Activity data are summarized in Table 16.

Road transport

Road transport is a diffuse source sector used for the inventory of emissions to air. According to BiPRO⁸, data in the inventory should sum up figures from NFR codes NFR 1A3b ‘fuel combustion in road transportation’, including (i-vii) combustion releases from passenger cars, light and heavy duty, mopeds and motorcycles, gas evaporation, tyre and brake wear and road abrasion, and NFR 1A3e ‘other transportation’ composed of pipeline compressors and other mobile machinery. Details regarding emission

⁵ Diffuse sources are the many smaller or scattered sources from which pollutants may be released to land, air or water, whose combined impact on those media may be significant and for which it is impractical to collect reports from each individual source

⁶ http://www.bipro.de/__prtr/sub/purpose_scope.htm

⁷ http://www.bipro.de/__prtr/sub/database.htm

factors are provided in Annex 1, Table 1.3 and 1.4. In the current project, activity data on fuel consumption as given in Table 16 have been available for all countries. For Denmark, activity data in units of driven kilometres in passenger cars divided into diesel and gasoline were available.

Shipping

Shipping is a diffuse source sector used for the inventory of emissions to air. In this context exclusively emissions from fuel combustion from NFR code 'national navigation' (NFR 1A3d ii) have been summed. Emissions from ships (NRF1A3d ii) are reported in Table 19 together with other diffuse and point sources originating from the use of fuels.

Aviation

Aviation is a diffuse source sector used in the inventory of emissions to air. In this context only emissions from domestic aviation (1A3a ii including LTO and cruise) have been summed. This source may be relevant but has not been included due to missing information concerning the relevance of the source for the emission of HCB and PCBs.

Rail

Railways are a diffuse source sector used in the inventory of emissions to air. In this context data compiled in the inventory refer solely to emissions from fuel combustion (NFR 1A3c). No information regarding this activity has been addressed during the review process. The source is considered not relevant for HCB and PCB emission.

Table 16 Activity data on fuel consumption within mobile combustion sources* [tonnes]

3. Transport			
a. Civil Aviation	Aviation Gasoline	Jet Kerosene	
Denmark	2 192	40 373	
Finland	881	102 910	
Norway	2 300	250 000	
Sweden	808	209 340	
b. Road Transportation	Gasoline	Diesel Oil	
Denmark	1 754 524	2 071 982	
Finland	1 739 093	2 013 333	
Norway	1 582 000	1 995 000	
Sweden	3 783 255	2 297 562	
d. Navigation	Residual Oil (Residual Fuel Oil)	Gas/Diesel Oil	Gasoline
Denmark	37 038	125 550	8 983
Finland	46 548	69 860	51 136
Norway	162 000	354 900	NO
Sweden	76 345	71 178	24 375

*IPCC nomenclature

References:

National expert knowledge and Inventory Reports submitted in 2007 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php

Military

Military is used as a diffuse source sector in the inventory on emissions to air. Figures reported for this sector correspond to ‘other stationary fuel combustion activities including military’ (NFR 1A5a) and ‘other mobile fuel combustion activities including military’ (NFR 1A5b). Stationary activities included as military installations are similarly scattered and widespread, as is the residential sector, and are not included in the reporting on ‘large’ point sources. The source has not been addressed in the present work as it is not judged of importance.

Domestic fuel consumption

The diffuse source category ‘Domestic fuel consumption’ has not yet been defined. It may be due to the fact that several investigations (Saarinen et al., 2007; Henriksen et al., 2006) have shown that this source may contribute significantly to the total emissions of dioxins and therefore potentially also PCBs and HCB. According to the data from chemical analysis performed in Poland, residential sources may emit stack gases containing concentrations of PCB around 3 times higher than industrial sources (excluding manufacturing industries) and concentrations of HCB around 2 times higher. This increase in source potential for HCB and PCBs from residential sources is however small compared to that for dioxins, where emissions 25 times higher were observed; co-combustion of domestic wastes with hard coal or wood in simple kitchen stoves or heating boilers was a possible explanation (Guidelines on BAT and Guidance on BEP, 2006).

Table 17 Activity data on domestic fuel consumption, 2005 [tonnes]

4. Other Sectors			
a. Commercial/Institutional	Coal	Wood*	MSW
Denmark	NO	52 765	16 440
Finland	NO	225 210	NO
Norway	NO	9 300	NO
Sweden	NO	93 866	NO
b. Residential	Coal	Wood*	MSW
Denmark	317	1 875 115	NO
Finland	510	3 413 445	NO
Norway	1316	1 564 000	NO
Sweden	NO	3 513 025	NO

NO: Not Occurring

*may include wood waste (national expert knowledge)

References:

National expert knowledge and Inventory Reports submitted in 2007 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php

The emission from residential combustion is reported in Table 21 and 22, Chapter 3, together with emissions from industrial combustion and other emission originating from fuel combustion activities.

A study on emission of PCDD/F, PCB, and HCB from combustion of firewood and pellets in residential stoves and boilers shows a general correlation between PCB and HCB levels with PCDD/F levels, except for intermittent pellet combustion and plastic waste combustion, which seem to favour dioxin formation rather than general POP formation. The PCBs generally contribute approximately 10% to the TEQ values (Hedman et al., 2006).

Solvent use

Solvent use includes emissions to air from degreasing, dry cleaning (NFR 3B) and other applications including products containing UPOPs. This source is included in the Chemical Industry emission estimates (NFR 3B and 3D); NFR 3A are not of relevance for any of the Nordic countries as the production, marketing and use of PCBs is prohibited in the Nordic countries (cf. Table 1).

Table 18 Activity data for solvent use in the Nordic Countries [tonnes]

Year	1999	2000	2001	2002	2003	2004	2005	Reference
Organic Chemicals production								
Chlorine-containing solvents - use								
Denmark	35 161	32 718	32 069	29 823	19 051	245	187	1
Finland	1 350	1 250	1 094	1 421	1 407	1 110	1 317	2
Norway	NR	NR	NR	NR	NR	NR	NR	
Sweden	NR	NR	NR	NR	NR	NR	NR	

NR: Not Reported

References:

- 1: Statistics Denmark
2: Saarinen et al, 2007

Solvent use is considered a diffuse source; solvent use in downstream industries (textile industry) or private use. The decline in the figures for Danish solvent use is due to the substitution and chlorinated solvent taxes (DEPA, 1999; Speck et al., 2006). The Finnish figures on solvent use are fairly constant over the years, indicating that only production and not use has been regulated in Finland. No knowledge concerning the use in Sweden and Norway has been reviewed as this sector is judged of minor importance.

Fossil fuel distribution of natural gas

Fossil fuel distribution of natural gas is a diffuse source sector used in the inventory of releases to air. The sector uses data from NFR 1B2b 'distribution of natural gas' because the emissions are expected to stem from non-point-sources such as pipelines. Data from NFR codes for fossil fuel distribution oil, other, venting and flaring are not taken into account, because activities are expected to occur predominantly at large point sources such as refineries and as such are reported under point sources. This source is not relevant for PCBs and HCB emissions.

Roofing and road paving with asphalt

According to the definition given by BiPRO, asphalt roofing and road paving with asphalt is a diffuse source sector used in the inventory of releases to air, summing data from NFR codes 2A5 and 2A6. An additional activity originating from asphalt production is polyurethane processing for use in asphalt blowing, NRF code 3C, which may be a source of PCB and HCB emission to air (Saarinen et al., 2007).

Table 19 Total Production of Hot Mix Asphalt in 1993–2005 [1000,000 tonnes]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Denmark	3.3	3.1	3.4	3.6	3.5	3.1	3.3	3.3	2.8	2.8	2.9	3.6	3.2
Finland	5.2	4.1	5.1	5.2	3.8	3.7	4.1	3.8	3.6	4.1	4.9	4.5	5.0
Norway	4.7	4.5	4.1	4.9	5.0	4.7	4.8	4.5	4.1	3.9	4.1	4.5	5.1
Sweden	7.5	7.6	7.3	5.8	5.3	6.3	7.3	7.2	6.7	6.7	6.6	6.8	7.2

Reference: European Asphalt Pavement Association. <http://www.eapa.org/>

In Sweden, a large country with a relatively low population density and high aggregate availability, some examples of recycling rates are: 45% of blast furnace slag, corresponding to 0.5 million tonnes used out of 1.1 million tonnes produced; 100% of steel slag, corresponding to 0.22 million tonnes used and produced; and 95% Reclaimed Asphalt Pavement (RAP) corresponding to 0.84 million tonnes used out of 0.88 million tonnes produced.

In Denmark, with a high population density and low natural aggregate availability, the recycling rates are: 100% of steel slag, corresponding to 0.066 million tonnes used and produced; 81% of crushed concrete, corresponding to 0.95 million tonnes out of 1.17 million tonnes produced; 100% of coal bottom ash, corresponding to 2 million tonnes used and produced; 100% of coal fly ash, corresponding to 1.17 million tonnes used and produced; and 100% of RAP, corresponding to 0.53 million tonnes used and produced.

Recycling rates in the asphalt industry are high, and there may be a need for further investigation of the quality requirements for the recycled material with respect to the risk of run-off and infiltration of soil; i.e. releases to soil and groundwater. In the report by BiPRO (BiPRO, 2006) it is stated that information on emissions in the industry is limited. BiPRO recommends a low priority for action, although only partially refer to unintentional releases of POPs.

Agriculture

With respect to releases to air, agriculture sums releases from fuel combustion in agriculture, fishing and forestry (NFR 1A4c), enteric fermentation (NFR 4D), manure management (NFR 4B), rice cultivation (NFR 4C), agricultural soils (NFR 4D), field burning of agricultural wastes (NFR 4F) and other agricultural processes (NFR 4G). According to Bi-

PRO, these subcategories are not always strictly diffuse, but it can be stated that a maximum of 10% of the releases compiled under agriculture as diffuse source sector in this inventory might originate from point sources as defined under E-PRTR. Activity data related to fuel combustion for energy production are shown below.

Table 20 Activity data on fuel consumption in agriculture, 2005 [tonnes]

c. Agriculture/Forestry/Fisheries	Coal	Wood	MSW
Denmark	73 347	8337	NO
Finland	6 000	421 429	NO
Norway	NO	4 300	NO
Sweden	NO	14 034	NO

Field burning of agricultural waste, NFR 4F, is not relevant for Denmark (Henriksen et al., 2006 and Saarinen et al., 2007; Statutory Order on Waste, no. 619 of 27 June 2000). Still, emission factors for accidental burning may be obtained from Annex 6.

2.3.2 Sources to emissions to water

Agriculture

With respect to releases to water, agriculture involves the sum of releases from agricultural processes. This is usually closely connected to releases from agricultural soils. Releases from this sector are mainly due to the application of artificial or natural fertilizer. Precipitation, erosion, digging and artificial irrigation, as well as natural leaching processes subsequently causes the release of the nutrients applied to the aquatic environment. As mentioned in Chapter 2.1 in relation to the chemical industry, chlorinated pesticides are not used in Sweden and Denmark, whereas there may still be some use in Norway and Finland. The release of HCB with the use of pesticides is judged of no importance for the unintentional emission of HCB (see Table 3.4 in Annex 3); therefore there is no risk of future water contamination via run-off.

Scattered Dwellings

Scattered dwellings represent a diffuse source sector used in the inventory of releases to water defined as discharge from households not connected to urban waste water treatment plants and other diffuse emissions as surface runoff from paved areas. The fraction of the population not connected to urban wastewater treatment systems corresponds to 10% of the population in Denmark (Thomsen and Lyck, 2005). The source is judged of no relevance for unintentional emission of UPOPs.

Surface runoff from paved areas may be a potential source of release to soil and continental water bodies of PCBs and HCB. In the case of the recycling of slag in the production of roads and pavements there may be a

risk of PCB release in surface rainwater runoff. In Denmark 85% of the residue material from combustion is recycled into the Energy and/or Industry sector. The cement, asphalt and building and construction industries use combustion residues as feed material for production processes.

Diffuse sources of release of HCB and PCBs to surface water may in general result from increased background concentrations caused by e.g. historical contaminated soils by e.g. accidental/minor leakages from old landfills, wash-off releases from contaminated buildings and precipitation of stack emissions from residential combustion and residues of old preserved woods and, in general, old equipment including PCBs and HCB. The diffuse sources are not quantifiable but assumed small and maybe comparable to releases from wastewater effluents in which both PCBs and HCB have low detection frequencies.

The main source of PCB and HCB pollution of surface waters is judged to be historical build-up of UOPs in the sediments due to diffuse and point sources as well as historical dumping activities and industrial activities in harbours; e.g. accidental waste oil spills and the use of ship paints containing PCBs.

2.3.3 Sources to releases to soil

Releases to soil from diffuse sources have yet to be defined on the BiPRO webpage (<http://www.bipro.de/>). Some obvious sources that may contribute to soil contamination are discussed below.

Deposition and Evaporation

Atmospheric deposition from scattered sources, e.g. residential combustion, may be considered a source, even though in some cases the source-sink relationship between air and soil points in the reverse direction; i.e. releases from soils to air is the governing process towards equilibrium distribution. Soil/air partition coefficient values for HCB range from 5.0 to 7.3 (Hippelein and McLachlan, 1998; Meijer et al., 2003) and both HCB and PCB exchange between soil and air occurs continuously (Kurt-Karakus and Jones, 2006); according to Barber and Jones (Barber and Jones, 2005) a re-emission from soil may occur in the case of HCB.

Several studies have measured distance to source concentration profiles in soil, both for industries and contaminated buildings (e.g. Capuano et al., 2005; Herrick et al., 2007; Sikkonen et al., 1997). Soil contamination from deposition from industrial point sources as well as contaminated buildings is considered of minor importance compared to other sources; however, local environments may be of concern in the case of vulnerable areas such as kindergartens. Emissions from contaminated building components such as sealants, plastics and windows (Andersson, 2002; Trap et al., 2006) may lead to soil contamination (Andersson et al., 2003; Meijer et al., 2003; Ottesen et al., 1999; Veritas, 2000) to a degree

that may involve elevated background soil concentrations above 0.5 mg/kg (Andersson et al., 2003). Furthermore, several studies address near exposure caused by indoor emissions from building materials. Several studies in Denmark, Finland, Norway and Sweden verify the significance of emissions from buildings including from PCB-containing sealants or other PCB-containing building components (e.g. SBI, 1999; Sverud and Estensen, 2000).

Sludge as fertilizer in agriculture and parks

A Danish investigation from 2002 (Vikelsøe et al., 2002) shows that the soil concentration of PCB is lower than the non-halogenated contamination level. When looking at the sludge to soil ratios for highly contaminated areas were above unity in depositing locations, with a PCB concentration at the level of 130, 550 and 0.1 to 0.4 µg/kg dry matter for respectively sludge, polluted soil and two agricultural soils. Depending on the pollution level soil may act as a sink or source with regard to UOPs.

Industrial activities and remediation

Industrial activities such as automobile repair facilities (Nordisk Ministerråd, 2007) may contribute to releases of PCBs from disposed car wrecks and parts including residue oils, etc. In addition, gasoline stations may have been classified as having polluted soils in national mapping of soil qualities according to land-use sensitivity criteria. In Denmark, many activities have been performed aimed at remediation of polluted soils, with special focus on clean-up of historical pollution from industry. Emissions from clean-up of PCB contaminated soil, at an initial concentration level of 37.5 mg/kg, by thermal desorption processes has been recorded at 1.14 g/h at uncontrolled conditions and 0.05 g/h under controlled conditions (IPPC, BAT on WT, 2006; Eklund et al, 1997).

Similar clean-up activity has been performed in Sweden, Norway and Finland and in this respect mapping of soil qualities has taken place as illustrated in the paragraphs below.

Polluted soils

In Norway 161 polluted locations have been identified (<http://www.sft.no/grunn/>); however, the concentration levels of soil pollution are not available. 474 locations are polluted with PCBs and 15 with HCB. Locations are described in detail and divided into the location types: polluted areas, industrial disposal sites and municipal disposal sites.

Sweden has divided polluted areas into industrial branches typical with regard to PCB pollution. As such secondary metal production and processes are listed together with the electronic industry, paper industry, ships and harbours, car scrap and scrap dealers (Naturvårdsverket, 1999).

In Denmark a mapping and characterization of areas according to soil quality criteria and land uses has been performed to ensure protection of

drinking water interests, environment and health (Lov om forurenet jord, §4, lov nr. 370 af 2. juni 1999). The so-called V1 and V2 mapping results will be available from the Danish environmental portal (<http://www.miljoeportal.dk/Jordforurening/>), which is under development. At this point the database is not publically available and only 4 locations have been identified as PCB polluted and no locations are listed as polluted with HCB.

Releases to soil, water and air from scattered sources are judged of minor importance compared to point source sectors when assessing sources of measured concentrations in the distal environment. Still, the concentrations of the total intake of the general European population measured indicate that human exposures from diffuse scattered sources in the proximal environment of humans may need further research. So, even though diffuse sources are of minor importance regarding total emissions of PCBs and HCB to soil, air and water, they may be important sources in relation to human exposure. Therefore, several studies address the increased background concentrations as a concern with regard to human exposure levels. In relation to the E-PRTR reporting scheme, this aspect is addressed in e.g. Wiberg et al., 2007.

3 Estimation of emissions and releases of HCB and PCBs

Emission estimates are based on specific activities at country level, as provided in Chapter 2 for each identified potential diffuse or point source for which the necessary data are available. Activity data are multiplied by the emission factor that is judged as most suitable or, if only one relevant emission factor has been found, the available one. Details concerning available and selected emission factors are given in Appendix 1 to 6. Information regarding emissions to soil and water from the energy and industry sectors is limited; nevertheless, activity data for these sources have as far as possible been included in Chapter 2. It is assumed that the potential major sources of release to soil and water may originate from off-site transfer of residue/waste products and wastewater discharge to the municipal sewer system. Therefore, potential sources of unintentional release of HCB and PCBs to soil and water have been included in Chapter 3.3, which presents available information relevant for PRTR code 5 'waste and wastewater management'.

The estimated emissions of PCBs and HCB to air are divided into point sources, according to Table 2, and diffuse sources as defined in Chapter 2. Large point sources and resulting reporting obligations become a requirement if the reporting thresholds as given in Table 2 are exceeded at the single-plant level. It is outside the scope of this work to perform a detailed investigation of the numbers of plants operating within each country. The current chapter presents, therefore, only indicative estimates of the importance of identified sources. It only to a limited extent takes into account that some countries may carry out more accurate inventories on these substances with national methodologies.

The indicative emission estimates should be divided by the number of plants operating within each sector to obtain an indication of the emission level compared with reporting thresholds. All figures in this chapter should be considered as indicative only.

The threshold values in the EU PRTR regulation for reporting at facility level (Regulation (EC) No 166/2006), are relevant, since a main aim of this project is to improve the ability of the Nordic countries to adequately report on emissions of unintentional emissions of HCB and PCB's. Where possible it will therefore be indicated whether emissions seem to be of a magnitude where reporting is required under the PRTR regulation. The threshold values for HCB are 10 kg/year per facility for emissions to air, while they are 1 kg/year for emissions to water and soil.

The threshold values for PCBs are 0.1 kg for emissions to air, water and soil alike.

3.1 Emissions related to energy production

Table 21 and 22 includes emission estimates for HCB and PCB respectively from energy production within the energy sector and the industrial sector. The tables include emissions from point sources as well as from fuel combusting activities categorized as diffuse sources. Activities for potential point and diffuse sources are described in Chapters 2.1 and 2.2, respectively.

Table 21 Indicative HCB emissions from fuel consuming activities (2005*)

Point sources			
Stationary combustion [g/yr]	Coal	Wood	MSW
Denmark	99	100	3 501
Finland	67	1 248	361
Norway	3	42	697
Sweden	13	749	3 250
Diffuse sources			
Mobile combustion [g/yr]	Gasoline	Diesel Oil	Fuel independent
Denmark	1	275	230
Finland			225
Norway			215
Sweden			365
Stationary combustion [mg/yr]	Coal	Wood	MSW
Denmark	2	9 903	17
Finland	3	19 321	NO
Norway	7	7 913	NO
Sweden	NO	18 504	NO

NO: Not Occurring

*or closest to, see Annex 1–6 for details regarding reference to specific activity data and emission factors

Table 21 indicates that the contribution to HCB emissions from diffuse sources is smaller than the contribution from point sources, except for combustion of wood. For Denmark, emissions for mobile combustion – mainly road transport – were divided into fuel types, and, as expected, emissions from diesel-fuelled vehicles dominate (see also Table 1.4. in Appendix 1). Mobile sources include national navigation, from which the contribution to the estimated emissions is insignificant.

Based on the estimated HCB air emissions from the Energy sector and energy consumption in the industrial sectors, none of the Nordic countries seem to be at risk of exceeding the PRTR reporting threshold value for HCB.

Table 22 Indicative PCB emissions from fuel-consuming activities [g/yr] (2005*)

Point sources			
Stationary combustion	Coal	Wood	MSW
Denmark	54 657	1 051	2 871
Finland	36 836	13 103	296
Norway	1 383	441	572
Sweden	7 402	7 863	2 665
Diffuse sources			
Mobile	Gasoline	Diesel Oil	Fuel independent
Denmark			19 133
Finland			18 762
Norway			17 885
Sweden			30 404
Stationary combustion	Coal	Wood	MSW
Denmark	147	1 917	13
Finland	13	3 977	NO
Norway	3	1 574	NO
Sweden	NO	3 586	NO

NO: Not Occurring

*or closest to, see Annex 1–6 for details regarding reference to specific activity data and emission factors

In table 22, the estimated emission level for PCB seems unrealistically high compared to the estimated level of HCB for point sources. Some investigations show that HCB emission levels to air significantly exceed the PCB emissions (e.g. Kim et al., 2004 and Bergquist et al, 2005). The same situation is valid for mobile sources and small combustion sources. An explanation may be that emission factors representative for the Nordic countries have been derived for HCB (e.g. Saarinen, 2007), while the same country-specific emission factors (EFs) have yet to be derived for PCBs (cf. Annex 1, Table 1.2 and 1.3).

PCB emission from petroleum refineries is categorized as a PRTR 1a activity. An emission factor to air for PCB of 1 mg/t refined fuel has been reported for the activity ‘Petrol Refinery’ (BiPRO, 2006). Based on this information, emission of PCBs from oil refinery processes is given in Table 23.

Table 23 PCB air emissions from production of refined petroleum [g/yr]

Petrol refinery	2001	2002	2003	2004	2005
Denmark	9 821	7 890	8 143	8 157	8 320
Finland	5 772	7 475	7 496	8 325	10 748
Norway	17 596	17 732	18 005	14 066	15 408
Sweden	19 593	19 314	19 662	20 612	19 920

The estimated PCB emission level from refineries is indicated to be of importance but to be below the emission estimates from road transport. The importance of stationary fuel-consuming point sources of PCB

emissions is particularly great in the case of Finland and Denmark, due to a high use of coal, which has a high emission factor (see Table 1.3 in Annex 1).

The estimated emission level for the energy sector is indicated to be above the E-PRTR reporting threshold for PCB.

3.2 Emissions from the metal, mineral and chemical industries

Table 24 Indicative HCB air emissions originating from industry [g/yr]

PRTR code	Source sector	2001	2002	2003	2004	2005
2	Metal industry					
	Denmark	1 504	796	12	13	13
	Finland	8 088	8 220	9 754	9 886	9 694
	Norway	12 713	5 078	1 778	1 828	1 816
	Sweden	4 897	5 034	4 713	4 842	4 660
3	Mineral industry					
	Denmark	27	28	26	29	28
	Finland	30	30	27	28	28
	Norway	14	13	13	14	14
	Sweden	31	31	30	31	32
4	Chemical industry					
	Denmark	63	9	NR	4 068	804
	Finland	8 190	2 480	460	16 700	NR
	Norway	NR	NR	NR	NR	NR
	Sweden	NR	NR	NR	NR	NR

NR: Not Reported

Table 24 shows the indicative HCB emissions originating from industry. When comparing the industrial sectors assumed to have the largest unintentional HCB emissions to air, the metal industry is clearly dominant as a source of unintentional emission of HCB to air. As mentioned in Chapter 2, the metal industry is also the most intensive industry regarding the production of output material in terms of waste and/or by-products.

The chemical industry is of major importance for Finland due to their potassium sulphate production. Some sources within the chemical industry may be insufficiently represented, e.g., as mentioned in Chapter 2 regarding pesticide production in Denmark. In general, more research on the chemical industry regarding potential emissions is required, as they may be of more importance than perceived earlier. For example, the estimated emission of HCB to air from the chemical industry in Sweden has been estimated at above 12 kg/yr in a study carried out by Bergquist et al., 2005.

The decreasing figures in table 24 for the Norwegian metal industry are due to the cessation of magnesium production in 2002. The generally

high figures for Finland are explained by the high activity in EAF plants in the iron and steel sector.

The use of chemicals is categorized as a diffuse source and the indicative emissions are given in Annex 3, Table 3.3 and Table 3.4. Data on pesticide use has only been identified for Finland resulting in an indicative HCB emission of 2g in 2006. Based on available information, the emission from the use of pesticides including residues of HCB is assumed of minor importance compared to that from organic solvent use (see Table 3.3 in Annex 3).

Table 25 Indicative PCB air emissions originating from industry [g/yr]

PRTR code	Source sector	2001	2002	2003	2004	2005
2	Metal industry					
	Denmark	1 180	649	61	68	68
	Finland	9 847	9 925	11 042	11 169	10 991
	Norway	1 729	1 982	1 942	2 250	2 289
	Sweden	8 059	7 795	7 554	8 099	7 949
3	Mineral Industry					
	Denmark	5 338	5 417	5 107	5 736	5 426
	Finland	2 956	2 728	2 660	2 875	2 972
	Norway	3 755	3 715	3 735	3 755	3 815
	Sweden	5 364	5 371	5 071	5 298	5 551

Table 25 shows indicative PCB emissions from industry. No sources of unintentional emission of PCB from the chemical industry have been identified. For Sweden and Finland the same pattern as for HCB is seen; i.e. that the metal industry is suggested to be the main emission source when compared to the mineral industry. For Norway and Denmark the figures suggest the opposite. The higher figures from the Finnish and Swedish metal industries compared to those in Denmark and Norway may be explained by the high activity in iron and steel production processes, i.e. sinter and EAF plants, as well as coke production.

The figures indicate activity levels above the reporting threshold, as given in Table 2, of 100 g/yr at single facility-level for sinter and EAF plants in Finland and Sweden. For cement-producing plants, the figures for Denmark are indicated to be above the reporting threshold (see Annex 2, Table 2.5). Depending on the number of cement production facilities in the remaining Nordic countries, reporting could be relevant.

Both the metal and to a lesser extent the mineral industries produce by-products; mass flows that will be registered as off-site transfer. More detailed mass flow analysis regarding the content of HCB and/or PCB needs to be undertaken in order to assess their contribution to unintentional releases to water and soil.

3.3 Emissions from waste and wastewater management

The EU directive on waste has contributed to the establishment of detailed waste categories for recycling and sorting as well as guidelines on their implementation, which are to be used at municipal level, for example at recycling stations. However, historical data are hard to categorize, since disposal categories, including for hazardous/non-hazardous waste, have varied between countries. The emissions estimated are therefore even more uncertain for this sector. Technical aspects and guidelines (e.g. Basel 2007a and 2007b) for best environmental practices may be found at the Basel webpage <http://www.basel.int/techmatters/index.html>.

3.3.1 Indicative emissions to air

EU directives as well as national regulation in the Nordic countries have been and are drivers for decreased final disposal of waste as landfill and increased combustion with energy recovery, using the organic burnable fraction of the household and industrial waste categories. Despite an increase in waste being combusted with and without energy recovery, a decrease in the emission of dioxins, and presumably also HCB and PCBs, has been observed, due to increased air pollution control requirements. In addition to high technology flue-gas cleaning, an increased sorting of waste, removal of precursor material such as metals and plastics and optimization of the combustion processes have resulted in the reduced emission of unintentional POPs.

In Denmark, shredder plants have been targeted as a possible major source of Danish PCB-emissions. PCB mainly exists in electric and electronic waste and building materials with a long lifespan. Despite regulation on separate collection of such waste, some ends up in shredder plants. A survey done in 2006 (ref lab 2006) for the 6 shredder plants in Denmark shows a mean of 11,3 $\mu\text{g}/\text{Nm}^3$ for measures of emissions to air for 2004–06. It further estimates a total emission of 3 kg/year from the 6 plants.

Waste incineration

The emissions from waste incineration (or combustion) have been divided into municipal waste and ‘hazardous waste’, where the term ‘hazardous’ covers classification terms like e.g. ‘problemavfall’ (‘problem waste’ – Finnish waste statistics), but is mostly to be read as ‘industrial waste’. In the Danish waste statistics report (DEPA 2006), the final waste disposal category ‘combustion’ includes municipal sludge, hazardous waste from households, service, industry and building and construction. It has not been possible to differentiate between waste incineration and combustion with energy recovery. The many and changing definitions and categorizations of waste types may be observed from reported emis-

sions factors (see Table 4.2 and 4.3 in Annex 4) and available data on combustion as the final disposal route (see Table 4.1, Annex 4).

The figures in Table 26 are therefore more uncertain than the remaining activity data presented in this report. The differences in amounts of waste may partly be explained by import-export loads of non-hazardous waste. Detailed coverage of the changes in the definitions of waste fractions and treatment technologies is not within the scope of the present work. See also see Table 4.1, Annex 4 for further information. A few comments to the figures in Table 26 are given below.

Table 26 HCB and PCB emission to air from combustion of waste with and without energy production

Activity [tonnes], average 2004–2005	EF_HCB [$\mu\text{g/t}$]	EF_PCB [$\mu\text{g/t}$]	Emission HCB [g/yr]	Emission PCB [g/yr]
Hazardous waste	10 000	5 000		
Denmark	86 490		865	432
Finland	7 214 751		72 148	36 074
Norway	574 246		5 742	2 871
Sweden	1 440 640		14 406	7 203
Municipal waste	2 000	820		
Denmark	1 468 500		2 937	1 204
Finland	239 924		480	197
Norway	226 843		454	186
Sweden	1 944 290		3 889	1 594

In the case of Denmark, 135,000 tonnes of ‘no reporting required’ waste explains the large amount of municipal waste. Another explanation for the relatively high amounts of municipal waste use for energy production may be the Danish waste strategy and a goal of no landfill disposal, increased reuse and increased waste to energy production.

Regarding the high amount of hazardous waste for combustion in Sweden and especially Finland, this may be due to import of e.g. shredder waste from Denmark and other countries.

According to the Swedish and the first Nordic report submitted to EU on waste statistics (EU regulation no. 1379/2007), the Swedish way of reporting waste statistics may differ slightly regarding e.g. the European waste categories on waste for incineration (Swedish Environmental Protection Agency, 2006). According to the Swedish waste management report, hazardous waste, given in Table 26, includes imported household waste (RVF, 2006).

Until recently waste has been categorized as hazardous or non-hazardous waste across all sectors (e.g. DEPA, 2007). The figures in Table 26 and Annex 4 may reveal a need for a more in-depth analysis of waste categories, import-export and final disposal and recovery categories. Details regarding available emission factors and waste types are addressed in Annex 4, table 4.1 to 4.3.

The emission factors given in Table 26 have been selected as either the most updated or the only available emission factors (see also Annex 4,

Table 4.2 and 4.3). The emission factors are expected to be overestimated in view of the actually applied waste treatment technologies in the Nordic countries and could be improved through monitoring of the stack gases. In the BREF for Municipal Solid Waste Incineration (MSWI) an average annual PCB emission factor of $<0.005 \text{ mg/Nm}^3$ is given (IPPC BREF on WI, 2006). For comparison, this would result in an emission of maximum 15000 g/yr for a Danish plant releasing $3.1 \cdot 10^9 \text{ Nm}^3$ stack gas per year. Approximately 12–13 of such waste combustions plants would result in an annual PCB emission from waste incineration of 200,000 g/yr, which according to BiPRO is low compared to other sectors (BiPRO, 2005). The latter is not confirmed by the present work.

Estimation in relation to dioxin emissions to air seems to confirm that emissions of HCB from waste incineration are overestimated, since cleaning flue gas for dioxin is generally considered to also reduce emissions of other substances, such as HCB. A recent Danish report (ref lab, 2007) estimates that dioxin emissions have been reduced from 21.1 g I-TEQ/year in 1999 to 0.38 g I-TEQ/year in 2006, a reduction of more than 98%.

Information and knowledge regarding releases to land, releases from diffuse sources and off-site transfers has not been prioritized for an in-depth analysis in this study as data are extremely scattered and sparse (e.g. Andrijewski et al, 2004; Naturvårdsverket, 2005; BiPRO, 2006).

Fugitive emissions from wastewater treatment plants (WWTP)

According to a Swedish survey, the emission of PCB from aeration tanks has been estimated to 150–200 g of total PCBs/yr to air in Sweden in 2004. For HCB, the estimate is 1–2 g/yr from Swedish sewage treatment plants (Naturvårdsverket, 2005).

According to the BREF for waste treatment technologies, an estimated annual emission from anaerobic digestion of MSW source-separated organic material is 0.73 mg PCB/tonne waste (IPPC BREF on WTI, 2006). Knowledge of the amount of source-separated organic fraction of MSW would allow for an estimation of the total PCB emission to air from anaerobic digestion of municipal organic waste.

Emissions from landfill fires and crematories

The available information on fires at landfill sites and other accidental fires only partly allowed for an estimation of HCB or PCBs emissions in this connection (Annex 6). This source may potentially be of importance for the total air emission of PCBs and HCB, depending on the chlorine and organic matter content of the material deposited at the landfills in question. Furthermore, emissions from crematoria were included for PCB, but are indicated to be of minor importance.

3.3.2 Potential emissions to water

Effluents from centralized WWTPs

Due to the development of centralized wastewater treatment systems in the Nordic countries, and Europe in general, the release to water from point sources is expected mainly to be related to these waste water treatment plants (WWTPs). Existing data on PCBs and HCB in water at sewage treatment plants are however limited. It is expected that potential sources to emissions with the effluent water vary widely, depending on the number and types of industries connected to the sewer system belonging to individual centralised WWTPs. The load of unintentionally formed POPs in process wastewater from individual industries may result in varying contributions at the centralized WWTPs receiving wastewater from these industries. PCBs and HCB have low solubility in water and therefore high affinity for sorption to organic particles. PCBs and HCB entering the WWTP with the influent wastewater therefore tend to partition into the sludge fraction during wastewater treatment, which expectedly results in lower levels in the effluent from the centralized WWTPs. However, a study by Bergquist et al., 2006, including ten PCB congeners, suggests a concentration of 0.3 ng/L and 1 ng/L PCB in the influent and effluent urban wastewater, respectively. Based on the congener patterns it is indicated that the source of PCB content in influent wastewater in Sweden originates from leakages from historic PCB pollution (Bergquist et al., 2006). Reported amounts of influent wastewater for Denmark are in the range of 600–800 million m³ in the years 1999–2003 (Thomsen and Lyck, 2005). This would imply an influent amount of PCB 0.18–0.24 kg/yr. The effluent amount of PCB depends on the sorption coefficient and the amount of effluent water; a reduction in the amount of effluent water may to some extent explain the increased measurement by Bergquist et al., 2006.

Effluent water from separate industries

Potentially, there may be a risk of release to water via discharge of treated scrubbing water. Wastewater from wet scrubbing processes includes dust particles. The presence of dust in the wastewater may increase the effluent load of PCB.

3.3.3 Potential emissions to soils

Potential sources have been mentioned in Chapter 2. Data regarding emission estimates is limited. Due to similar concentration levels at WWTP slightly above background soil concentrations it is suggested that a recirculation deposited UPOP, and additional contributions from surface runoff, result in re-entrance at WWTPs and a re-emission by spreading of the sludge on agricultural soils.

Releases with sludge

According to a Swedish study, PCBs occur at higher concentrations than dioxins in sludge, but represent a lower toxicity potential (Naturvårdsverket, 2005). Swedish concentrations of PCB in sewage sludge show a decreasing trend throughout the 1990s. The few data available on HCB indicate that levels of this compound are lower than those of PCBs. Swedish investigations indicate a total quantity of PCB₇ in sludge in 2003 of around 2.2 kg and that the mean concentration weighted by the annual sludge production showed a slight downward trend (Naturvårdsverket, 2005). In Denmark around 80,000 tonnes sludge was used as fertilizer within the agricultural sector annually from 2000–2002 (DEPA, 2003), resulting in an annual release to soil of 0.4–9.6 kg HCB/yr and 0.6–1.4 kg PCB/yr. The yearly releases to soil are based on the Danish release factors that are at the same levels as given for PCBs (see Chapter 2.1.5).

In addition, deposition from primary sources, even subject to long-distance transport, may contribute to soil concentrations today. Therefore the origin of sources for an estimation of the total deposition is difficult to address.

As the total quantities of PCBs and HCB currently to be found in and around different contaminated sites today may be substantial (see Chapter 2.3.3), such sources could be of appreciable significance for the release of PCBs and HCB, now and/or in the future. Release from soil may be just as important as deposition or release with respect to the environmental fate of PCBs and HCB. Due to the high binding affinity both of HCB and PCBs, risk of contamination of groundwater is minimal (e.g. Naturvårdsverket, 2005).

3.4 Relative importance of emissions to air in the Nordic countries

The findings regarding emissions to air can be summarized in the tables below. The tables do not contain the estimated emission numbers, since this could be interpreted as if the estimations have a satisfactory degree of certainty, which is not the case. Instead, the sources have been grouped into 3 categories: Main, medium and lesser, reflecting their probable relative contribution within the separate countries. It was decided not to include sources with an estimated emission under 200 g/yr, since they seem to be insignificant.

In order to be more readily understandable and closer to wording normally used in common language, some of the names in the table differ from those used in the previous tables in this chapter: Energy production corresponds to “Point sources. Stationary combustion” in table 21. “Mobile sources (road transport)” corresponds to “Diffuse source. Mobile combustion” in table 21, and “Residential combustion” corresponds to “Diffuse

source. Stationary combustion” in table 21. It is also reflected in the names in the tables that in Denmark, all combustion of waste is combined with energy production, while this is not the case in the other Nordic countries.

Table 27 HCB emissions to air: Probable sources of importance

Country	Main source	Medium source	Lesser source
Denmark	Residential combustion (wood) Energy production (waste)*	Energy production (combustion of hazardous waste) Chemical industry	Mobile sources (road transport)
Finland	Combustion of hazardous waste** Residential combustion (wood) Chemical industry	Metal industry Energy production (wood)	Energy production (waste) Combustion of municipal waste Mobile sources (road transport)
Norway	Residential combustion (wood) Combustion of hazardous waste	Metal industry	Energy production (waste) Combustion of municipal waste Mobile sources (road transport)
Sweden	Residential combustion (wood) Combustion of hazardous waste	Metal industry Combustion of municipal waste Energy production (waste)	Energy production (wood) Mobile sources (road transport)

*Recent studies on dioxin indicate otherwise, see ref lab (2007).

**The data on emissions from the sources are very uncertain, see also section 3.3.1

Table 28 PCB emissions to air: Probable sources of importance

Country	Main source	Medium source	Lesser source
Denmark	Energy production (coal) Mobile sources (road transport)	Petroleum refineries Mineral industry Waste treatment (shredder) Energy production (waste)	Residential combustion (wood) Energy production (wood)
Finland	Energy production (coal) Combustion of hazardous waste	Mobile sources (road transport) Energy production (wood) Metal industry Petroleum refineries	Residential combustion (wood) Mineral industry Energy production (municipal waste)
Norway	Mobile sources (road transport) Petroleum refineries	Mineral industry Combustion of hazardous waste Metal industry	Residential combustion (wood) Energy production (coal) Energy production (waste) Energy production (wood)
Sweden	Mobile sources (road transport) Petroleum refineries	Metal industry Energy production (wood) Energy production (coal) Combustion of hazardous waste Mineral industry	Residential combustion (wood) Energy production (waste) Combustion of municipal waste

4. Conclusion

This study has pointed to a number of likely sources to unintentional releases of HCB and PCBs in the Nordic countries and possible emission magnitudes, and has thereby brought the countries a step closer to being able to report on emissions. However, it has also revealed that with the knowledge available today, a complete assessment of the emissions is not possible and will require further knowledge, including filling the identified gaps.

At an early stage in the elaboration of the study, the significant shortcomings in the existing data and knowledge in general became clear, and focus was therefore directed towards trying to identify the most relevant sources for each country.

Data and information for deriving emissions estimates have shown to be biased towards air releases, with very little information on levels of pollutants in solid residues or liquid discharges. Adequate information was not available on the presence of HCB or PCB in solid and liquid residues.

4.1 Emission sources

Overall, the indicative air emission estimates suggest that combustion processes may be a main source of unintentional emission of HCB and PCBs. Regarding HCB, it seems that emissions from residential combustion of wood, a diffuse source, and combustion of waste, especially hazardous waste, are more important sources than combustion processes within the industry and point source energy sectors. The picture is more differentiated regarding PCB emissions, but energy production from coal, mobile sources (road transport) and petroleum refineries seem to be general main sources.

4.1.1 Country-specific summary of sources of air emissions

Denmark

HCB: Residential combustion may represent one of the main sources of unintentional emissions of HCB. Combustion of waste, which in Denmark is always combined with energy production, may be another. However, a recent study on trends in dioxin emissions from combustion of waste indicates that this may no longer be the case. Combustion of hazardous waste and the chemical industry are also likely sources. Road

transport, seem to be of lesser importance. Metal and mineral industries, being very small in Denmark, seem to be insignificant sources.

PCBs: Energy production based on combustion of coal seems to be the main source to unintentional emission of PCB, but road transport may also be of main importance. Petroleum refineries, the mineral industry, waste treatment at shredder plants and energy production from waste may also be sources of some significance, while residential combustion and energy production of wood are likely to be minor sources.

Finland

HCB: The study points to combustion of hazardous waste, residential combustion of wood and the chemicals industry as being the main sources. However, in a recent national study in Finland, the chemical industry was estimated to contribute with up to 81 % of the total emissions in 2004 (Saarinen et al., 2007). This is not consistent with the results of this study, which underlines the uncertainties involved. The Finnish estimation is likely to be more correct. The metal industry and energy production based on combustion of wood are indicated to be sources of some importance. Energy production of waste, combustion of municipal waste and road transport are suggested to be of minor importance.

PCBs: Energy production based on combustion of coal and combustion of waste seem to constitute the main sources of PCB. Road transport, energy production based on combustion of wood, metal industry and petroleum refineries are indicated to be sources of some importance. Residential combustion, the mineral industry and energy production from municipal waste seems to represent sources of lesser importance.

Norway

HCB: Emissions from residential combustion of wood and combustion of hazardous waste seem to be the main sources in Norway. The metal industry is indicated to be a source of some importance. Energy production from waste, combustion of municipal waste and road transport are indicated to be sources of lesser importance.

PCBs: Road transport and petroleum refineries seem to be the main sources to PCB emissions. The mineral industry, combustion of hazardous waste and the metal industry are indicated to sources of some importance. Residential combustion and energy production seem to represent minor sources.

Sweden

HCB: Residential combustion of wood and combustion of hazardous waste seem to comprise the main sources of emission of HCB in Sweden. Other sources that may be important are the metal industry, combustion of municipal waste and energy production from waste. Energy production from wood and road transport, seem to be lesser sources.

PCBs: Road transport and petroleum refineries seem to be the main sources to PCB emissions. Emissions from the metal industry, energy production of wood and coal, combustion of hazardous waste and the mineral industry may also be of importance. Residential combustion of wood, energy production from waste and combustion of municipal waste are indicated to be source of lesser importance in Sweden.

4.1.2 Release to water and soil

Output from wastewater treatment plants in terms of effluents to surface waters and sludge for final disposal, e.g. as fertilizer, is of significance. There seems to be a risk of increased effluent concentrations due to the presence of dust particles from wet scrubbing processes. However, information is very limited and no effort to derive data from separate industries has been performed. Releases with effluent wastewater are expected to be of minor importance compared to sludge. Measured concentrations in sludge are still indicated to be low compared to e.g. solid residues from combustion processes (see below).

4.2 Data gaps and need for further investigations

4.2.1 Emission factors - waste combustion

In general the reported emission factors for PCB and HCB seem high, especially for PCB. Regarding combustion processes involving waste, the emission factors are highly variable depending on the types of waste in question. The relative importance of flue-gas cleaning techniques contra the e.g. chlorine and organic content of feed material needs to be reflected in the emission factors used or to be documented as of minor importance. The selection of a fuel independent emission factor as in the Finnish inventory is only valid assuming the governing factor for the size of the emission factor is the technical aspects; i.e. air pollution control devices (APCDs). There seems to be a need for deriving the relationship between APCD and other technological aspects for waste types and resulting emission factors; e.g. in accordance with the new reporting obligations of waste types (EU Regulation on waste R and D categories, 2007).

4.2.2 Emission factors - In general

As may be observed from Annex 1 to 6, high uncertainty exists with regard to emission factors. More studies and selection and derivation of the most suitable emission factors reflecting technological developments seem to be required to obtain more realistic emission factors, especially for PCB. This need is exemplified by the fact that some studies show that

HCB is in general emitted in concentration levels that exceed those of PCB, but this is not reflected in the results of this study. HCB emission factors were chosen from the Finnish inventory report on HCB where possible (Saarinen et al, 2007).

4.2.3 Release factors into mass flows

There may be a problem regarding re-emission of unintentional POPs and, therefore, further knowledge needs to be obtained, and the IPPC BREF documents adjusted, in relation to treatment technologies for residue products such as fly ash from municipal waste incineration (e.g. Misaka et al., 2006) as well as wastewater treatment technologies (e.g. Nollet et al., 2003). Effective control of the wastewater treatment technologies and the capability to deal with dissolved and particle-bound influent PCB and HCB at trace levels are required to secure the maximum possible decrease in the concentration levels in effluent water (e.g. Bergquist et al, 2006).

Regarding mass flows of HCB and PCB from sources to final disposal or recovery process, in particular demolition and EEE waste, shredder and waste oils may represent important unintentional sources. Data regarding mass flows and content of unintentional POP's should be further addressed with the purpose of verifying proper treatment technologies and practices and to document that hazardous residues are combusted at HWI plants with high destruction efficiencies. Such information is needed for the verification of the effectiveness of the relevant directives (Directive 2000/53/EC on end-of life vehicles, Directive 75/439/EEC on the disposal of waste oils, Directive 2002/96/EC on waste electrical and electronic equipment, Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment).

Measures controlling the final disposal or recovery of material from end-of-life products could be relevant in order to produce available data for evaluation of secondary sources. Information on mass flows within specialized recycling industries should be evaluated and emission factors for specific processes at e.g. shredder plants would need to be derived in order to improve future assessments of emissions. Activity data on the final disposal categories for residue products and quality assessment of material to prohibit circulation of impurities in recycling is needed. Control monitoring could be relevant in relation to ensuring a high reduction and destruction efficiency and corresponding correction of emission factors.

Finally, import and export of residue products and waste for treatment at specialized high technology plants needs to be addressed in relation to future unintentional releases of HCP and PCBs.

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Annex 1. Potential sources originating from fuel consumption

The figures provided in this annex present data and information that was available and accessible at the time the work was carried out on the report. It may be possible to attain a higher level of detail regarding feed material and plant type and size. Therefore the annex represents a screening level review of potential sources to UPOPs from the energy sector as well as fuel consumption from activities categorized as diffuse sources.

The fuel combustion data in Table 1.1 is obtained from the countries most recent submission to the UNFCCC; this for all four countries is the 2007 submission. Where possible, detailed fuel consumption data from the National Inventory Report is used, otherwise data from the CRF tables is used; data from waste incineration for Norway stems from Statistics Norway. The heating values of the fuels necessary to calculate the mass of fuels combusted are taken from the countries' National Inventory Reports, or in the case of Norway, from national expert knowledge on heating values. All submissions to the UNFCCC can be downloaded from the UNFCCC website:

- http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php

Table 1.1 Activity data regarding solid and liquid fuel consumption within the Energy, Industry sectors and diffuse sources [tonnes]

PRTR code	IPCC code			
	A. Fuel Combustion Activities	Fuel type		
	1. Energy Industries			
	a. Public Electricity and Heat Production	Coal	Wood	MSW
1	Denmark	5 904 545	1 358 527	3 316 932
	Finland	3 053 373	6 995 210	361 290
	Norway	47 000	151 000	697 000
	Sweden	426 902	7 659 748	3 250 000
	2. Manufacturing Industries and Construction	Coal	Wood	MSW
	Denmark	306 480	309 362	184 000
	Finland	1 132 549	13 802 605	NO
	Norway	110 200	548 700	94 000
2, 3	Sweden	414 223	4 820 756	NO
	3. Transport			
	a. Civil Aviation	Aviation Gasoline	Jet Kerosene	
	Denmark	2 192	40 373	
	Finland	881	102 910	
	Norway	2300	250 000	
	Sweden	808	209 340	
	b. Road Transportation	Gasoline	Diesel Oil	
	Denmark	1 754 524	2 071 982	
	Finland	1 739 093	2 013 333	
	Norway	1 582 000	1 995 000	
	Sweden	3 783 255	2 297 562	
	d. Navigation	Residual Oil (Residual Fuel Oil)	Gas/Diesel Oil	Gasoline
Diffuse sources	Denmark	37 038	125 550	8 983
	Finland	46 548	69 860	51 136
	Norway	162 000	354 900	NO
	Sweden	76 345	71 178	24 375
	4. Other Sectors			
	a. Commercial/Institutional	Coal	Wood	MSW
	Denmark	NO	52 765	16 440
	Finland	NO	225 210	NO
	Norway	NO	9 300	NO
	Sweden	NO	93 866	NO
	b. Residential	Coal	Wood	MSW
	Denmark	317	1 875 115	NO
	Finland	510	3 413 445	NO
	Norway	1316	1 564 000	NO
	Sweden	NO	3 513 025	NO
	c. Agriculture/Forestry/Fisheries	Coal	Wood	MSW
	Denmark	73 347	8 337	NO
	Finland	6 000	42 1429	NO
	Norway	NO	4 300	NO
	Sweden	NO	14 034	NO

Table 1.2 Air emission factors (EF) for HCB from fuel consuming activities

SNAP code*	Activity and/or Fuel type	EF	unit	Scientific literature source	Internet available source	www
stationary sources						
01+02+03	Hard coal	16	µg/t	Pacyna, 1999	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_HCB.pdf
		13	µg/t	Andrijewski, 2004	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematy_czne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
01+02+03	Firewood	60	µg/t	Pacyna, 1999	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_HCB.pdf
	Residential combustion	500	µg/t		Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
	Power production	10	µg/t		Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
201	Non-industrial, commercial and institutional plants	10	µg/t		Saارين et al., 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
202	Non-industrial, residential plants	5	µg/t		Saارين et al., 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
202	Non-industrial, residential plants, hard coal	125	µg/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematy_czne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
202	Non-industrial, residential plants, wood	60	µg/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematy_czne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
203	Non-industrial, plants in agriculture, forestry and aquaculture	5	µg/t		Saارين et al., 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
203	Non-industrial, plants in agriculture, forestry and aquaculture, hard coal	13	µg/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematy_czne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
203	Non-industrial, plants in agriculture, forestry and aquaculture, wood	60	µg/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematy_czne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
809	Residential, Household, oak/wood, residential, fireplace, woodstove	13-990	µg/t	Gullett, 2003		
Mobile sources						
	Leaded gasoline	0.87	ng/km	Cohen, 1995	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_HCB.pdf
	Unleaded gasoline	0.024	ng/km	Cohen, 1995	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_HCB.pdf
	Diesel	21	ng/km	Cohen, 1995	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_HCB.pdf
	Transport	60	µg/t		Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
701	Passenger cars (r)	0.06	mg/t	Joas, A. 2006	Saارين, 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
702	Light duty vehicles < 3.5 t (r)	0.06	mg/t	Joas, A. 2006	Saارين, 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
703	Heavy duty vehicles > 3.5 t and buses (r)	0.06	mg/t	Joas, A. 2006	Saارين, 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
704	Mopeds and Motorcycles < 50 cm ³	0.06	mg/t	Joas, A. 2006	Saارين, 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
804	Ships, residual oil	0.07	mg/t	Cooper, 2005	Cooper, 2004	http://www.ivl.se/rapporter/pdf/B1620.pdf
804	Ships, gas oil	0.398	mg/t	Cooper, 2005	Cooper, 2004	http://www.ivl.se/rapporter/pdf/B1620.pdf

*SNAP: Source Nomenclature of Air Pollutants

The emissions factors marked in bold have been used for estimating HCB emissions to air. Assuming that all combustion plants have adopted the best available APCDs, the emission factors provided in the Corinair guidebook (EEA,2006) may be overestimated in relation to the EF values for small combustion sources used in the Finnish IR (Saarinen et al, 2007). Adopting a precautionary or 'worst case' approach, the default EFs given in the Corinair guidebook were used for the Energy and Manufacturing Industries as well as Construction (cf. Table 1.1 in this annex).

For non-industrial commercial and institutional as well as residential energy production the EF value taken from the Finnish IR has been used in the estimated emissions given in Table 1.4. This EF is however 'fuel independent' which implies that the potential emission is equal regardless of the fuel type used for energy production. Data from Gullett et al., 2005 suggest that variations in emissions according to combustion parameters may be more important than fuel type, which may justify the selection of the Finnish lowest EF values. However, the selection of emission factors that are lower for residential combustion compared to large industrial and energy producing plant is in conflict with the fact that residential combustion generally has higher EF values due to ineffective combustion conditions (e.g. Gullett et al., 2003).

Table 1.3 Air emission factors (EF) for PCB fuel consuming activities

SNAP code*	Activity and/or Fuel type	EF	unit	Scientific literature source	Internet available source	www
Stationary sources						
	Hard coal	8 800	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
	Firewood	630	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
20103	commercial and institutional plants (coal)	1 646.4	µg/t	AEAT Environment, 2001		
	small industrial wood-burning furnace	556	µg/t	AEAT Environment, 2001		
202	Hard coal, residential	1 250	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
202	Peat briquette, residential	900	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
202	Firewood, residential	600	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
809	Hard coal, domestic combustion	600	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
809	Peat briquette, domestic combustion	600	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
809	Firewood, domestic combustion	350	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
	oak/wood, residential, fireplace, woodstove	8 370	µg/t	Gullett, 2003		
	Small combustion sources	1 400	µg/t	Bipro, 2006		http://ec.europa.eu/environment/dioxin/pdf/report.pdf
	Residential combustion coal	2 000	µg/t	Bipro, 2006		http://ec.europa.eu/environment/dioxin/pdf/report.pdf
	Residential combustion wood	1 000	µg/t	Bipro, 2006		http://ec.europa.eu/environment/dioxin/pdf/report.pdf
Mobile sources						
	Road transport	5 000	µg/t	Bipro, 2006		http://ec.europa.eu/environment/dioxin/pdf/report.pdf
	Road transport, unleaded motor gasoline	200	µg/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
	Road transport, diesel, cars and light duty vehicles	0.05	ng/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
	Road transport, diesel oil, heavy duty vehicles	5.39	ng/t		Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
	Marine transport	600	µg/t	Bipro, 2006		http://ec.europa.eu/environment/dioxin/pdf/report.pdf
804	Ships, residual oil	0.07	ng/t	Cooper, 2005	Cooper, 2004	http://www.ivl.se/rapporter/pdf/B1620.pdf
804	Ships, gas oil	0.40	ng/t	Cooper, 2005	Cooper, 2004	http://www.ivl.se/rapporter/pdf/B1620.pdf
90201	Domestic or municipal waste	820	µg/t		EEA, 2006	http://reports.eea.europa.eu/EMEP_CORINAIR4/en/sources_of_PCB.pdf

*SNAP: Source Nomenclature of Air Pollutants

The emissions factors marked in bold have been used for estimating the PCB emissions to air. Assuming that all combustion plants have adopted the best available APCDs, the emission factors provided in the Corinair guidebook (EEA, 2006) may be overestimated. For non-industrial, commercial and residential combustion, the emission factors provided by

BiPro have been used as these are the latest reported values and are expected to be the most recently updated. It should be mentioned that lower EF values have been used in the Polish NIP (Andrijewski, 2004).

Table 1.4 Estimated HCB air emissions from fuel consuming activities

PRTR code	HCB air emissions for potential stationary PRTR sources [g/yr]				
	A. Fuel Combustion Activities		Fuel type		
	1. Energy Industries				
	a. Public Electricity and Heat Production	Coal	Wood	MSW	
1	Denmark	94	82	3 317	
	Finland	49	420	361	
	Norway	1	9	697	
	Sweden	7	460	3 250	
		2. Manufacturing Industries and Construction	Coal	Wood	MSW
2, 3	Denmark	5	19	184	
	Finland	18	828	NO	
	Norway	2	33	NO	
	Sweden	7	289	NO	
	HCB air emissions [mg/yr], except for navigation which is given in [ng/yr]				
	3. Transport				
	a. Civil Aviation	Aviation Gasoline	Jet Kerosene		
Diffuse sources	Denmark	NE	NE		
	Finland	NE	NE		
	Norway	NE	NE		
	Sweden	NE	NE		
		b. Road Transportation	Gasoline	Diesel Oil	Fuel independent*
	Denmark**	770	274 708	229 590	
	Finland	NE	NE	225 146	
	Norway	NE	NE	214 620	
	Sweden	NE	NE	364 849	
		d. Navigation	Residual Oil (Residual Fuel Oil)	Gas/Diesel Oil	Gasoline
	Denmark	3	50	NE	
	Finland	3	28	NE	
	Norway	11	141	NE	
	Sweden	5	28	NE	
		4. Other Sectors			
	a. Commercial/Institutional	Coal	Wood	MSW	
Denmark	NO	528	17		
Finland	NO	2 252	NO		
Norway	NO	93	NO		
Sweden	NO	939	NO		
	b. Residential	Coal	Wood	MSW	
Denmark	1.6	9 376	NO		
Finland	2.5	17 067	NO		
Norway	6.6	7 820	NO		
Sweden	NO	17 565	NO		
	c. Agriculture/Forestry/ Fisheries	Coal	Wood	MSW	
Denmark	0.4	0.04			
Finland	0.03	2.1			
Norway	NO	0.02			
Sweden	NO	0.07			

*'fuel independent' refers to the use of the EF from Joas et al., 2005, which is also used in the Finnish IIR, 2006. **Mobile transport divided into fuel types and given in units of km/yr is only available for Denmark. Numbers for 2004 were used corresponding to 13 and 32 billion driven km on diesel and gasoline, respectively.

Table 1.5 Estimated PCB air emissions from fuel consuming activities

Total Energy		PCB emission [g/yr]		
PRTR code	A. Fuel Combustion Activities	Fuel type		
Diffuse sources	1. Energy Industries			
	a. Public Electricity and Heat Production	Coal	Wood	MSW
	Denmark	51 960	856	2 720
	Finland	26 870	4 407	296
	Norway	414	95	572
	Sweden	3 757	4 826	2 665
	2. Manufacturing Industries and Construction	Coal	Wood	MSW
	Denmark	2 697	195	151
	Finland	9 966	8 696	NO
	Norway	970	346	NO
	Sweden	3 645	3 037	NO
	PCB air emissions [g/yr], except for navigation which is given in [µg/yr]			
	3. Transport			
	a. Civil Aviation	Aviation Gasoline	Jet Kerosene	
	Denmark	NE	NE	
	Finland	NE	NE	
	Norway	NE	NE	
	Sweden	NE	NE	
	b. Road Transportation	Gasoline	Diesel Oil	"fuel independent"
	Denmark			19 133
	Finland			18 762
	Norway			17 885
	Sweden			30 404
	d. Navigation	Residual Oil (Residual Fuel Oil)	Gas/Diesel Oil	Gasoline
	Denmark	18	135	NE
	Finland	23	75	NE
	Norway	80	381	NE
	Sweden	38	76	NE
	4. Other Sectors			
	a. Commercial/Institutional	Coal	Wood	MSW
	Denmark	NO	33	13
	Finland	NO	142	NO
	Norway	NO	6	NO
	Sweden	NO	59	NO
	b. Residential	Coal	Wood	MSW
	Denmark	1	1 875	NO
	Finland	1	3 413	NO
	Norway	3	1 564	NO
	Sweden	NO	3 513	NO
	c. Agriculture/Forestry/Fisheries	Coal	Wood	MSW
	Denmark	147	8	NO
	Finland	12	421	NO
	Norway	NO	4	NO
	Sweden	NO	14	NO

Table 1.6 Activity data for the petroleum industry - crude petroleum and refinery products.

Commodity		2001	2002	2003	2004	2005
Denmark	Petroleum:					
	Crude	thousand 42-gallon barrels	123 800	132 900	133 000	135 000
	Refinery products:					
	Liquefied petroleum gas	do.	1 224	1 195	1 232	1 250
	Gasoline	do.	16 496	15 205	15 264	15 400
	Naphtha	do.	13 000	--	--	--
	Jet fuel	do.	3 981	3 878	4 479	4 800
	Distillate fuel oil	do.	23 606	23 886	25 300	26 000
	Refinery gas	do.	2 221	2 141	2 331	2 200
	Residual fuel oil	do.	11 488	11 540	11 136	11 300
	Total	do.	72 000	57 845	59 700	61 000
Finland	Petroleum refinery products	thousand 42-gallon barrels	42 318	54 801	54 956	61 037
						78 796
Norway	Petroleum:					
	Crude ⁵	thousand 42-gallon barrels	1 138 400	1 092 800	1 041 400	1 024 400
	Natural gas liquids ⁶	do.	41 000	41 000	42 000	52 695
	Refinery products: ⁶					
	Naphtha	do.	27 000	27 000	27 000	8 741
	Gasoline	do.	26 000	26 000	27 000	23 913
	Kerosene	do.	9 000	9 000	9 000	4 774
	Distillate fuel oil	do.	46 000	46 000	47 000	45 765
	Residual fuel oil	do.	12 000	12 000	12 000	13 823
	Other products	do.	4 500	5 000	5 000	3 351
	Refinery fuel and losses	do.	4 000	5 000	5 000	2 757
	Total	do.	129 000	130 000	132 000	103 124
						112 964
Sweden	Petroleum, refinery products:⁹					
	Liquefied petroleum gas	thousand 42-gallon barrels	3 000	3 000	3 000	3 000
	Naphtha	do.	500	500	500	500
	Gasoline, motor	do.	40 000	40 000	41 000	41 000
	Jet fuel	do.	1 500	1 500	1 600	1 600
	Kerosene	do.	50	50	50	50
	Distillate fuel oil	do.	57 000	58 000	58 000	59 000
	Residual fuel oil	do.	39 000	40 000	40 000	41 000
	Other	do.	7 800	7 800	8 000	8 000
	Refinery fuel and losses	do.	5 000	5 000	5 000	5 000
	Total	do.	154 000	156 000	157 000	159 000
						161 000

Reference: US Geological survey , <http://minerals.usgs.gov/minerals/pubs/country/europe.html>

A conversion factor from gallon barrels to tonnes of 0.1364⁹ has been used for deriving the activity data given in the Table 3 of the main report.

⁹ Source:<http://www.globalngonline.com/index.asp?q=cf&ID=1024>

Annex 2. Potential sources within the metal and mineral industry sectors

The figures provided in the annex provide data and information that was available at the time the work was carried out on the report. To the best efforts of the authors, data covers all information regarding relevant sources within the metal and mineral industries. Still, processes outside the knowledge of the authors may very well exist. Therefore the annex represents a screening level review of knowledge on potential sources of UPOPs.

Table 2.1 Activity data for industrial production processes within metal and mineral industries

PRTR code	SNAP code	Activity [tonnes]	2001	2002	2003	2004	2005	reference
2e	030310	Aluminium metal, primary (aluminium casting)						
		Denmark	NO	NO	NO	NO	NO	6
		Finland	NO	NO	NO	NO	NO	6
		Norway	1 034 000	1 044 000	NR	NR	NR	4
		Sweden	101 000	99 000	NR	NR	NR	4
2e	030310	Aluminium metal, secondary						
		Denmark	18 000	18 000	18 000	20 000	20 000	1
		Finland	34 252	28 014	23 652	24 629	20 242	1
		Finland	34 252	28 014	23 652	24 629	20 242	5
		Norway	223 900	271 000	256 800	348 700	362 400	1
		Sweden	25 000	28 000	30 000	29 000	30 000	1
3c	30311	Cement production						
		Denmark	2 047 000	2 010 000	2 020 000	2 050 000	2 070 000	1
		Denmark	2 660 972	2 698 459	2 546 295	2 861 471	2 706 371	8
		Finland	1 325 000	1 198 000	1 493 000	1 691 000	1 321 000	1
		Finland	1 324 705	1 194 676	1 185 886	1 295 058	1 347 007	3
		Norway	1 870 000	1 850 000	1 860 000	1 870 000	1 900 000	1
		Sweden	2 600 000	2 700 000	2 650 000	2 700 000	2 800 000	1
		Sweden	2 640 600	2 642 000	2 491 000	2 604 700	2 730 700	6

To be continued

PRTR code	SNAP code	Activity [tonnes]	2001	2002	2003	2004	2005	reference
3c	30311	Lime production						
		Denmark	115 000	114 000	115 000	116 000	250 000	1
		Denmark	105 498	134 647	99 270	90 376	85 078	9
		Finland	33 300	35 000	43 400	43 200	44 000	1
		Finland	2 042 200	2 259 900	1 919 000	1 900 300	1 852 400	7
		Norway	100 000	100 000	100 000	100 000	100 000	1
2		Sweden	550 000	580 000	590 000	590 000	600 000	1
		Coke production						
		Denmark	NO	NO	NO	NO	NO	1
		Finland	909 000	912 000	895 217	903 723	893 628	2
		Norway	NO	NO	NO	NO	NO	1
		Sweden	1 200 000	1 200 000	1 250 000	1 300 000	1 400 000	1
2b	30301	Sweden	1 184 900	1 073 300	1 059 700	1 179 000	1 188 000	6
		Sinter plants						
		Denmark	NO	NO	NO	NO	NO	6
		Finland	2 852 000	2 828 000	3 092 000	1 042 000	3 522 000	1
		Finland	2 650 000	2 573 693	2 815 000	2 782 000	2 857 000	2
		Norway	60 000	80 000	90 000	90 000	90 000	1
2b	40207	Sweden	3 614 000	3 703 000	3 700 000	3 600 000	3 500 000	1
		Sweden	3 725 100	3 815 100	3 816 100	3 992 000	3 844 000	6
		Electric arc furnaces***						
		Denmark, crude steel production	746 000	392 000	NO	NO	NO	1
		Finland, pig iron production	2 852 000	2 828 000	3 092 000	1 042 000	3 522 000	1
		Finland	3 938 000	4 003 000	4 766 000	4 833 000	4 738 000	2
		Norway, crude steel production	635 000	694 000	698 000	695 000	690 000	1
		Sweden	5 518 000	5 754 000	5 707 000	5 949 000	6 000 000	1
		Sweden, total crude steel production	5 518 000	5 754 000	5 707 000	5 949 000	5 725 000	6
		Sweden only Electric arc furnaces production	1 870 100	1 941 000	1 819 000	1 874 000	1 802 000	6

To be continued

PRTR code	SNAP code	Activity [tonnes]	2001	2002	2003	2004	2005	reference
2e	30310	Magnesium production						
		Denmark	NO	NO	NO	NO	NO	1,4
		Finland	NO	NO	NO	NO	NO	1,4
		Norway	36 000	10 000	0	0	0	1,4
2e	030305	Sweden	NO	NO	NO	NO	NO	1,4
		Primary zinc						
		Denmark	NO	NO	NO	NO	NO	1,4
		Finland	36 253	61 580	70 652	69 333	72 474	1
		Finland, primary zinc	248 816	235 337	265 853	284 525	281 904	6
		Finland, smelting in hot dip galvanizing process	43 125	47 716	51 684	49 890	49 403	6
		Norway	129 300	137 300	143 500	140 900	133 300	1
		Sweden	156 334	148 600	185 900	197 000	214 600	1
		Secondary zinc production						
		Denmark	NO	NO	NO	NO	NO	1,4
2e	030305	Finland	NO	NO	NO	NO	NO	6
		Norway	NO	NO	NO	NO	NO	1
		Sweden	NO	NO	NO	NO	NO	1
		Primary copper production						
		Denmark	NO	NO	NO	NO	NO	1,4
2e	30306	Finland, anode copper**	169 250	160 900	160 566	151 647	157 933	6
		Norway, including also secondary production	26 700	30 500	35 900	35 600	38 500	1,4
		Sweden	173 000	188 000	185 000	206 000	192 000	1
		Secondary copper smelting refining						
		Denmark	NO	NO	NO	NO	NO	1
2e		Finland	NO	NO	NO	NO	NO	1
		Norway, included above	NO	NO	NO	NO	NO	1
		Sweden	35 000	35 000	30 000	30 000	30 000	1

To be continued

PRTR code	SNAP code	Activity [tonnes]	2001	2002	2003	2004	2005	reference
2e		Wrought copper product manufacturing						
		Denmark	NR	NR	NR	NR	NR	
		Finland	120 449	115 477	109 683	114 007	110 707	3
		Norway	NR	NR	NR	NR	NR	
2e		Sweden	NR	NR	NR	NR	NR	
		Cathode copper**						
		Denmark	NR	NR	NR	NR	NR	
		Finland	115 471	114 906	125 635	124 635	124 225	5
2e		Norway	NR	NR	NR	NR	NR	
		Sweden	NR	NR	NR	NR	NR	
		Lead production						
		Denmark	NO	NO	NO	NO	NO	1,4,6
2e		Finland	NO	NO	NO	NO	NO	1,4,6
		Norway	NO	NO	NO	NO	NO	1,4
		Sweden	NO	NO	NO	NO	NO	1,4
		Precious metals (Au)						
2e		Denmark	NO	NO	NO	NO	NO	
		Finland	6	5	6	5	3	5
		Norway	NO	NO	NO	NO	NO	
		Sweden	5	5	4	5	4	6
2e		Precious metals (Ag)						
		Denmark	NO	NO	NO	NO	NO	
		Finland	23	30	34	34	35	5
		Norway	1	1	1	1	1	6
		Sweden	306	320	300	292	NR	4

References:

- 1: US Geological survey; <http://minerals.usgs.gov/minerals/pubs/country/europe.html>;
- 2: Association of Finnish Steel and Metal Producers
- 3: VAHTI (data system of the Finnish Environmental Institute)
- 4: Finland: Teknologiateollisuus Technology Industries
- 5: European Association of Mining Industries; <http://www.euromines.org/>
- 6: Teknologiateollisuus, Year books 2004 and 2007; www.teknologiateollisuus.fi
- 7: National expert knowledge
- 8: Kemita Kemi, 6/2006 p. 67 & 6/2003 p. 58
- 9: Figures from the Danish producer, Aalborg Portland Cement
- 9: Statistics Denmark

*This is not the amount of primary zinc produced but the amount of zinc smelted during the hot dip galvanization. Primary zinc production volumes for Finland can also be found in the Finnish activity data table when needed. This emission source is based on information (expert estimation) from industry and emission factor used (Toda, 2006) and is highly uncertain. Therefore, this information should be used carefully.

**According to national expert knowledge, the figures in the Finnish year book represent production amounts of cathode copper, which is purified anode copper. Anode copper can also be sold and as such production volumes of anode copper represent best the production of primary copper.

*** The figures from Finland and Sweden have been obtained from national expert knowledge. By looking at the percentage production that uses EAFs according to Swedish expert knowledge, emission estimated based on the figures for Denmark and Norway results in overestimation as the activity data for these countries are based on crude steel production. EAF are used for the production of pig iron. As such, the uncertainty in data from the US Geological Surveys may be assessed by comparing the Finnish activity data for this production process.

For some of the production processes, figures for the same activity from different literature references and knowledge sources are provided. In most cases the figures agree, as observed from Table 2.1, which indicates that the data are at a suitable quality level for the purpose of this screening level assessment of potential sources to UPOP emissions.

In the case of primary zinc production, the figures from Finland are specific to smelting in hot dip galvanizing process. Such specialized information has not been available for this present work. Still, the Finnish data for primary zinc production by smelting in hot dip galvanizing process are at the same level as the data extracted from the US Geological Survey database and assumed to represent primary zinc production as a source of unintentional HCB emission at an acceptable level of accuracy for the purpose of this screening level assessment of sources of UPOP emissions.

Table 2.2 Air emission factors (EF) for HCB from industrial production processes within metal and mineral industries.

PRTR code	SNAP code	Activity [tonnes]	EF [$\mu\text{g/t}$]	Reference*	www
2e		Aluminium metal, primary (aluminium casting)	295	Saarinen et al., 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
2e	030310	Aluminium metal, secondary	5 000 000	EEA,2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
			2 200 000	Bailey,2001	
			20 000	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
			660	Saarinen et al., 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
			1 365	Finland, Expert knowledge	
3c	30311	Cement production	11	EEA,2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
			17–1 700	Bailey,2001	
			21	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
			10	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
3c	30311	Lime production	8	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2	30301	Sinter plants	32	EEA,2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
			150–15 000	Bailey,2001	
			2 300	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
			140	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
2d	40207	Electric arc furnaces	2 000	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2b	30310	Magnesium production	90 000–3 000 000	EEA,2006	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf
			300 000	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
			500 000	Bipro, 2006	
2e	030305	Primary zinc smelting in hot dip galvanizing process	1 456	Toda, 2005	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
2e	030305	Secondary zinc production	10 000	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2e	30306	Secondary copper smelting refining	3 900–390 000	Bailey,2001	
			39 000	Pacyna, 2003	
			20 000	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2e		Wrought copper product manufacturing	17 524	Japan Inventory, 2005	
2e		Lead production	300	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2e		Precious metals	204 000	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2		Iron foundries	40	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
6		Pulp and Paper	9	Bipro,2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf

*Detailed information on the references may be found in the List of references

Emission factors used for deriving estimated HCB emissions to air are marked in bold. EF values from the most up-to-date references have been selected, preferable to those from European studies.

Non-ferrous, e.g. aluminium casting, may occur in Norway and Sweden as the figures provided by the European Association of Mining Industries covers only 2000–2002 (see Table 2.1).

Table 2.3 Air emission factors (EF) for PCB from industrial production processes within metal and mineral industries.

PRTR code	SNAP code	Activity [tonnes]	EF [$\mu\text{g/t}$]	Reference	www
1a		Petrol refinery (residual oil)	1 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2e	030310	Aluminium metal, secondary	3 400	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
3c	30311	Cement production	2 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
			7	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIPPoland-eng.pdf
3c	30311	Lime production	150	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2e		Coke production	3 600	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2	30301	Sinter plants	200	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_PCB.pdf
			500	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
			1 000–13 000	IPPC, BREF IS, 2001	
			65	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
2d	40207	Electric arc furnaces	3 600	EEA, 2006	http://reports.eea.europa.eu/EMEPC_ORINAIR4/en/sources_of_PCB.pdf
			1 500–4 500	IPPC, BREF IS, 2001	
			5 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
			1 500	IPPC, BREF IS, 2001	
2	030305	Secondary zinc production	1 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2	30306	Primary copper production	100	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2		Secondary copper smelting refining	2 600	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2		Lead production	7 250	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2		Precious metals	160 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
2		Iron foundries	500	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
		Shredder	5 200	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
6		Pulp and Paper	700	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf

*Detailed information on the references may be found in the List of references.

Emission factors used for deriving estimated PCB emissions to air are marked in bold. EF values from the most up-to-date references have been selected, preferable to those from European studies.

The Nordic countries have no iron foundries or lead production. Still, the emission factors have been included for the purpose of an overview of potential sources to emissions where such activities are present.

Table 2.4 Estimated HCB air emissions from the metal and mineral industries [g/yr]

PRTR code	SNAP code	Production process	2001	2002	2003	2004	2005
2e	030310	Aluminium metal, primary (aluminium casting)					
		Denmark	NO	NO	NO	NO	NO
		Finland	NO	NO	NO	NO	NO
		Norway	305	308	NR	NR	NR
		Sweden	30	29	NR	NR	NR
2e	030310	Aluminium metal, secondary					
		Denmark	12	12	12	13	13
		Finland	23	18	16	16	13
		Norway	148	179	169	230	239
		Sweden	17	18	20	19	20
2e		Secondary copper smelting refining					
		Denmark	NO	NO	NO	NO	NO
		Finland	NO	NO	NO	NO	NO
		Norway (rep. und. Prim. as sum of secondary and prim.)	NR	NR	NR	NR	NR
		Sweden	700	700	600	600	600
2e		Wrought copper product manufacturing					
		Denmark	NR	NR	NR	NR	NR
		Finland	36	35	33	34	33
		Norway	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR
2b	30310	Magnesium production					
		Denmark	NO	NO	NO	NO	NO
		Finland	NO	NO	NO	NO	NO
		Norway	10 800	3 000	0	0	0
		Sweden	NO	NO	NO	NO	NO
2e	030305	Primary zinc smelting in hot dip galvanizing process					
		Denmark	NO	NO	NO	NO	NO
		Finland	63	69	75	73	72
		Norway	188	200	209	205	194
		Sweden	228	216	271	287	313
2e		Precious metals					
		Denmark	NO	NO	NO	NO	NO
		Finland	6	7	8	8	8
		Norway	0.3	0.2	0.2	0.2	0.2
		Sweden	63	66	62	61	1
2b	30301	Sinter plants					
		Denmark	NO	NO	NO	NO	NO
		Finland	85	82	90	89	91
		Norway	2	3	3	3	3
		Sweden	119	122	122	128	123
2b	40207	Electric arc furnaces					
		Denmark	1 492	784	NO	NO	NO
		Finland	7 876	8 008	9 532	9 666	9 476
		Norway	1 270	1 388	1 396	1 390	1 380
		Sweden	3 740	3 882	3 638	3 748	3 604
3c	30311	Cement production					
		Denmark	27	27	25	29	27
		Finland	13	12	12	13	13
		Norway	13	12	12	13	13
		Sweden	26	26	25	26	27
3c	30311	Lime production					
		Denmark	0.84	1.08	0.79	0.72	0.68
		Finland	16.34	18.08	15.35	15.20	14.82
		Norway	0.80	0.80	0.80	0.80	0.80
		Sweden	4.40	4.64	4.72	4.72	4.80

Table 2.5 Estimated PCB air emissions from the metal and mineral industries [g/yr]

PRTR activity	SNAP	Production processes	2001	2002	2003	2004	2005
2e	030310	Aluminium metal, secondary					
		Denmark	61	61	61	68	68
		Finland	116	95	80	84	69
		Norway	761	921	873	1 186	1 232
		Sweden	85	95	102	99	102
2e	30306	Primary copper production					
		Denmark	NO	NO	NO	NO	NO
		Finland, anode copper**	17	16	16	15	16
		Norway, including also secondary production	3	3	4	4	4
		Sweden	17	19	19	21	19
2e		Secondary copper smelting refining					
		Denmark	NO	NO	NO	NO	NO
		Finland	NO	NO	NO	NO	NO
		Norway	NO	NO	NO	NO	NO
		Sweden	91	91	78	78	78
2e		Precious metals					
		Denmark	NO	NO	NO	NO	NO
		Finland	5	10	11	11	11
		Norway	0.2	0.2	0.2	0.2	0
		Sweden	50	52	49	48	1
2b	30301	Sinter plants					
		Denmark	NO	NO	NO	NO	NO
		Finland	530	515	563	556	571
		Norway	12	16	18	18	18
		Sweden	745	763	763	798	769
2b	40207	Electric arc furnaces					
		Denmark	1 119	588	NO	NO	NO
		Finland	5 907	6 006	7 149	7 250	7 107
		Norway	953	1 041	1 047	1 043	1 035
		Sweden	2 805	2 912	2 729	2 811	2 703
2		Coke production					
		Denmark	NO	NO	NO	NO	NO
		Finland	3 272	3 283	3 223	3 253	3 217
		Norway	NO	NO	NO	NO	NO
		Sweden	4 266	3 864	3 815	4 244	4 277
3c	30311	Cement production					
		Denmark	5 322	5 397	5 093	5 723	5 413
		Finland	2 649	2 389	2 372	2 590	2 694
		Norway	3 740	3 700	3 720	3 740	3 800
		Sweden	5 281	5 284	4 982	5 209	5 461
3c	30311	Lime production					
		Denmark	16	20	15	14	13
		Finland	306	339	288	285	278
		Norway	15	15	15	15	15
		Sweden	83	87	89	89	90

Annex 3. Potential sources within the Chemical industry

Table 3.1 Activity data and emission factors for Production and use of chlorinated solvents

PRTR code	SNAP	Tonnes	1999	2000	2001	2002	2003	2004	2005
4a									
					Chlorinated solvent production				
		Denmark*	63	9	0	4,068	804	NR	NR
		Finland	0	0	0	0	0	0	0
		Norway	NR	NR	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR	NR	NR
40413	tetrachloromethane								
		Denmark	0	0	0	0	0	0	0
		Finland	0	0	0	0	0	0	0
		Norway	NR	NR	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR	NR	NR
40413	trichloroethylene								
		Denmark	0	0	0	0	0		
		Finland	0	0	0	0	0	0	0
		Norway	NR	NR	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR	NR	NR
40413	tetrachlorosthylene								
		Denmark	61	9	0	0	0	0	0
		Finland	0	0	0	0	0	0	0
		Norway	NR	NR	NR	NR	NR		NR
		Sweden	NR	NR	NR	NR	NR		NR
	1,1,1-trichloroethane								
		Denmark	0	0	0	0	0	0	0
		Finland	0	0	0	0	0	0	0
		Norway	NR	NR	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR	NR	NR
40413	perchloroethane								
		Denmark	0	0	0	0	0	0	0
		Finland	0	0	0	0	0	0	0
		Norway	NR	NR	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR	NR	NR
Diffuse	60406								
					Chlorine-containing solvents - use				
		Denmark	35 161	32 718	32 069	29 823	19 051	245	187
		Finland	1 350	1 250	1 094	1 421	1 407	1 110	1 317
		Norway	NR	NR	NR	NR	NR	NR	NR
		Sweden	NR	NR	NR	NR	NR	NR	NR

*,unspecified total

Data on production and uses in the Nordic countries are very limited and scattered. Activity data have been extracted from Statistics Denmark. For Finland, the data were taken from the Finnish IIR (SYKE, 2007). Data reported in the EUROSTAT PRODCOM database were either confidential or reported as zero. It has not been possible to derive reliable data from statistics Norway and Sweden. For Denmark data was extracted from Statistics Denmark, both on the production and use of chlorinated organic chemicals. Emission factors are given below.

HCB emission from the use of chlorinated chemicals is calculated by multiplying the amount of imported chlorinated chemicals by an emission factor of 2 mg/t (EEA, 2006).

Table 3.2 Emission factors for unintentional HCB emissions from production and use of organic chlorinated solvents.

SNAP	EF [µg/t]	Reference	www
Chemical industry			
Chlorinated solvent production	1 000 000	Bailey, 2001	
40413 tetrachloromethane	10 000 000	EEA, 2005	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_HCB.pdf
40413 trichloroethylene	4 000 000	EEA, 2005	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_HCB.pdf
	1 200 000	UK NAEI, 2004	
40413 tetrachlorosthylene	6 000 000	EEA, 2005	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_HCB.pdf
	2 400 000	UK NAEI, 2004	
1,1,1-trichloroethane	1 000 000–6 000 000	Pacyna, 2003	
	2 400 000	UK NAEI, 2004	
40413 perchloroethane	3 000 000–10 000 000	Pacyna, 2003	
60406 Chlorine-containing solvents - use	2 000	EEA, 2005	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_HCB.pdf
60307 PCB-containing paint use (open application)	80 000 000 000	Corinair guidebook	http://reports.eea.europa.eu/EMEPCO_RINAIR4/en/sources_of_PCB.pdf

Table 3.3 HCB emission from the production and use of chemicals [g]

PRTR activity	SNAP	Emission [g]	1999	2000	2001	2002	2003	2004	2005
4a	40413	Chlorinated solvent production							
		<i>Denmark</i>	63	9	NR	4068	804	NR	NR
		<i>Finland</i>	0	0	0	0	0	0	0
		<i>Norway</i>	NR	NR	NR	NR	NR	NR	NR
		<i>Sweden</i>	NR	NR	NR	NR	NR	NR	NR
	60406	Chlorine-containing solvents - use							
		<i>Denmark</i>	70	65	64	60	38	0	0
		<i>Finland</i>	3	3	2	3	3	2	NR
		<i>Norway</i>	NR	NR	NR	NR	NR	NR	NR
		<i>Sweden</i>	NR	NR	NR	NR	NR	NR	NR
	4b	Inorganic chemicals production							
		Potassium sulphate							
		<i>Denmark</i>	NR	NR	NR	NR	NR	NR	NR
		<i>Finland</i>	NR	NR	8 190	2 480	460	16 700	NR
		<i>Norway</i>	NR	NR	NR	NR	NR	NR	NR
		<i>Sweden</i>	NR	NR	NR	NR	NR	NR	NR

Table 3.4 Activity data and emission factors for use of pesticides including HCB impurities

Active ingredient	HCB impurity concentration [mg/kg]
Lindane	1
Dacthal	40
Pentachlorophenol	500
Atrazine	1
Simazine	1
Picloram	8
PCNB	500
Chlorothalonil	10
Endosulfan	0.1
Clopyralid	2.5

None of the above-listed active ingredients in pesticide formulation are allowed for use in Denmark. Sales statistics from Finland reports 873 kg of the active ingredient clopyralid was sold in 2006. In use, this diffuse source corresponds to 2 g HCB released in 2006. Compared to the air emissions from the use of organic chlorinated solvents, at least in Denmark (Table 3.3.), this amount seems of minor importance.

Annex 4. Activity data and emission factors related to waste and wastewater management

Table 4.1 Activity data for waste incineration [tonnes]

PRTR code	SNAP code	Activity [tonnes]	2001	2002	2003	2004	2005	Reference
	90202	Industrial waste						
		Denmark	NA	NA	NA	NA	NA	
		Finland	NA	NA	NA	15400	NA	1
		Finland	5 773 700	5 051 650	4 041 600	7 129 470	6 812 528	2
		Norway	NA	NA	NA	544 572	491 320	3
		Sweden	NA	1 115 730	1 264 860	1 243 840	1 637 440	4
		Hazardous waste (including paint production waste and chlorine-containing wastes)						
		Denmark	NA	NA	NA	90 599	82 381	5
		Finland	NA	NA	NA	80 000	NA	1
		Finland	187 200	195 000	183 500	271 829	215 286	2
		Norway	65 000	63 000	74 400	66 600	46 000	6
		Sweden	NA	NA	NA	NA	NA	
		Contaminated timber (wood)						
		Denmark	NA	NA	NA	NA	NA	
		Finland	NA	NA	NA	100	NA	1
		Norway	NA	NA	NA	NA	NA	
		Sweden	NA	NA	NA	NA	NA	
		Solid wastes						
		Denmark	NA	NA	NA	NA	NA	
		Finland	NA	NA	NA	3 900	NA	1
		Norway	NA	NA	NA	NA	NA	
		Sweden	NA	NA	NA	NA	NA	
	90205	Sewage sludge from WWTP						
		Denmark	NA	NA	NA	54 000	43 000	5
		Finland	NA	NA	NA	7 300	NA	1
		Finland	1 800	2 000	2 100	2 500	0	2
		Norway	NA	NA	NA	NA	NA	
		Sweden	NA	NA	NA	411 000	NA	
	90207	Hospital waste						
		Denmark	NA	NA	NA	NA	NA	
		Finland	207	104	94	94	94	2
		Norway	143.8	143.8	143.8	143.8	143.8	
		Sweden	NA	NA	NA	NA	NA	
	90201	Domestic or municipal waste						
		Denmark	NA	1 491 000	1 463 000	1 470 000	1 467 000	5
		Finland	NA	NA	NA	48900	NA	
		Finland	229 566	189 431	222 806	235 924	226 843	2
		Norway	445 000	492 000	544 000	539 000	NA	
		Sweden	NA	1 675 180	1 867 670	1 944 290	2 181 890	7

References:

- 1: Finnish waste statistics; http://www.tilastokeskus.fi/til/jate/2004/jate_2004_2006-09-05_tau_001_sv.html?til/jate/2004/jate_2004_2005-12-13_tau_001.html
- 2: Finnish waste statistics and expert judgement
- 3: Statistics Norway; <http://www.ssb.no/emner/01/05/20/avfind/tab-2006-12-22-03.html>
- 4: Statistics Sweden; http://www.avfallsverige.se/m4n?oid=1444&_locale=1
- 5: DEPA, 2006; <http://www2.mst.dk/udgiv/publikationer/2006/87-7052-284-7/html/default.htm>
- 6: Norwegian waste statistics and expert judgement
- 7: Norwegian waste statistics and expert judgement; http://statbank.ssb.no/statistikkbanken/Default_FR.asp?PXSid=0&nvl=true&PLanguage=0&tilside=selecttable/hovedtabellHjem.asp&KortnavnWeb=avfkomm
- 8: Henriksen, T.C. et al., 2006; <http://www.dmu.dk/Pub/FR602.pdf>

Table 4.2 Emission factors for HCB by waste incineration of different types of waste [µg/t]

PRTR code	SNAP code	Incineration	EF [µg/t]	Original reference	Internet available secondary reference	www
5c	90201	Domestic or municipal waste	2 000	Berdowski et al., 1997	EEA, 2006	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
			1 000	EEA, 2006		http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
			2 900	Bailey, 2001		http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
			10 000	Pacyna, 2003		http://www.mos.gov.pl/1 strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska_NIP-Poland-eng.pdf
			150	Andrijewski, 2004	Saarinén et al., 2007	http://www.mos.gov.pl/1 strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska_NIP-Poland-eng.pdf
5a, 5g	90202	industrial waste	139	Andrijewski, 2004		http://www.mos.gov.pl/1 strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska_NIP-Poland-eng.pdf
			19 000	Andrijewski, 2004		http://www.mos.gov.pl/1 strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska_NIP-Poland-eng.pdf
		pcb				
		tetrachloromethane	8 000 000	Duiser & Veldt, 1989	EEA, 2006	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		trichloroethylene	3 000 000	Duiser & Veldt, 1989	EEA, 2006	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		tetrachloroethylene	6 000 000	Duiser & Veldt, 1989	EEA, 2006	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		polyvinyl chloride	5 000 000	Duiser & Veldt, 1989	EEA, 2006	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		hazardous waste (including paint production waste and chlorine-containing wastes)	10 000	EEA, 2006		http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		hazardous waste incineration (HWI)	150	Bipro, 2006		http://ec.europa.eu/environment/dioxin/pdf/report.pdf
		contaminated timber (wood)	2 000	EEA, 2006		http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		Solid wastes	10 000	Cohen et al., 1995	EEA, 2006	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
		Other solid waste	1 000	Saarinén et al., 2007		http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
5f	90205	sewage sludge from WWTP	500 000	Cohen et al., 1995		http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
			470	Bailey, 2001		http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv
5c	90207	hospital waste	19 000	Cohen et al., 1995	Saarinén et al., 2007	http://reports.eea.europa.eu/EMEPCORINAIR4/en/sources_of_HCB.pdf
			2 900	Bailey, 2001	Saarinén et al., 2007	http://www.ymparisto.fi/download.asp?contentid=67644&lan=sv

To be continued

PRTR code	SNAP code	Incineration	EF [µg/t]	Original reference	Internet available secondary reference	www
			295	Andrzejewski, 2004		http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
			29 000	Andrzejewski, 2004		http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
		medical waste	857 000	EEA, 2006		http://reports.eea.europa.eu/EMEP/CORINAIR4/en/sources_of_HCB.pdf
	909	Cremation				
	907	Open burning of agricultural waste	1 000			
		Deep-seated landfill fires, domestic waste	0–19 000	Lönnemark, 2007	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
		Surface fire	1 000 000–1 500 000	Lönnemark, 2007		

Bold figures represent emission factors used for deriving indicative emission estimates.

Table 4.3 Emission factors for PCB by waste incineration of different types of waste [µg/t]

PRTR code	SNAP code	Incineration	EF [µg/t]	Reference	www
5c	90201	domestic or municipal waste	820	EEA, 2006	http://reports.eea.europa.eu/EME/PCORINAIR4/en/sources_of_PCB.pdf
		municipal solid waste (MSW)	50 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
5a, 5g	90202	industrial waste	5 000	EEA, 2006	http://reports.eea.europa.eu/EME/PCORINAIR4/en/sources_of_PCB.pdf
			380	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
		pcb	10 000 000	EEA, 2006	http://reports.eea.europa.eu/EME/PCORINAIR4/en/sources_of_PCB.pdf
		hazardous waste (including paint production waste and chlorine-containing wastes)			
		hazardous waste incineration (HWI)	30	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
5f	90205	sewage sludge from WWTP	5 000	EEA, 2006	http://reports.eea.europa.eu/EME/PCORINAIR4/en/sources_of_PCB.pdf
5c	90207	hospital waste	20 000	EEA, 2006	http://reports.eea.europa.eu/EME/PCORINAIR4/en/sources_of_PCB.pdf
			390	Andrijewski, 2004	http://www.mos.gov.pl/1strony_tematyczne/ochrona_powietrza/konwencje_ekologiczne/konwencja_sztokholmska/NIP-Poland-eng.pdf
	909	Cremation	400	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
	907	Open burning of agricultural waste	35 000	Bipro, 2006	http://ec.europa.eu/environment/dioxin/pdf/report.pdf
	90208	waste oil incineration			
		Barrel Burning of Household Waste	126 000	Lemieux, 2002	
		Deep-seated landfill fires, domestic waste			
		WHO-PCB	14 000–140 000	Lönnemark et al, 2008	
		PCB7	1 800–16 000	Lönnemark et al, 2008	
		Surface fire	10 000–40 000	Lönnemark, 2007	

Bold figures are selected emission factors used for deriving indicative emission estimates.

Annex 5. Chlorine in fuel types and waste fractions

Table 5.1 Chlorine content in different fuel types and waste fractions (Zevenhoven and Kilpinen, 2001)

Chlorine in fossil fuels [mg/kg]	
Coal, lignite	50–2 000
Peat	~500
Estonian oil shale	~2 000
Petroleum coke, 'petcoke'	~300
Light fuel oil	-
Heavy fuel oil	~<20
Orimulsion TM	~700
Natural gas	-
Chlor in biomass and waste streams [mg/kg]	
Wood (firewood)	0.08 – 0.13
Bark	0.02 – 0.4
Straw	0.1 – 1.5
Landfill gas	~50 ppmw CCl ₄
Textile	~0.25
Newsprint paper	~0.11
Leather waste	~0.7–3
Sewage sludge	0.03–1
Polyurethane foam (containing CFC11)	~8
PVC	~50
Municipal solid waste (MSW)	0.05–0.25
Refuse derived fuel (RDF)	0.3–0.8
Packaging derived fuel (PDF)	1–4
Car tyre scrap	500–700
Auto shredder residue (ASR)	0.5–2
Computer circuit boards (epoxy or phenolic resins)	0.1–0.5
Computer monitor housings	0.1
Electric & electronic equipment waste plastics	~3.5
Mixed medical waste	1–4
Black liquor solids	0.05–0.2

Table 5.2 Chlorine in European waste fraction for combustion (Jacquinot et al. (2000).

Waste fraction	Amount weight-%	Chlor content weight-%
Household waste	35	0.76
Paper	25	0.37
Plastic	8	2.36
Glass	9	0.01
Metal	4	0.03
Total combustible (textiles, etc)	19	1.0
Total	100	0.74

Annex 6. Cremation and Uncontrolled/Accidental burning

Crematoria and animal carcass burning

Currently cremation is not well addressed at country level (BiPRO, 2006). Still, information from the Swedish dioxin survey estimates a flue-gas volume of 600 m³ per cremation (Bergquist et al., 2005). In Sweden 75 crematories are reported to be in operation; no information on technical details is available. Data on the number of cremations are limited, but in Sweden 57,000 cremations took place in 1990 and 61,237 in 1993.

The Danish numbers are given in Table 6.1 below. According to BiPRO (2006) the emission factor for PCB is 0.4 mg/ t

Table 6.1 Activity rates for cremations [cremation/yr]

Cremations	1990	1993	2001	2002	2003	2004	2005	Reference
Denmark	40 991	43 194	41 707	42 539	41 997	41 555	40 758	1
Finland	NR	NR	13 351	14 354	14 847	15 508	16 108	2
Norway	NR	NR	NR	NR	NR	NR	NR	
Sweden	57 000	61 237	NR	NR	NR	NR	NR	3

References:

1: http://www.dkl.dk/statistik_1990_1999.aspx (in Danish)

2: www.shk.fi (in Finnish)

3: Naturvårdsverket, 2005

Assuming an average dead body weight of 70 kg, the level of emission to air would be as illustrated in Table 6.2

Table 6.2 Potential PCB emission to air from cremations [mg/yr]

Cremations	1990	1993	2001	2002	2003	2004	2005
Denmark	1 148	1 209	1 168	1 191	1 176	1 164	1 141
Finland	NR	NR	374	402	416	434	451
Norway	NR	NR	NR	NR	NR	NR	NR
Sweden	1 596	1 715	NR	NR	NR	NR	NR

Taking the number of reported cremations in Sweden into account, emissions from crematoria are judged to be below the E-PRTR reporting threshold of 0.1 kg/yr pr crematorium.

Uncontrolled/Accidental burning

According to an investigation of uncontrolled burning of garden and domestic waste (Hedman et al., 2005), a general emission factor for PCDF and PCB may be in the range of 4–72 ng/kg, with a median value of 20 ng/kg (WHO-TEQ); including values for the most common types of waste and excluding values from highly contaminated wastes which have to be added separately. The investigation suggests that backyard burning could generate similar amounts of emissions to combustion in municipal waste incinerators (MWI), even if the amounts of waste involved were 125-fold lower.

Open burning of waste is however forbidden in the Nordic countries (e.g. SFT, 2001) and Table 6.3 shows that burning of household waste in barrels as well as landfill fires are potential contributors to the total emission of PCBs and HCB. For comparison the national emission inventory from the UK showed that dioxin emissions from accidental fires contributed with 20% of the total dioxin emission. By comparing the emission factors (EF) for surface fires it is indicated that this may be a source of concern to unintentional emission of HCB and PCB.

Table 6.3 Emission factors for accidental fires [$\mu\text{g}/\text{kg}$]

Barrel Burning of Household Waste	EF
PCDD/F	5.8
PCB	126
Burning dumps and landfill fires	
PCB	15.5–590
Deep-seated landfill fires, domestic waste	
PCB7	14–140
WHO-PCB	1.8–16
HCB	0–19
Surface fires, landfill	
PCB	10–40
HCB	1000–1500
dioxins	0.05–0.9

Reference: Lemieux, 2002, Lönnemark, 2007 and 2008.

PCB7 and HCB were measured in the runoff water at levels below 0.02 $\mu\text{g}/\text{L}$ and for HCB below 0.5 to 1 $\mu\text{g}/\text{L}$.

Table 6.4 Amount of waste burnt during spontaneous landfill fires [tonnes]

Landfill fires	2001	2002	2003	2004	2005	Reference
Denmark	NA	NA	NA	15 000	15 000	1
Finland	42 384	37 316	38 084	28 256	26 874	2
Norway	NA	NA	NA	NA	NA	
Sweden	NA	NA	NA	NA	NA	

References:

1: Henriksen, T.C. et al., 2006

2: Finnish waste statistics and expert judgement

Minimum reported emission factors for landfill surface fires have been used in Table 6.5 and Table 6.6 for the estimated number of fires.

Table 6.5 Estimated HCB emissions from landfill fires [kg/yr]

Year	2001	2002	2003	2004	2005
Denmark	NA	NA	NA	15	15
Finland	42	37	38	28	27
Norway	NA	NA	NA	NA	NA
Sweden	NA	NA	NA	NA	NA

Table 6.6 Estimated PCB emissions from landfill fires [g/yr]

Year	2001	2002	2003	2004	2005
Denmark	NA	NA	NA	150	150
Finland	424	373	381	283	269
Norway	NA	NA	NA	NA	NA
Sweden	NA	NA	NA	NA	NA

As observed in Table 6.5 and Table 6.6, landfill fires may represent important sources of unintentional emissions of HCB and PCBs. Still, as mentioned in Chapter 2, landfill as it is known to date is becoming a historical phenomenon; lower amounts of burnable waste are being deposited at landfill sites. The waste is deposited and sorted, and landfill sites are used as e.g. long-term mineralization reservoirs for the production of compost.