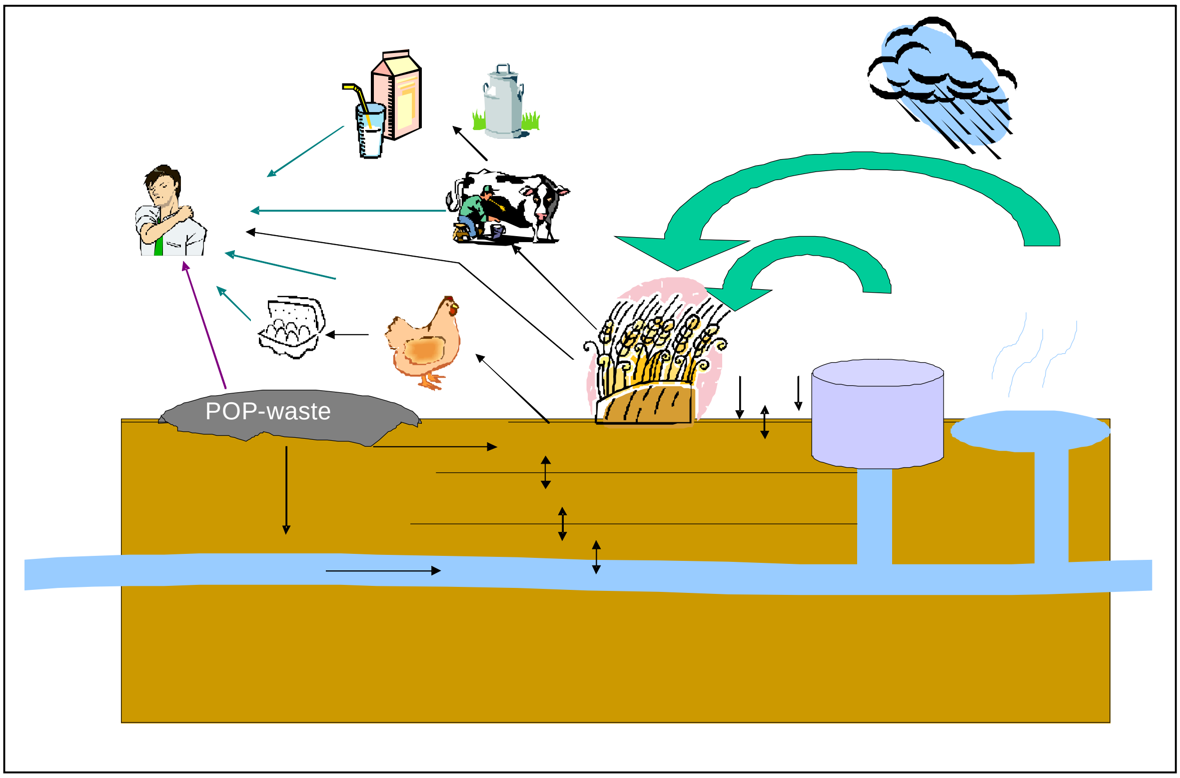
European Commission, Brussels

# Study to facilitate the implementation of certain waste related provisions of the Regulation on Persistent Organic Pollutants (POPs)

REFERENCE: ENV.A.2/ETU/2004/0044

## SYNTHESISREPORT

August 2005




BiPRO

Beratungsgesellschaft für integrierte Problemlösungen

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# 1 Background and Objectives

The background of the project is formed by several internationally binding instruments on POPs. Of most importance is the "Stockholm Convention" aiming at reducing and eliminating the production, use and releases of persistent organic pollutants. It includes specific provisions for the environmental sound management of wastes consisting of, containing or contaminated by POPs (hereafter called “POPs waste”). The European Regulation on persistent organic pollutants (2004/850/EC) implements the international commitments. Annex IV lists14 POPs substances and substance classes for which concentration limits must be adopted until the end of 2005. Above those limits the POPs content in waste shall be subject to destruction or irreversible transformation. Waste containing POPs above the concentration limits may be otherwise managed if destruction or irreversible transformation does not represent the environmentally preferable option. This derogation applies only to wastes which meet the maximum concentration limits to be laid down in Annex V andother conditions therein.

Against this background there are four major objectives of the project stated by the European Commission:

- compile and evaluate existing data on occurrence and levels of POPs in different waste categories and on existing concentration limits for POPs in waste.
- elaborate and apply a methodology to propose specific low and maximum concentration limits for the 14 POPs substances and substance classes laid down in the Regulation.
- elaborate and apply methodology, processes and criteria to assess the cases in which destruction or irreversible transformation do not represent the environmentally preferable option for management of waste with a POP content above the established limit values.
- propose reference measurement methods for the determination of the 14 POPs substances and substance classes in waste.

There are four reports available for the results of the project:

- Executive Summary (4 pages)
- Summary Report (15 pages)
- Synthesis Report (99 pages)
- Full Report (468 pages)

The following sythesis report provides short versions of all chapters of the full report.

# 2 Sources of Information

The results are mainly based on the following sources of information:

- Use of existing material from the European Commission
- Questionnaires
- Discussion with national authorities
- Meetings and interviews with industry and other stakeholders
- Use of available statistics and data bases
- Literature and internet research work.

***Questionnaires***

Three different types of questionnaires were elaborated and sent to

- Member States and authorities (70 questionnaires, including TAC, OEWG, permanent representatives etc.)
- Industry (130 questionnaires)
- Scientific and other institutions (335 questionnaires)

The project team received completed questionnaires from 19 Member States. Contacts and expert discussions (more than 50 bilateral discussions) took place with all Member States.

From the industry side the following feedback is available:

| Branch | Personal contact | Questionnaire |
|---|---|---|
| waste incineration | 4 | 7 |
| hazardour waste incineration | 2 | 8 |
| Landfill | 1 | 3 |
| underground disposal | 2 | 1 |
| non ferrous metal | 5 | 9 |
| iron and steel | 2 | 2 |
| Paper | 2 | 2 |
| sewage sludge | 1 | 1 |
| construction waste | 3 | 2 |
| shredder industry | 2 | 3 |
| adhesive and sealing material | 1 | 1 |
| chemical industry | 3 | 8 |
| waste oil | 4 | 3 |
| construction material | 1 | 1 |
| paint and lacquers | 1 | 1 |
| power production | 1 | |
| electro- and electronic industry | 1 | |
| Sum | 35 | 51 |

Table 2-1: Feed back to the questionnaire from industry

From scientific and other institutions 21 questionnaires have been returned. They provide in particular information on measurement technologies.

***Statistics and data bases***

The following data bases were investigated on relevant information for the project:

- EuroStat statistics, mainly on activity data for various industrial branches
- Stockholm, Basel Convention
- Stockholm BAT-BEP Guidelines (UNEP)
- EU BREF documents for the relevant industry sectors
- EEA databases for emission and waste
- EMEP databases for environmental contamination and deposition
- ISWA country reports
- Basel Technical Guidelines
- EU POP Regulation
- Aarhus POPs Protocol
- Databases from national EPAs
- Annual reports and databases from European and national Industry associations
- Literature/Database/websites

***Workshop with stakeholders and TAC Meeting***

For the discussion of draft results an expert workshop was organized by the Commission Services the 11 May 2005 in order to discuss the mass flow and first results of the assessment methodology for limit values. Comments of the participating experts have been evaluated and integrated into the drafting of the final report.

Members of the project team participated in the Meeting of the Committee for the Adaptation to scientific and technical Progress of EC-Legislation on Waste, 16 June 2005, Brussels in order to present the results of the draft final report. Member States have been invited to comment. Comments have been integrated as far as possible into the final report.

# 3 Overview on POP mass flows

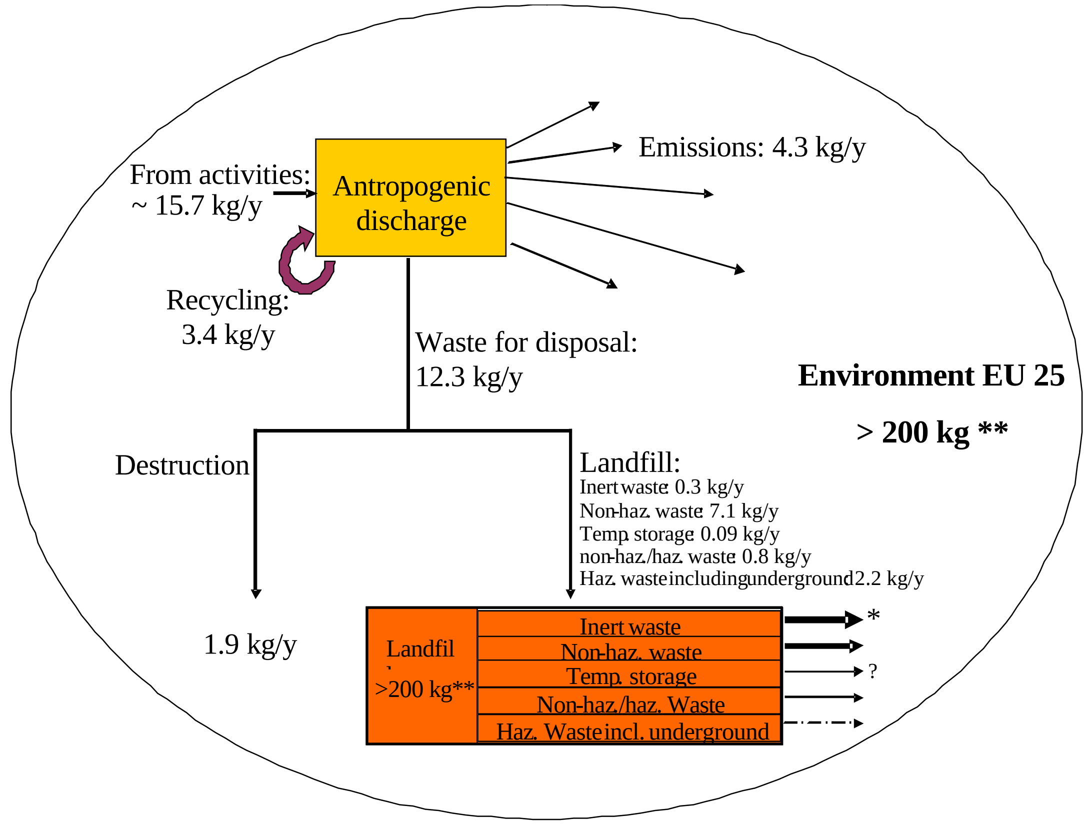
## 3.1 PCDD/PCDF[1] quantities and concentrations

PCDD and PCDF have never been produced intentionally but can be formed unintentionally during a number of production processes as well as via new formation from precursor substances in a specific temperature frame (200 – 450°C) during combustion processes in various industrial sectors (power production, waste incineration, metallurgical industry, cement production, domestic burning, etc.). New formation is especially important if certain catalysts (e.g. copper) or chlorine precursors are present in the feed material.

Besides industrial and domestic "sectors" PCDD/PCDF originate from natural sources like forest fires or volcanic eruptions. PCDD/PCDF are ubiquitously present in the environment via emissions, long-range transport, atmospheric deposition and environmental cycling. In consequence they also occur in waste streams like municipal solid waste, municipal sewage sludge, compost or waste from agricultural production.

Investigated mass flows of PCDD/PCDF amount to a dimension of 20 kg PCDD/PCDF-TEQ/y in Europe with 20% emitted to air and around 80% discharged in the form of solid process residues entering the waste regime. Overall air emissions seem to be dominated by domestic combustion of coal and derivatives. Most important sectors for discharge of PCDD/PCDF via residues are municipal solid waste (35%), municipal solid waste incineration (16.5%), power production (18.6%) and the ferrous metal industry with electric arc furnaces (10.3%) and sinter plants (8.4%). Detailed results and material flows on macro and micro dimension are available in the report.

[1] Polychlorinated dibenzodioxins and polychlorinated dibenzofurans




* The thickness of the arrow lines shall represent the release potential from the different landfill options
** The accumulated amounts of PCDD/PCDF in environment and landfills are estimated (note: they are equal by coincidence)

Figure 3-1: Major pathways and amounts of PCDD/PCDF distributed in EU 25

As illustrated in the figure above the PCDD/PCDF flow is characterised by relatively small amounts which are constantly formed and discharged while remarkable stocks awaiting elimination do not exist. As air emissions account for only 20% of the overall discharge from anthropogenic sources the waste sector, which divides into waste disposal operations (63% of the total discharge/y) and recycling and recovery (16% of the total discharge/y) is of considerable importance.

The share of landfill is high in comparison to other pathways. It has to be noted that much of this path is non-hazardous waste landfill due to the high contribution of MSW, which alone accounts for almost 7 kg/y from low contaminated wastes. Hazardous waste landfill and underground storage have a significant share due to large amounts of relatively high contaminated ashes directed to this waste management option. The almost 2 kg/y which have not been possible to allocate to either hazardous and non-hazardous waste landfill include PCDD/PCDF from sinter plants, EAFs, iron smelting and biomass power plants, thus including higher and lower contaminated wastes.

The 3.4 kg/y proceeded for recycling and recovery are dominated by low contaminated ashes from power production (almost 2 kg/y) and other low contaminated wastes such as compost and sewage sludge and bottom ashes from incineration.

Residues from metallurgical processes, which are reused in secondary thermal processes for metal recovery contribute with only 0.8 kg/y which in addition is further reduced in the processes.

To conclude, the waste sector is important for the overall discharge of PCDD/PCDF, but the major share of PCDD/PCDF discharge via waste will not be covered by the POPs Regulation. The reason is the importance of high volume but low contaminated wastes – mainly MSW, but also bottom ashes, slags, sewage sludge, compost. Further it can be concluded that potentially higher contaminated wastes (such as fly ashes) are already largely directed to hazardous waste landfills or underground. Only 2 kg PCDD/PCDF-TEQ/y are contained in wastes that are disposed off or used as secondary construction material at non-hazardous waste landfills and that might be influenced by the POP regulation.

The landfill directive (1999/31/EC) prohibits the landfilling of untreated waste, and might lead to enhanced incineration of all combustible fractions from June 2005. Therefore the importance of PCDD/PCDF discharge via non hazardous waste landfilling of MSW will probably decline in future, increasing the importance of the pathway destruction and hazardous waste disposal. Secondary high temperature metallurgical processes only receive a small fraction of the PCDD/PCDF discharges. These technologies should be not blocked by new legislation as they have the potential to further destroy PCDD while the metal content of the waste can be reused.

### 3.2 PCB[2] quantities and concentrations

PCB were produced from 1954-1980 in amounts of 1– 2 million tons worldwide and were used mainly in the northern hemisphere. The total amount produced in Europe has been estimated to about 700,000 t. PCB have been used for example as plasticisers in open applications mainly for construction purposes and as hydraulic or insulating oils in electric and mining equipment. Besides this PCB can form during thermal processes by the same mechanisms as PCDD/PCDF. However based on available data the total PCB mass flow from all major combustion sectors amounts for 39 t/y which is less than 0.5 % of the current overall flow.

PCB enter the waste regime mainly via long-lasting products and construction material reaching its waste stage. The dimension of the these mass flows can be added up to about 6,250 t/y.

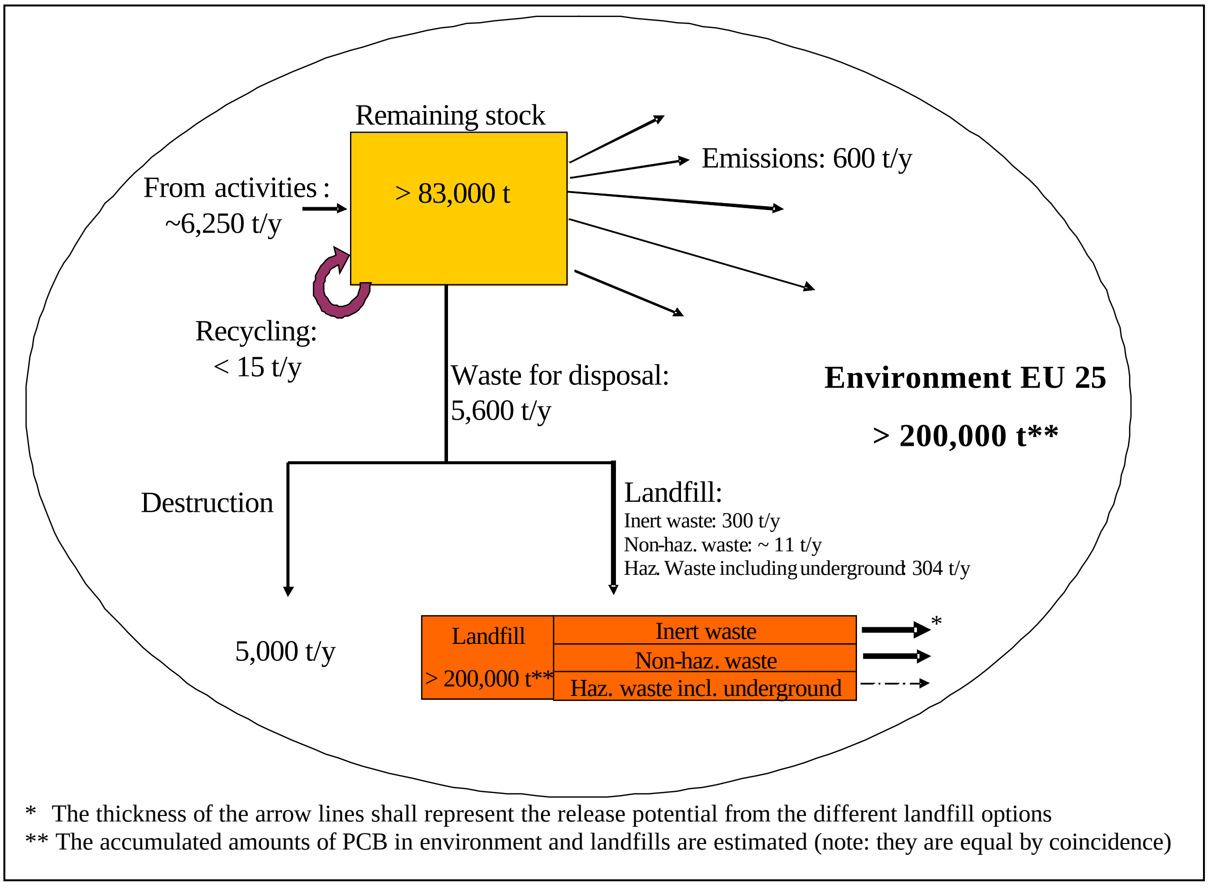



Figure 3-2: Major pathways and amounts of PCB distributed in EU 25

The emissions/discharges are quoted on an annual basis whereas the environmental load has been calculated as a minimum estimate on the basis of literature data [UK 1994] which state that about 30% of the estimated 700,000 tons produced has already been spilled to the environment. The remaining stocks have been calculated on the basis of best estimates from the mass flow including besides other data from country reporting on large PCB containing equipment (transformers, capacitors, hydraulic machinery), small capacitors in white goods, shredder residues and waste oils.

[2] Polychlorinated Biphenyls

Figures for PCB represent total PCB[3] numbers. For large PCB containing equipment the figures have been calculated as pure PCB contained in the liquids.

In relation to the remaining stocks recycling operations currently can not be regarded important as they account for only 0.2 ‰ of the total discharge. However, they may get a higher importance when the stocks will be eliminated. They have a qualitative importance as they contribute to keep the PCB in the environmental cycle.

Other than in the PCDD/PCDF flow destruction (thermal or combined) is already currently the dominating waste management option.

It has to be stated that much of the amount of PCB annually entering the waste regime (~80%) is already regulated by the PCB disposal directive and the WEEE directive, so that there will be no strong additional benefits from the POP regulation. However the about 10% of annual PCB discharge directed to landfill via C&D waste could be regulated and reduced by the POP regulation.

To conclude it can be stated that - based on the limited data available on the PCB mass flow - the destruction of PCB containing equipment still has to be regarded as priority action for the reduction of the overall PCB load. The second important measure to be taken seems to be the control and thorough separation of PCB from C&D waste in order to further reduce and prevent discharge of PCB from poorly sealed landfills.

For both measures regulation already exists, however it is probably not sufficient for the C&D sector, as there is only one single limit of 1ppm for inert waste landfill. Limit values in the POP regulation may have an additional effects on lower contaminated wastes which will gain a higher relative importance as highly contaminated liquids will increasingly be destroyed. However, the situation may be different in single Member States where large PCB containing equipment has already been decontaminated. Furthermore, it will become different at European scale when the stocks of equipment have been eliminated by 2010. A review of the situation should then reveal whether the regulative measures to separate and destroy potentially PCB contaminated parts and liquids (ELV directive, waste oil directive, WEEE directive) have been effective.

### 3.3 POP pesticide quantities and concentrations

POP pesticides like Aldrin, Dieldrin, Endrin, Chlordane, DDT, Heptachlor, Chlordecone, Mirex, Toxaphene have been largely produced and used as insecticides for crop and wood protection namely in the fifties and sixties of the past century and stockpiles are still existing in a number of countries. HCH including γ-HCH (Lindane) are discussed in the mass flow of other POPs as the mass for reasons of clarity, because a strict separation of quantities pertaining to pesticide use or to use as technical HCH/ non-pesticide use is not possible.

[3] Sum 6 congener multiplied by 5

In addition there is ongoing production of DDT which is mainly used as precursor for Dicofol. Consequently two mass flows have to be distinguished for POP pesticides. However as production of DDT and use of Dicofol is not yet related to the waste regime only the reduction of stockpiles has currently to be considered. Provided a constant reduction over a period of ten years (2000-2010), this sector has a dimension of 537 t/y.

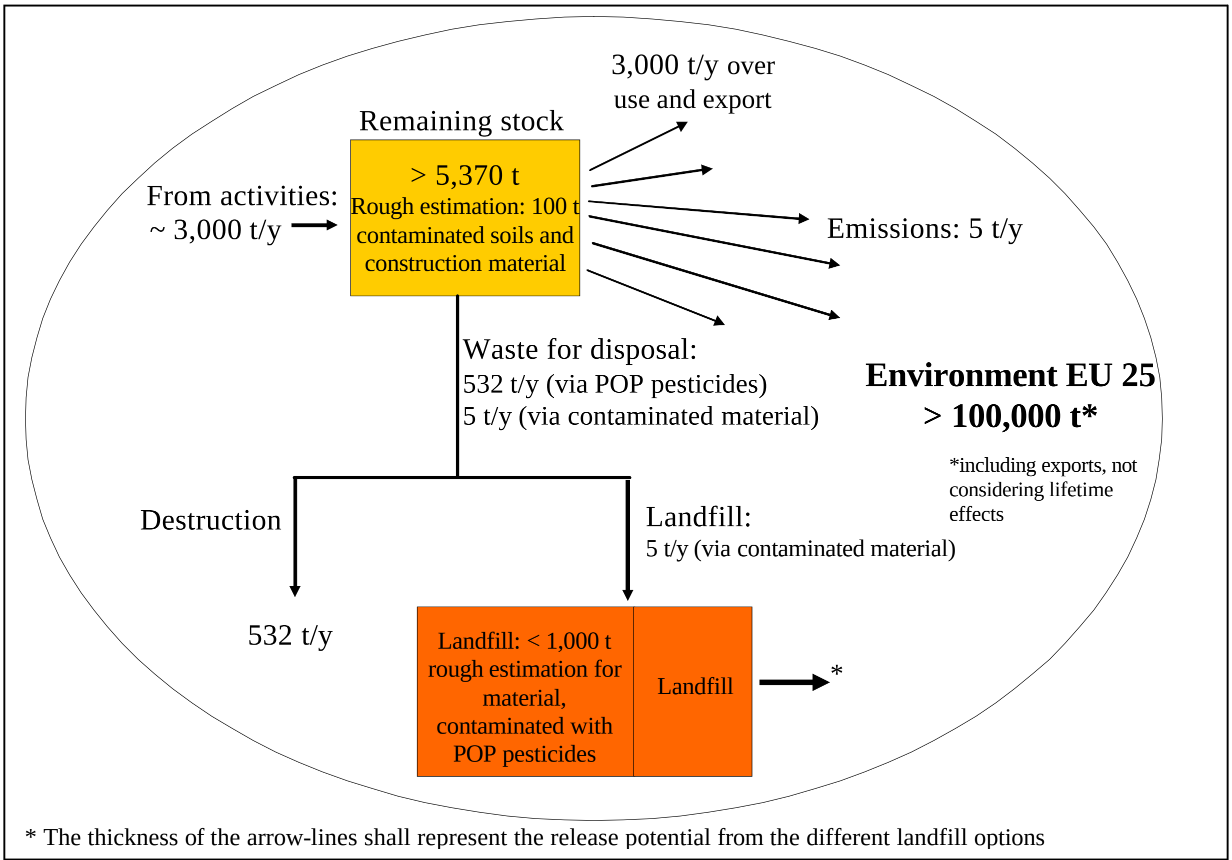



Figure 3-3: Major pathways and amounts of POP pesticides distributed in EU 25

As stated above the judgement on the effectiveness of legislation depends on the relations between pollutant streams affected by the proposed limit values and those unaltered.

The annual input to the overall flow consists of the reduction of remaining pesticide stocks including HCH and HCB assumed as linear over a period of 10 years and the estimated production figure for DDT.

The environmental load has been calculated as a minimum estimate on the basis of production figures [COWI 2002, 6th Pesticides Forum]. Amounts of α-,β- and δ-isomers as HCH production residues dumped at former production sites or spilled into soil are not included in the figure. They are discussed separately in the overall flow for “other POPs”.

As PCB, POP pesticides are no longer produced in significant amounts. Therefore anthropogenic discharge mainly results from remaining stocks.

Other than in the PCDD/PCDF flow destruction (thermal) is the only treatment option recommended for POP pesticides. As management of remaining stockpiles of POP pesticides as POP wastes is stipulated in the European POP Regulation[4] destruction of the remaining stocks over a period of 10 years (2000-2010) has been used as assumption for the mass flow. Based on this premise destruction will be the dominating pathway for POP pesticides in the waste regime. Another important pathway which however could only be quantified with significant uncertainty due to missing data is the landfilling of contaminated C&D waste including excavated soils from contaminated sites.

Based on the limited data available for POP pesticides - the destruction of remaining stockpiles and the controlled disposal of contaminated soils and C&D waste has to be regarded as priority action under the scope of the waste regime.

Limit values in the POP regulation will have a significant effects on both waste streams as levels can generally be assumed to lay above the low POP content limit.

### 3.4 Other POP quantities and concentrations

Like in the mass flows for PCB and POP pesticides the reduction of remaining stocks plays an important role in the mass flow of other POPs. In addition there is an ongoing production of γ-HCH, which however does not concern the waste regime.

While the emissions/discharges are reported on an annual basis, the environmental load has been calculated as a minimum estimate on the basis of production figures [COWI 2002, 6th Pesticides Forum, UNEP Mediterranean Regional report].

[4] (12) In particular, existing stockpiles […] should be managed as waste as soon as possible.

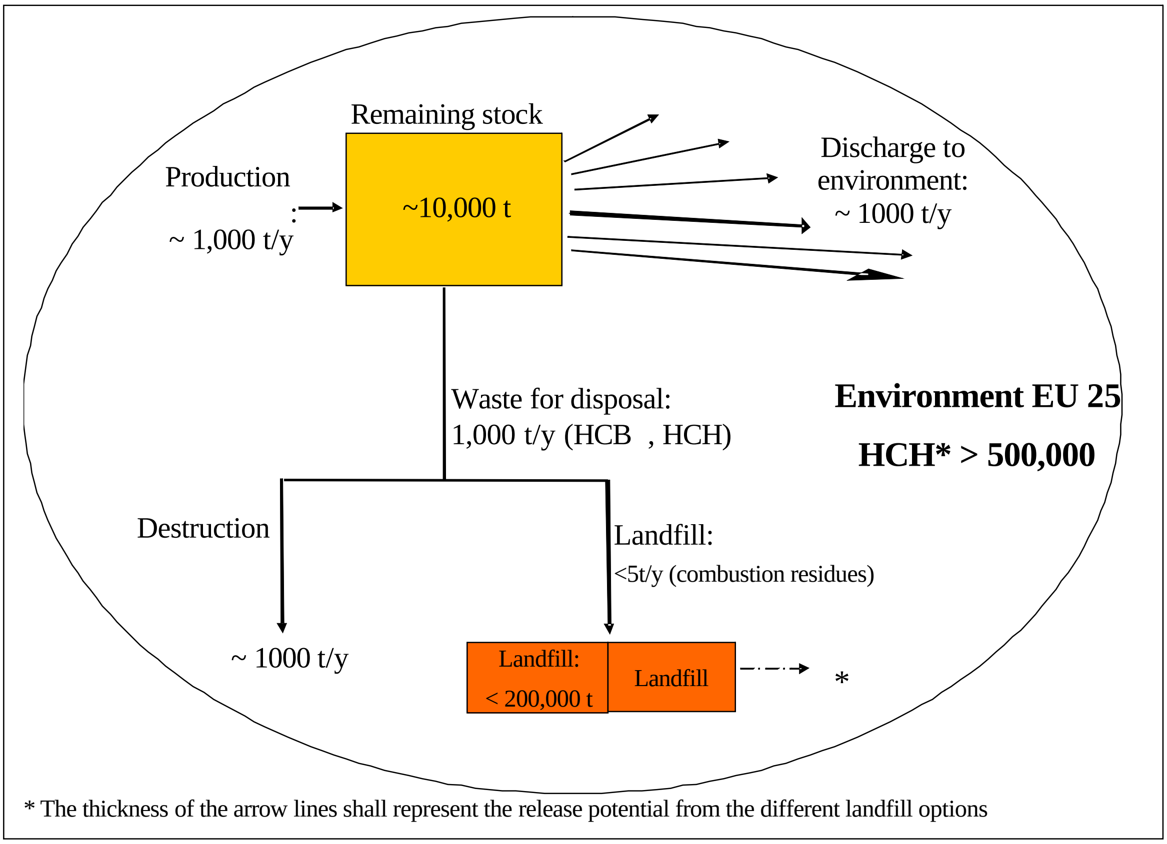



Figure 3-4: Major pathways and amounts of other POPs distributed in EU 25; HCH figures are sum figures for α,β,γ,δ-isomers.

As illustrated in the figure an estimated linear reduction of the remaining stocks of HCH and less HCB in dump sites at former producers leads to an annual waste stream of estimated 1,000 tons mainly directed to destruction operations. In addition there is a mass flow of < 5 t/y directed mainly to landfills via FGT residues from different combustion processes (waste incineration, power production, metallurgical industry). As the data base is very limited a more precise evaluation is not possible. In addition a non-quantifiable amount of other POPs is directed to landfill via C&D waste and soils from contaminated sites. Further data will be needed for this. While concentration in FGT residues is low concentrations in stocks and C&D waste typically exceed proposed limits under the POP regulation. Thus it can be stated that the regulatory potential is significant.

# 4 Detailed mass flows analyses

## 4.1 Objectives and methodology

The results of the mass flow have to enable a number of conclusions:

- comparison of the path "emission" to the path "waste"
- comparison of the importance of the various POPs
- comparison of the importance of various industrial, public and domestic sectors
- comparison of different handling and disposal options
- relative coverage of wastes and pollutant by different POP limit values
- establish scenarios on the consequences of different limit values
- provide a basis for a prognosis of future developments.

Furthermore the methodology has to be flexible to allow inclusion of new data and update the established data base in order refine/precise conclusions and future prognosis with increased knowledge.

Following these different purposes the mass flows have been calculated by means of a computer based system. As input parameters we used activity data, waste generation factors and specific contamination data for emissions and solid residues in the 25 EU Member States as far as accessible in international data bases (Eurostat, IEA, EEA, EMEP, national statistics) and literature (BREF documents, UNEP documents on BAT/BEP with respect to POPs) plus unpublished data directly communicated by industry associations, scientific experts or NGOs.

Based on these data the project team calculated figures on annual generation of divers residues and annual discharge of specific POPs from important sectors on EU 25 and Member State level. Overall mass flows indicating the relative importance of annual discharges to wastes in relation to air emissions and environmental loads have been established on EU 25 level.

In order to give an overview on the situation in EU 25 the calculation is based on mean values but ranges and Member State specific values are available in the report. Extrapolations on per capita basis had to be used in a number of cases and uncertainty is not negligible. Nevertheless the results for the first time provide an overview on the dimension and distribution of POP contamination in waste and give a scientific base to the discussion on feasible limits for POP waste in Europe and under the Stockholm Convention.

As illustrated below the overall structure of the mass flows (macro dimension) follows a material flow station approach, including emissions and discharge to products, but focussing on solid residues (waste) and its management .

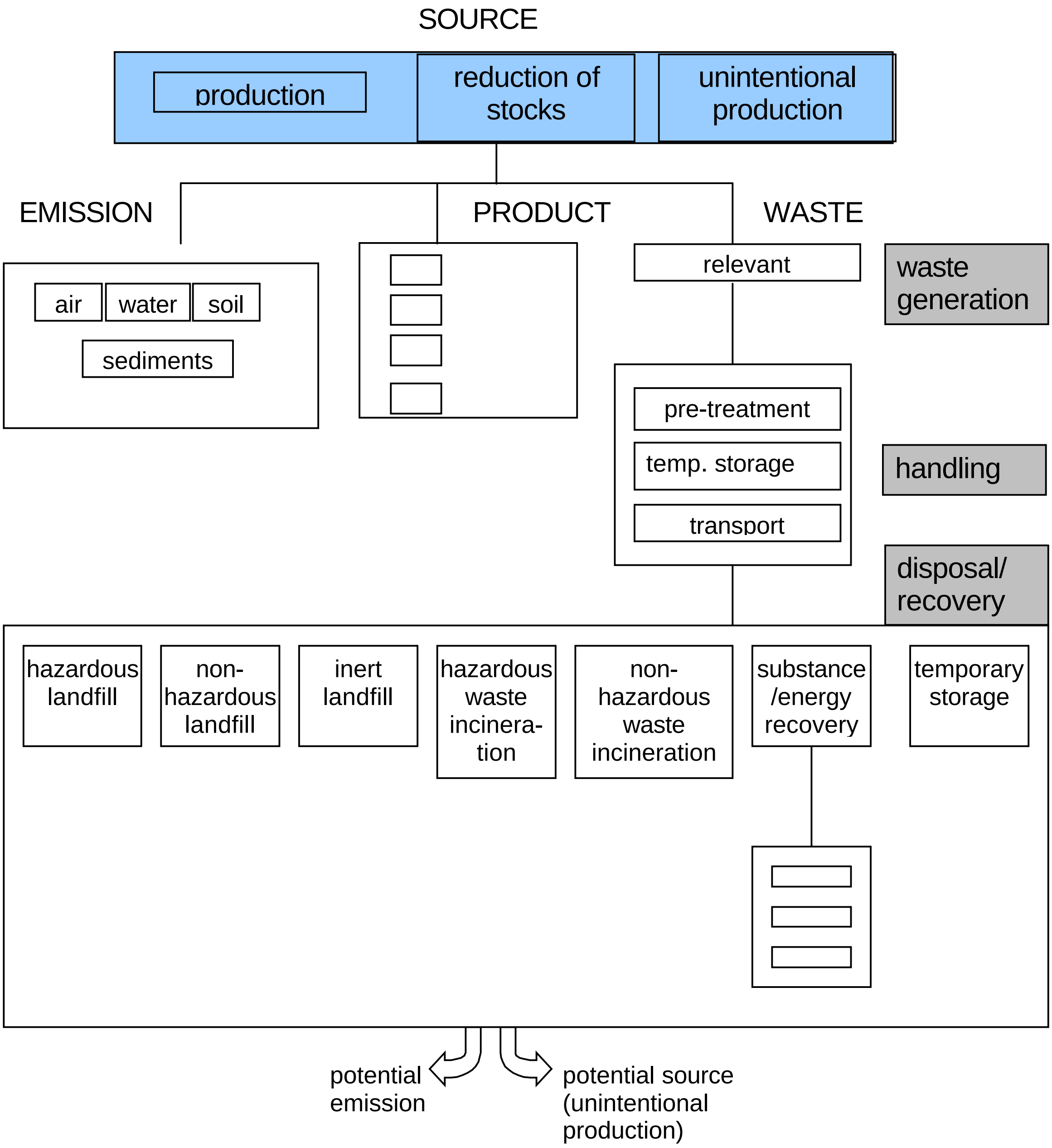



Figure 4-1: General structure of mass flow (macro dimension)

In order to identify relevant inputs and waste fractions the various stages of the applied process technology have to be taken into consideration for each investigated source sector. To this end important processes have been analysed in detail on the basis of existing information and expert interviews. On the basis of detailed process analyses the relevant process steps with respect to the flow or generation of POPs have been identified and relevant input and output streams of the processes have been determined (micro dimension of the mass flows). As far as possible, the often complex and manifold processes have been condensed to simplified and schematic flow charts that represent the relevant input and output streams resulting in flow charts as illustrated below.

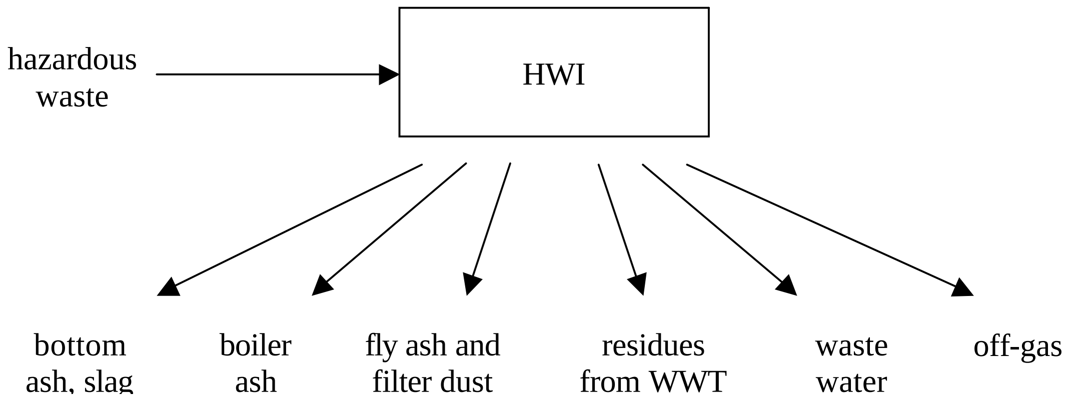
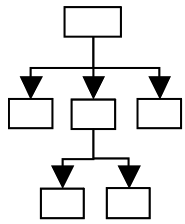


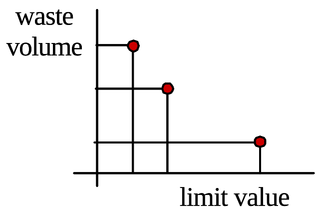

Figure 4-2: Example for process specific differentiation of residues and emissions in the mass flow (micro dimension)

In order to be able to derive recommendations and conclusions concerning limit values two types of information are important to be taken into consideration in this chapter. This consist of the following:

1. Quantities of pollutants formed and released (mass flows)



2. Volumes and POP concentrations for contaminated wastes related to waste management operations (waste flows)




Thus mass flows for the four different groups of POP substances as are in the scope of the European POP regulation and in the full report - PCDD/PCDF, PCB, POP pesticides and other POPs - as well as waste flows for the different investigated sectors are drawn up in this chapter. More details for both the POP mass flows and the waste flows are presented in the full report.

The methodology to combine macro- and microdimension enables the exclusion of double-counting of material flows. Every operation is characterised by its inputs and outputs. “Sources” and “ “Endpoints” are calculated separately. Processes that both receive and discharge POPs appear consequently twice.

***Investigated sectors***

Sectors included into the mass flow have been selected depending on their relevance for the mass flows according to information from literature, database and substance properties. Besides industrial sectors which have been identified either as potential sources for the formation of the substances in question (e.g. waste incineration, power production, metallurgical industry, chemical industry) or as sectors acting as transport/distribution sector (e.g. waste oil refining, shredder industry) and material known or suspected to contain POPs (e.g. large and domestic electrical and electronic equipment, obsolete POP pesticides) also "non-industrial" sectors representing a more general "generic" or "environmental" contamination due to ubiquitary pollution (i.e. sewage sludge from municipal solid waste water treatment, compost from composting operations, domestic burning of wood and coal and road traffic) have been investigated in order to assess the relative importance of the industrial sectors in relation to the overall mass flow.

Effectively the following sectors have been selected for inclusion into the mass flow:

- municipal solid waste incineration
- hazardous waste incineration
- hospital waste incineration
- power production (coal and biomass)
- iron and steel industry (sinter plants, EAF, iron smelting)
- non-ferrous metal industry (secondary aluminium, copper, zinc)
- chemical industry
- domestic burning (coal, wood)
- sewage sludge
- compost
- road traffic

In addition rough estimations on POP flows have been made for the following sectors:

- mechanical biological treatment
- accidental fires

Via this approach a broad overview on relevant sectors has been assured.

## 4.2 Sources for POP discharge to environment and waste

### *4.2.1 PCDD/PCDF*

PCDD/PCDF have never been produced intentionally but can be formed unintentionally during a number of production processes as well as via new formation in a specific temperature frame (200 –450°C) during combustion processes in various industrial sectors (power production, waste incineration, metallurgical industry, cement production, domestic burning, etc.). New formation is especially important if certain catalysts (e.g. copper) or chlorine precursors are present in the feed material. This type of POP is consequently called U-POP in contrast to POPs that have been produced intentionally. This is of high significance for the prognosis of the mass flow.

It has however to be taken into account that the new formation in the thermal processes does only occur in the flue gas cooling process, while the high temperature combustion process itself - applied in waste incineration, power production and metallurgical processes - does almost completely destroy all PCDD/PCDF and other POPs entering the process with the feed material. Thus the processes can be regarded as “sources” and as “sinks” in the applied mass flow methodology.

Besides industrial "sources" PCDD/PCDF have natural sources like forest fires or volcanic eruptions. PCDD/PCDF are ubiquitously present in the environment via atmospheric deposition and environmental cycling. In the consequence they do also occur in waste streams like municipal solid waste, municipal sewage sludge, compost or waste from agricultural production.

A complete quantification of all relevant sources for mass flows in Europe is a difficult task due to missing or incomplete data. In the detailed mass flow analysis relevant sources according to literature and international discussions have been investigated.

All figures for PCDD/PCDF given in the full report are PCDD/PCDF-TEQ values according to international measurement conventions. It is not always clear however whether they represent I-TEQ or WHO-TEQ value. In relation to the overall uncertainty of the figures the related effect is negligible.

### *4.2.2 PCB*

PCB were produced from 1954-1980 in total amounts of 1– 2 million tons world-wide and were used mainly in the northern hemisphere. The total amount produced in Europe under trade names such as Apirollo, Blacol, Clophen, Chlorofen, Delor, Fenchlor, Phenochlor, Pyralene, Pyroclor or Tarnol) has been estimated to account for about 700,000 t [DEMEX 2003, UNEP regional reports 2002, national reporting].

| Country | Amount [t] | Year | Reference |
|---|---|---|---|
| DE | 200,000 to 300,000 | 1930 to 1982 | [RECETOX, 2000] |
| FR, IT, ES | 300,000 | 1954 -1985 | [De Voogt, Brinkmann 1989] |
| PL | 1,700 (+2,000 by products) | 1966-1976 | [Sulkowski, Kania] |
| Czechoslovakia | 25,000 | 1959 -1984 | [NIP] |
| UK | 67,000<br>(national use ~40,000) | 1955 up to 1980 | [DEMEX] |
| Europe total | ~700,000 | | |

Table 4-1: PCB estimated total production in Europe

PCB were used as a dielectric fluid in electrical equipment (such as capacitors and high-voltage oil-cooled transformers) and as hydraulic fluids owing to their high stability, good heat conduction, electrical isolating, fire retardant capabilities etc.. Furthermore PCB have been produced for so-called 'open' uses. Important examples are flame retardants in plastics, plasticiser in paints, varnishes, sealants for house construction and surface coatings; lubricants, adhesives, inks and ink solvents in carbonless paper and in mixtures with penta-chlorophenols (PCP) wood treatment preparations. In addition PCB were used as carrier substances for insecticides.

The share of open and closed uses differs among countries, and detailed figures are not available, however from specific calculations (UK, Scandinavian countries) an equal distribution of 50% for both types of use can be assumed as a first approach.

According to model calculations [UK 1994-Department of the Environment; Waste management paper No 6] about 30% of the total PCB produced have been spread to the environment but a significant part still remains in long-life equipment and products. So, although production has stopped many years ago, the annual reduction of remaining stocks leads to important mass flows towards the environment via emissions and waste.

Besides intentional production unintentional formation of PCB occurs during combustion processes (waste incineration, fossil fuel burning, etc.) according to the same principle as for PCDD/PCDF, however, the corresponding concentration is relatively low so that on the EU 25 scale the related amounts are significantly less importance than the mass flow from remaining stocks. The situation may be different on the national scale especially in countries where large, high contaminated PCB containing equipment has already to a large part been disposed of.

All figures for PCB given in this report are figures for total PCB figures. No information is currently available on the related PCB-TEQ concentrations. However it is known that the technical mixtures whose remaining represent the largest share of the overall PCB mass flow did only contain small amounts of dioxinlike congeners. The exact share varied in each product, but the dimension of the ratio total PCB/PCB-TEQ is about $10^5$ to $10^6$ [Taniyasu

2004; Heinzow 2004; EPA PCB Identification sheets[5]]. In order to have comparable figures the calculation of total PCB in this report is based on the measurement of 6 Indicator PCB multiplied by a factor of 5. This has to be taken into consideration in the interpretation of given concentrations, discussed analytical sensitivity and proposed limit values.

### *4.2.3 POP pesticides*

POP pesticides like Aldrin, Dieldrin, Endrin, Chlordane, DDT, Heptachlor, Chlordecone, Mirex, Toxaphene have been produced in large quantities and were extensively used as insecticides for crop and wood protection and for malaria prevention.

The intensity as well as the period and the types of pesticides used varied between European Countries although specific data are often not available. In general, it can be stated that use was most intensive in the fifties and sixties with a decline in use to the eighties, when most of the substances (aldrin, dieldrin, heptachlor, chlordane and HCH) were banned in the old Member States (EU 15) by the EU Plant Protection Product Directive 79/117/EEC and in "new Member States by national legislation. So the mass flow of POP pesticides to the waste regime is mainly due to remaining stockpiles of these substances. Due to different economic systems the issue of stockpiles seems to be more important in the "new" Member States which have reported remaining stocks in a dimension of 5,000 tons of pure POP substances, whereas "old Member States reported that stocks have already been eliminated.

Besides this DDT is still being imported or produced in Europe as a precursor for Dicofol.

Also HCH, namely γ-HCH - better known as Lindane - has been largely used as pesticide. However the amount of identified stocks that are remaining in EU 25 is not high (270 t which - provided a linear stock reduction - corresponds to an annual contribution of 27 t) These stocks are included in the pesticide mass flow. As however HCH and HCB are also industrial chemical or by-product and as such classified as other POP in the corresponding Conventions, it has been decided for the purpose of this report to generally discuss HCB and HCH in this category.

All figures for POP pesticides given in this report are figures for total amounts.

### *4.2.4 Other POPs*

HCB has been used since 1945 as an intermediate and as additive in various manufacturing processes, including the production of synthetic rubber, pyrotechnics and ammunition, dyes, and pentachlorophenol (PCP) used in wood preservation. The use of HCB as pesticide has been discontinued in Europe since the early nineties. According to industry experts and national authorities currently there is neither production nor import of this chemical in EU 25. In addition HCB is known to be formed as U-POP through the same processes that create PCDD/PCDF and occurs as unwanted by-product in certain chemical production processes.

[5] www.epa.gov/toxteam/pcbid/aroclor_comp_frame.htm

γ-HCH or Lindane is still used and produced for specific applications e.g. as a local insecticide in public health and veterinary medicine. Besides this stocks of pesticide preparations from the extensive use as insecticide in agriculture, household, wood and textile production - most important was Lindane as a highly pure γ-HCH - do exist in a number of countries. An unknown amount of HCH may enter the waste regime via contaminated construction and demolition waste from historic production and storage sites. Due to lack of contenting information this source however has not been included into the calculation.

Figures for HCH are summary figures mainly of α-, β-, δ- HCH as far as contaminated soils, and construction and demolition waste are concerned, while production figures refer to γ-HCH (Lindane). Due to the limited number of data and the overall uncertainty the mass flow presents the overall result of the figures.

Hexabrominated Biphenyl (HxBB) was produced in the USA until 1974 and has been as flame retardant in thermoplastics for electric isolation (cars, television, computers). As thirty years have passed since HxBB was banned and due to the fact that only a limited amount of products have been imported to the EU there are probably only very limited - if any - stocks left. However there is no knowledge nor data about HxBB in wastes.

All figures for other POPs given in this report are figures for total amounts.

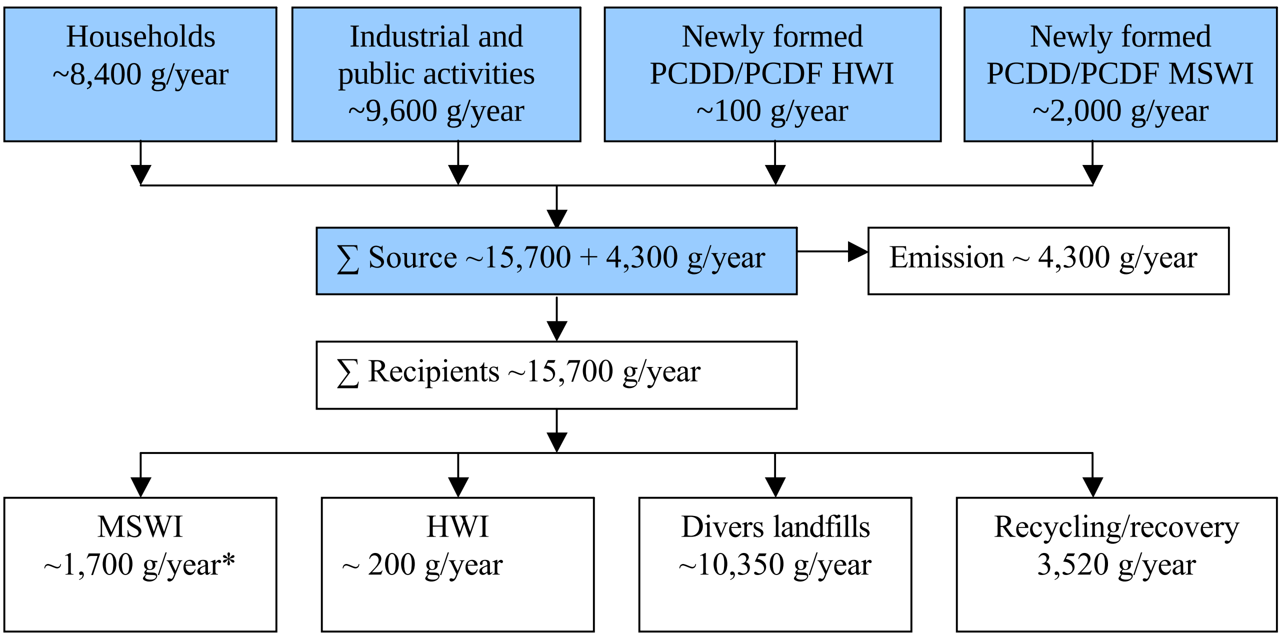
## 4.3 Total POP mass flows

Total mass flows for the different POP substance groups to investigate are based on the results of the detailed mass flows. To give information on the relative importance of different disposal/recovery pathways they provide summarised information from all investigated "sources". Detailed information on the contribution of specific sectors to different disposal/recovery pathways is discussed in the corresponding paragraphs of the full report.

### *4.3.1 Total flow PCDD/PCDF*

The following figure shows the overall result of the detailed PCDD/PCDF mass flow analysis. The individual streams from each activity are listed in Table 4-2 and are discussed for each activity in the corresponding detailed PCDD/PCDF flow.

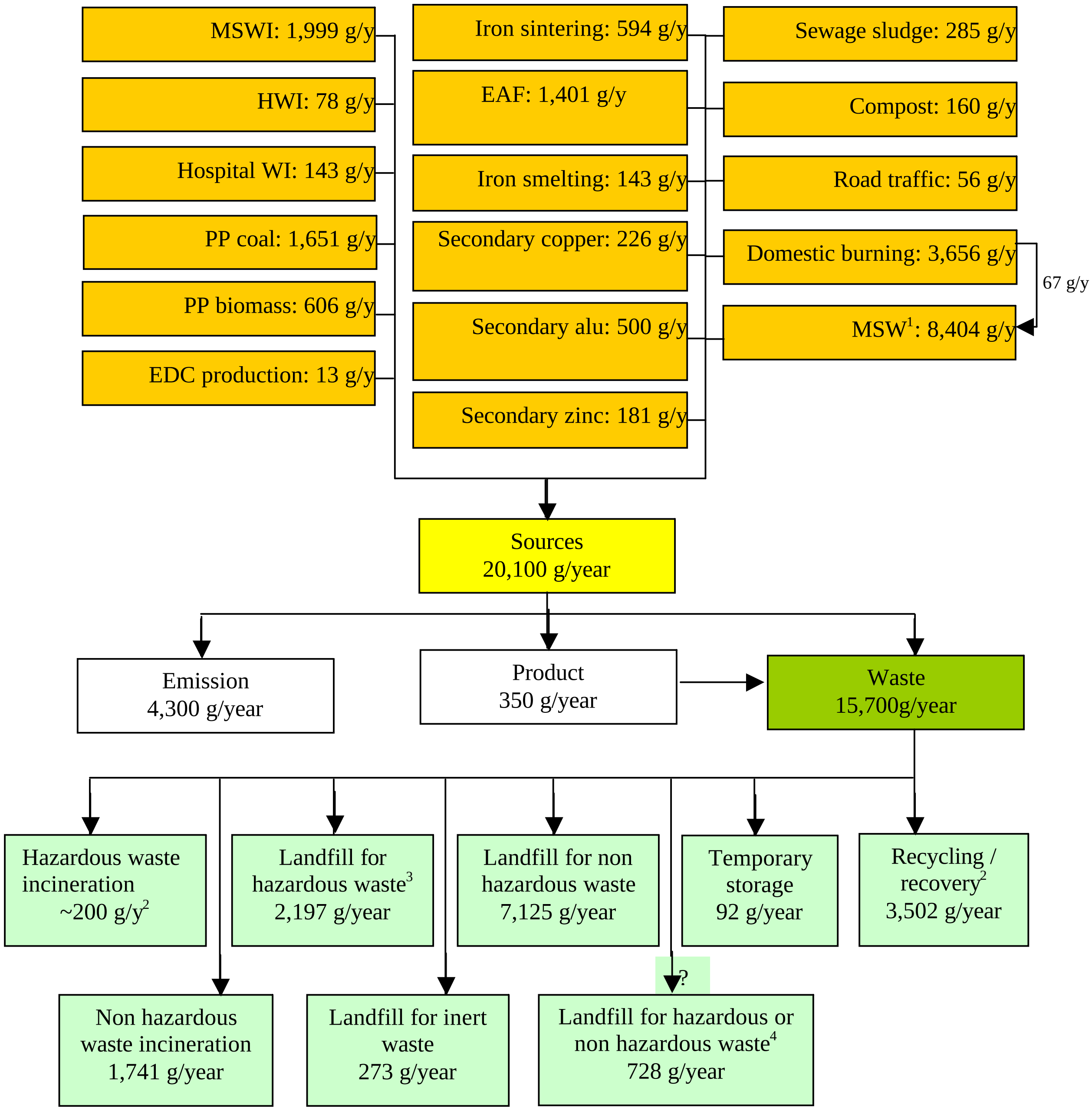
Based on the information presented in the full report it can be stated that > 90% of the PCDD/PCDF in waste are covered in the total mass flow.




* plus 16 t PCB from MSW, plus other precursors

Figure 4-3: Overview on material flow stations of the PCDD/PCDF mass flow in EU 25

More details are available from the following figure:




[1] MSW from household and commerce, share of domestic burning included
[2] estimation, quantification difficult
[3] including underground
[4] allocation not possible

Figure 4-4: Overall mass flow of PCDD/PCDF from sources to current disposal/recovery operations in investigated sectors in EU 25

As illustrated in Figure 4-5 below, the most important source for emission to air is domestic burning of coal and fossil fuels with 77%, followed by sinter plants in the ferrous metal industry (9.4%), electric arc furnaces in the iron and steel industry (4%), hospital waste incineration (2.6%, only new Member States), secondary copper and aluminium production and road traffic.

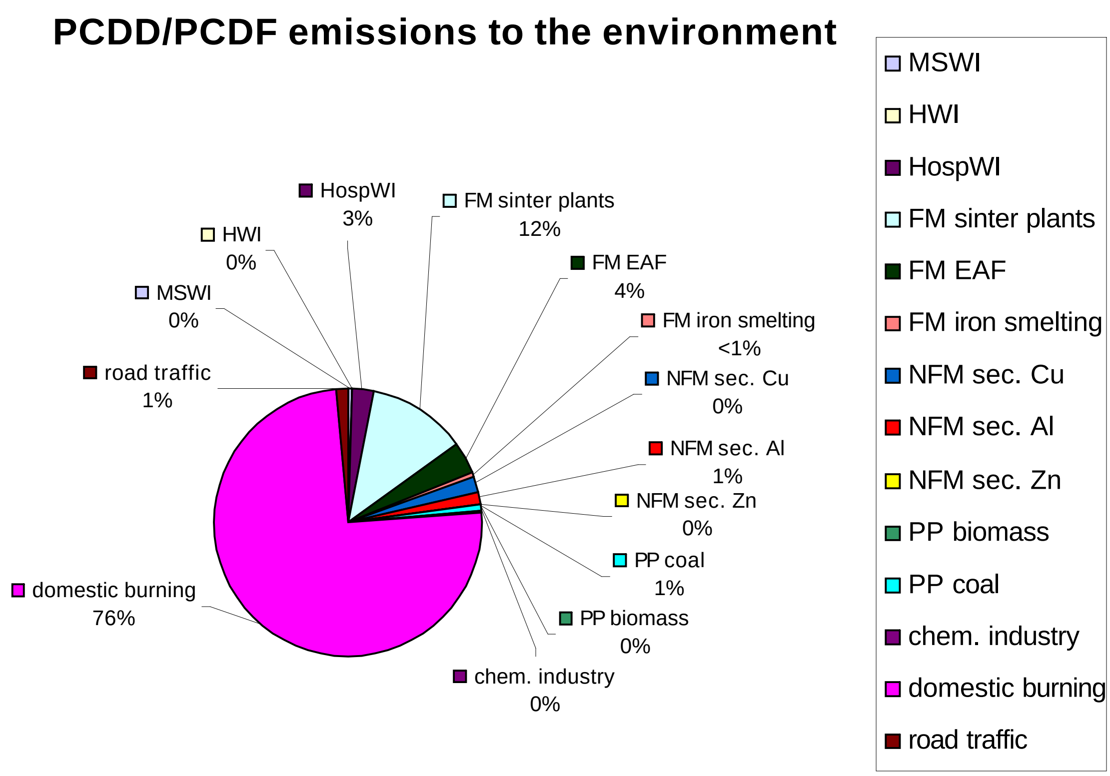



Figure 4-5: Relative distribution of air emissions from investigated sectors in EU 25

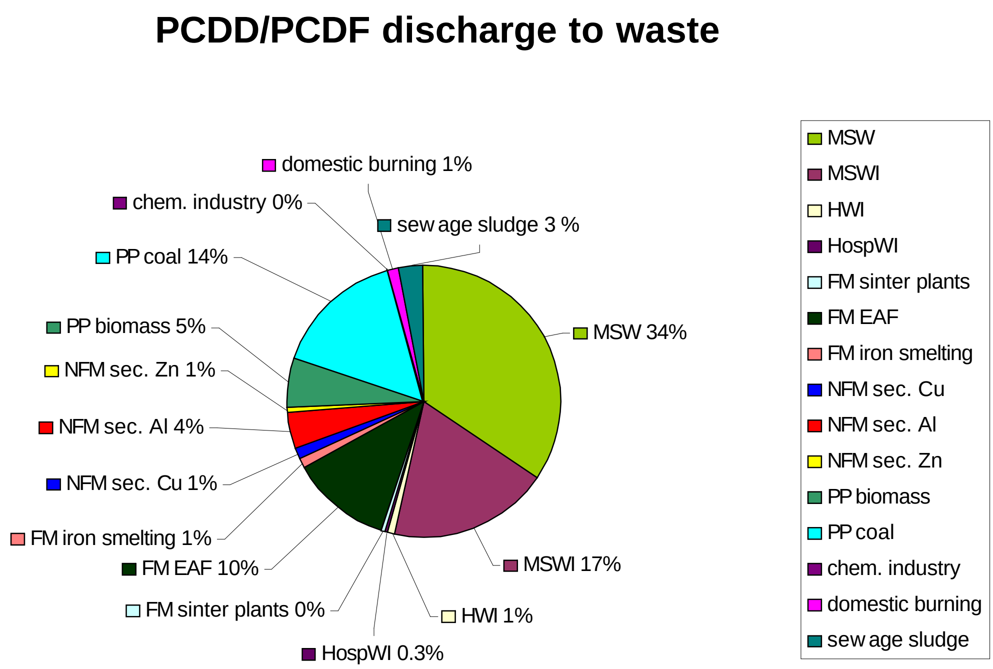



Figure 4-6: Relative distribution of discharge to waste from investigated sectors in EU 25

Unlike emissions to air discharges to waste show a more even distribution for the investigated sectors. Based on the results from the mass flows the most important sources for discharge to waste are municipal solid waste from households and commerce (including a share of waste from domestic burning) (34.7%), the municipal solid waste incineration (16.5%), power production (18.6%) and the ferrous metal industry with electric arc furnaces (15.4%) and sinter plants (10.3%). The shares of the emissions from the relevant activities are shown in Figure 4-6.

It has however to be taken into account that MSWI is not only a source but receives significant amounts of PCDD/PCDF, PCB and other precursor substances. Furthermore it is important to take into consideration the beneficial effect of a concentration of PCDD/PCDF in waste in comparison to an emission into the air and the reduction in waste volumes achievable with MSWI.

PCDD/PCDF discharged to waste are directed to different waste management operations including disposal and recovery operations. As the environmental relevance of the different operations differs it is of interest to trace the amounts of each “source” sector directed to specific management sectors and to distinguish the relative share of each operation in relation to the overall POP discharge to waste.

Table 4-2 illustrates how the selected activities contribute to the PCDD/PCDF flow to specific disposal/recovery operations, whereas Figure 4-7 illustrates the importance of current waste treatment options with respect to the PCDD/PCDF mass flow.

| Treatment / Activity | g TEQ/y | Comment |
|---|---|---|
| Non Hazardous waste incineration | | |
| MSW | 1,641 | 44.7 Mt of MSW (mean 0.037 ppb) |
| Sewage sludge | 100 | 3 Mt (mean 0.03 ppb) |
| Total | 1,741 | |
| Hazardous waste incineration | | |
| EDC production | 1 | |
| Other hazardous waste input | ~ 200 | 4.8 Mt of hazardous waste (range 0.01-10ppb) |
| Total | ~ 200 | |
| Landfill for hazardous waste (including underground storage) | | |
| Municipal solid waste incineration | 1,707 | 1.36 Mt APC residues (mean 1.26 ppb) |
| NFM secondary aluminium | 315 | 0.03 Mt of filter dusts (mean 10 ppb; 0.005 Mt of WWT sludges (mean 1.6 ppb) |
| HWI | 67 | 0.36 Mt APC residues (mean 0.19 ppb) |
| NFM secondary copper | 35 | 0.005 Mt of filter dusts (mean 6 ppb) |
| NFM secondary zinc | 30 | 1.5 Mt of slag (mean 0.02 ppb) |
| HospWI | 30 | 0.01 Mt of APC residues (mean 2.25 ppb) |
| PP coal | 20 | 32.6 Mt mixed ashes (mean 0.016 ppb) |
| Total | 2,204 | |
| Landfill for non hazardous waste | | |
| MSW | 6,763 | 181 Mt (mean 0.04 ppb) |
| Domestic burning | 289 | |

| Treatment / Activity | g TEQ/y | Comment |
|---|---|---|
| Sewage sludge | 73 | 2 Mt (mean 0.03 ppb) |
| Total | 7,125 | |
| Landfill for inert waste | | |
| Municipal solid waste incineration | 106 | 5.15 Mt of bottom ash (mean 0.02 ppb) |
| PP coal | 163 | 9 Mt of mixed ashes (mean 0.016 ppb) |
| HWI | 4 | 0.34 Mt of bottom ash (mean 0.01 ppb) |
| HospWI | | 0.008 Mt of bottom ash (mean 0.16 ppb) |
| Total | 273 | |
| Landfill for hazardous or non hazardous waste | | |
| FM sinter plants | 70 | 0.06 Mt of FGT residues (mean 1.1 ppb) |
| FM EAF | 437 | 5 Mt slags and filter dusts (mean 0.11 ppb) |
| FM iron smelting | 118 | 0.07 Mt FGT residues (mean 1.7 ppb) |
| PP biomass | 103 | 0.09 Mt of mixed ashes (mean 1.14 ppb) |
| Total | 728 | |
| Recycling / recovery | | |
| PP coal | 1,401 | 55.4 Mt of mixed ashes (mean 0.016 ppb) |
| FM EAF | 736 | 5.6 Mt of filter dusts (mean 0.1 ppb) |
| PP biomass | 502 | 0.4 Mt of mixed ashes (mean 1.14 ppb) |
| Municipal solid waste incineration | 164 | 5.15 Mt of bottom ash (mean 0.02 ppb; 0.04 Mt fly ash (mean 1.5 ppb) |
| Compost | 160 | 15 Mt (mean 0.01 ppb) Application to land |
| NFM secondary aluminium | 128 | 0.01 Mt of filter dusts (mean 10 ppb) |
| Sewage sludge | 124 | 3 Mt (mean 0.03 ppb) Application to land |
| NFM secondary copper | 107 | 0.56 Mt of slag (mean 0.02 ppb); 0.1 Mt of furnace oxide (mean 1 ppb) |
| Domestic burning | 62 | Application to land |
| NFM secondary zinc | 55 | 0.005 Mt of absorption and filter material (mean 0.26 ppb); 0.9 Mt of oxide (mean 0.1 ppb); 2.7 Mt of slags (mean 0.02 ppb) |
| FM iron smelting | 4 | 0.8 Mt of used sands (mean 0.005 ppb) |
| HWI | 4 | 0.34 Mt of bottom ash (mean 0.01 ppb) |
| HospWI | 1 | 0.008 Mt of bottom ash (mean 0.16 ppb) |
| Total | 3,520 | |
| Temporary storage | | |
| NFM EAF | 61 | 0.5 Mt of slags and filter dusts (mean 0.1 ppb) |
| PP coal | 29 | 1 Mt of mixed ashes (mean 0.016 ppb) |
| HWI | 1 | 0.0005 Mt of APC residues (mean 0.19 ppb) |
| HospWI | 1 | 0.0004 Mt of APC residues (mean 2.3 ppb) |
| Total | 92 | |

Table 4-2: Quantitative contribution of PCDD/PCDF from different sectors to currently used disposal/recovery operations in EU 25

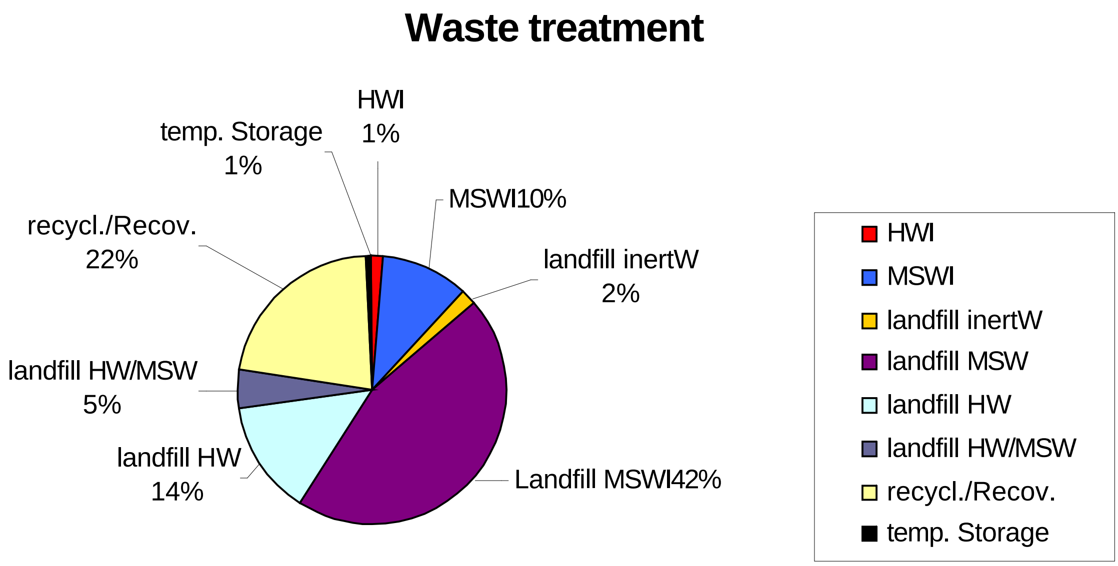



Figure 4-7: Relative importance of different waste treatment options with respect to the PCDD/PCDF mass flow in EU 25

***Waste flows related to PCDD/PCDF***

While the relative contribution of industrial, public and domestic sectors on the overall POP release is interesting for the assessment of potential environmental impact and the assessment of the overall flow and the effectiveness and significance of potential regulation, important information on the potential effects impacts and implications of potential regulation can only be drawn when the amounts of concerned waste streams are known.

Thus besides the mass flows on POPs waste flows have to be established for each investigated sector as well. As for the POP mass flows detailed information is contained in the corresponding paragraphs of the full report. Here you will find a compilation of the related waste streams and corresponding contamination levels on the EU 25 scale. The corresponding contribution to the overall discharge of PCCD/PCDF is added for better orientation.

| | waste and product | annual generation | Contamination data [ng TEQ/g] | | | PCDD/PCDF | share of total PCDD/PCDF to waste and products |
|---|---|---|---|---|---|---|---|
| | | [kt/y] | mean | min | max | (g/y) | [%] |
| MSWI | Fly ash, filter dust and other FGT residues | 1,048 | 1.5 | 0.0 | 35.7 | 1,530 | 9.1 |
| | Bottom ash | 10,124 | 0.0 | 0.0 | 0.4 | 212.6 | 1.3 |
| | Boiler ash | 155 | 0.2 | 0.02 | 0.7 | 35.7 | 0.2 |
| | Hydroxide sludge | 187 | 1.1 | 0.4 | 1.3 | 198.2 | 1.2 |
| HWI | Fly ash and residues from FGT | 198 | 0.3 | 0.0002 | 2.4 | 61.8 | 0.4 |
| | Boiler ash | 158 | 0.0 | 0.003 | 0.7 | 4.9 | 0.0 |
| | Bottom ash | 669 | 0.0 | 0.0001 | 5.8 | 8.7 | 0.1 |
| Power production coal | ashes | 100,819 | 0.0 | 0.00005 | 0.1 | 1,613 | 9.6 |
| Power production biomass | fly ash and other solid residues | 533 | 1.1 | 0.001 | 16.2 | 604.5 | 3.6 |
| Hospital waste incineration (EU10) | bottom ash | 16 | 0.2 | 0.015 | 0.3 | 2.5 | 0.0 |
| | boiler ash | 0 | 0.2 | 0.02 | 0.7 | 0.1 | 0.0 |
| | fly ash | 13 | 2.3 | 0.7 | 4.5 | 29.1 | 0.2 |
| EDC Production | sludge | 2 | 0.5 | | | 1.0 | 0.0 |
| MBT (DE, AT) | heavy fraction | 1,749 | 0.1 | | | 129.4 | 0.8 |
| Sinter plants | Residues from FGT | 64 | 1.1 | 0.0001 | 3.1 | 1,002 | 0.4 |
| electric arc furnaces | Slag | 9,600 | 0.0 | 0.0002 | | 9.6 | 0.1 |
| | Filter dust | 1,113 | 1.1 | 0.1 | 10.0 | 1,225 | 7.3 |
| Iron smelting | Slag and dross (furnace residues) | 0 | 0.0 | 0.0002 | 0.1 | | 0.0 |
| | Used sand | 780 | 0.0 | | | 3.9 | 0.0 |
| | Residues from FGT | 69 | 1.7 | 0.2 | 4.9 | 117.9 | 0.7 |
| secondary copper | Furnace lining | | negligible | | | | 0.0 |
| | Filter dust | 6 | 6.0 | | 23.0 | 35.5 | 0.2 |
| | Slag | 600 | 0.0 | | | 12.0 | 0.1 |
| | Furnace-oxide | 95 | 1.0 | | | 94.6 | 0.6 |

| | waste and product | annual generation | Contamination data [ng TEQ/g] | | | PCDD/PCDF | share of total PCDD/PCDF to waste and products |
|---|---|---|---|---|---|---|---|
| | | [kt/y] | mean | min | max | (g/y) | [%] |
| secondary aluminium | Filter dust | 43 | 10.0 | 0.5 | 33.8 | 433.8 | 2.6 |
| | Sludge from WWT | 5 | 1.6 | | | 8.3 | 0.0 |
| | Furnace lining | 0 | 0.0 | | | | 0.0 |
| | Salt slag | | negligible | | | | 0.0 |
| secondary zinc | Slag | 4,262 | 0.0 | | | 83.1 | 0.5 |
| | Absorption and filter material | 2 | 0.7 | 0.002 | 1.4 | 1.6 | 0.0 |
| | Waelz oxide | 945 | 0.1 | | <0.2 | 94.5 | 0.6 |
| Sewage Sludge | Sewage Sludge | 9,900 | 0.0 | 0.00002 | 1.8 | 297.0 | 1.8 |
| Compost | Compost | 16,000 | 0.0 | 0.0008 | 0.0 | 160.0 | 1.0 |
| domestic burning | ash (fossil fuels) | 2,716 | 0.1 | 0.00022 | 0.2 | 152.1 | 0.9 |
| | ash (wood) | 868 | 0.1 | 0.0001 | 0.5 | 95.5 | 0.6 |
| | soot (fossil fuels) | 14 | 6.2 | 0.1 | 10.0 | 88.8 | 0.5 |
| | soot (wood) | 15 | 4.0 | 0.02 | 14.4 | 61.2 | 0.4 |
| total industrial and domestic | | 163,617 | | | | 8,409 | 50.0 |
| MSW | | 228,000 | 0.04 | 0.002 | 0.05 | 8,404 | 50.0 |
| total | | 391,617 | | | | 16,813 | 100.0 |

Table 4-3: Annual amounts of PCDD/PCDF containing residues (wastes and products) and ranges of contamination with PCDD/PCDF and corresponding PCDD/PCDF amount in investigated sectors in EU 25

Based on the data of the detailed mass flows and the contamination data compiled in Table 4-3 an overview on current levels of contamination as well as their corresponding ranges is illustrated in Figure 4-8 below.

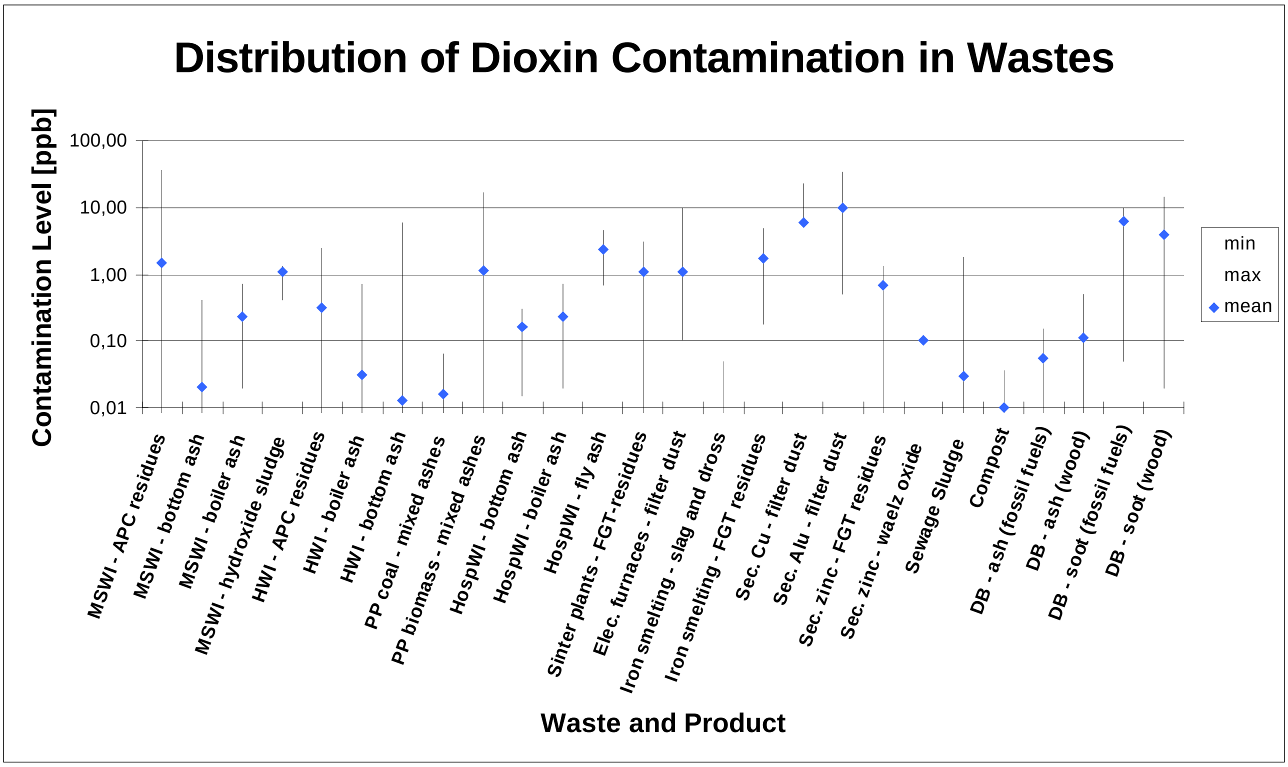



Figure 4-8: Means and ranges of recent PCDD/PCDF contamination in different waste types in EU 25

As shown in the figure and summarised in Table 4-3 (based on available data) mean concentrations and maximum limits of many high volume waste streams lay below 1 ppb, whereas as number of other waste streams show mean concentrations around 1ppb with maximums up to 10 ppb. Only a limited number of waste types is significantly exceeding the 10 ppb level.

### *4.3.2 Total PCB flow*

The following figure shows the overall result of the detailed PCB mass flow analyses. The individual streams from each activity are listed in Table 4-5 and are discussed in detail for each activity in the corresponding paragraphs of the PCB mass flow in the full report.

Base on the information presented in the full report it can be assumed that > 90% of PCB in waste are covered in the total mass flow. This estimation is based on wastes that are not covered in the total mass flow, such as the municipal solid waste which includes about 80 tons of PCB.

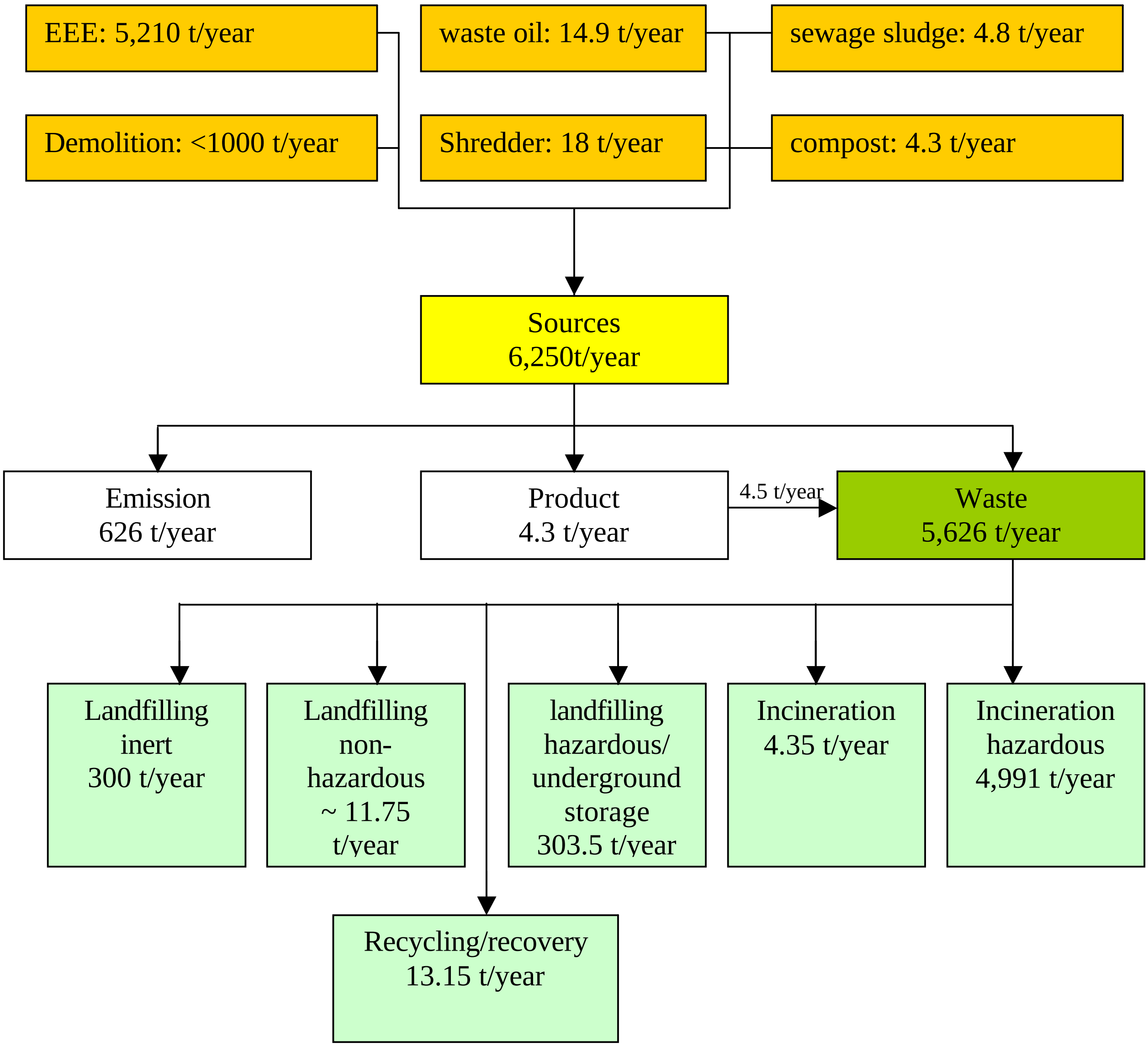



Figure 4-9: Overall mass flow of PCB from sources to current disposal/recovery operations in investigated sectors in EU 25

It has to be taken into account that due to limited data for a number of sectors and countries the mass flow is partly based on assumptions and extrapolation. However, the mass flow can give an impression on the dimension of the PCB flow to the environment and to waste and on the relative contribution of major relevant sectors related to PCB.

Based on the calculations discussed in more detail in the corresponding paragraphs of the detailed mass flow for PCB, major sources for the current flow of PCB can be pointed out. These are the EEE sector (large PCB containing equipment and so-called white goods) with 5,210 t/y, the construction and demolition sector with about 1000 t/y. Shredder residues (non-metallic fraction 18 t/y). and waste oils (14.9 t/y) which are contaminated at levels below 50 ppm and thus are not classified as "POP" under the European PCB directive (1996/59/EC), waste water treatment (PCB content in sewage sludge 4.8 t/y) and composting (PCB content in compost 4.3 t/y) do not play an important role in the total PCB mass flow.

As illustrated the overall discharge of PCB from the investigated sources in Europe accounts for about 6,250 t/y with an overall distribution of the discharge of about 10% to air and around 90% to waste.

In the following table (Table 4-4) the importance of relevant sectors have been distinguished for "old" and "new" Member States in order to allow a more specific differentiation of various sectors in both regions.

| sector/activity | emission (t/y) | product (t/y) | waste (t/y) | total (t/y) |
|---|---|---|---|---|
| PCB containing equipment EU 25 | 520 (0.8 – 1,040) | 0 | 4,690 (7 – 9,370) | 5,210 (7.8 – 10,410) |
| PCB containing equipment EU 15 | 460 (0.7 – 0.9) | 0 | 4,160 (6.3 –8,307) | 4,620 (7 – 9,207) |
| PCB containing equipment EU 10 | 60 (0.06 – 118) | 0 | 530 (0.5 – 1,062) | 590 (0.6 - 1,180) |
| C&D waste EU 25 | 100 | 0 | 900 | 1,000 |
| C&D waste EU 15 | No data | 0 | No data | No data |
| C&D waste EU 10 | No data | 0 | No data | No data |
| shredder EU 25 | 1 | 0 | 17 | 18 |
| shredder EU 15 | No data | 0 | No data | No data |
| shredder EU 10 | No data | 0 | No data | No data |
| waste oil EU 25 | 5.3 | 4.3 | 5.3 | 14.9 |
| waste oil EU 15 | 4.4 | 3.5 | 4.4 | 12.3 |
| waste oil EU 10 | 0.9 | 0.7 | 0.9 | 2.9 |
| sewage sludge EU 25 | 0 | 0 | 4.8 | 4.8 |
| sewage sludge EU 25 | 0 | 0 | 4.3 | 4.3 |
| sewage sludge EU 10 | 0 | 0 | 0.5 | 0.5 |
| compost EU 25 | 0 | 4.5 | 0 | 4.5 |
| compost EU 15 | 0 | 0 | 3.7 | 3.7 |
| compost EU 10 | 0 | 0 | 0.8 | 0.8 |
| Sum 25 | 626 | 8.8 | 5,617 | 6,252 |
| Sum 15 | > 464 | 7.2 | > 4,169 | > 4,640 |
| Sum 10 | > 61 | 1.6 | > 548 | > 607 |

Table 4-4: Emissions and discharge of PCB from investigated sources in EU 25

A rough plausibility check can help with the dimensions. If it is assumed that the total produced amount of 700,000 t has been reduced within 50 years (1960 – 2010), this would correspond to an annual average mass flow of 14,000 t/y. However the descent in volumes cannot be expected to have been linear, but it can be assumed that a larger share has already been disposed off. Therefore an order of magnitude of 6,250 t/y seems reasonable in the present situation.

Unintentional formation of PCB arises during combustion processes (waste incineration, fossil fuel burning, etc.), however, the corresponding amounts are significantly less important than those from PCB containing equipment/material. In a calculation for hazardous waste incineration the resulting annual discharge of PCB from this sector is <0.2 tons/y which is negligible in comparison to other sectors. Domestic burning of wood and coal results in another small stream of 0.56 tons/y.

On the other hand municipal solid waste, due to large annual quantities represents a PCB source which can not completely be neglected. Although the concentration of PCB in municipal solid waste is low (<0.4 ppm) a yearly PCB discharge of 87 tons arises from municipal solid waste. Provided a European average for landfilling of 85% about 66 tons of PCB are annually disposed of at non-hazardous waste landfills, while about 2 tons/y can be assumed to arise from MSWI. However with an overall amount of 70 tons/y only 1% is added to the investigated mass flows via municipal solid waste.

Waste oil refining and shredder residues are less important sectors, however data are based on thorough implementation of the separation principle set down in the ELV and WEEE Directive for the shredder fraction and used German standards for waste oil recovery. So a higher share for shredder residues could result if shredder infeed is not carefully sorted and a higher share for waste oil may be expected in some countries as current European legislation allows substance recovery of waste oils up to 50 ppm.

As both sectors can contribute to the cycling of PCB in the production process they might have a higher relative importance.

As illustrated in the following pie charts large PCB containing equipment – already subject to the PCB Directive – as well as C&D waste are the dominating sources for the overall PCB discharge, even if a relatively large uncertainty has to be taken into account due to incomplete data on the definite PCB content in the liquids.

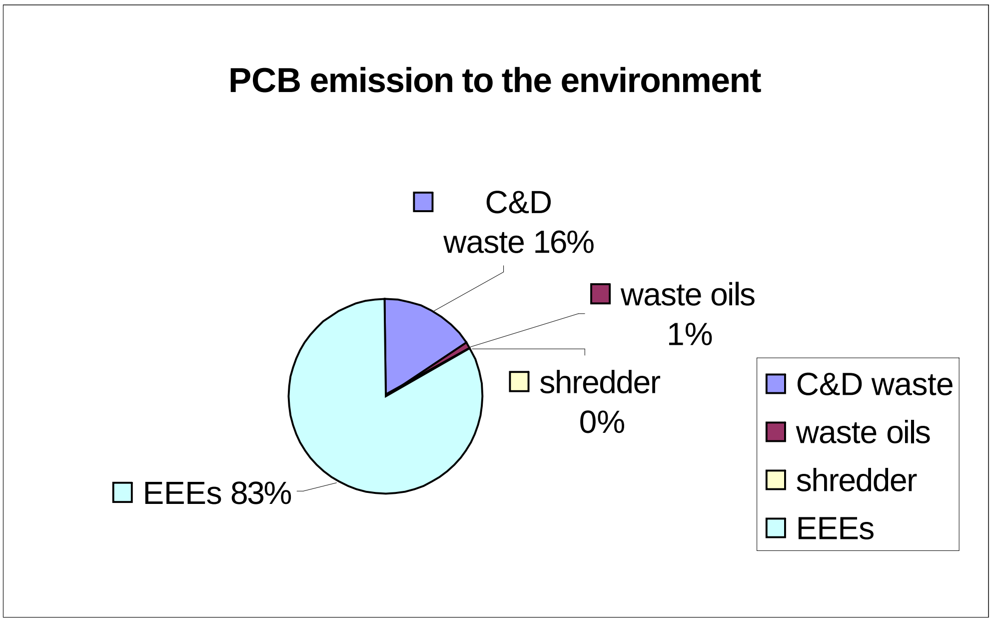



Figure 4-10: Relative distribution of environment emissions from investigated sectors in EU 25

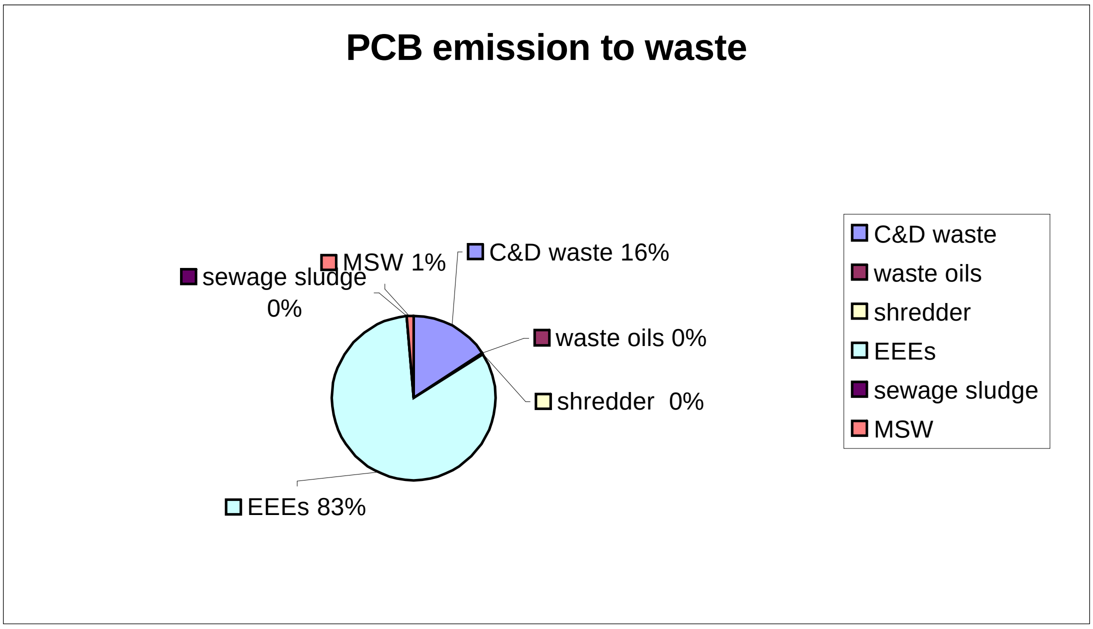



Figure 4-11: Relative distribution of discharge of PCB to waste from investigated sectors in EU 25

PCB discharged to waste are directed to different waste management operations including disposal and recovery operations. As the environmental relevance of the different operations differs, it is of interest to trace the amounts of each “source” sector directed to specific management sectors and to distinguish the relative share of each operation in relation to the overall POP discharge to waste.

The following table shows how the selected activities contribute to the mass flow to specific disposal/recovery operations.

| Disposal/Recovery option | PCB tons/y | Comment |
|---|---|---|
| Incineration hazardous | | |
| WEEE | 4,690 | 0.02 Mt (>500ppm); Combustible hazardous parts of separately collected and pre-treated equipment |
| Construction and demolition waste | 300 | combustible fraction of demolition waste classified as hazardous according to the European waste catalogue |
| Shredder residues | 1.0 | In Austria incineration is the only option allowed from 2004; other Member States will increase this share by 2005 –2007 |
| **Total** | **4,991** | |
| Recycling/Recovery | | |
| Shredder residue | 3.5 | 0.1 Mt of cable residues (mean 30 ppm) |
| Sewage sludge | 2.0 | 3 Mt (mean 0.6 ppm) Application to land |
| Compost | 4.5 | 14 Mt (mean 0.3 ppm) Application to land |

| Disposal/Recovery option | PCB tons/y | Comment |
|---|---|---|
| Waste oil | | 0.9 Mt (mean 2.6 ppm) |
| **Total** | **10** | |
| Non hazardous waste incineration/co-incineration | | |
| Shredder residues | 2.0 | 0.6 Mt of non-metallic fraction (mean 3.6 ppm);<br>In Austria incineration is the only option allowed from 2004; other Member States will increase this share by 2005 –2007 |
| Sewage sludge | 1.7 | 3 Mt (mean 0.6 ppm) includes co-combustion in power production and cement industry |
| Waste oil | 4.8 | ~ 2 Mt (mean 2.5 ppm) |
| **Total** | **5.35** | |
| Landfilling (inert) | | |
| Construction and demolition waste | 300 | demolition waste with unknown contamination not classified or classified as not hazardous |
| **Total** | **300** | |
| Landfill for non hazardous waste | | |
| Shredder residues | 8.0 | 2.4 Mt of ELV residues (mean 3.6 ppm);<br>So far the majority of residues is landfilled, however the share will be reduced in the coming years. |
| Waste oil | 2.65 | 1 Mt (mean 2.6 ppm);<br>The exact share is unknown based on the fact that collection and recovery of waste oils is incomplete so far on the European level |
| Sewage sludge | 1.1 | 2 Mt (mean 0.6 ppm) average share calculated on the basis of national reporting |
| **Total** | **11.75** | |
| Landfill for hazardous waste (including underground storage) | | |
| Construction and demolition waste | 300 | demolition waste classified as hazardous according to the European waste catalogue |
| Shredder residues | 3.5 | 0.1 Mt of waste cable residues (mean >50 ppm) |
| **Total** | **303.5** | |

Table 4-5: Quantitative contribution of PCB from different sectors to currently used disposal/recovery operations in EU 25

The following pie chart illustrates the importance of current waste treatment options with respect to the PCB mass flow.

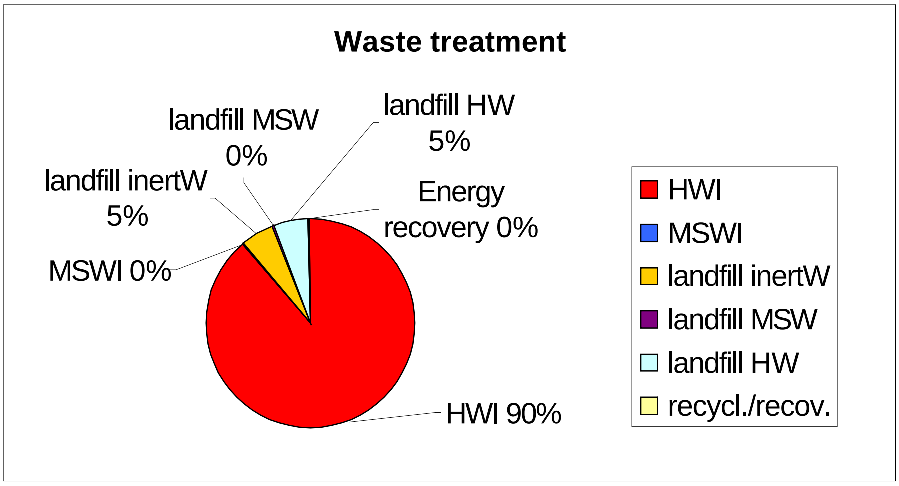



Figure 4-12: Relative importance of different waste treatment options for the PCB mass flow in EU 25

As illustrated above, energy recovery and hazardous waste incineration of EEEs, C&D waste and shredder waste represent about 89% of the controlled final disposal of PCB. Provided a sufficient incineration temperature, the PCB will be destroyed almost completely.

Only estimated 0.2% of the mass flow of PCB is kept in circulation via substance recovery of waste oils and PVC recycling from waste cables with potential emissions to the environment or is applied to land (compost, sewage sludge) with inevitable emissions to the environment. An assumed remaining 5.5% of the PCB flow are currently directed to landfills for non-hazardous and inert waste from where PCB might be discharged to the surrounding environment.

***Waste flows related to PCB***

While the relative contribution of industrial, public and domestic sectors on the overall POP release is interesting for the assessment of potential environmental impact and the assessment of the overall flow and the effectiveness and significance of potential regulation, important information on the potential effects impacts and implications of potential regulation can only be drawn when the amounts of concerned waste streams are known.

Thus besides the mass flows on POPs waste flows have to be established for each investigated sector as well.. Here you will find a compilation of the related waste streams and corresponding contamination levels on the EU 25 scale. The corresponding contribution to the overall discharge of PCB is added for better orientation.

| | waste | amount | Contamination data (mg/kg) | | | PCB discharge | PCB to waste & products | share of total PCB to waste and products |
|---|---|---|---|---|---|---|---|---|
| | | [kt/y] | mean | min | max | (t/y) | (t/y) | [%] |
| EEEs | large equipment | 14.5 | 359,214 | 500.0 | 1,000,000.0 | 5,209 | 4,688 | 84.1 |
| | household equipment | 0.6 | 25.0 | 0.0 | 50.0 | 15.2 | | 0.0 |
| | | | | | | | | 0.0 |
| Demolition & Construction | D&C waste | 205,124 | 4.6 | | | 943.6 | 849.2 | 15.2 |
| Waste oils | higher contaminated | 29 | 15.0 | | 50.0 | 0.4 | 0.3 | 0.0 |
| | lower contaminated | 5,793 | 2.5 | 0 | 5.0 | 14.5 | 9.6 | 0.2 |
| Shredder | white goods and vehicles | 3,000 | 3.6 | 0.5 | >50 | 10.8 | 9.7 | 0.2 |
| | waste cable | 225 | 30.0 | 0 | >50 | 6.8 | 6.8 | 0.1 |
| | Compost | 14,487 | 0.0 | 0.005 | 0.8 | 4.3 | 4.3 | 0.1 |
| | Sewage Sludge | 8,051 | 0.6 | 0,003 | 1.5 | 4.8 | 4.8 | 0.1 |
| HWI | bottom ash | 669 | 0.0 | 0.0001 | 0.1 | 0.0 | 0.0 | 0.0 |
| | boiler ash | 158 | 0.0 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| | fly ash | 198 | 0.0 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | | | | | | 6,209 | 5,573 | 100.0 |

Table 4-6: Annual amounts of PCB containing residues (wastes and products) and ranges of contamination with PCB and corresponding PCB amount in investigated sectors in EU 25

Based on the data of the detailed mass flows in the full report and the contamination data compiled in Table 4-6 an overview on current levels of contamination as well as their corresponding ranges is illustrated in Figure 4-13 below.

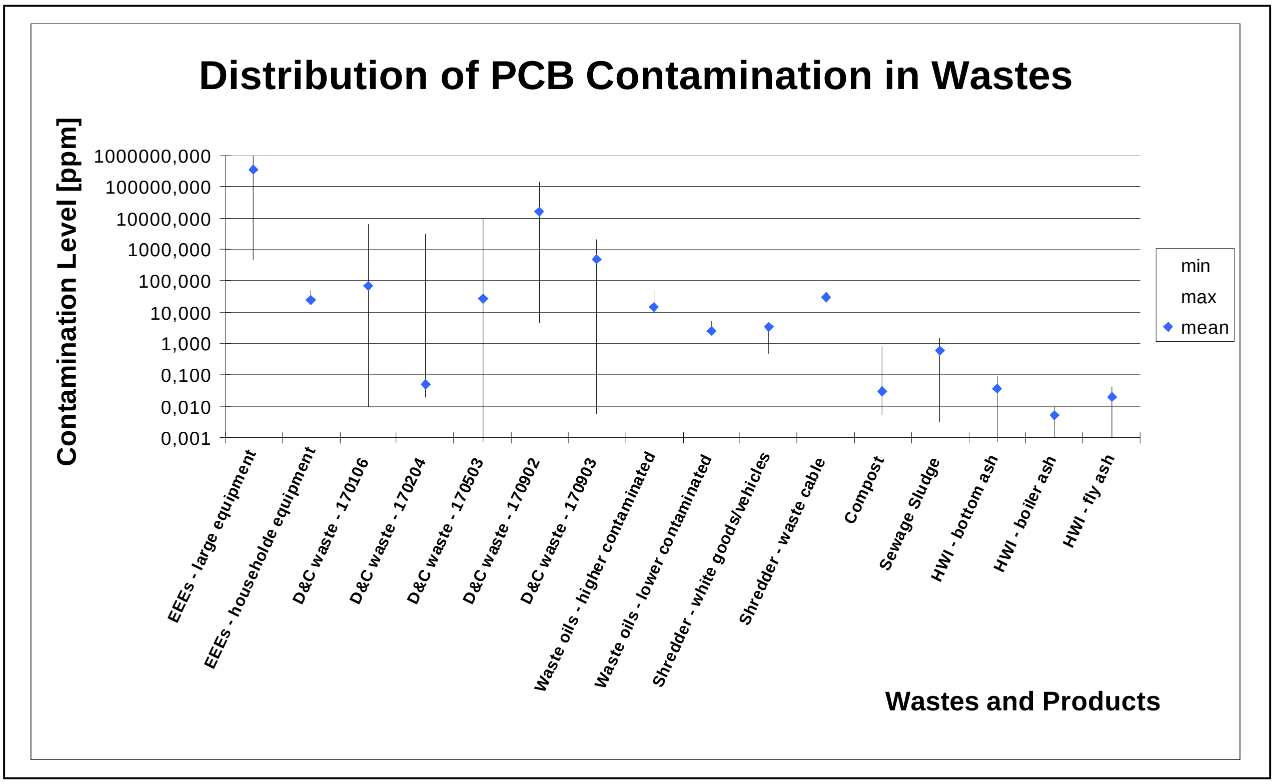



Figure 4-13: Means and ranges of recent PCB contamination in different waste types in EU 25

As shown in the figure and summarised in Table 4-6 (based on available data) mean concentrations and maximum limits of a number of high volume waste streams lay below 1 ppm, whereas as number of other waste streams show mean concentrations < 100 ppm. Only a limited number of waste types show concentrations in the range of % thus dominating the overall result.

### *4.3.3 Total mass flow of POP pesticides*

The following figure shows the overall result of the POP pesticides mass flow analyses. The individual streams are discussed in the corresponding paragraphs of the full report. The two flows for POP pesticides from reduction of stocks and from production have completely different characters. The combination of both of them results in the following total mass flow.

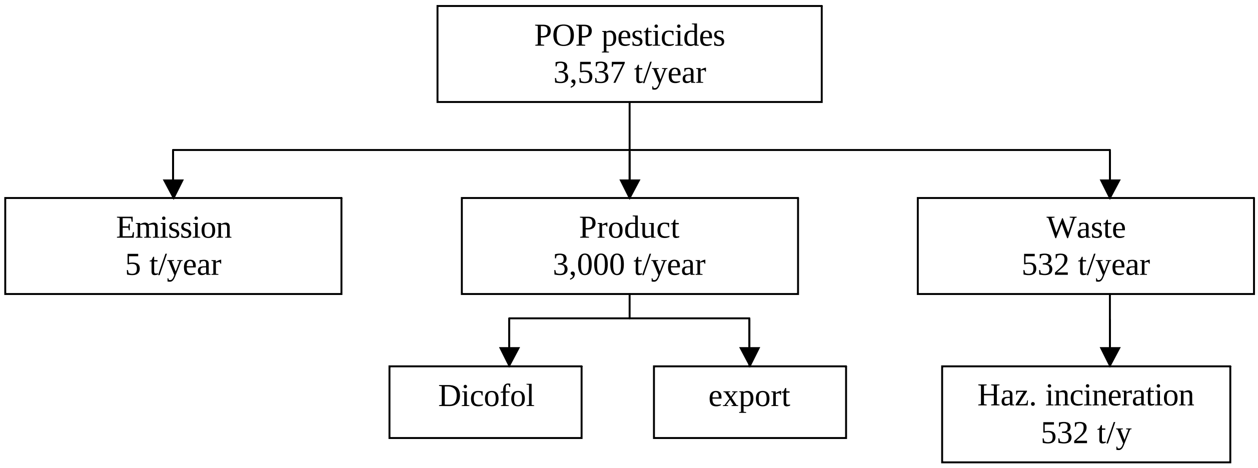


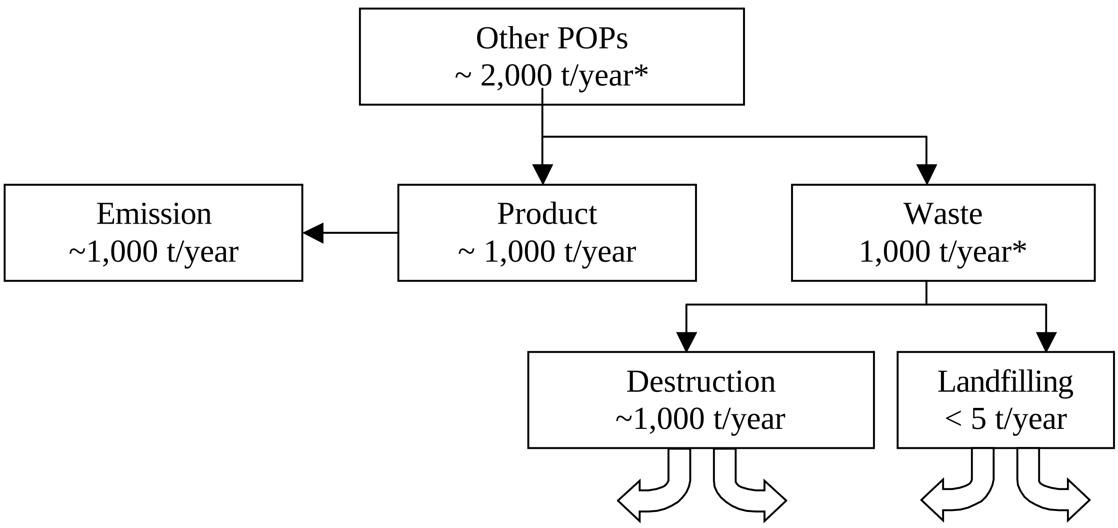

Figure 4-14: Total flow of POP pesticides

While ongoing import/production and use has a dimension of 3,000 t/y directed towards products, the reduction of stockpiles from former production accounts for about 573 t/y provide that stocks will be reduced until 2010.

As discharge to waste from the ongoing production an estimated amount of >3,000 t DDT is hard to assess, only the 537 tons of POP pesticides, which enter the waste regime each year via reduction of POP pesticides stockpiles, have been used for the calculation of the mass flow. Air emissions may only arise from volatilisation and airborne erosion from stored products and soils and are assumed to reach about 5 tons /y.

### *4.3.4 Total mass flow of other POPs*

The following figure shows the overall result of the mass flow analysis for other POPs. The individual streams are discussed in the corresponding paragraphs of the full report. The combination of the mass flows from ongoing production and from reduction of stocks results in the following total mass flow.




* figure refers to estimated Lindane production; Landfill refers to estimated HCB in combustion residues; destruction refers to stocks of production residues (HCH)

Figure 4-15: Total flow of other POPs

The mass flows for HCB and HCH initiate at two types of sources: The ongoing production of Lindane with an estimated volume of ~1,000 t/y and the reduction of stocks of former production (mainly HCH).

As the exact amount of HCH retained in contaminated soils and C&D waste could not be quantified estimated amounts from HCH dumping at former production sites and HCB from combustion processes form the source of a mass flow to waste in a dimension of 1,000 t/y.

## 4.4 Disposal and recovery pathways

The minimisation of annual waste amounts as well as the maximisation of material and energy recovery have high priorities in the waste management strategy in Europe and form an important element of a comprehensive approach to resource management. As a consequence, many Member States have started initiatives or already implemented legal measures to reduce landfilling of waste by a general ban on the landfilling of any combustible or biodegradable waste, or by landfill taxes in favour of waste incineration and recovery processes.

The mass flow analysis has shown that, from the investigated sectors, about 15 kg PCDD/PCDF-TEQ, 5,600 t total PCB, 530 t POP pesticides and estimated 1,000 t other POPs enter the waste regime every year.

The following treatment options for POP wastes have been identified in the mass flows:

- Hazardous waste incineration (including other destruction methods)
- Non-hazardous waste incineration (MSWI)
- Landfill for hazardous waste (including underground storage)
- Landfill for non hazardous waste
- Landfill for inert waste
- Recycling / recovery
- Temporary storage

As the treatment of waste generally depends on the waste category and not on the contaminants contained, the discussion in this paragraph is structured basically by the treatment options currently used for the different waste categories concerned.

The relevance of the amounts of specific waste categories for different POP substances is given in the corresponding paragraphs of the mass flow.

When reflecting upon the relevance for the ecosystem ("eco-relevance") of the POP contamination in the wastes according to the different treatment options it is noteworthy that the different treatment options may have different eco-relevance. Against the consideration that POPs can not cause any harm to the environment or human health as soon as they are withdrawn from the ecosystem, the eco-relevance can be assessed on the question whether a treatment option leads to a permanent withdrawal from the ecosystem of the POP contamination or not. Withdrawn POPs have no eco-relevance. POPs that remain in the ecosystem are eco-relevant.

For the above mentioned waste treatment options these considerations can be used to establish a kind of “evaluation” of their eco-relevance as shown in the following table:

| Waste treatment option | Withdrawal from the ecosystem | Eco-relevance |
|---|---|---|
| Landfill for hazardous waste | High isolation due to high standard lining layers; however no unlimited effect | very low eco-relevance |
| Underground storage (salt) | virtually complete as the POP content is no longer available in the long term | virtually no eco-relevance |
| Hazardous waste incineration (including other destruction methods) | complete to a far degree as incoming POPs are destroyed. Low emissions; the bulk of newly formed POP is released to waste and landfilled as hazardous waste or stored underground | low eco-relevance provided BAT is applied |
| Non-hazardous waste incineration | complete to a far degree as incoming POPs are destroyed. Low emissions; the bulk of newly formed POP is released to waste and landfilled as hazardous waste or stored underground | low eco-relevance provided BAT is applied |
| Landfill for non-hazardous waste | Long-time withdrawal from the ecosystem might be not ensured for POPs | limited eco-relevance |
| Landfill for inert waste | not assured as the long term withdrawal from the ecosystem is not ensured for POPs | eco-relevant |
| Recycling / recovery | not assured as the final destiny of the POPs is not determined | eco-relevant |
| Temporary storage | not assured as the final destiny of the POPs is not determined | eco-relevant |

Table 4-7: Considerations on the eco-relevance of relevant waste treatment options

Eco-relevance is a parameter which reflects the ratio to which a pollutant may be emitted to the biosphere. This corresponds either to the destruction ratio or to the exclusion from environmental cycling achieved by specific management options. While this is a function of air pollution control standards for incineration processes it is related to the geological barrier function for disposal operations (landfills).

### *4.4.1 Hazardous waste incineration/destruction*

Hazardous waste incineration is relevant for a yearly amount of about 200 g of PCDD/PCDF-TEQ (rough estimation), 5,000 t total PCB (see Table 4-5), 532 t POP pesticides (seeFigure 4-14) and ~1,000 t other POPs (see Figure 4-15). For the input of PCDD/PCDF to the hazardous waste incineration sector, no specific data have been available.

For POP pesticides and liquids with PCB contents >50 ppm, incineration in hazardous waste incinerators or other irreversible destruction options are the unique treatment option. New member states which do not have sufficient national capacity export PCB and POP pesticides for final destruction to other Member States e.g. Germany, France, Finland or the Netherlands.

For some waste categories the alternative to hazardous waste incineration is hazardous waste landfill. The ratio between incineration and landfilling varies significantly between the European Member States with a high share of incineration in France and the Netherlands and currently zero incineration in some countries like Lithuania, Cyprus and Malta.

Strict low POP content limit and maximum POP content limits have the effect to increase mass flows directed to hazardous waste incineration.

### *4.4.2 Landfills for hazardous waste and underground disposal*

Landfills for hazardous waste receive a yearly amount of 2,600 g TEQ PCDD/PCDF ( 2.2 kg plus ~ 0.34 kg from wastes that could not be allocated to either hazardous or non-hazardous disposal see Table 4-2) and 300 t PCB (see Table 4-5). Small amounts of other POPs (<5 t) are disposed of with combustion residues. The current storage of POP pesticides is not intended as final disposal but is regarded as temporary storage. No information is available about the amounts of PCBs, POP pesticides and other POPs disposed of with C&D waste and soil from contaminated sites.

According to decision 2003/33/EC the allocation of hazardous waste to either non-hazardous or hazardous landfilling is closely related to its leaching properties with respect to heavy metals, the TOC and pH level. No specific provisions are set with respect to POPs.

For underground storage sites the site-specific safety assessment following national mining law is the limiting factor for acceptance of waste.

Hazardous waste landfills and underground storage sites are currently used for almost the same categories of waste and therefore are not individually discussed in this chapter. While in Germany most of the amounts allocated to the path “hazardous waste landfill” can be supposed to be stored underground, the majority of Member States uses landfills for the same purpose. Export to German salt mines has been reported from Denmark, Austria and Italy. However due to the principle of self-sufficiency the legal framework in general promotes national solutions allowing export only if no alternative is available.

Adequate geological formations for safe underground storage such as salt mines do not exist in most of the European Member States. Coal mines can not be regarded as safe with respect to hydrogeological stability and isolation. In practice long-term experience with underground storage only exists in Germany. In France one mine had been closed after an accident and in the UK, where a suitable site exists, it is not used due to opposition of public opinion.

Wastes which currently have to be disposed of at hazardous landfills or underground are classified as hazardous due to high contents of heavy metals or acids. This contamination is in most cases much more important than the POP contamination. Thus the disposal path is mainly influenced by legislation with respect to heavy metals.

A strict low POP content limit may, however, have the effect to increase mass flows that go to hazardous waste landfills.

### *4.4.3 Non hazardous waste incineration (MSWI) and non-hazardous waste landfill*

Municipal solid waste incineration is relevant for yearly amounts of 1.7 kg TEQ PCDD/PCDF. These result from the incineration of sewage sludge, wood ashes from domestic burning and MSW (see Table 4-2). Additionally, about 5 tons of PCB (see Table 4-5) and 350 t of other POPs resulting are incinerated along with municipal solid waste.

Non-hazardous waste landfills are still largely used for the disposal of municipal solid waste. Currently about 7 kg PCDD/PCDF-TEQ plus 0.34 kg from wastes that could not be allocated to either hazardous or non-hazardous disposal (see Table 4-2), estimated 12 tons of PCB and 2,800 tons of other POPs are directed to non-hazardous waste landfills. According to decision 2003/33/EC, municipal solid waste classified as non-hazardous and other non-hazardous waste fractions can be admitted to this category without testing. From 2005, only pre-treated waste will be accepted to landfill. Apart from this according to 2003/33/EC, stable, non-reactive hazardous waste can be accepted. This means that leaching shall not change adversely in the long-term.

The ratio between incineration and landfilling varies significantly between the European Member States with the Netherlands, Luxembourg and Denmark incinerating more than half of their total output, while other countries like Ireland and Greece, Lithuania, Slovenia do not incinerate at all[6].

The strictness of low POP content limit and maximum POP content limits is not expected to have effects on mass flows directed to municipal solid waste incineration and municipal solid waste landfills.

[6] BREF document on waste incineration

### *4.4.4 Landfills for inert waste*

Landfills for construction and demolition waste are relevant for yearly amounts of 273 g TEQ PCDD/PCDF (see Table 4-2) and 300 tons of PCB contained in construction and demolition waste (Table 4-5). Other POPs and Pesticides may reach landfills via contaminated soils and other C&D waste, however figures are not known.

According to Council Decision 2003/33/EC, the 4 categories of landfills (inert waste, non-hazardous waste, hazardous waste, underground storage) requiring different acceptance criteria have to be distinguished.

Landfills for inert waste may accept glass based fibrous materials, glass packaging, concrete, bricks, tiles, ceramics, mixtures of the materials mentioned above as well as soils and stones without testing. Only in case of suspicion testing should be applied or the waste refused. With respect to POPs a limit of 1 mg/kg has been set for PCB.

Construction and demolition waste from reconstruction measures in buildings dating from the 60ties and the 70ties are potentially contaminated with PCB due to the use of PCB containing paints, sealants, elastic fillers and floor coatings used in this period of time .

Taking into account these residues, the European waste list contains specific waste codes for construction and demolition waste classified as hazardous. These wastes are not allowed to be disposed of at landfills for construction and demolition waste.

In a number of countries like Germany[7], national legislation requires the separation of waste fractions on-site or in specialised sorting facilities. According to the German classification of demolition waste, POP could be expected mainly in the mixed demolition waste fraction and in the hazardous demolition waste fraction.

Strict low POP content limit and maximum POP content limits have the effect to decrease mass flows to landfills for inert waste.

[7] Kreislaufwirtschafts- /Abfallgesetz

### *4.4.5 Recycling / Recovery*

Recycling and recovery operations are relevant for yearly amounts of about 3.5 kg TEQ PCDD/PCDF (see Table 4-2), 13 t PCB (see Table 4-5) and almost 0 t other POPs. The sector covers substance and energy recovery but does not include internal recycling in metallurgical processes.

Substance or energy recovery in all industrial sectors is strongly promoted by the European recycling strategy in order to save resources and reduce the amounts of waste generated as far as possible. Furthermore there are economic pressures that enhance the search for recovery operations.

Thus recovery is currently used in the majority of the investigated sectors and is relevant for the mass flow of PCDD/PCDF and PCB. There is no recovery operation related to POP pesticides.

*Dusts, slags and FGT residues from metallurgical production processes*

Solid residues are formed during different steps of metallurgical production processes and consequently contain different amounts and different patterns of contaminants.

In general one has to distinguish between slags and drosses as residues from the smelting processes and dusts and flue gas treatment residues which arise in the off gases and from their cleaning. Slags and drosses are loaded with metals and other impurities but due to process characteristics do not contain PCDD/PCDF in detectable amounts. Dusts and FGT residues are also loaded with metals, but due to new formation of PCDD/PCDF during the cooling of the off gases also contain small amounts of PCDD/PCDF.

In order to comply with the principle of waste prevention and material recycling under national and European policies and strategic approaches and due to shortness in primary material on the world market the metallurgical industry in Europe has intensively invested in processes for metal recovery from waste products and process residues. In consequence secondary metal production has developed into an important industry in Europe. According to information received from the industry, the major part of process residues from metallurgical production are currently internally recycled or recovered in other production processes. In some cases dusts, fly ashes or FGT residues can even be main products of the production process.

Hereby it has to be taken into consideration that due to the high temperatures generally used in the processes PCDD/PCDF entering the process with feed material will be almost completely destroyed.

Slags are largely used as secondary raw material in construction and cement production. Drosses and skimmings are recycled into the process for recovery of the containing salts and metals.

*Ashes from waste incineration*

During incineration processes, ashes are formed in different steps of the destruction processes as well. As in the case of smelting, they consequently contain different amounts of contaminants, predominantly PCDD/PCDF.

Again, one has to distinguish between bottom ashes and slags as residues from the incineration process itself and fly ashes or fly gas treatment residues which arise in the off gases and their cleaning.

Bottom ashes and slags are formed of the incombustible parts of the incinerated waste. They are loaded with metals and other impurities but due to process characteristics do not contain PCDD/PCDF in significant amounts. Fly ashes/FGT residues are also loaded with metals but due to new formation of PCDD/PCDF during the cooling of the off gases also contain a certain amount of PCDD/PCDF. The latter is correlated to the amount of PCDD/PCDF or precursors and catalysts in the incoming waste.

Bottom ashes form the huge share of all residues and account for about 30% by weight of the incoming waste. In accordance with the principle of waste prevention and material recycling under national and European policies and strategic approaches, bottom ashes are recovered to a relevant extent in a number of Member States.

Due to a shortness of primary material as well as due to specific beneficial properties, it is a valuable raw material in road construction and cement production. Its use is promoted in the Netherlands (>90% used), Denmark (90%), Germany (80%), France (>70%), Belgium and the UK (21%)[8].

In the Netherlands and Belgium also fly ashes are currently recycled and recovered in the asphalt production in order to safe the limited national resources of lime which would be needed as filling material in asphalt instead of the ashes.

| Residue | treatment option |
|---|---|
| Bottom ashes, slags | road construction , cement production |
| fly ashes, filter cakes, FGT residues | hazardous waste disposal site (category III), underground stowage or storage (Germany) |
| fly ashes from MSWI | recovery as filling material in asphalt (only NL and BE) |

Table 4-8 Treatment options for residues from waste incineration

[8] BREF waste incineration

*Ashes from power production and residential combustion*

About 80% of all residues from power production are used for recovery operations either in the construction sector or as a filling material in mines.

*Waste oil*

Waste oil is excluded from either thermal or substance recovery if exceeding the low POP content limit of 50 ppm (mg/kg) laid down in the European Waste Oil Directive (75/439/EEC). Oils containing PCB above the limit are subject to the PCB disposal Directive 1996/59/EC and have to be incinerated in dedicated hazardous waste incinerators.

Oil below the low POP content limit may be used for substance recovery and for energy recovery in co-incineration facilities, namely cement kilns.

A number of countries like Finland, Sweden, Germany, Austria have set up stricter national rules for substance recovery in order to promote the elimination of PCB from the environment.

*Shredder fractions from ELV, WEEE and waste cables*

The outputs of the shredder process can be divided into a metallic fraction and a non-metallic fraction. The metallic fractions are completely recycled as secondary raw materials in the iron & steel industry and the non-ferrous metal industry. The non-metallic fraction, the shredder residue, may be sent to the following operations:

- R 1 Use as secondary fuel
- R 5 Recycling/reclamation of other inorganic materials
- use as a Reductant
- use of Chemical Properties of Plastic fraction.

According to the European Ferrous Recovery & Recycling Federation [EFR 2004] the major part of the light fraction is currently landfilled, the rest is incinerated or used for energy recovery. No exact data are available, however a calculation for 2006 provided by the EFR results in a share of 80% for landfilling and about 10% each for incineration and energy recovery. Therefore it is assumed in the mass flow that about 8 tons are landfilled, 1 ton is incinerated and 1 ton is used for energy recovery. With respect to the plastic fraction of cable shredding the relations reported are somewhat different. Based on German data a fifty-fifty distribution for substance recovery in the PVC production and for landfilling has been used for this report.

In general it has to be mentioned that strict low POP content limits have the effect to decrease mass flows to recycling for a number of industrial processes namely secondary metallurgy, construction, cement and asphalt production and PVC recycling and may cut off supply of important amounts of raw material for specific industrial sectors.

### *4.4.6 Temporary Storage*

Storage is relevant for yearly amounts of 92 g TEQ PCDD/PCDF (see Table 4-2). Latvia reported that pesticides are burned in a recently constructed hazardous waste incinerator. As up to date there is no suitable installation for final disposal ashes will be temporarily stored awaiting final disposal in a hazardous waste disposal facility which is scheduled for 2006-2007.

## 4.5 Sectors not covered and assessment of uncertainty

A number of anthropogenic sectors of production and waste management have not been assessed in the mass flow model because of their limited importance due to low contamination with the substances in question, or because data available on the amount of residues or on the contamination level have not been sufficient to draw up a mass flow.

The mass flows have been based on recent data from various sources. Sources included primary sources such as measurement data reported from waste holders and disposal companies or stored in authority databases as well as secondary sources such as European or international reports (e.g. BREF documents, BAT-BEP Guidelines, Eurostat and EEA reports) compiling high quality existing expert knowledge on the various sectors investigated and data collected and compiled by national or regional authorities.

The realisation of the mass flow system is based on the following basic input data:

- activity data (e.g. amounts of waste incinerated, fuel incinerated for power and heat production, production figures for industrial activities, amounts of sewage sludge generated, amounts of demolition waste arising, etc.)
- factors for the generation of emissions or residues (in particular average amounts of residues resulting from specific activities)
- average contamination levels of input and output streams with POPs
- factors for typical treatment of output streams

These data had to be collected in principle for every Member State and for every POP. Using BREF documents, statistics, the questionnaire feedback and the other sources described in the full report it was possible to collect a wide range of basic data.

However it has to be stated that due to lacking measurement obligations and high costs for analysis the data base is often incomplete and data are not equally represented from all Member States.

Consequently, the flow assessments are related to specific uncertainties in particular due to:

- incomplete or not reliable activity data for the relevant time frame
- missing or incomplete information on generated emissions or residues
- missing or only few data on contamination levels of relevant materials
- incomplete information on ranges and averages of contamination levels

- heterogeneous situation of the application of specific processes and technologies in the relevant activities
- missing or incomplete information on actual waste treatment activities

The project team is aware that due to the restrictions and limitations there remains a relatively large overall uncertainty with respect to contamination levels, which furthermore differs from sector to sector.

Nevertheless the chosen approach allows to indicate the dimension of the mass flows and provides a sufficient data basis for conclusions on the impacts of proposed limit values.

Furthermore the developed methodology is flexible and open to new information, thus providing a valid tool to regularly update the mass flows with upcoming knowledge and to refine impact assessment and scenarios.

To conclude the overall uncertainty for the different pollutant flows can be assessed as indicated below.

| POP substance or substance group | activity data | concentration levels in wastes |
|---|---|---|
| PCDD/PCDF | good | Medium |
| PCB | medium | Low |
| POP pesticides | low | Medium |
| Other POPs | low | Medium |

Table 4-9: Assessment of the uncertainty related to the different POP flows

# 5 Environmental levels of POPs

### *POP levels in air*

Mean levels of PCDD/PCDF, PCB and HCBs in ambient air, as modelled in the EMEP data base, are compiled for all European Member States in the full report. As levels in ambient air are generally very low it is not astonishing that levels are six to eight orders of magnitude lower than the "low POP" content limits proposed in the general technical guideline on environmental sound management of POPs under the Basel Convention [UNEP GTGESM final 2005].

### *POP levels in water*

Like in air, levels are expected to be low in general, and difficult to measure as the hydrophobic contaminants strongly bind to suspended particles. Thus results may significantly differ in accordance to the content of suspended particles in the sample and shall not be used as more than a rough estimate. A compilation of reported contamination levels in relation to the proposed limit values for POPs under the Basel Convention is given in the full report.

### *POP levels in sediments*

A compilation of reported contamination is given in the table below.

| | | contamination levels in sediments |
|---|---|---|
| PCDD/PCDF | range of levels in EU 25 | <6-479 ng TEQ/kg ; |
| | Finnish hot spot and in harbours | max 0.5 ppb |
| PCB | range of levels in EU 25 | <1-400 µg/kg; |
| | hot spot level in Slovakia | 2mg/kg (ppm) |
| total POPs pesticides | Ebro river | 0.02-1.7 ng/g (ppb) in the |
| Dieldrin | Cyprus | 1.7-133 ng/g (ppb); max. 0.12 ppm |
| DDT | Mediterranean river estuaries | <1-50 ng/g (ppb) |
| Toxaphene | UK surface sediments | 0.42 ng/cm² |
| HCB | Mediterranean river estuaries | 0.8-40 ng/g (ppb) |
| HCHs | Mediterranean river estuaries | ~1 ng/g (ppb); max 0.1 ppm |

Table 5-1: Selected contamination levels in sediments

***POP levels in soils***

Levels in soils are generally very stable and therefore reflect local pollution as well as atmospheric deposition over a long period of time. As demonstrated in the tables of the full report, average levels are three to five orders of magnitude lower than the "low POP" content limits proposed in the general technical guideline on environmental sound management of POPs under the Basel Convention [UNEP GTGESM final 2005].

However significant regional differences in contamination levels can be noted.

***POP levels in vegetation***

Levels in vegetation are generally highly dependent on the season and reflect the regional air pollution of the preceding vegetation period.

In general the overall levels are two to four orders lower than the “low POP” limits proposed under the Basel and Stockholm Convention.

***POP levels in wildlife***

Information on levels of PCDD/PCDF, PCB and POP pesticides in wildlife has been collected in numerous studies. Due to the bioaccumulating effect of the lipophilic POPs, levels in wildlife are usually found to be high in comparison to levels in other environmental compartments and would be most likely to come closer to proposed limit values for POPs under the Basel Convention.

***POP levels in food***

According to the UNEP regional report for region III Europe, background values for dairy products in European countries range from 0.6–1.1 pg WHO-TEQ/g fat (0.0006-0.05 ppb), thus lying three to four orders of magnitude below the envisaged “low” PCDD/PCDF content of 15 ppb even for highly contaminated sea food. According to this report, PCB levels range from <0.01 ppm in vegetables, cereals and fruits, over 0.02-0.2 ppm in animal fats and milk, to 0.01-0.5 ppm fat in fish. Certain fish species like eel or fish products like fish liver and fish oils contain levels up to 1 ppm.

***POP levels in human milk***

Recent exposure data for human tissues show that measures introduced to control PCDD/PCDF releases have resulted in a substantial reduction in intake of these compounds. However since 1995 the decreasing tendency observed since the mid eighties is levelling out (COM (2001) 593 final) and parts of the population may still be exposed at levels exceeding the ADI. This underlines the necessity to destroy POPs or to isolate them durably from the biosphere.

# 6 Existing concentration limits and corresponding policies

POP substances and POP containing preparations are subject to a number of regulations arising from different policy sectors and including international conventions as well as European and national legislation.

Of major importance for the subject of this report are the Basel Convention and the Stockholm Convention. An overview on all relevant international regulations is provided in the full report.

On the Community level legislation in place relating to persistent organic pollutants extends to the following environmental policy sectors:

1. waste management
2. chemicals – classification, production, and use
3. atmospheric pollution – air emissions and ambient air
4. water protection
5. food and feed safety
6. specific legislation on POPs implementing international conventions

Corresponding legislation is described in the full report.

***Legislation on waste management***

The basic legislation with respect to waste management is the waste directive (75/442/EEC) containing definitions for waste as well as waste categories and disposal and recovery operations. Properties and characteristics rendering a waste hazardous are defined and listed in the hazardous waste directive (91/689/EEC).

Council Decision 2000/532/EC lists properties and characteristics that render a waste hazardous and contains a harmonised list of wastes allowing for standardised reporting in all Member States. Wastes considered as a hazardous waste are marked with an asterisk.

Legislation regarding waste incineration focuses mainly on air emissions of PCDD/PCDF and is compiled under "atmospheric pollution".

In 1996 a specific PCB/PCT directive (96/59/EC) has been put into force for the management of all PCB containing material. According to this directive all preparations or equipment containing > 50 mg/kg PCB are considered PCB. Equipment containing > 5 $dm^3$ PCB has to be registered and decontaminated until 2010 at the latest. Equipment containing liquids with a PCB content >500 mg/kg have to be decontaminated in such a way that the resulting content is <500 mg/kg and near to 50 mg/kg if possible. Equipment with PCB concentrations between 50-500 mg/kg has to be registered but may be used until its life time expires, due to its low risk to the environment.

Recovery and Disposal of waste oil is regulated in the waste oil directive (75/439/EEC). This directive is focused on PCB. According to this directive basic oils recovered from waste oils may not contain PCB concentrations >50 mg/kg (ppm). Neither may oils used as secondary fuel for thermal recovery in incineration processes contain more than 50 ppm.

Council Regulation 93/259/EC on shipment of waste covers all POPs. While PCB and PCDD/PCDF are listed as RA 010 and RC 010,020 in Annex IV (red list), POP pesticides are contained in Annex III (amber list) under the code AD 020.

Council decision (2003/33/EC) on acceptance criteria for landfill of waste restricts the use of PCB containing waste, as wastes with PCB concentrations >1 mg/kg may not be accepted at a landfill for inert waste. For the other landfill categories the decision refers to the definition of hazardous waste laid down in the hazardous waste directive (91/689/EEC) and the European waste list (2000/532/EC), but does not specify any additional POP related requirements.

Directive 2000/53/EC on end-of-life vehicles sets up basic requirements for shredder plants. POPs are concerned by the obligation to separate all material possibly containing PCB.

The WEEE-Directive (2002/96/EC) on the reuse, recycling and recovery of electrical and electronic equipment stipulates the removal of PCB containing capacitors in Annex II. The directive is related to PCB management as it will help to control so far unregistered equipment potentially contaminated with PCB.

***POP regulation***

The European Parliament and the Council of the European Union adopted a Regulation on Persistent Organic Pollutants (2004/850/EC) in April 2004.

The main objectives of the Regulation are the following:

- Production and use of hexachlorocyclohexane (HCH) including Lindane should be confined to a minimum and ultimately phased out by 2007 at the latest.
- Stockpiles of prohibited substances should be treated as waste. In particular this shall apply as soon as possible for stockpiles which consist of or are contaminated with persistent organic pollutants.
- Releases of unintentional by-products of industrial processes should be identified and reduced as soon as possible with the ultimate aim of elimination. Appropriate national implementation should be drawn up and implemented.
- Programmes and mechanisms shall be established to provide adequate monitoring data on the presence of PCDD/PCDF and PCB in the environment under economically and technically viable conditions.
- Common concentration limits for POP substances and substance groups shall be established before 31 December 2005.

***Proposed "low POP content" levels under the Basel and Stockholm Convention***

Currently the OEWG under the Basel Convention is working on the definition of "low POP content" levels for the POP substances and substance group subject to the Stockholm Convention. In case the POP content of a waste in question will exceed these limits, the POP content will have to be destroyed or irreversibly transformed to levels below the "low POP content".

Currently the following provisional limit values have been adopted in October 2004 by COP7 to the Basel Convention and been confirmed by the first meeting of the Conference of the Parties (COP) to the Stockholm Convention in May 2005. The limits are published in the General Technical Guideline on POPs [UNEP GTGESM final 2005].

| | |
|---|---|
| PCB | 50 mg/kg (ppm) |
| PCDD/PCDF | 15 µg TEQ/kg (ppb) |
| POPs pesticides | 50 mg/kg (ppm) |

Table 6-1: Limit values proposed under the Basel Convention

Additional legislation has been established on Community level and in a number of Member States and is documented in the full report.

# 7 Reference measurement methods for POPs analysis in waste

Concerning concentration limits for 14 POPs substances as to be stipulated by the regulation on persistent organic pollutants (2004/850/EC) reliable and comparable analytical methods have to be available.

In this respect some basic aspects related to sampling and analysis of POPs and other pollutants have to be taken into account:

1. Sampling / Transport
2. Pretreatment: grinding, centrifugation, filtration
3. Extraction: liquid / liquid
   shaking / ultrasonic
   soxhlet and ASE
4. Clean-up: gel permeation
   multi-layer silica
   carbon
   alumina
5. Measurement: GC: - ECD
   - MS / HRMS

Furthermore it has to be considered, that the term “waste” in this context comprises a wide range of different matrices such as water, homogeneous and inhomogeneous solids and oil with correspondingly different requirements from an analytical point of view. Even within one type of waste the samples to be analysed can show highly variable properties which - in practise – necessitates certain modifications or introduction of additional steps to standard analytical methods to make samples measurable.

| | | | | |
|---|---|---|---|---|
| • “WASTE” | = | liquids | ←→ | solids |
| | | “soil like” | ←→ | “plastics” |
| | | homogeneous | ←→ | complex mixture |
| | | << interferences | ←→ | >> interferences |

→ no fixed matrix “waste” from an analytical point of view

→ no fixed method for matrix “waste” from an analytical point of view

→ no fixed analytical sensitivity as no fixed matrix

Figure 7-1: Problem of matrix inhomogenicity for measurement of POPs in waste matrices:

Thus it can be stated that from the variety of available analytical methods including pre-treatment, extraction, clean-up, and measurement not every method may be applicable for every waste matrix.

On this basis it is clear that there hardly can be only one single measurement standard (reference method) covering all analytical challenges of the matrix “waste”.

On the other hand, POPs analysis shall provide reliable and comparable data regardless the individual waste matrix. Especially for the control of regulatory limits this means that analysis should be – as far as possible - based on methods that meet certain quality criteria and – on this basis – provide comparable results.

It is primarily the task of standardisation bodies such as CEN, ISO and national standardisation bodies to provide standardised and validated methods.

For the scope of the European Union CEN as the Community standardisation organisation constituted by national standardisation bodies is the relevant institution for this task. CEN has already been mandated by the Commission to develop important waste related standards. It can be recommended to continue along this line.

In this context the project HORIZONTAL that has started in 2002 developed recommendations and basic requirements for harmonised European standards in the field of sludge, soil and treated biowaste. The experiences obtained in this project will be an important support for the development of taylor-made waste standards based on CEN- Work and already provides important information with respect to sampling and analysis of PCBs [ Harmsen 2004].

## 7.1 PCDD/PCDF

Table 7-1 summarises the selected results of a survey on standardised analytical methods to be considered for PCDD/PCDF analysis. More details are available in the full report.

| Method (Reference) | Matrix (acc. to method scope) | Extraction | Clean-up | Detection |
|---|---|---|---|---|
| EN 1948-2<br>EN 1948-3 | Stationary source emissions | Soxhlet / Toluene (solids, filter)<br>Liquid/liquid, toluene or dichloromethane (liquids) | - gel permeation<br>- multi layer silica<br>- carbon<br>- alumina | HRGC/HRMS |
| EPA Method 23 | Stationary source emissions | Soxhlet / Toluene | - multi layer silica<br>- alumina<br>- carbon | HRGC/HRMS |
| CARB 428 | Stationary source emissions, | Soxhlet / Benzene<br>Soxhlet / Toluene | - silica gel<br>- alumina<br>- carbon | HRGC/HRMS<br>HRGC/LRMS |
| JIS K 0311 | Stationary source emissions, | Soxhlet / Toluene | - multi-layer silica<br>- alumina<br>- carbon | HRGC/HRMS |
| EPA 1613, B | Water, soil, sediment, sludge, tissue | Not described | - gel permeation<br>- multi layer silica<br>- carbon<br>- alumina<br>- C18 | HRGC/HRMS |
| EPA 8280 | Water, soil, fly ash, chemical waste, fuel oil, | Dichloromethane<br>Soxhlet / Toluene | - multi layer silica<br>- carbon<br>- silica<br>- alumina | HRGC/LRMS |
| EPA 8290 | Soil, sediment, water | Soxhlet / Toluene<br>Dichloromethane<br>Dean-Stark Toluene<br>Soxhlet/Hexane-Dichloromethane | - multi layer silica<br>- carbon<br>- silica<br>- alumina | HRGC/HRMS |
| AbfKlärV, Germany | Sewage sludge | Soxhlet / Toluene | - alumina<br>- multi layer silica<br>- gel permeation | GC/MS |
| SAEFL Guidelines | Soil | Soxhlet / Toluene | - metallic mercury<br>- multi layer silica<br>- carbon | HRGC/HRMS<br>HRGC/LRMS |
| DIN 38412-24 | Sediment<br>Sludge | Soxhlet / Toluene | - multi layer silica<br>- $AgNO_3$-silica<br>- alumina<br>- gel permeation | HRGC/HRMS<br>HRGC/LRMS |

Table 7-1: Standardised analytical methods for PCDD/PCDF [HORIZONTAL DRAFT 2004, extended]

Critical performance/quality criteria taken from these methods include e.g. amount and number of congeners of the isotope labelled standards used, recovery rates of added isotope labelled standards, signal:noise ratio of isotope labelled standards, tolerance for deviation from theoretical isotope ratio, tolerable retention time deviations, chromatographic separation efficiencies, trueness and accuracy requirements. Example for such performance/quality criteria for the methods listed in Table 7-1 are summarised in Table 7-2.

| Method (Reference) | Scope | Recovery ratio of extraction standard (%, min – max) | Deviation of Isotope ratios from theoretical value |
|---|---|---|---|
| EN 1948-2<br>EN 1948-3 | Control of 0,1 ng I-TEQ/m$^3$ ("0,1 ng/m$^3$ and below") | 50 – 130 ($Cl_4$-$Cl_6$)<br>40 – 130 ($Cl_7$-$Cl_8$) | ± 20% |
| EPA Method 23 | | 70 – 130 | ± 15% |
| CARB 428 | Ng – pg/m3 | 60 - 140 | |
| JIS K 0311 | < 0,1 I-TEQ/m3 | 50 – 120 | ± 20% |
| EPA Compendium Method TO 9A | 0,02 – 0,15 pg/m3 ($Cl_4$ – $Cl_6$)<br>0,05-0,25 pg/m3 ($Cl_7$-$Cl_8$) | 50 – 120 | |
| VDI 3498 | MDL 0,5 – 3 fg/m3 | 50 – 130 | |
| ISO 18073 | "few pg/l) | 50 – 130 ($Cl_4$-$Cl_6$)<br>40 – 130 ($Cl_7$-$Cl_8$) | |
| EPA 1613, B | Minimum:<br>Cl4 1 ng/kg<br>Cl5-Cl7 5 ng/kg<br>Cl8 10 ng/kg | | |
| EPA 8280 | >/= 10*method calibration limit | 40 - 135 | |
| EPA 8290 | 2 ng/kg (TCDD),<br>20 pg/l (TCDD) | 40 – 120 | |
| AbfKlärV, Germany | ng/kg | > 70 (OCDD/F > 40) | |
| SAEFL Guidelines | 50 fg/µl – 5 ng/µl | 50 – 115 | |
| DIN 38412-24 | Minimum:<br>1 – 10 ng/kg per congenere | ≥ 50% | 15% from calibration run |

Table 7-2: Examples for performance/quality criteria for PCDD/PCDF [HORIZONTAL DRAFT 2004, extended]

The individual methods are designed to detect PCDD/PCDF at quite low levels in the corresponding matrices, however, it has to be emphasised that the achievable levels can vary and strongly depend on the individual matrix to be analysed.

On the other hand it can be stated that for PCDD/PCDF – especially on the measurement side – quite homogenous performance criteria are included in all available standards (e.g. recovery ratio, deviation from isotope ratio).

## 7.2 PCB

The following table (Table 7-3) summarises selected results of a survey on standardised analytical methods to be considered for PCB analysis. More details are available in the full report:

| Method (Reference) | Matrix (acc. to method scope) | Extraction | Clean-up (options) | Detection |
|---|---|---|---|---|
| EPA 1668 | water,<br>soil, sediment,<br>sludge,<br>biosolids,<br>tissue,<br>other | SPE<br>Dean-Stark/Toluene<br><br>Soxhlet / Hexane-Dichloromethane | - Gel permeation<br>- multi-layer silica<br>- carbon<br>- silica gel<br>- florisil<br>- carbon | HRGC/HRMS |
| DIN 38414-20 | sewage sludge, sediments | Soxhlet/hexane or pentane | - $AgNO_3$-silica | GC/ECD |
| DIN EN 12766-1<br>prEN 12 766-3 | petroleum products and used oils | Solving in heptane, hexane, cyclohexane or 2,2,4-trimethylpentane | - silica gel<br>- alumina<br>- $H_2SO_4$<br>- copper<br>- TBA<br>- thermal shock | GC/ECD |
| EN 61619 | insulating liquids | | | GC/MS |
| ASTM 4059 | insulating liquids | Solving in hexane or heptane | | GC/ECD |
| ASTM 6160 | waste materials | Mixing with acetone/hexane | | GC/ECD |
| AbfKlärV | sewage sludge | Soxhlet, hexane | - alumina<br>- $AgNO_3$/silica gel<br>- TBA | GC/ECD |
| EPA 8082 | solid and aqueous samples | Soxhlet, hexane-acetone ore dichloromethane-acetone<br>Liquid/liquid dichloromethane | - $H_2SO_4/KMnO_4$ | GC/ECD |
| EPA 8270 | solid waste, soils, air samples. water | | | GC/MS |

Table 7-3: Standardised analytical methods for PCB

Critical performance/quality criteria taken from these methods include target PCB to be analysed (total amount, technical mixture equivalent, individual congeners), quantification method (internal / external standard. method, isotope dilution), recovery rates, tolerable retention time deviations, chromatographic separation efficiencies.

Examples for such performance/quality criteria for the methods listed in Table 7-3 are summarised in Table 7-4.

| Method (Reference) | Minimum for application, or validated span | Quantification | Recovery | Identification: |
|---|---|---|---|---|
| EPA 1668 | Water:<br>Minimum LOQ for PCB 126 = 5 pg/l<br>Solids:<br>0.4 – 40 ng/kg per congener | Isotope dilution | | RT, Isotope ratio |
| DIN 38414-20 | 1 µg/kg per congener | Internal std. Method (209) | Recovery rate < 15% deviating from theoretical value | Retention time,<br>2nd column confirmation<br>PCB pattern obvious |
| ISO 10382 | 10 µg/kg per congener | Internal std. method (143, 155) | | RRT (0.2% criteria) |
| DIN 38407-3 | 1 ng/l (ECD)<br><br>10-100 ng/l (MS) | Internal std. method or<br><br>isotope dilution (GC/MS) | > 60%<br><br>40 –150% | Retention time,<br>2nd column confirmation (ECD) |
| ISO 6468 | 1 – 10 ng/l per congener | External calibration method | > 60% | Retention time,<br>2nd column confirmation (ECD) |
| DIN 38407-2 | | Internal standard method (hexabromobenzene, PCB, trichlorotoluene) | > 60% | Retention time (0.02 min), RRT (0.1%), 2nd column confirmation (ECD), altern. GC/MS |
| DIN EN 12766-1 | | Internal standard method | | Retention time, relative retention time |
| ASTM 4059 | | External standard method | | Retention time, |
| ASTM 6160 | 2 – 50 ppm (total PCB) | External standard. method | | Retention time, |
| AbfKlärV | | Internal standard method | > 80% | Retention time, confirmation : 2nd column (ECD) or GC/MS |
| ASTM 5175 | 0.5 – 50 µg/l<br>(total PCB) | External standard method | | Retention time, |
| EPA 8082 | 0.05 – 0.9 µg/l (MDL, as Aroclor), 5-25 ng/l per congener<br>57-70µg/kg (MDL as Aroclor), 160 – 800 ng per congener | External standard method (Aroclor)<br>Internal standard method (congeners) | 80 – 120% | Retention time, confirmation : 2nd column (ECD) or GC/MS |
| EPA 8270 | | Internal standard method | | RRT |

Table 7-4: Examples for performance/quality criteria for PCB

Due to possible interference in PCB analysis confirmation procedures are included in several methods (e.g. second GC column with ECD or GC/MC method). If PCB have been detected, the laboratory has to demonstrate that such interferences do not influence the results. Among others, such interferences can be tetrachlorobiphenlymethane mixtures, chlordane, chlorinated paraffins, PCN, PCT, PBB, toxaphene, PCDE, PBDE, low volatile organochlorine compounds or sulphur.

### 7.3 POP Pesticides and other POPs

Standardised measurement methods including analysis of POPs pesticides and other POPs are listed in Table 7-5. It is indicated which individual compounds are listed in each the corresponding method's scope.

However, even if a specific substance is not mentioned, the listed methods are generally appropriate to cover the missing POP compound after corresponding validation. E.g. Mirex is already used as internal standard in a number of the indicated methods.

The Pesticide analysis is based on the same methods as listed for PCDD/PCDF and PCB (extraction and clean-up methods), detection is again based on GC/ECD or GC/MS methods.

| Method (Reference) | Matrix (acc. to method scope) | Aldrin | Dieldrin | Endrin | Chlordane | DDT | Heptachlor | Chlordecone | Mirex | Toxaphene | HCH | HCB | HxBB | Detection |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPA 8081 | Solid and liquid matrices | ● | ● | ● | ● | ● | ● | | | ● | ● | ● | | GC/ECD |
| EPA 8270 | Solid waste, soils, air,, water | ● | ● | ● | ● | ● | ● | | ● | ● | ● | ● | | GC/MS |
| ISO 10382 | Soil | ● | ● | ● | | ● | ● | | | | ● | ● | | GC/ECD |
| DIN 38407-2 | Water | ● | ● | ● | | ● | ● | | | | | ● | | GC/ECD |
| EPA 608 | Wastewater | ● | ● | ● | ● | ● | ● | | | ● | ● | | | GC/ECD |
| EPA 625 | Wastewater | ● | ● | ● | | ● | ● | | | ● | ● | ● | | GC/MS |

Table 7-5: Standardised analytical methods for organochlorine pesticides and related compounds

Some of the methods (e.g. EPA 8270, ISO 10382) are valid for PCB analysis as well. This indicates the general possibility of multi-component analysis in the field of organochlorinated compounds (e.g. unique extraction techniques, available clean-ups to separate certain POPs, GC based separation methods and ECD or MS based detection methods).

# 8 Scenarios and prognosis on future developments

## 8.1 Implications of low POP content limits

The stricter the low POP content limit for POP waste will be the more wastes will be classified as POP waste and consequently will require incineration, physico-chemical treatment or disposal on hazardous waste landfills in hard rock formation or underground.

This means that existing mass flows will change in the following way in case of a stricter low POP content limit:

hazardous waste incineration: ↑

hazardous waste landfilling: ↑

municipal solid waste incineration: ↑

hazardous waste landfilling and underground disposal: ↑

non-hazardous waste landfilling: ↓

inert waste landfilling: ↓

recovery operations: ↓

Waste incineration as well as hazardous waste landfilling and underground storage will receive all waste volumes that will be classified as POP waste and thus increase in volume in relation to the decrease in volume of non-hazardous waste landfilling, inert waste landfilling and recovery operations.

## 8.2 Implications of maximum POP content limits

The stricter the maximum POP content limit for POP waste will be the more wastes will require incineration or other destruction or irreversible transformation methods to reduce the POP content.

This means that existing mass flows will change in the following way in case of a stricter maximum POP content limit:

hazardous waste incineration: ↑

hazardous waste landfilling: ↓

municipal solid waste incineration: ↑

hazardous waste landfilling and underground disposal: ↓
(if no MPCL will be established for underground storage the effect will be: ↑)

non-hazardous waste landfilling: ↓

inert waste landfilling: ↓

recovery operations: ↓
(except of operations in which the POP content is destroyed/irreversibly transformed)

### 8.3 Scenarios

Based on the available data the following effects of different potential limits can be observed:

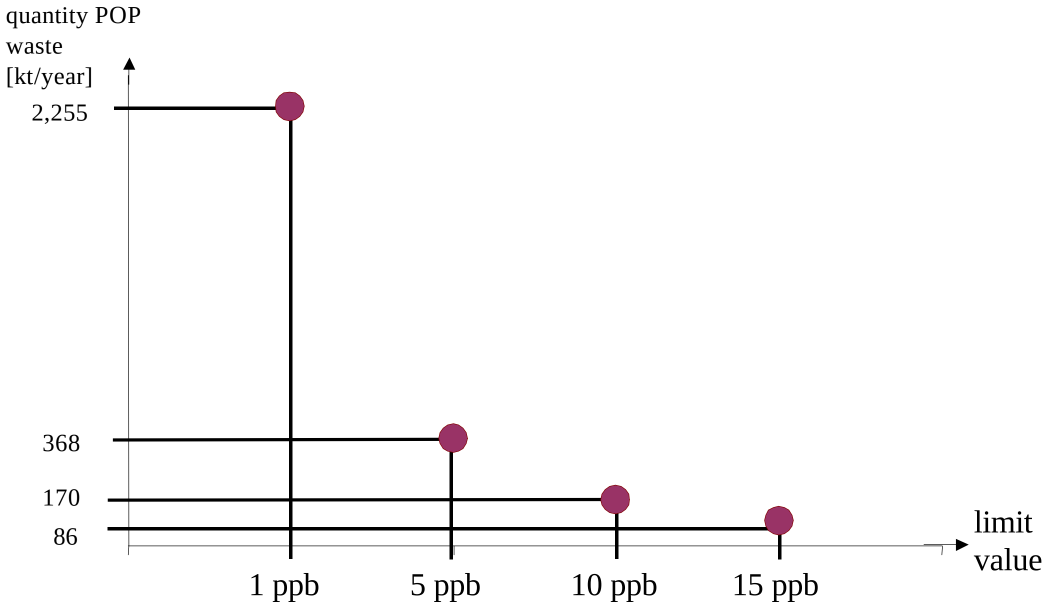



Figure 8-1: Estimated annual quantities of waste classified POP waste due to its PCDD/PCDF concentration (ng TEQ/g) in relation to different low POP content limits

A more detailed compilation illustrating the contribution of individual waste types is given in the full report.

Problems with substance recovery operations and landfilling can be expected for filter dusts and solid FGT residues in several sectors of the secondary metal industry, from municipal solid waste incineration and biomass power plants and for soot from domestic burning if the low POP content limit for PCDD/PCDF is low.

This effect starts at 15 ppb with some filter dusts from EAF steel production, some internal dusts from secondary copper production , some FGT residues from secondary aluminium production and municipal solid waste incineration and some ashes from biomass power plants. While there is a limited increase of concerned amounts down to 5 ppb a almost 10-fold raise in amounts occurs at a limit value of 1 ppb.

In detail the following impacts are expected in different affected sectors:

In the secondary copper industry copper-loaded feed material has an estimated average contamination of 6 ppb with peak contamination levels in recycled and reused dusts from other metallurgical processes of up to 25 ppb, so that part of the feed material might not be available anymore. The same principle applies for filter dusts from the EAF iron and steel industry which are used for zinc oxide production in secondary zinc production processes. Although average PCDD/PCDF levels are quite low (1.1 ppb) they can reach up to 20 ppb, thus would be affected by low POP content limits <15 ppb.

This is important as the secondary melting processes themselves apply high temperatures over a long residence time, so that the PCDD/PCDF in the feed material are destroyed.

Filter dusts in the secondary aluminium production show average contamination levels of about 10 ppb and thus use as secondary raw material at landfills sites could be affected.

Limitations for recovery in the waste incineration sector would occur for APC residues which normally show PCDD/PCDF levels below 5 ppb but partly exceed even 10 or 15 ppb. The same applies for mixed ashes from biomass combustion plants which show contamination levels up to 16 ppb and for soot from domestic burning where PCDD/PCDF concentrations up to 14 ppb were measured.

However it has to be stated that the large amounts of PCDD/PCDF containing wastes are not concerned by any of the discussed limits as PCDD/PCDF concentration is low.

Except of bottom ash from hospital waste incineration which shows an average value of 0.16 ppb and can reach 0.3 ppb, recovery of bottom ashes and slags from other investigated sectors, mixed ashes from coal combustion, reuse of compost and sewage sludge and landfilling of MSW would only be affected by a low POP content limit of <0.1 ppb.

In total only 24% of the overall discharge of PCDD/PCDF-TEQ to waste is covered by the lowest discussed limit of 1 ppb. The situation would even not change significantly at a limit of 0.1 ppb. This is due to high volume low contaminated wastes streams like MSW, bottom ashes and slags, sewage sludge and compost which transport the remaining 76%.

The overall relation of the share of total PCDD/PCDF discharge covered at different potential limit values and the contribution of different waste sectors is given for the discussed low POP content limits in the figures below.

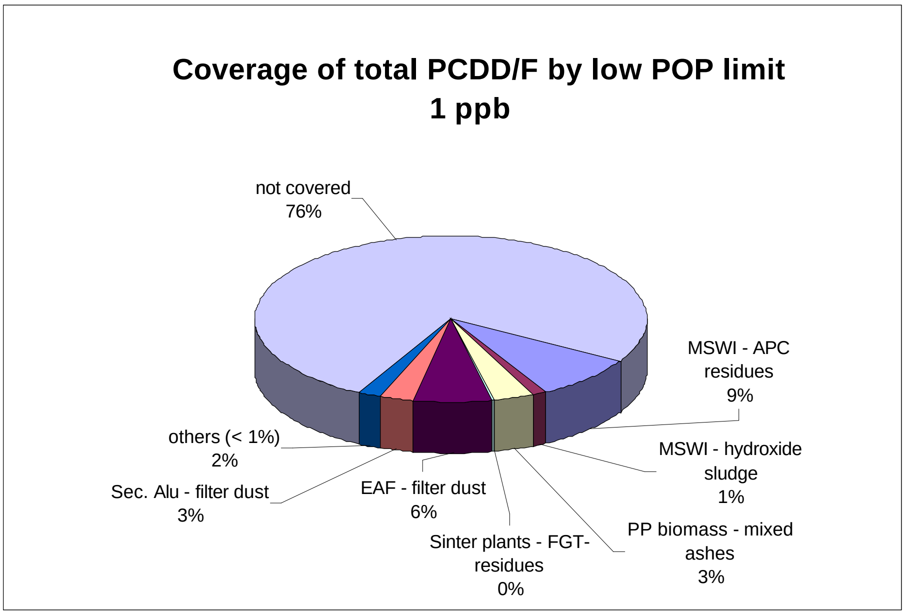



Figure 8-2: Share of total annual PCDD/PCDF discharge to waste in EU 25 covered by potential low POP content limits

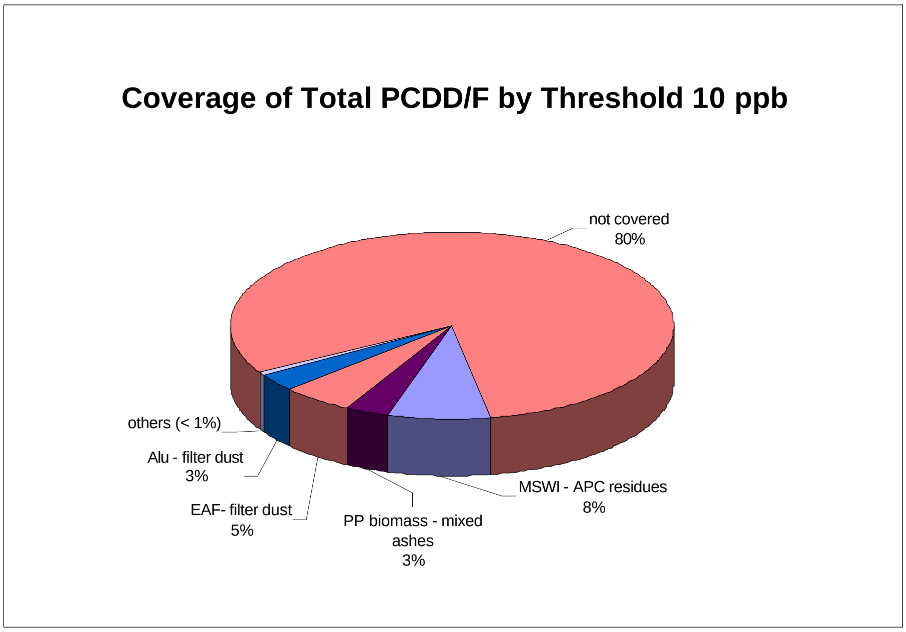



Figure 8-3: Share of total annual PCDD/PCDF discharge to waste in EU 25 covered by potential low POP content limits

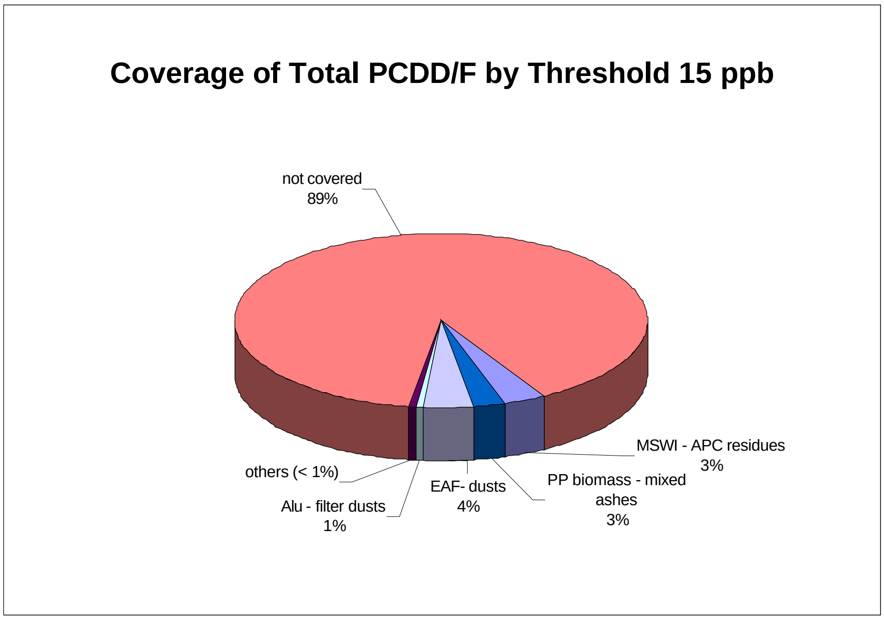



Figure 8-4: Share of total annual PCDD/PCDF discharge to waste in EU 25 covered by potential low POP content limits

Similar scenario analyses for the other POPs are available in the full report.

## 8.4 Prognosis on future developments

PCDD/PCDF Flow for 2015

For the prognosis of the PCDD/PCDF mass flow in the year 2015 it is expected that all Member States will have adopted BAT standards for incineration processes in municipal solid waste incineration, power production and metallurgical industry as major contributors to the PCDD/PCDF mass flow.

It seems that in MSWI there is still a certain improvement potential and it is expected that processes in municipal solid waste incineration will lead to a balanced or positive PCDD/PCDF balance of this activity. Expected annual emissions to waste would be around 1 kg (currently 1.9 kg). In addition PCDD/PCDF discharge via MSW may have declined to estimated 7 kg. In conjunction with smaller reductions in other sectors, this would reduce the annual PCDD/PCDF contribution to waste from the investigated sources to approximately 14 kg TEQ. Air emissions which are largely due to domestic burning may not decline so fast and are assumed to reach 3.5 kg/y. This prognosis does not yet take into account an expected shift from landfill of municipal solid waste to an increased share of incineration. For this aspect data are still missing. Also impacts of future legislation have not been taken into consideration.

With respect to technical progress in the production process a further reduction of organic content in the fed material as well as a further reduced de-novo synthesis of PCDD/PCDF in the flue gases could also be imaginable. Consequently a slightly reduced mass flow as illustrated in Figure 8-5 is expected for 2015.

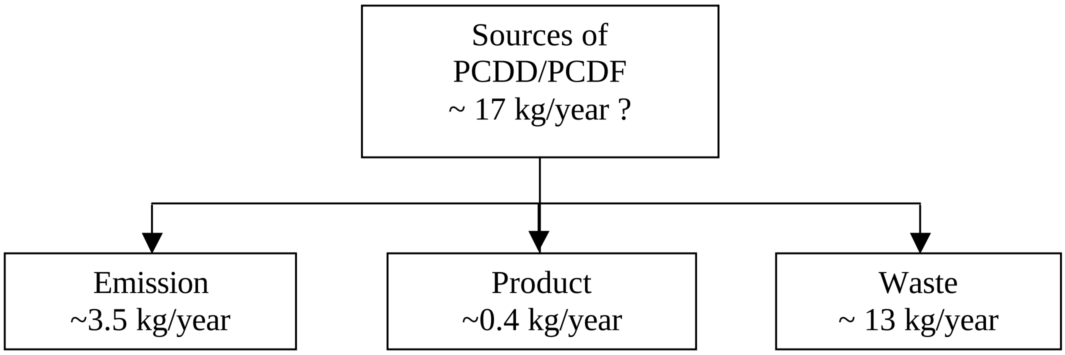



Figure 8-5: Prognostic mass flow of PCDD/PCDF in the year 2015

A prognosis in relation to proposed low POP contents is given in the full report.

PCB Flow for 2015

For the prognosis of the mass flow in the year 2015 it is expected that all electronic and hydraulic equipment containing liquids with PCB >500 ppm will be eliminated. Provided a lifetime of 15 years for white goods and cars, also small equipment with liquid containing PCB < 50ppm will have been disposed of, even more as the WEEE directive requires separation of all PCB containing material. Accordingly contamination with PCB in ELV shredder residues will probably have declined to almost zero.

In the construction sector PCB containing material ceased to be used in the mid of the eighties. Provided a reconstruction cycle of 35 years these materials would also have been completely replaced. Given an effective lifetime of buildings and waste cables of up to 50 years a relatively constant amount of PCB wastes from the construction and demolition sector (<900 t/y) can still be assumed for 2015. Due to a comparable lifetime a small input of PCB via waste cables can also be expected (~2 t/y).

In the waste oil sector there is a potential that oils containing PCB < 50 ppm are recycled and circulating in all Member States that have not set lower limit values for substance recovery of waste oils in their national legislation. The input of PCB containing oil from electronic and hydraulic equipment and white goods will not have ceased completely, so that a reduced mass flow via waste oil could be assumed. As a rough estimation ¼ of the current mass flow (<4 t/y) is estimated based on the assumption that about 50% of the oils in question are incinerated and the input from small capacitors and transformers is levelling off.

The contributions of sewage sludge and compost as representatives of the environmental background contamination will remain more or less stable due to the slow degradation of PCB in the environment (9 t/y). MSW with an estimated 60 t/y of and combustion residues with and overall mass flow from all major combustion processes of 35 t/y will gain higher importance and add to the amounts directed to MSWI, non-hazardous waste landfill and hazardous waste landfill.

Consequently a small mass flow of PCB can still be expected for PCB in Europe.

The expected mass flow for 2015 results as

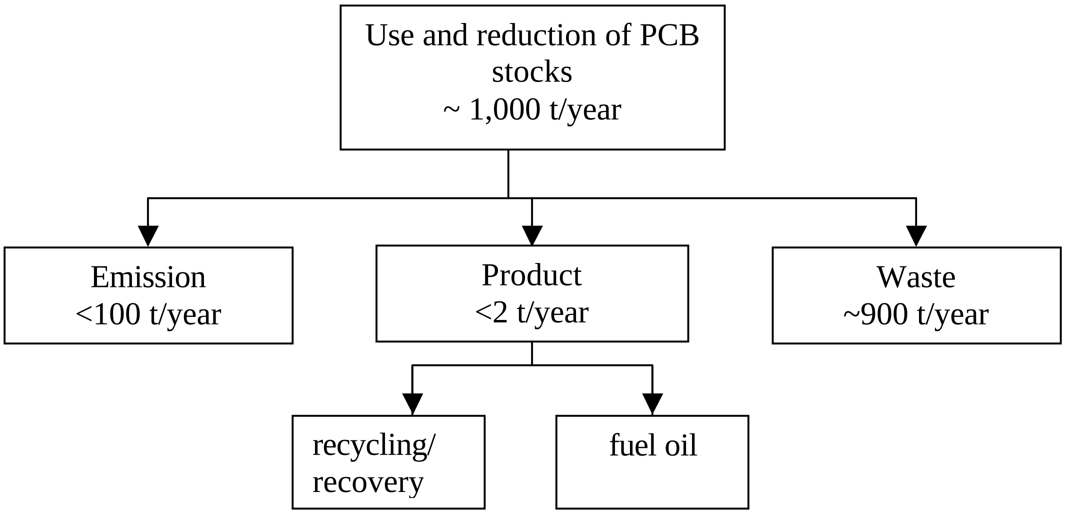



Figure 8-6: Prognostic mass flow of PCB in the year 2015

To conclude it can be assumed that (taking into account that the contribution of shredder, waste electronic equipment and stocks of higher contaminated equipment will constantly decline) the importance of waste oil and construction and demolition waste will even increase in a prognosis up to 2015, provided that no changes in legislation occur.

With respect to PCB in waste oil it has to be taken into account that, provided an effective collection system, most of the oil will be recycled and only a small fraction will be emitted to the environment.

With respect to construction and demolition waste the careful separation and destruction of PCB containing material will be a crucial factor to assure elimination of the PCB from the environment.

A prognosis in relation to proposed low POP contents is given in the full report.

<u>POP Pesticides Flow for 2015</u>

For the prognosis of the mass flow in the year 2015 it is expected that there are no remaining mass flows from the reduction of stocks. Consequently there is no waste and no emission problem expected in Europe.

However, import and production of DDT as an intermediate for Dicofol might remain until better solutions are developed or until new regulations are applied that can stop these productions. In that case production and import will decrease to zero. It is not expected that production will increase.

The expected mass flow for 2015 results as

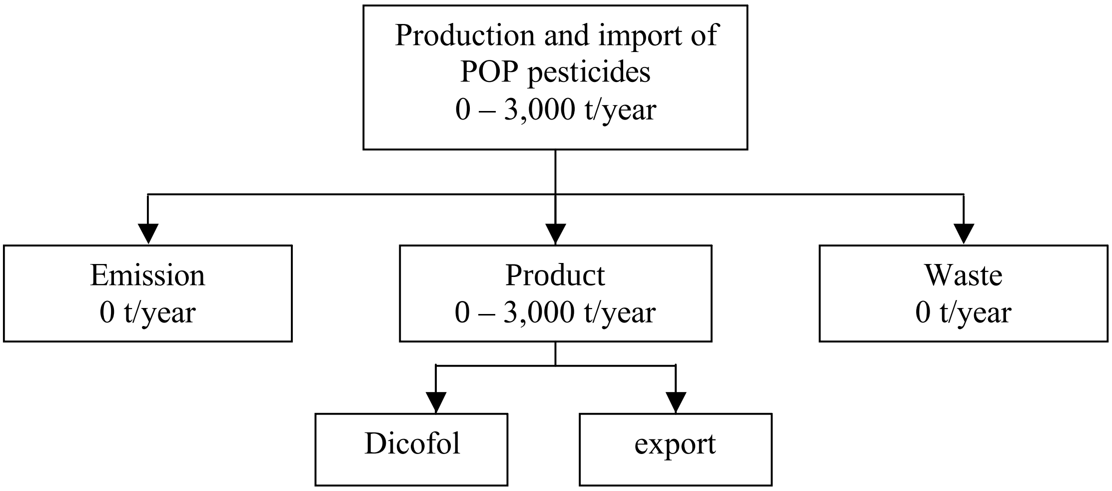



Figure 8-7: Prognostic mass flow of POP pesticides in the year 2015

A prognosis in relation to proposed low POP contents is given in the full report.

Other POPs Flow for 2015

For the prognosis of the mass flow in the year 2015 it is expected that there are no remaining mass flows from the reduction of stocks. Consequently there is no waste and no emission problem expected in Europe. Production of Lindane will have stopped. Thus except of some remaining C&D wastes and contaminated soil there will be no mass flow for other POPs.

# 9 Low POP content limit and maximum POP content limit for POP waste

## 9.1 Methodology

For the requirements laid down in the annexes to the European POP Regulation (2004/850/EC) two limit values are of major importance. For the purposes of this study the project team has distinguished between "low POP content limit" and "maximum POP content limit":

The **"low POP content limit" (LPCL)** serves to classify whether a waste must be managed in accordance with Annex V of the Regulation. POP concentrations above the LPCL require the destruction/irreversible transformation of the POP content in the waste. Individual limits may be established for different POPs.

The "**maximum POP content limit"** restricts derogations from the obligation to destroy or irreversibly transform the POPs content in waste to those waste meeting these limit values. Also the maximum POP content limit can be different for different POPs.

Figure 9-1 shall illustrate which limit values for POPs have had to be proposed in the course of the present study, how they are related to Annex IV and V of Regulation 2004/850/EC and which methods have been applied for establishing proposals for low POP content limit values and for maximum limit values.

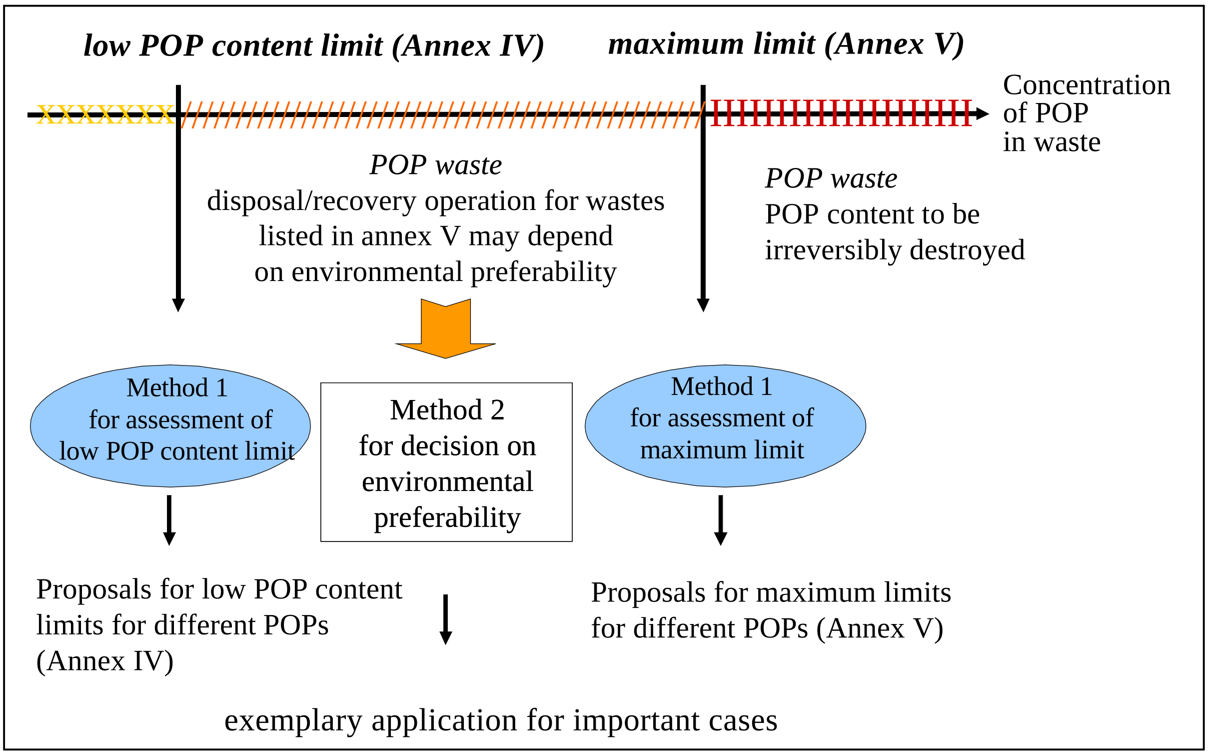



Figure 9-1: Limit values and corresponding methods

With respect to the requirements of Regulation 2004/850/EC, a methodology ("Method 1") should enable the derivation of proposals for low POP content limit values and maximum POP content limit values. The application of this methodology should generate proposals for limit values for different POPs. Method 1 is further explained in this chapter.

A second methodology ("Method 2") has been designed as a decision tool in order to decide on the environmental preferability of the operations listed in Annex V with respect to the management of certain waste codes. Method 2 can be applied when the POP concentrations of a relevant waste are between the low POP content limit value and the maximum POP content limit value and if a disposal and recovery operation other than D9, D10 or R1 is intended.

## 9.2 Basic principles of the Methodology for the Establshment of Low POP Content Limit Values

The basic principles of Method 1 are lower and upper limitation criteria limiting the range of feasible low POP content limits to propose.

- A: Analytical potential
- B: Environmental background contamination
- C: Disposal/recovery capacities
- D: Economic feasibility

*Upper limitation criteria:*

- X: Z: Existing limit values already agreed by the European Union
- Y: Worst case scenario for human health risks
- Z: Precautionary principle

For the assessment of criterion A relevant measurement techniques and corresponding limits of detection and quantification for all POPs are described in the report. Beyond that it is recommended to further develop sampling and analysis standards, update the results and mandate CEN with the development of European standards. Criterion Y includes various environmental aspects and criteria.

A strict application of criterion X (precautionary principle) requires the proposal of the lowest possible value as low POP content limit. Thus it works as a target function and reduces the range of possible limits to the highest "lower limitation" criterion. A less strict application enables a second option for the low POP content limit.

### *9.2.1 Criterion A: Analytical potential*

From the economic and technical point of view the lower edge of possible low POP content limits is marked by the limitations imposed to the system in terms of analytical accuracy and related costs. A limit which is not measurable in all Member States at reasonable economic conditions can not be implemented. Thus the criterion of laboratory capacity and the relation between detection limit and costs of different analytical methods is a major criterion for the finding of the lower boundary of low POP content limit options. The methodological approach is demonstrated below.

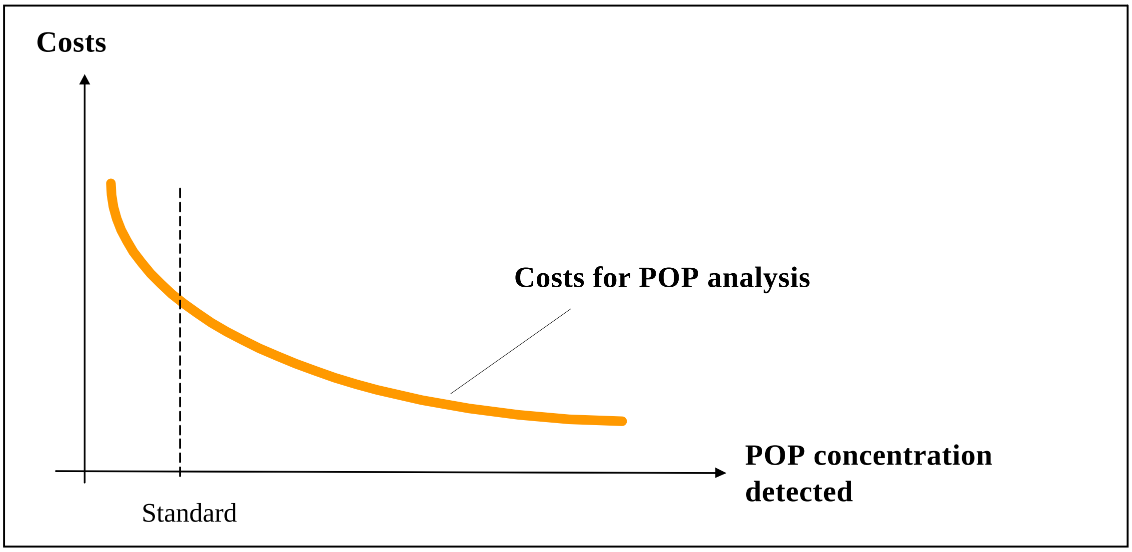



Figure 9-2: Feasible level of quantification as a function of costs and analytical sensitivity (schematic curve)

The "standard" detectable concentration of a pollutant reflects the performance of a widely available measurement technique with the POP substance enclosed in a usually prevailing matrix. The standards do not represent the minimum limit of detection (LOD) achievable for the corresponding POP substance, but reflect limits of quantification (LOQ) for established analysis standards for POP containing matrices, as far as available. In case that no specific standard for analysis in waste is currently available for the corresponding POP extrapolations have been used for the assessment of reduction in sensitivity or additional requirements with respect to sampling, pre-treatment, extraction and clean-up which limit the overall sensitivity achievable.

In order to be implementable applied standards will have to be applicable on-site for a quick control of delivered waste fractions at landfill sites or recovery installations. Thus standards have to comply especially with the provisions set up in Directive 1999/31/EC on the landfill of waste Article 11 (waste acceptance procedure) specified in Annex II (3, Level 2[9] and Level 3 On-site verification[10]). Measurement techniques will have to be validated and issued as CEN

[9] Compliance testing. This constitutes periodical testing by simpler standardised analysis and behaviour testing methods.

[10] This constitutes rapide check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents

standards in order to be added to the “sampling and test methods” as required in Article 3 of Council Decision 2003/33/EC on acceptance criteria for waste at landfills.

Standards might be different for different matrices and wastes. Furthermore, standards are not available for various wastes with possible POP contamination. Related costs are a function of analytical effort related to the sought level of sensitivity. Therefore in a large series of “cost-sensitivity” curves results for the various available standards and waste matrices.

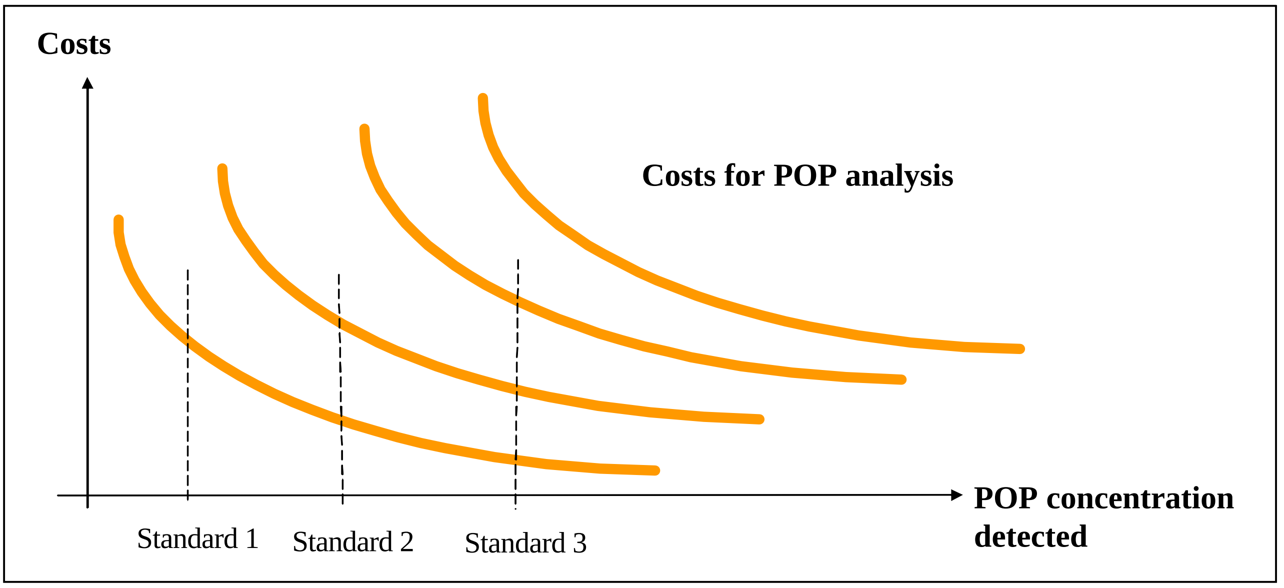



Figure 9-3: Series of cost-measurable concentration curves (schematic curves)

As mentioned above the POP concentrations that can be measured in wastes respecting all parameters stated above and containing sufficient statistical strength have to be reduced by application of the target function I in order to allow a proposal feasible for implementation and enforcement.

Thus the limitation on potential limit values arising from Criterion A have to be based on the results achievable for the most unfavourable matrix.

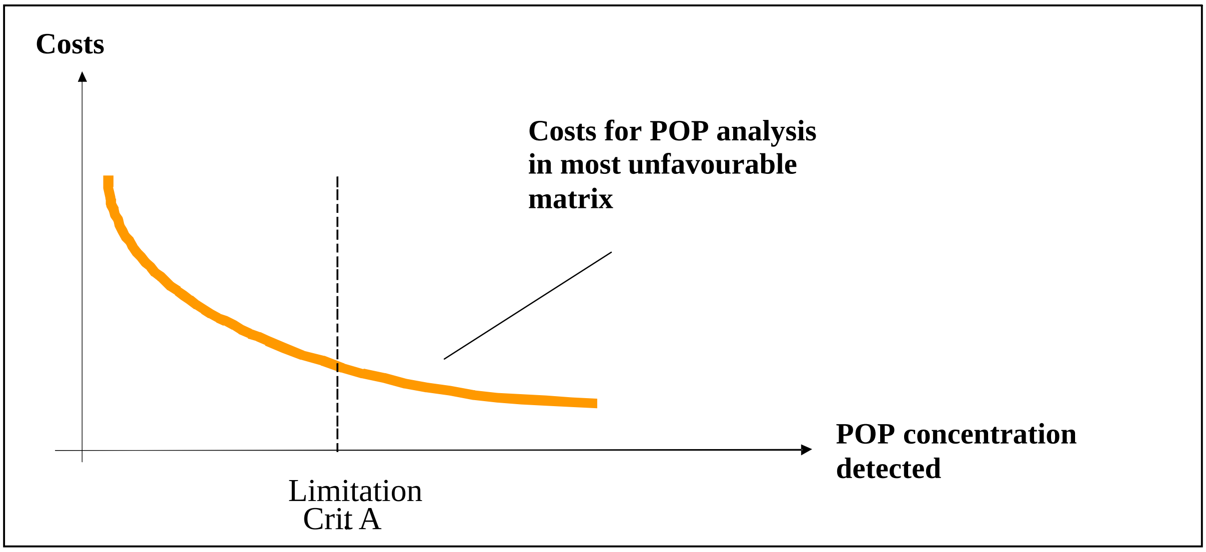



Figure 9-4: Limitation for most unfavourable matrix (schematic curve)

Besides quality requirements that have to be fullfillable in all EU 25 Member States availability of capacities depends on the measurement cost incurred by the applicants of a technique. A limit value giving rise to unacceptable cost cannot be enforced. In the course of time, though, the use of more sophisticated technologies can become affordable.

Such development corresponds to a shift of Limitation Criterion A in the direction of lower concentrations. Likewise, the “standard” mark can shift to smaller values with technical progress or extra effort at laboratory level, e.g. for additional cleaning steps. That procedure has been followed for all POPs.

### *9.2.2 Criterion B: Environmental background contamination*

The evaluation of environmental levels should take into account the fact that the lower boundary for the development of low POP content limits for POPs might be set by elevated POP concentrations in various environmental media. Any limit value should be significantly higher than average or background levels observed in the environment. A low POP content limit value below environmental background concentrations would cause severe economic problems and problems of acceptability if e.g. a soil with usual background concentration would have to be treated as POP waste as soon as it is excavated and the owner intends to get rid of it. This would furthermore help to focus on the elimination of stockpiles as major potential sources of further contamination, and may allow to set provisions for the remediation of hot spots.

Therefore background contamination levels need to be investigated. For this assessment common environmental contamination levels of the regarded pollutants in European Countries have been compiled in the full report. “Hot spot” data indicate the factor by which common values are likely to be exceeded. Combining both types of information and the number of data available, a level of contamination and an “uncertainty factor” (that expresses the uncertainty related to the availability of representative data) are derived that lead to a value for the lower limitation criteria.

### 9.2.3 *Criterion C: Disposal/recovery capacities*

Proposals for limit values should take into account that with a large number of waste types classified as POP wastes, considerable waste amounts must be expected to concentrate on a small number of specific disposal/recovery operations. Therefore the proposals for a low POP content limit should take into account whether sufficient disposal/destruction capacities exist or can be established on national and community level for the management of the resulting POP waste streams. Therefore the possibilities to use or build up necessary capacities are evaluated. This process takes advantage of the material flow analysis and follows the scheme below.

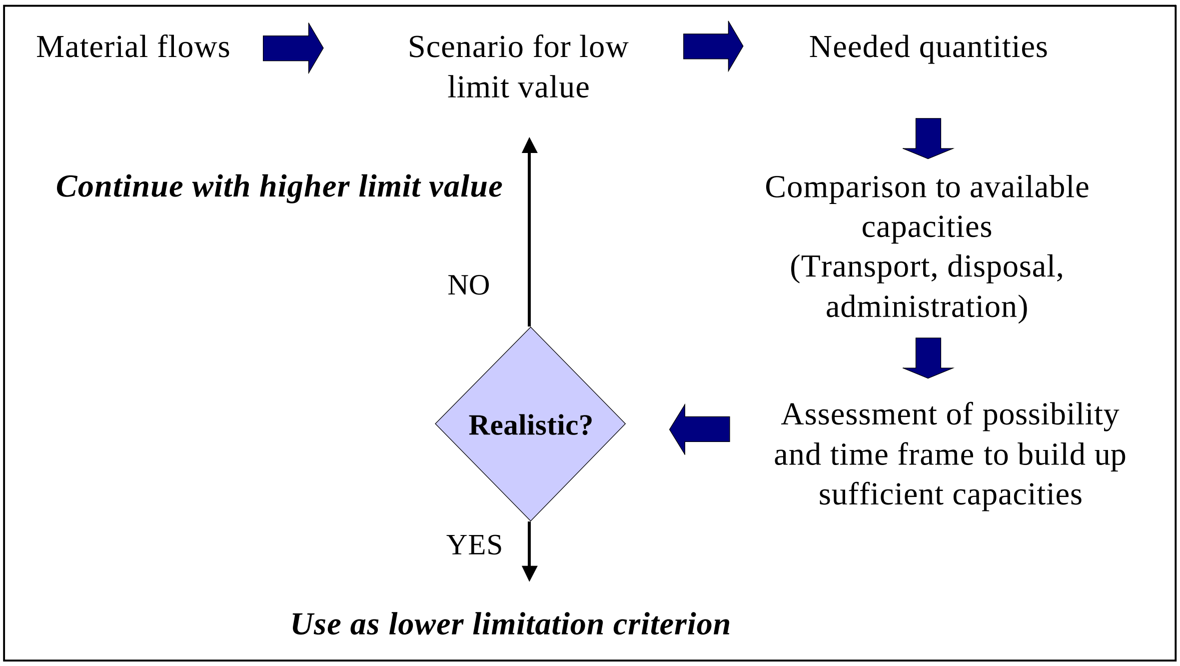



Figure 9-5: Impact on mass flow and disposal/recovery capacity as a limitation criterion for the definition of the low POP content limit

It is difficult to come to consensual results with respect to "realistic" capacities as the involved stakeholders have different interests. Therefore scenarios have been developed to identify the relation between potential limit values and resulting waste quantity becoming subject to the management provisions set in Annex V to the POP regulation. This approach is demonstrated in Figure 9-6 exemplarily:

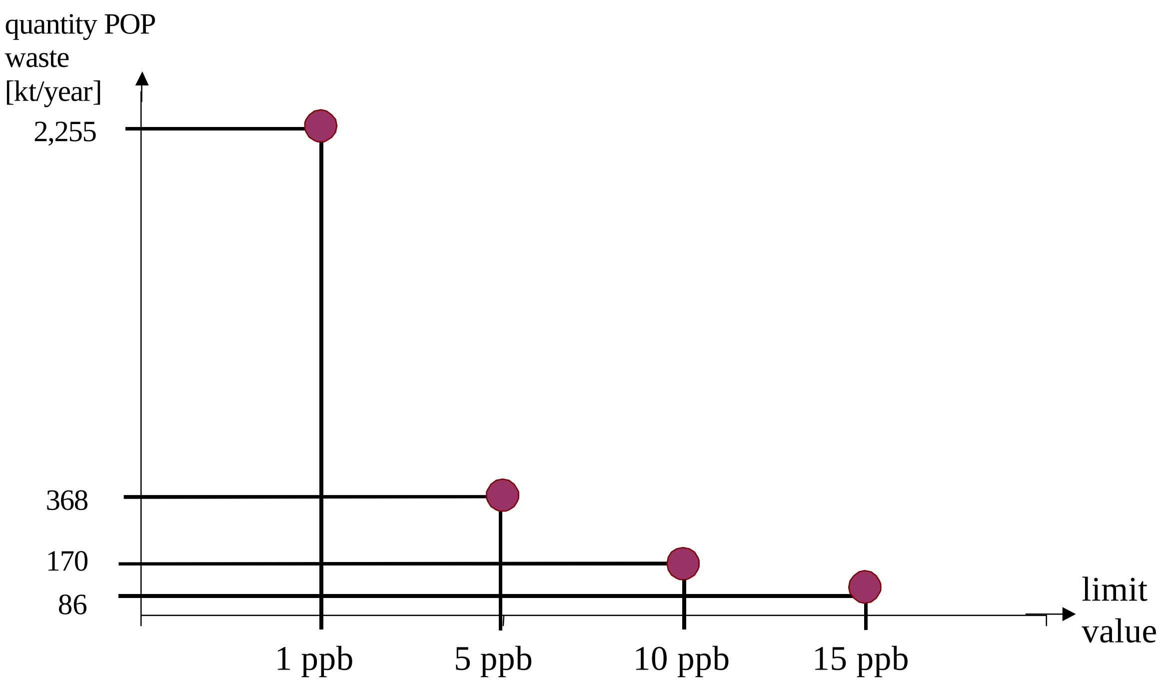



Figure 9-6: Exemplary correlation of low POP content limit and quantities waste exceeding the concentration

The results of these scenarios are also used for the assessment of economic impacts (criterion D).

Combining PCDD/F and PCB amounts the following table results:

| **PCDD/F/ PCB** | **additional amounts at 10 ppm PCB** | **additional amounts at 5 ppm PCB** | **Additional amounts at 1 ppm PCB** |
|---|---|---|---|
| **additional amounts at 10 ppb PCDD/F** | unproblematic | problematic | problematic |
| **additional amounts at 5 ppb PCDD/F** | unproblematic | problematic | problematic |
| **additional amounts at 1 ppb PCDD/F** | problematic | problematic | problematic |

Table 9-1: Combined effects of PCDD/F and PCBs related waste streams with respect to disposal/recovery capacity

It has to be taken into account that results from criterion C will change with technical development and political decisions. Thus it may not be used as finally limiting factor for the decision on limit values. However it is important for the assessment of the effects and the implementability of potential limit values.

### *9.2.4 Criterion D: Economic feasibility*

The valuation of a possible low POP content limit against this criterion depends on the induced POP waste quantities as well. Costs arise when material classified as POP waste requires specific treatment, or is excluded from profitable recovery operations.

As for criterion C, again an iteration along a simple scheme is proposed, which is depicted in Figure 9-7.

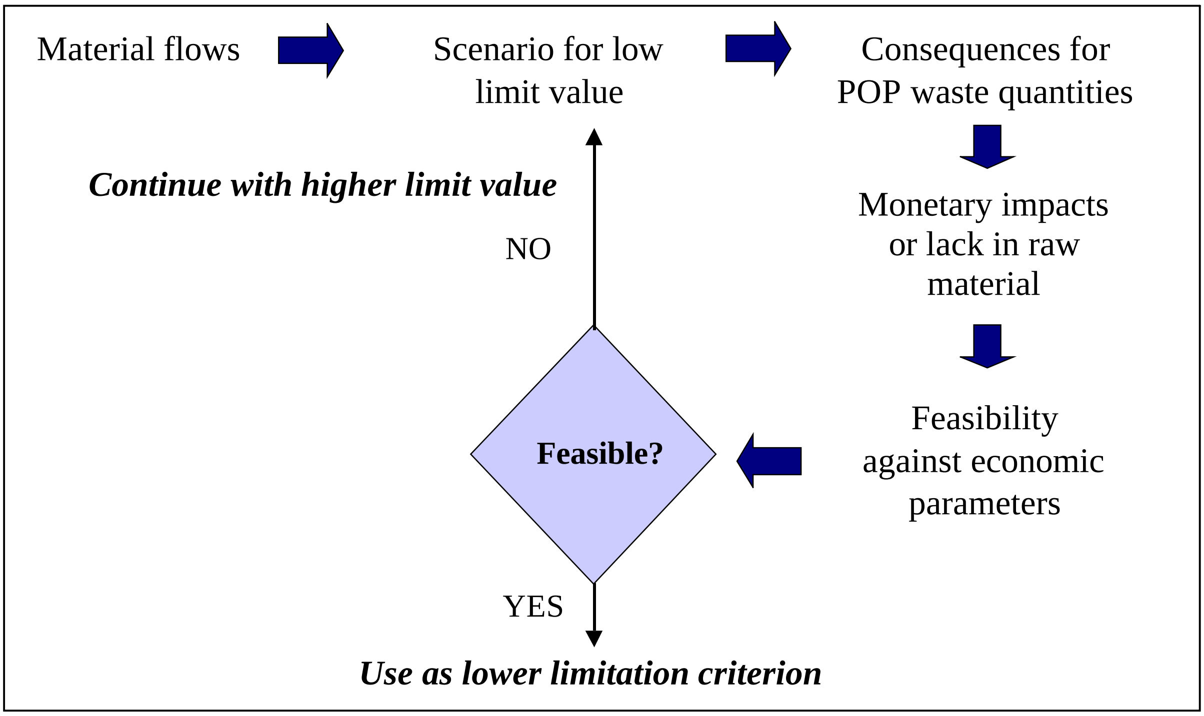



Figure 9-7: Economic impacts as a limitation criterion for the definition of low POP content limits

In the scope of this project a rough assessment of the dimension of economic impacts can be performed for PCDD/PCDF and PCB. This leads to the following overview:

| PCDD/PCDF | Limit value<br>10 ppb | Limit value<br>1 ppb |
|---|---|---|
| Concerned amount | 90 kt | 1.1 Mt |
| Concerned additional costs | 18 million € | 230 million € |

Table 9-2: Economic impacts of potential low POP content limit value related to PCDD/PCDF

| PCB | Limit value<br>30 ppm | Limit value<br>5 ppm | Limit value<br>1 ppm |
|---|---|---|---|
| Concerned amount | 180 kt | 1,600 kt | 4,000 kt |
| Concerned additional costs | 26 million € | 150 million € | 220 million € |

Table 9-3: Economic impacts of potential low POP content limit value related to PCB

Wider cost-benefit aspects and environmental impact from operations potentially concerned have to be taken into account in a complete economic impact assessment. The scope of this project however does not allow a complete economic and environmental risk assessment.

### *9.2.5 Criterion Z: Existing limit values agreed by the European Union*

Proposed low POP content limits should not exceed existing limits agreed by the Community or by international conventions. To define the upper limitation of the limit range, existing European legislation or international agreement in the field of waste management have been accounted for. Stricter regulation in single Member States must not pose a constraint for the upper limitation of the range to discuss.

The analysis is supported by results of chapter 6, where existing concentration limits and corresponding policies are discussed. A distinction was made between

- International conventions
- EU legislation
- Member States legislation

was made.

Related legislation and established limit values were structured into the fields of

- waste management
- chemicals – classification, production, and use

- atmospheric pollution – air emissions and ambient air
- water protection
- food and feed safety
- specific legislation on POPs implementing international conventions

### *9.2.6 Criterion Y: Worst case scenario for human health risks*

Compliance with the agreed limit values will not exclude all risk adherent to the POP substances in question, however they allow for the conclusion that acute risks do not emanate from wastes with lower contamination. However, the risk that substances may pose to humans and the environment is not only a function of its toxicological properties. It is also strongly correlated to its specific bioavailability and potential to enter the food chain, which is basically a function of physico-chemical properties of the waste in combination with the specific waste management.

Criterion Y targets the following risk components: the possible events of damage that can occur along a waste's life cycle, their severity, and the realistic probability of a damage event. Consequently, the assessment methodology with respect to criterion Y combines elements of Life Cycle Assessment, conventional Risk Assessment and Impact Assessment.

Starting out from the toxicological properties and exposure as the two key components of a Risk Assessment, it is possible to assess the extent to which the probability of adverse health and environmental effects can be influenced by the established low POP content limit values.

Generally spoken risks to humans occur via inhalative, dermal and oral exposure and occupational and residential exposure settings have to be taken into consideration for a risk assessment. However a number of factors can be excluded from in depth investigation due to a low probability to produce relevant impacts or because the risk potential is not influenced by the classification of waste under the POP regulation.

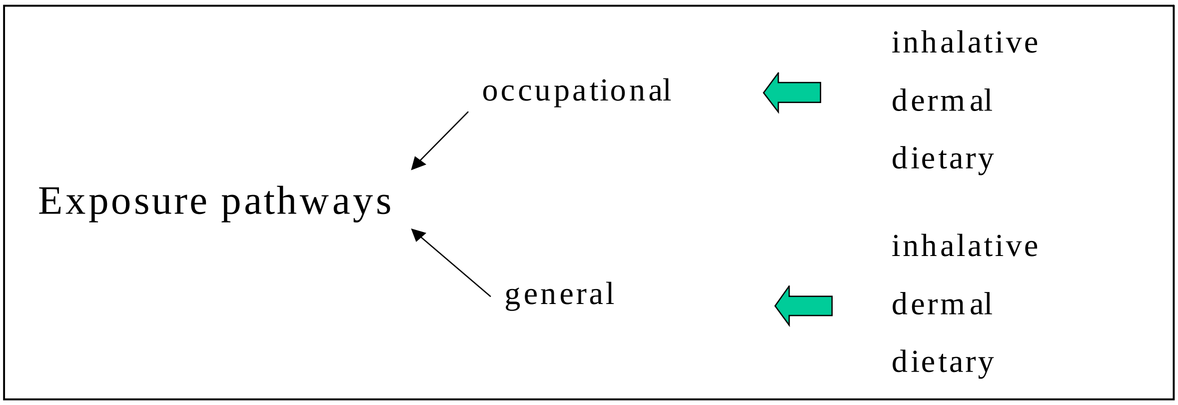



Figure 9-8: Exposure model according to the Risk Assessment methodology

Performing a complete risk assessment for the different exposure settings is not in the scope of the project, even less as crucial parameters such as leakage from different applications, environmental transfer rates, and effects on food contamination have not yet been quantified, and can be controversially discussed. Instead existing information from literature is used and investigations are targeted to identify those risks that can be mitigated by means of a limit value concept, and that are not covered by the Basel convention. An approach in the style of a life cycle analysis helps to systematise possible sources of risk.

As illustrated in the figure below relevant stages of the waste life cycle that have to be investigated are the waste generation, waste treatment, transport, and finally the disposal/recovery of the waste.

Key Issue : Risk reduction by classification of wastes as POP waste

***Relevant steps within life cycle of waste:***

Generation → Treatment → Transport → Disposal/Recovery

↓ ↓ ↓ ↓

Question to be answered: Are there risks for human health or environment, that can be excluded via POP regulation based on threshold limit values..

- Occupational exposure
- Public exposure / environmental impact

When the relevant sectors have been identified, bioavailability and toxicological properties of the substance in question define the potential health effects in case of exposure, and limit the acceptable exposure levels for humans or wildlife.

It is explained in detail in the full report that the disposal/recovery sector has been identified as the only relevant sector as regards the scope of the POP regulation. Thus the potential impacts from this sector on environment and humans have to be investigated. For this purpose literature has been reviewed for information on environmental transport and fate and risk assessment for the general population. This led to an overview on environmental pathways and major human exposure scenarios which is illustrated below. A ranking of pathways to environment and food– although only qualitative – is possible on the available information.

After identification of the most critical pathway existing legislation was cross-checked for potential restrictions/limitations imposed to it.

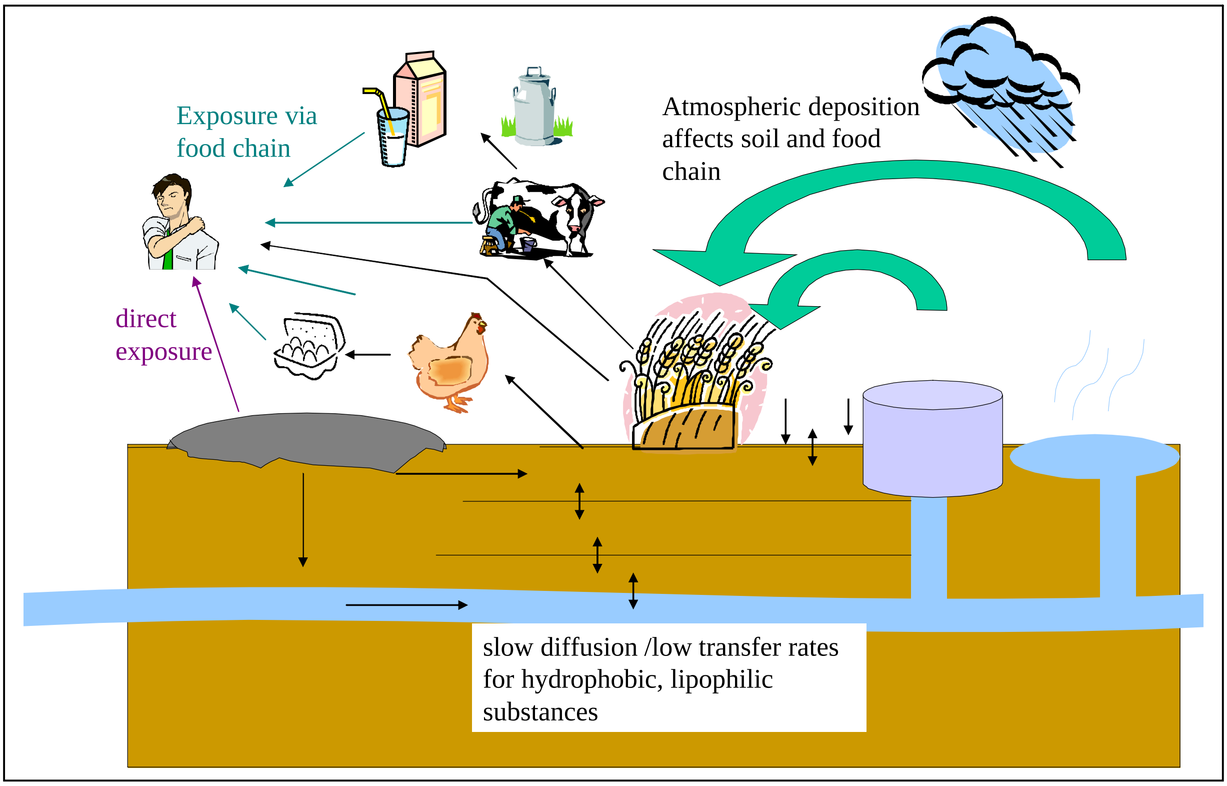



Figure 9-10: Releases from application of PCDD/PCDF contaminated material to soil

Then information on potential links between contamination in environment and food was used for a very first evaluation on potential effects on humans.

The results were then compared with maximum limits set for food and soil for a plausibility check. The project team is aware that the results are loaded with a considerable uncertainty and that further research on transfer rates from waste material to environment, food and humans is urgently needed, however the assessment showed that there might be some areas in current waste legislation where potential risks from recovery of POP contaminated material cannot be completely excluded.

### *9.2.7 Criterion X: Precautionary principle*

According to the provisions set in the Stockholm Convention and the Community Strategy on PCDD, PCDF, and PCB (COM(2001) 593), the precautionary principle shall be applied to all POP related issues. This aims at reducing emissions and discharge to the highest possible extent, in order to protect the environment and human health. Thus, due to the high persistency and the potential long-term effects, the precautionary principle demands to opt for the lowest of concentration limits acceptable by the before mentioned limitation criteria A-D, Y and Z.

Criterion X therefore is used in the decision making process as target function II in order to reduce the range of potential limits to a precise, recommendable low POP content limit.

## 9.3 Results of the application of the methodology

Based on the evaluation of the different limitation criteria the following low POP content limit values are suggested:

### *9.3.1 Results for low POP content limit PCDD/PCDF*

For PCDD/PCDF the proposal of a LPCL is complex, because results from lower and upper limitation criteria lead to controversial requirements. There is a contradiction between the requirements from the upper limitation criteria Y with the lower limitation criteria C and D.

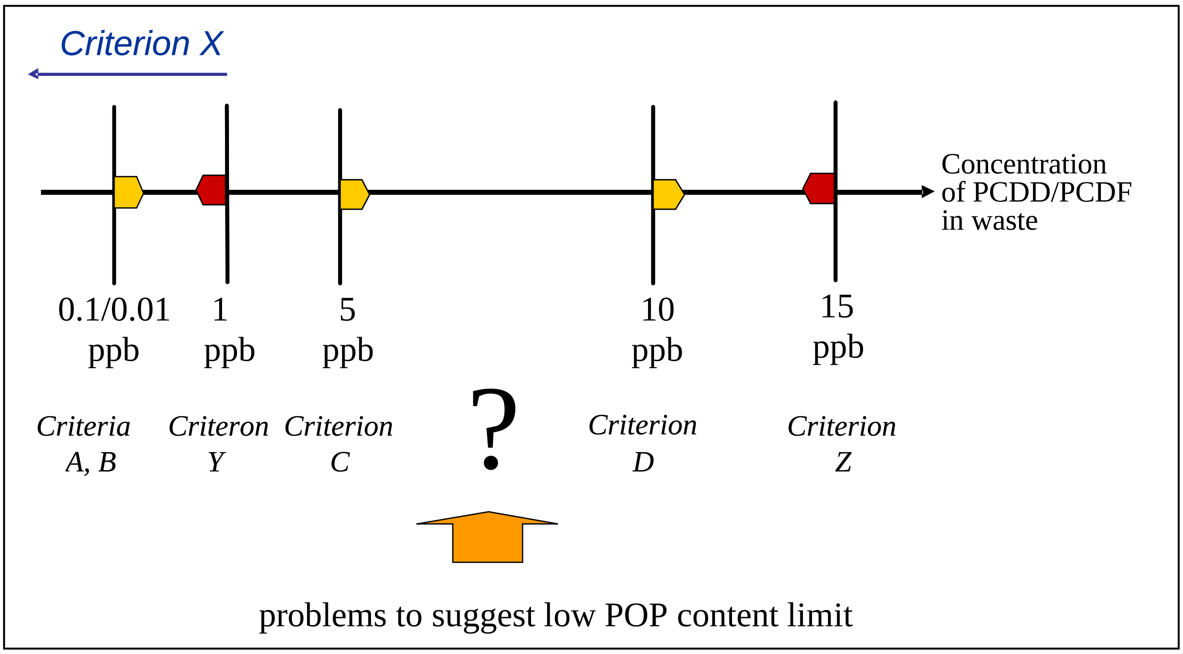



Figure 9-11: Problems to suggest a low POP content limit

Two solutions to solve this conflict are suggested:

1. Stabilisation and solidification is required as additional prerequisite for the recovery / recycling of wastes following Art. 7 Nr. 6 of the POPs Regulation for wastes exceeding 1 ppb PCDD/PCDF concentration thus banning R10 operation or other uses where the material is directly put only or mixed with soil (e.g. road basement, etc.). If this condition is applied the result for the upper limitation criteria for PCDD/PCDF concentration would be 15 ppb. According to the precautionary principle this would result in a recommended low POP content limit of 10 ppb (see Figure 9-12) as option 1 and of 15 ppb as option 2.

2. The result of 1 ppb for PCDD/PCDF contamination is kept as a result from upper limitation criterion Y. Annex V of the POPs Regulation is correspondingly amended to include further recycling/recovery options (e.g. secondary metallurgical processes) in order to ascertain economic feasibility and sufficient disposal capacity (see Figure 9-13). In this case option 1 and option 2 equally result in a low POP content limit value of 1 ppb.

On the basis of solution one, the upper limitation due to Criterion Y will shift to 15 ppb. As criterion X (precautionary principle) demands to propose the lowest possible value as low POP content limit, this results in a proposed limit of 10 ppb. In case of a different application of the precautionary principle a limit of 15 ppb would result as alternative limit proposal under solution one.

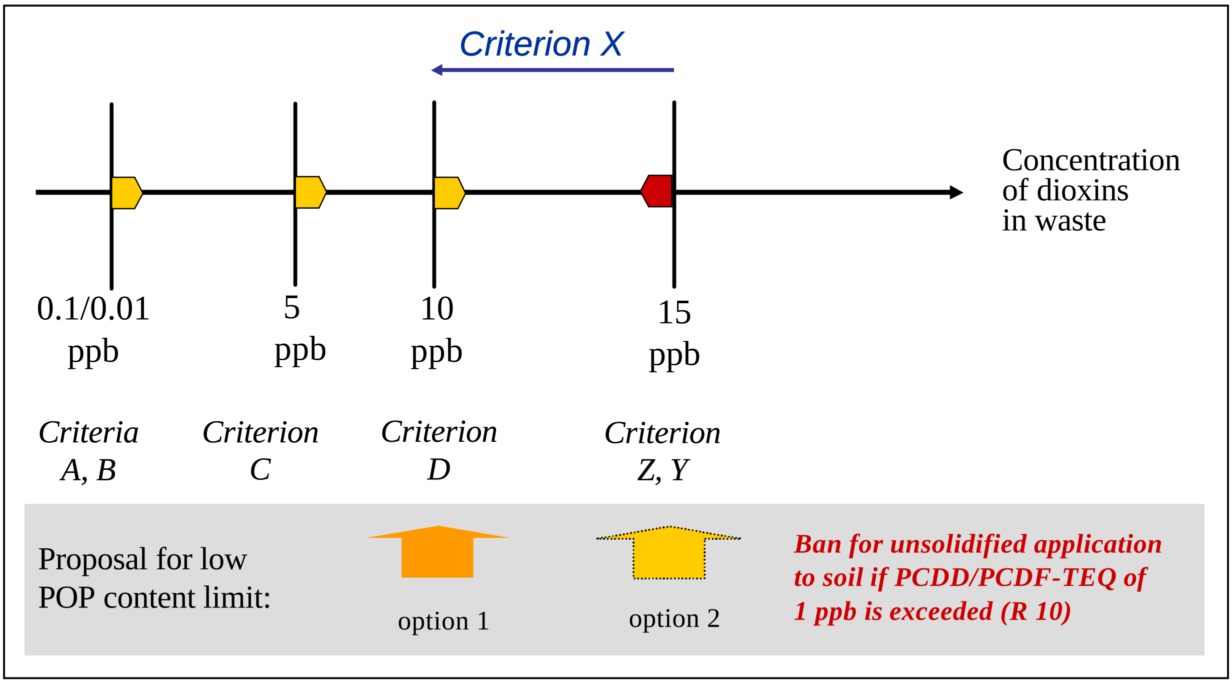



Figure 9-12: Recommended low POP content limit for PCDD/PCDF (expressed as I-TEQ) provided there is a ban for unsolidified application of contaminated material to soil (e.g. R 10)

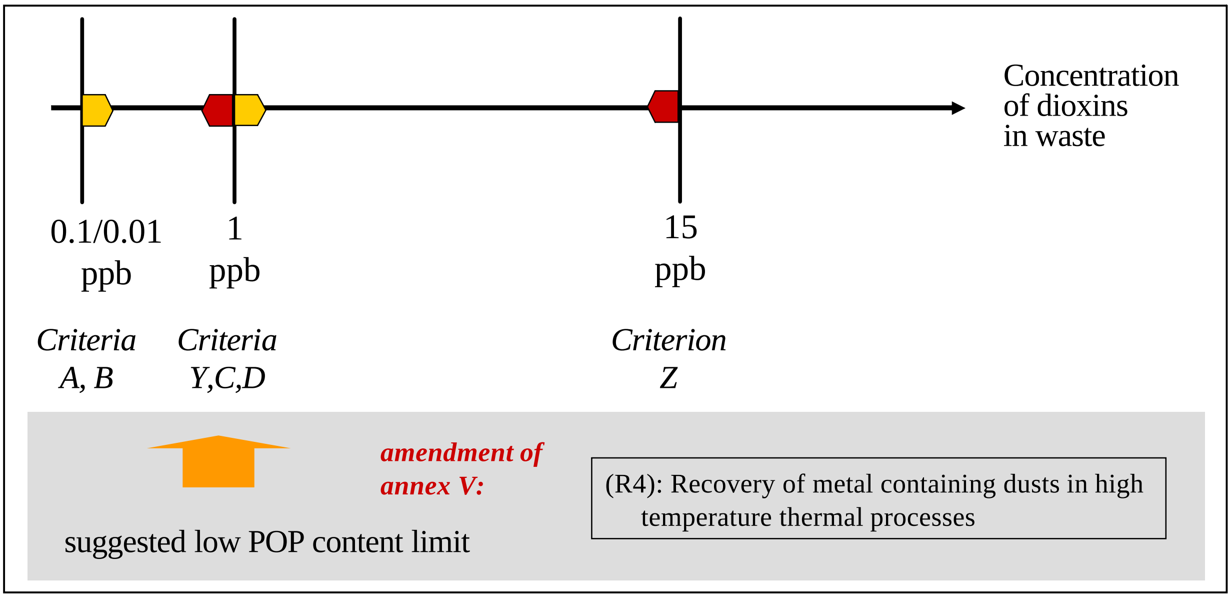



Figure 9-13: Recommended low POP content limit for PCDD/PCDF (expressed as I-TEQ) provided Annex V to the POP regulation is amended accordingly

### 9.3.2 Results for low POP content limit Polychlorinated Biphenyls (PCB)

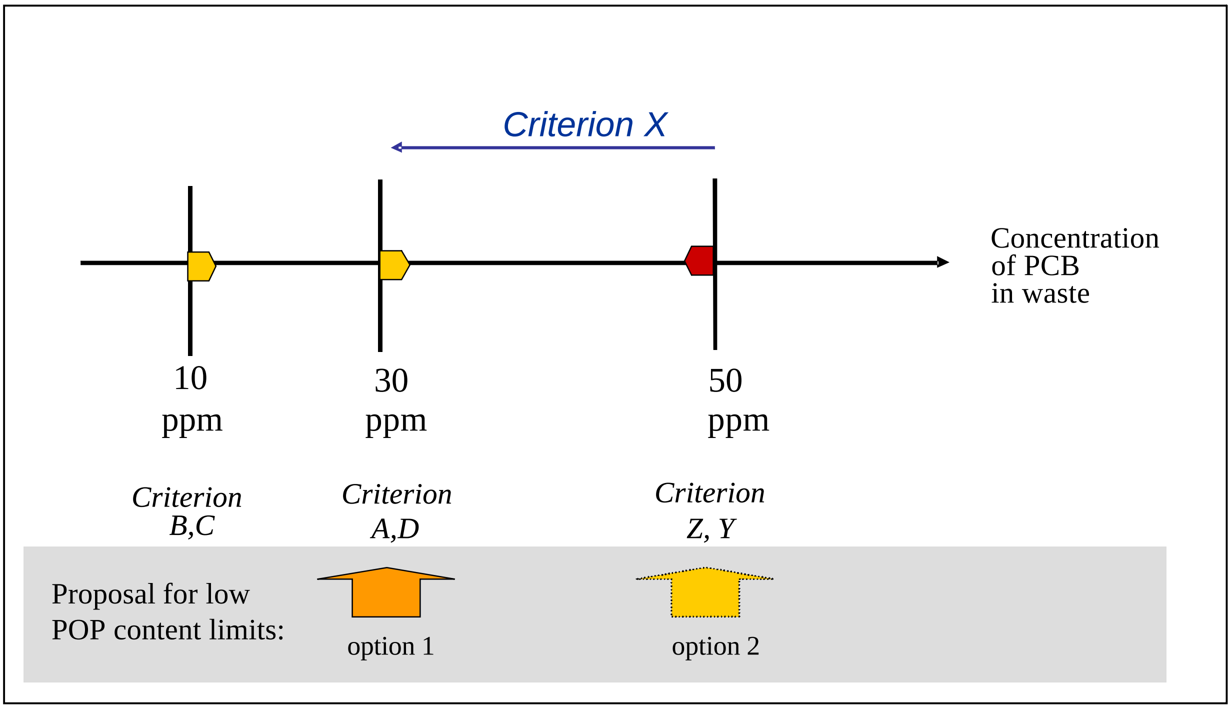



Figure 9-14: Recommended low POP content limit for PCB (total expressed as Sum 6 x 5) based on assessment method 1

The result of the limitation criteria is shown in Figure 9-14.

For PCB therefore a low POP content limit of 30 ppm is recommended as option 1, based on a total PCB calculated as Σ 6 Congeners multiplied by 5. An alternative option 2 might be a low POP content limit of 50 ppm.

### 9.3.3 Results for low POP content limit POP Pesticides

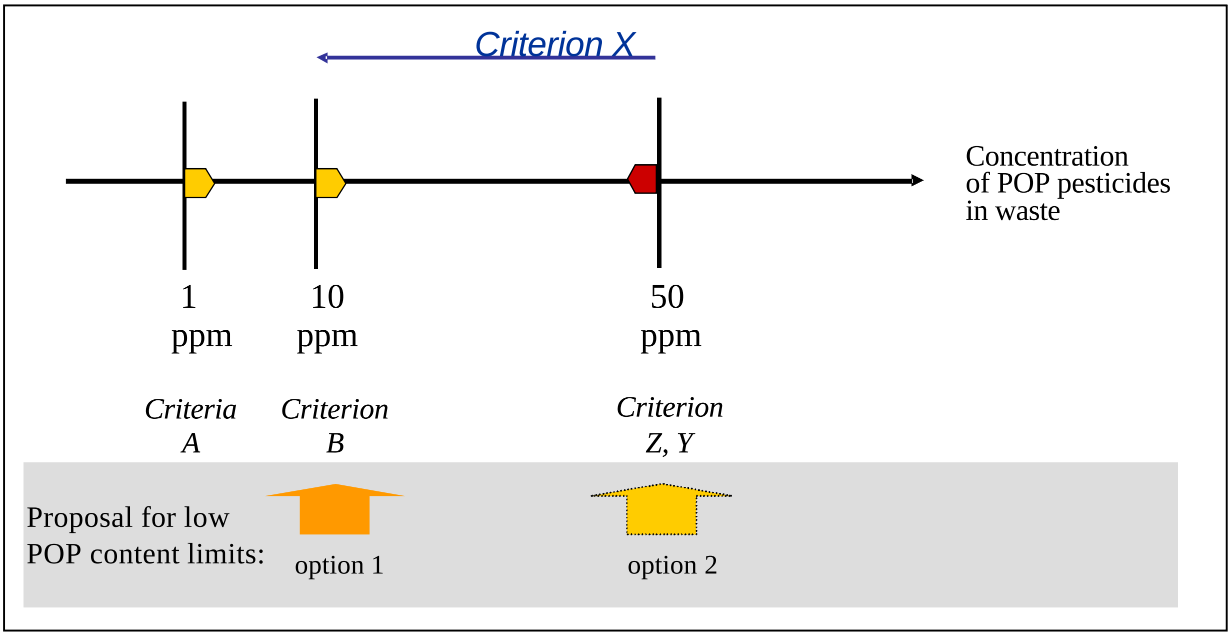



Figure 9-15: Recommended low POP content limit for POP pesticides and other POPs based on assessment method 1

Following the results of the limitation criteria (Figure 9-15). For POP pesticides a low POP content limit of 10 ppm is recommended as option 1. For option 2 a limit value of 50 ppm results.

### 9.3.4 Results for low POP content limit other POPs

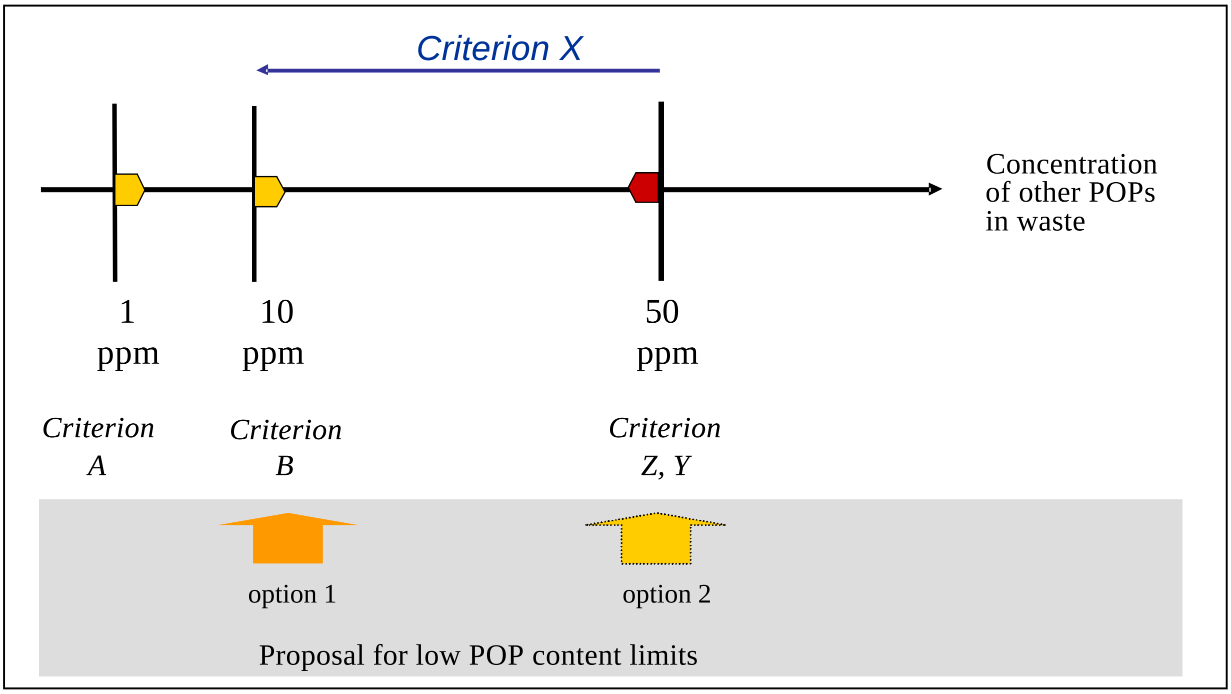



Figure 9-16: Recommended low POP content limit for POP pesticides and other POPs based on assessment method 1

For other POPs 10 ppm as option 1 is recommended and 50 ppm results as option 2.

## 9.4 Maximum POP content limits

These limits are exclusively deducted from the upper limitation criterion “Potential risks to human health and the environment. The evaluation of results from leaching tests and information on permeability of sealing layers and mobility of POPs in soil resulted in the following proposal for maximum POP content limits for non hazardous and hazardous landfills, provided the provisions of the landfill directive and appropriate technical requirements (e.g. solidification by a leachate rate below 0,01%/100 years) are fulfilled:

| | |
|---|---|
| PCDD/PCDF: | 5,000 ppb |
| PCB: | 2,000 ppm |
| POP pesticides: | 5,000 ppm |
| other POPs: | 5,000 ppm |

Based on current knowledge the long-term safety of salt mines and deep hard rock mines seems such that no reasons for restrictions for any of the pollutant classes have been identified for these disposal routes. A detailed analysis is available in the full report.

# 10 Environmental preferability of waste management options

The assessment method to provide information on the environmental preferability of waste management operations is supposed to meet several requirements. These refer mainly to the completeness of information required for the evaluation of environmental effects and the applicability of the method by the persons who will apply the method.

Basic requirements should allow a judgement on environmental preferability. To this end the methodology should cover environmental risks and burdens and take into account in particular differences in:

- expected pollutant discharges
- other emissions
- possible risks to human health and the environment

The methodology should be applicable throughout all Member States by different types of stakeholders (e.g. authorities but also waste owners) including personal with limited expert know how in relevant fields. Therefore it should be understandable, traceable and easily applicable. Related basic requirements are:

- limited complexity and clearness
- simplicity
- intuitive, conceivable judgement
- limited need for analytical requirements and specific expert know-how
- limited effort for co-ordination and evaluation (i.e. limited assessment costs)

In practice frequently specific data gaps occur. However the method shall enable a decision on the basis of the available knowledge. Therefore it is essential that the method is

- applicable to decisions characterised by incomplete information.

In order to establish a realistic approach that takes into account all necessary requirements regarding completeness of the evaluation of environmental effects as well as applicability, the method will adopt the framework of a Multi-criteria analysis including elements of LCA, RA, EIA, and TA.

The following elements of the existing assessment methodologies have been selected for inclusion in the methodology:

- The comparative assessment of two systems serving the same defined purpose. As in LCA, it shall rely on the inventory of environmental burdens, both regarding the resource and the emission side. These arguments will be reflected by the first two criteria applied to judge the performance of a system. They are denoted by criteria ① and ② in Figure 10-1.

- The characteristic scoring model of an MCA, generating a performance matrix: Pros and cons of alternative waste treatment options with respect to environmental preferability shall be juxtaposed in a clear and simple arrangement. Figure 10-1 below shows the basic performance matrix set up.

- The use of a benchmark:
  Both LCA and RA face the problem of quantifying environmental effects by introducing a benchmark. This approach is especially convenient for the problem of environmental preferability, which refers to an appraisal against the default option of destruction or irreversible transformation. The performance of any waste treatment option will thus be assessed against a benchmark, which will be destruction by a suitable combustion process. However, the method itself allows to compare any other benchmark technology to possible alternatives.
  The benchmark is to be specified in step 1 of the assessment, and evaluated against all relevant performance criteria in step 3.

- The distinction of judgement between comparable processes employing different technologies:
  The influence of a chosen technology on the environmental performance of a process, subject of TA, must be explicitly taken into account. Therefore, differing technologies shall undergo distinct evaluation as two or more separate options. Judgements will be based on different specifications in step 2 of the assessment procedure described below.

- The coverage of potential environmental impacts:
  According to EIA methodology, the effects of a regular operation and of possible hazardous incidents on the environment need to be assessed separately. While regularly expected impacts are covered by performance criteria ① and ②, an extra criterion ③ will represent accidental adverse effects on human health and the environment.

- Consideration of local conditions:
  In valuing environmental impacts, EIA also takes regard of the circumstances present at the site of operation. The proposed methodology foresees the weighting of credits awarded to an option in reference of the performance criteria. The weighting process is supposed to reflect the priorities set by local conditions, such as disposal/recovery capacities, contamination hot spots, or infrastructure.

- Attention to exposure:
  The methodology shall display the risk posed to human health as well as ecosystems by an operation. RA differentiates between two risk components, the severity of possible damage, and the probability of its occurrence. (The first component is fully covered by the above mentioned criterion ③) The second component becomes manifest in the potential of a pollutant to enter the food chain, which will largely depend on the carrying media and transmission pathways it enters. Consequently, performance credits awarded to an operation shall require justification that takes regard of dissemination and exposure pathways.

- Use of estimations and justified expert judgement in case of missing information: Different possibilities exist for dealing with data gaps. As scenario approaches complicate the assessment without leading to an unambiguous judgement, the proposed method goes along with EIA, educing suppositions on the basis of present expertise (cf. step 4).

The assessment covers three basic dimensions of environmental performance, these are:

- emission of POPs
- emission of other pollutants
- possible risks to human health and the environment

The relative performance of an option compared to the benchmark is reflected by a score of -2, -1, 0, 1, or 2 credits. Credits are allocated according to the following scheme:

Environmental performance:

| | |
|---|---|
| equivalent to benchmark | 0 |
| inferior to benchmark | -1 |
| remarkably inferior to benchmark | -2 |
| stronger than benchmark | 1 |
| remarkably stronger than benchmark | 2 |

The allocation of credits for the three basic dimensions has the advantage that it enables an objectified procedure according to the state of knowledge of the individual user of the methodology. The allocation of credits forces the user to take a decision against the background of the available knowledge including all data gaps. If data are missing a justified expert judgement has to be met. However it must be clear that the precise allocation of credits shall not represent a corresponding accuracy what concerns the corresponding environmental and health impacts.

The credits awarded for different performance dimensions can be weighted differently in order to enable consideration of specific, local, regional or national requirements. Priorities can be set by the competent authority, depending on local contamination settings, geological preconditions, space restrictions, limited waste treatment capacities or shortage in primary raw material within a pre-set range. The sum of weighting factors used shall be 3, with a minimum value of 0.5, and a maximum factor of 2. This has still to be discussed for the final report.

The total performance of an option will be visualised in a performance matrix, as is illustrated below. Environmental preferability is given if the sum of the credits obtained by an option is above 0.

| Performance \ Criteria | Bench-mark | Option X | Rela-tion | Credits | Weight | Total Perfor-mance | Verbal justifi-cation |
|---|---|---|---|---|---|---|---|
| ① POP emissions<br>• air<br>• water<br>• waste | | | | | | | |
| ② Other emissions, (e.g. heavy metals, GHG, ozone pre-cursors, acidifying substances) | | | | | | | |
| ③ Risks, uncertainties | | | | | | | |
| Total | | | | | 3 | | |

Figure 10-1: Performance matrix to determine an environmentally preferable solution

Applying the methodology involves seven steps, leading to a completed performance matrix, and to a distinct suggestion for the choice of treatment. A guidance through the steps is outlined in the full report.

# 11 Categorisation and reporting tools

## 11.1 Categorisation

In order to facilitate the implementation of the EU POP Regulation and focus monitoring and control of wastes to the relevant sectors, a categorisation of the waste codes listed in the European waste list[11] has been proposed as a result of the project. The categorisation has been made in view of the potential of wastes to contain POPs in concentrations exceeding the limit values to be established under the European POP Regulation.

All waste codes following Decision 2000/53/EC are categorised into three groups:

- Group A: low likelihood to exceed the low POP content limits
- Group B: high likelihood to exceed the low POP content limits
- Group C: uncertain risk
  either due to varying contamination levels or due to point contamination in individual samples. (levels may either be above or below; contaminants may be present or absent)

For waste codes allocated to Group A or C a testing and measurement procedure is elaborated if disposal or recovery as non POP waste is intended.

Tables that show whether a waste code belongs to Group A, B or C are available in the full report.

## 11.2 Reporting tool

In order to support the application of the methodology to decide on environmental preferability (concentration of a waste above low POP content limit and below maximum POP content limit, no destruction or irreversible transformation foreseen) several case studies and a reporting format are elaborated in the report.

In exceptional cases, Member States may allow wastes listed in Annex V, containing or contaminated with POP concentrations up to the maximum POP content limit, to undergo alternative operations as indicated in Annex V. This is foreseen in Article 7, paragraph 4(b)i-iii of the European POP regulation. A precondition is that the owner of the waste concerned has demonstrated to the satisfaction of the competent authority that decontamination of the waste was not feasible and destruction or irreversible transformation of the Pop content according to BAT do not represent the environmentally preferable option. Furthermore, he must prove that the alternative operation is in accordance with relevant Community legislation, and that the Member State concerned has informed the other Members and the Commission of its authorisation and the justification for it.

In order to assure a standardised and comparable reporting for all Member States taking account of all relevant considerations, a reporting format has been developed.

[11] Decision 2000/532/EC

The reporting format contains all aspects that have to be covered by the authorisation procedure and will present the results as a performance matrix.

The following aspects are seen as essential parts of the reporting format:

1. General description of waste, intended disposal route, and benchmark (destruction, irreversible transformation technology):
   Waste code
   Origin
   Contamination
   Amount
   Period of disposal
   Packaging, Labelling
   Transport (distance to disposal/recovery site, means of transport)
   Handling

2. Description of technology and precautionary measures applied for intended disposal/recovery including pre-treatment and/or stabilisation or solidification measures applied or required.

3. Comparative description of environmental performance by means of a performance matrix containing information on:

   - POP emissions to air, water, residues

   - Emissions/Discharge of other contaminants (greenhouse gases, heavy metals) to air, water, residues

   - Risks due to accidents or uncertainties and knowledge gaps on long-time performance

Where precise data are lacking and qualified estimations have been used, this will be indicated.

4. Description of credits/scores applied to each criterion based on the results of point 3.

5. Description on weighting of criteria according to local/national particularities and the quality of the data basis (voluntary; Sum for all criteria may not exceed 4).

6. Calculation of total performance for both options

7. Decision/Justification on environmental preferability based on performance outcome
   (Total > 0 addicts environmental benefit to alternative operation; total < 0 addicts environmental preferability to destruction or irreversible transformation.)

The following reporting format is proposed as a tool for reporting from Member States to the Commission:

| **Notification of treatment and disposal of POP waste authorized as environmentally preferable to destruction or irreversible transformation** | |
|---|---|
| Commission (Competent body with address): | To be forwarded to (Contact Member States): |
| Notifying authority (Name, address):<br><br>Contact person:<br>Tel.:<br>Fax:<br>e-mail | Date: |
| Waste generator (Name, address)<br><br>Contact person:<br>Tel.:<br>Fax:<br>e-mail | Waste disposer (Name, address)<br><br>Contact person:<br>Tel.:<br>Fax:<br>e-mail |
| Site of generation and process: | Actual site of disposal/recovery: |
| General description of waste:<br>Waste code:<br>Origin:<br>Contamination:<br>Amount: | Intended disposal route:<br><br>Intended date or period of disposal |
| Measurement information:<br><br>Measurement data:<br><br>Measurement methods | Technology and precautionary measures applied, incl. pre-treatment and/or solidification or stabilisation measures:<br><br>Tests on leakage rate available:<br><br>Measurement data:<br><br>Measurement methods: |
| Transport to disposal/recovery site (distance, means): | Considered benchmark:<br><br>Specifications: |
| Additional specification regarding waste handling: | |

Table 11-1: Draft reporting format

Annex to the reporting format: Outcome of method to check environmental preferability against benchmark

| | ***Performance related to benchmark*** | | | |
|---|---|---|---|---|
| | ***credits*** | ***weight*** | ***total performance*** | ***evidence and justification*** |
| ① POP emissions | | | | |
| Air | | | | |
| Leachate | | | | |
| Waste | | | | |
| ② Other emissions | | | | |
| $CO_2$ emission for destruction/solidification | | | | |
| $CO_2$ emission for transport | | | | |
| Other emissions (Greenhouse gases, heavy metals, acidifying gases) | | | | |
| ③ Risks, uncertainties | | | | |
| legal compliance | | | | |
| long term safety | | | | |

Table 11-2: Draft reporting format - Performance matrix for justification of alternative waste management operations under Annex V to the EU POP regulation

# 12 Conclusions and recommendations

## 12.1 Conclusions concerning POP mass flows

***PCDD/PCDF***

The waste sector is important for the overall discharge of PCDD/PCDF, but the major share of PCDD/PCDF discharge via waste will not be covered by the POPs Regulation. The reason is the importance of high volume but low contaminated wastes – mainly MSW, but also bottom ashes, slags, sewage sludge, compost. Further it can be concluded that potentially higher contaminated wastes (such as fly ashes) are already largely directed to hazardous waste landfills or underground. Only 2 kg PCDD/PCDF-TEQ/y are contained in wastes that are disposed of or used as secondary construction material at non-hazardous waste landfills and that might be influenced by the POP regulation.

***PCB***

It can be stated that much of the amount of PCB annually entering the waste regime (~80%) is already regulated by the PCB disposal directive and the WEEE directive, so that there will be no strong additional benefits from the POP regulation. However about 10% of annual PCB discharge directed to landfill via C&D waste could be regulated and reduced by the POP regulation.

The destruction of PCB containing equipment still has to be regarded as priority action for the reduction of the overall PCB load. The second important measure to be taken seems to be the control and thorough separation of PCB from C&D waste in order to further reduce and prevent discharge of PCB from poorly sealed landfills. For both measures regulation already exists, however it is probably not sufficient for the C&D sector, as there is only one single limit of 1ppm for inert waste landfill

***POP pesticides***

Thermal destruction is the only treatment option recommended for POP pesticides. As management of remaining stockpiles of POP pesticides as POP wastes is stipulated in the European POP Regulation[12] destruction of the remaining stocks over a period of 10 years (2000-2010) has been used as assumption for the mass flow. Based on this premise destruction will be the dominating pathway for POP pesticides in the waste regime. Another important pathway which however could only be quantified with significant uncertainty due to missing data is the landfilling of contaminated C&D waste including excavated soils from contaminated sites.

The destruction of remaining stockpiles and the controlled disposal of contaminated soils and C&D waste has to be regarded as priority action under the scope of the waste regime. Limit values in the POP regulation will have a significant effects on both waste streams as levels can generally be assumed to lay above the low POP content limit.

[12] (12) In particular, existing stockpiles […] should be managed as waste as soon as possible.

***Other POPs***

An estimated linear reduction of the remaining stocks of HCH and less HCB in dump sites at former producers leads to an annual waste stream of estimated 1,000 tons mainly directed to destruction operations. In addition there is a mass flow of < 5 t/y directed mainly to landfills via FGT residues from different combustion processes (waste incineration, power production, metallurgical industry). As the data base is very limited a more precise evaluation is not possible. In addition a non-quantifiable amount of other POPs is directed to landfill via C&D waste and soils from contaminated sites. While concentration in FGT residues is low concentrations in stocks and C&D waste typically exceed proposed limits under the POP regulation. Thus it can be stated that the regulatory potential is significant.

## 12.2 Recommendations for concentration limits for the POPs Regulation

The developed methodology provides favourable options for the low POP content limit values. Option I follows a more restrictive approach with a broader coverage of waste flows and higher economic impacts, option II includes less wastes and shows less consequences. For PCDD/PCDF two different legal approaches (A,B; see below) are followed.

It is recommended that the low POP content limit values are established within the ranges that are defined by the options.

| | | Option 1 | Option 2 |
|---|---|---|---|
| PCDD/PCDF | **A** | 10 ppb* | 15 ppb* |
| | **B** | 1 ppb** | 1 ppb** |
| PCBs*** | | 30 ppm | 50 ppm |
| POP pesticides | | 10 ppm | 50 ppm |
| Other POPs | | 10 ppm | 50 ppm |

* Ban of unsolidified application to soil if PCDD/PCDF concentration of 1 ppb is exceeded (R10); solidification is fulfilled if a leachate rate of 0,01%/100 years is not exceeded

** Annex V , part 1 amended: (R4) for waste codes 100207 (-08), 100504 (-03), 100603 (-04) following Decision 2000/232

*** total PCB in terms of Σ Cong. x 5

Obviously also an appropriate combination of options is possible. Concerning the proposal for PCB it is alternatively possible to apply the analytical method based on sum 7 approach. In this case the suggested low POP content limit values have to be adapted correspondingly (7 ppm and 11.7 ppm).

The amendment of Annex V part 1 can be also done by addressing the corresponding processes of secondary metallurgical industry instead of the suggested waste codes. It might be necessary to foresee a possible review process for Annex V part 1 following industrial changes and technological progress.

For the maximum POP content limits the evaluation of results from leaching tests and of information on permeability of sealing layers and mobility of POPs in soil resulted in the following proposal for maximum POP content limits for non hazardous and hazardous landfills, provided the provisions of the landfill directive and appropriate technical requirements (e.g. solidification by a leachate rate below 0,01%/100 years) are fulfilled:

| | | | |
|---|---|---|---|
| PCDD/PCDF: | 5,000 ppb | PCB: | 2,000 ppm |
| POP pesticides: | 5,000 ppm | other POPs: | 5,000 ppm |

Based on current knowledge the long-term safety of salt mines and deep hard rock mines seems to be in a dimension that no reasons for restrictions for any of the pollutant classes have been identified for these disposal routes.

Due to high long-term isolation from biosphere it is recommended to establish no maximum POP content limit values for salt mines or safe hard rock formations.

The developed methodology for the low POP content limit values was accepted by a large majority of Member States and stakeholders. However, it suffers in certain part of a lack of data and causal chains. It is therefore recommended to

- Further develop sampling and analysis standards for higher sensitivity and update the results of criterion A within a review procedure of the POPs Regulation
- Mandate CEN with the development of European standards
- Intensify research activities that help to understand the transfer rates from waste to soil and food and feed and corresponding risk to human health
- Up-date risk assessment on health risks
- Elaborate a more detailed European overview on existing capacities divided into hazardous waste incineration, hazardous waste landfill, non thermal destruction technologies (consequences on logistics, administration and costs should be highlighted on a function of European POP waste volumes that have to be disposed of)
- Intensify research on longtime leaching behaviour and long-term safety of landfills in order to derive leachate based limits for POPs that can added to 2003/33/EC.

With respect to the methodology for the maximum limit values there is still a discussion whether these limit values can or should stimulate the development of new environmentally friendly destruction technologies. The project team recommends to separate this objective from the purely risk based assessment.

## 12.3 Conclusions and recommendations concerning environmental preferability

Essential parameters for an assessment methodology on environmental preferability covering elements of LCA, RA, EIA, TA and MCA are POP emissions, other emissions and potential risks. Furthermore the methodology should be applicable throughout all Member States by different types of stakeholders without specific expert know how and therefore should be understandable, traceable and easily applicable even in cases where data gaps occur.

The most obvious decision criterion is POP emissions/discharge, which can be into air, water and solid residues. With respect to their potential to enter the food chain emissions to air or natural water (groundwater or surface water) imply a higher risk for environment and/or health impact than emissions to waste or waste water which can be well controlled.

As environmental and health impacts also arise from of other pollutants (greenhouse gases, heavy metals), these have to be considered as the second decision criterion.

The third decisive criterion for the environmental impact of a waste treatment option are potential risks including uncertainties and knowledge gaps e.g. related to long-term safety.

Based on these criteria the performance of a potential option is evaluated in relation to a benchmark option. The evaluation of the relative performance is reflected in credit scores ranging from –2 to +2.

In order to allow consideration of specific local, regional or national requirements the competent authority may attribute additional weighting factors depending on local contamination settings, geological preconditions, space restrictions, limitations in treatment capacity or shortage in primary raw material.

It is recommended to visualise the results in a performance matrix. Environmental preferability is given if the total performance in relation to the benchmark totals above 0.

The case studies elaborated in this report can be seen as a first step in the direction of a European case study collection. This should be promoted as it enables a harmonised and coordinated assessment of environmental preferability within EU 25.

It is expected that applying the developed methodology will result in more or less justified decisions. As many case studies will appear in the same way in different Member States a high comparability and transparency on the judgement of environmental preferability seems to be necessary. This can be reached e.g. with an internet based publication of case studies (due to possibly confidential data in an area with restricted access for authorities only).

It is not recommended to leave the proof of environmental preferability completely to the waste owner without giving guidance of a methodological framework as this would result in incomparable decisions and long lasting different enforcement of the POPs Regulation.

## 12.4 Recommendations for implementation

In order to facilitate the implementation of the EU POP Regulation and focus monitoring and control of wastes to the relevant sectors, a categorisation of the waste codes listed in the European waste list[13] has been proposed in the project. The categorisation has been made in view of their potential to contain POPs in concentrations exceeding the limit values to be established under the European POP Regulation.

The grouping will categorise all waste codes in one of the following groups:

- Group A: low likelihood to exceed the low POP content limits
- Group B: high likelihood to exceed the low POP content limits
- Group C: uncertain risk

While little testing effort is foreseen for group B, testing will be required in group C in particular if disposal/recovery as non POP waste is intended.

If testing is required testing and sampling has to assure that a representative information on the contamination level throughout the whole batch of waste can be taken as granted and has to respect state of the art. If possible schemes under 2003/33/EC should be used.

It is recommended to discuss the reporting format with Member States and include remarks and additional ideas before launching its application. However, the reporting format should in any case enable comparability of decisions and should be suitable for building up a database to enable a European wide support of authorities.

[13] Decision 2000/532/EC

# 13 List of Abbreviations

| | |
|---|---|
| AA-EQS | annual average environmental quality standard |
| ADI | acceptable daily intake |
| APC | air pollution control |
| BAT | best available technology |
| BCD | base catalysed decomposition |
| BEP | Best environmental practice |
| BREF | Best available technology reference document |
| C&DW | construction and demolition waste |
| CEPI | confederation of European paper industries |
| CHMI | Czech hydro meteorological institute |
| CLRTAP | Protocol to the regional UNECE Convention on Long-Range Transboundary Air Pollution |
| COP | Conference of Parties |
| d.w. | dry weight |
| w.w. | wet weight |
| DG SANCO | Directorate general health and consumer protection of the European Commission |
| EAF | Electric arc furnaces |
| ECD | electron capture detection |
| ECVM | European council of vinyl manufactures |
| EDC | ethylene dichloride |
| EEA | European environment agency |
| EEE | electrical and electronic equipment |
| EFR | European Ferrous Recovery & Recycling Federation |
| EIA | environmental impact assessment |
| ELV | end-of-life vehicles |
| EMEP | European monitoring and evaluation programme under CLRTAP |

| | |
|---|---|
| ESM | environmental sound management |
| ESP | electrostatic precipitators |
| EWC | European waste catalogues |
| FGT | Flue-gas treatment |
| FNADE | Fédération Nationale des Activités de la Dépollution et de l´Environnement |
| FM | ferrous metal |
| GC | gas chromatography |
| GHG | green house gas |
| GTGESM | general technical guidelines for the environmentally sound management of wastes consisting of containing or contaminated with persistent organic pollutants to the Basel Convention |
| HELCOM | HELsinki COMmission |
| HospW | hospital waste |
| HPLC | high-pressure liquid chromatography |
| HRGC | high resolution gas chromatography |
| HW | hazardous waste |
| HWI | hazardous waste incineration |
| HxBB | Hexabromobiphenyl |
| IARC | international agency for research on cancer |
| ISO | international organization for standardization |
| ISWA | international solid waste association |
| LCA | life cycle analysis |
| LOAEL | Lowest observed adverse effect level |
| LOQ | limit of quantification |
| MAC-EQS | maximum allowable concentration environmental quality standard |
| MBT | mechanical biological treatment |
| MCA | multi-criteria analysis |

| | |
|---|---|
| MSW | Municipal Solid Waste |
| MSWI | Municipal Solid Waste Incineration |
| Mt | Mega tons |
| NFM | non ferrous metal |
| NGO | non governmental organisations |
| NIP | national implementation plans |
| NOAEL | no observed adverse effect level |
| OECD | organisation for economic co-operation and development |
| OEWG | open ended working group |
| OSPARCOM | OSlo and PARis COMmission |
| PAH | polycyclic aromatic hydrocarbons |
| PBB | polybrominated biphenyl |
| PBDE | polybrominated diphenyl ether |
| PCB | polychlorinated biphenyls |
| PCDD | polychlorinated dibenzodioxins |
| PCDF | polychlorinated dibenzofurans |
| PCP | pentachlorophenols |
| PCT | polychlorinated terphenyl |
| PIC | Prior Information Consent |
| POPs | persistent organic pollutants |
| POPCYCLING | *BALTIC Project: environmental cycling of selected persistent organic pollutants (POPs)* |
| PP | power production |
| PVC | polyvinyl chloride |
| R&D | research and development |
| RA | risk assessment |
| ROHS | restriction of hazardous substances in electrical and electronic equipment |
| SETAC | society of environmental toxicology and chemistry |

| | |
|---|---|
| SME | small and medium sized enterprises |
| T / T+ | toxic / very toxic |
| TA | technology assessment |
| TCDD | tetrachlorodibenzodioxin |
| TEQ | toxic equivalent |
| TOC | total organic carbon |
| TWG | technical working group |
| UNECE | united nations economic commission for Europe |
| U-POPs | unintentionally produced POPs |
| UWW | urban waste water |
| VLAREA | Vlaams Reglement inzake Afvalvoorkoming |
| VLAREBO | Vlaams Reglement Bodemsanering |
| VOCs | volatile organic compound |
| WCC | World Chlorine Council |
| WEEE | Waste electrical and electronic equipment |
| WMO | waste management options and climate change 2001 |
| WWT | Waste water treatment |
| Xn | harmful |