

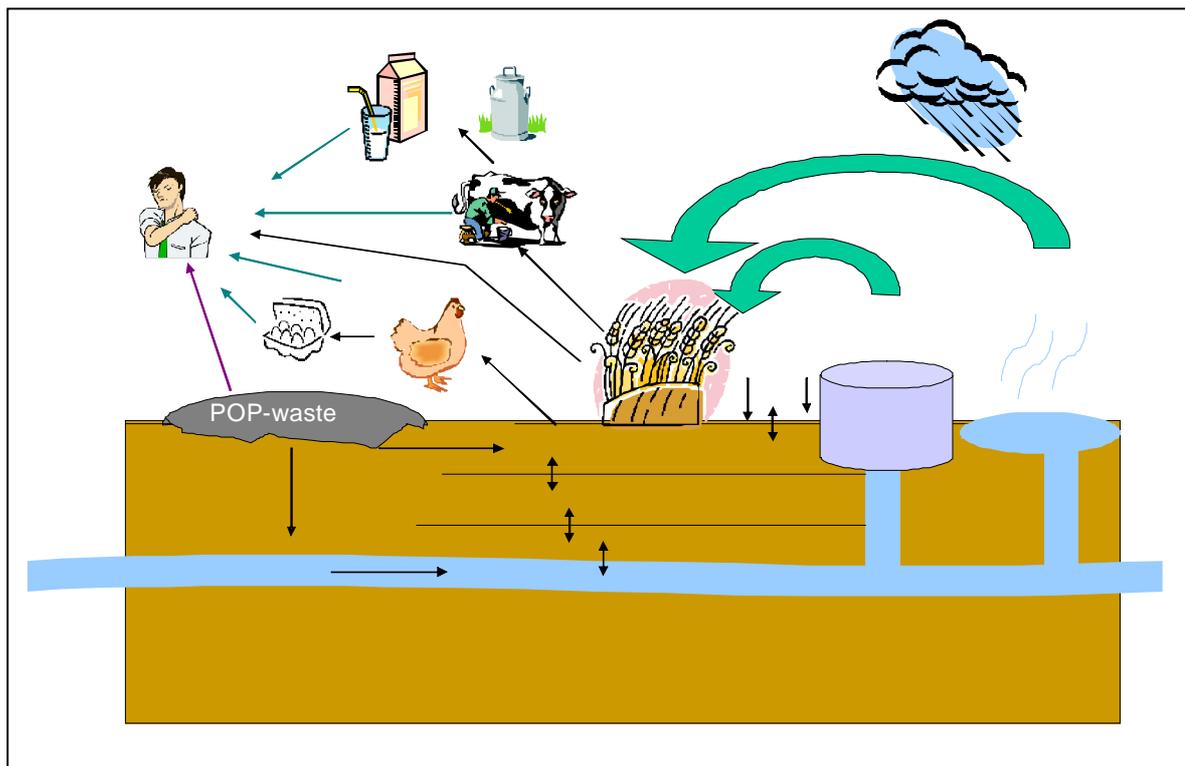
European Commission, Brussels

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

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Annex

1 Background and Objectives

1.1 Overview on background and objectives

An important background of the project is formed by the international, legally binding instruments "Protocol to the regional UNECE Convention on Long-Range Transboundary Air Pollution" (CLRTAP) and the "Stockholm Convention" which aim to reduce and eliminate the production, use and releases of persistent organic pollutants (POPs) in all countries of the participating parties. Amongst other issues these regulations contain in particular provisions on the environmentally sound management of wastes consisting of, containing or contaminated by POPs (hereafter called "POPs waste").

In order to ensure a coherent and effective implementation of the Convention which entered into force in May 2004 the European Parliament and the Council of the European Union adopted a Regulation on persistent organic pollutants (2004/850/EC) amending Directive 79/117/EEC in April 2004. In the framework of the overall objective to continuously reduce releases of POP to the environment the regulation will define concentration limits for 14 POPs substances and substance classes above which the POPs content in waste shall be subject to destruction or irreversible transformation so called "low POP content limits" (LPCL).

In exceptional cases waste above the limits may be otherwise managed with specified operations for specified waste types if destruction or irreversible transformation does not represent the environmentally preferable option and other described conditions are met.

Maximum POP content limits (MPCL) for these operations are to be established.

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

- First, to compile and evaluate existing data on occurrence and levels of POPs in different waste categories and on existing concentration limits for POPs in waste.
- Second, to propose specific concentration limits for the 14 POPs substances and substance classes above which the POPs content shall be destroyed or irreversibly transformed.
- Third, to 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.
- Fourth, to propose reference measurement methods for the determination of the 14 POPs substances and substance classes in waste.

The proposals will be based on existing information and experience from European and other developed countries and on assessment methodologies that will be developed during the project period.

1.2 Health and environmental background

Persistent organic pollutants (further referred to in this report as POPs) give rise to concern as per definition they are

- persistent in the environment and in human tissues,
- bio accumulate in the food chain due to their lipophilic properties,
- have the potential for long-range environmental transport

and

- show adverse effects ranging from acute to chronic toxicity.

Although substantial progress has been achieved in limiting the use and application of these substances and reduce their emissions to environment there are ongoing releases to the environment as well as a constant cycling of substances released in former times so that they still pose a threat to human health and further action has to be taken.

In the Stockholm Convention a first set of 12 POPs has been defined as high priority substances, however the option to include further substance either existing or newly developed is one of the important provisions in order to dispose of a flexible tool for the control of potentially dangerous substances and preparations.

16 POP substances are listed in the UNECE –POP-Protocol (Aarhus Protocol).

With respect to the objectives of the project the 14 POP substances or substance groups which are currently defined as POPs subject to control in the European POP regulation (2004/850/EC) are investigated:

A compilation of the substances is given in Table 1-1:

POP substance (CAS-N)	classification	use	ban /restrictions according to directive 79/117/EC	Hazardous properties
Aldrin (309-00-2)	enviro- and humanotoxic (T, N), Carc. Cat. 3	manufactured commercially since 1950 for control of soil pests, grasshoppers and wood protection against termites	use banned without exception since 1990	H5, H6, H7, H11, H14
Dieldrin (60-57-1)	enviro- and humanotoxic (T, N), Carc. Cat. 3	manufactured commercially since 1948 for control of soil pests, wood and textile protection; metabolite of Aldrin	ban on use since 1979	H5, H6, H7, H11, H14
Endrin (72-20-8)	highly toxic to humans and environment (T+, N), Carc.Cat. 3	widely used since 1950 for control of soil pests and rodents,	use restricted since 1985; banned since 1990; European production already had ceased in 1982	H6, H14

POP substance (CAS-N)	classification	use	ban /restrictions according to directive 79/117/EC	Hazardous properties
Chlordane (57-74-9)	enviro- and humanotoxic (Xn, N), Carc. Cat. 3	used since 1945 for control of cockroaches, ants, termites and household pests	ban on use since 1997	H5, H7 H14
DDT (1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane) (50-29-3)	enviro- and humanotoxic (T, N), Carc. Cat. 3	widely used since 1940 for malaria control and crop protection	use restricted in 1983 and 1985; all uses prohibited in 1990; The use as intermediate for the production of dicofol is allowed until 2014; production ongoing in IT and ES	H6, H7, H11, H14
Heptachlor (76-44-8)	enviro- and humanotoxic (T, N), Carc. Cat. 3	used against soil insects, termites grasshoppers and in malaria prevention	use banned without exception since 1985	H6, H7, H11, H14
Chlordecone (143-50-0)	enviro- and humanotoxic (T, N), Carc. Cat. 3	used as insecticide	all uses prohibited	H6, H7, H11, H14
Mirex (2385-85-5)	harmful to environment and health (Xn, N) Carc. Cat. 3	Used since mid 1950s for ant control (mainly in US) and as fire retardant in plastics, paint and paper	all uses prohibited	H5, H7, H10, H11, H14
Toxaphene (Camphechlor)	enviro- and humanotoxic (T, N), Carc. Cat. 3	Used since 1949 for control of ectoparasites and as insecticide	use banned without exceptions in 1983	H4, H5, H6, H7, H11, H14
HCH including (Hexachloro-cyclohexanes) (608-73-1) Lindane (58-81-9)	enviro- and humanotoxic (T, N), Carc. Cat. 3	Widely used since early 1940s as insecticide in agriculture, household, wood and textile protection	use as pesticide banned in 1990; until 2007 Technical HCH allowed as intermediate, Lindane restricted to use in public health and veterinary as topical insecticide; until 2006 HCH allowed as professional remedial and industrial treatment of lumber, timber and logs and for indoor applications production in France, Italy and Germany	H5, H6, H14
HCB (Hexachloro-benzene) (118-74-1)	enviro- and humanotoxic (T, N), Carc. Cat. 2	used since 1945 as fungicide and for fireworks and synthetic rubber;	banned as pesticide since 1979; derogation on use as intermediate in Poland production in Germany	H5, H6, H7, H14

POP substance (CAS-N)	classification	use	ban /restrictions according to directive 79/117/EC	Hazardous properties
PCB (polychlorinated biphenyls) (1336-36-3)	harmful to environment (N); low acute toxicity; endocrine disrupting effects Carc. Cat 2 (possible carcinogen to humans)	used from 1930 as dielectric fluids in transformers, capacitors heat exchanger and hydraulic machinery as well as in lubricating and cutting oils and as plasticiser in sealants, adhesives, lacquers and paints.	production and use stopped in the mid eighties; articles in use may be further used and maintained according to the provisions of directive 1996/59/EC; phase out of all equipment >500 ppm until 2010; equipment 50-500 at end of lifetime	H14, H10
HxBB (Hexabromobiphenyl) (36355-01-8)	harmful to environment; moderate toxicity; endocrine disrupting effects Carc. Cat 2 (possible carcinogen to humans),	Produced in the USA; used since 1970 as fire retardant in thermoplastics for various products, in coatings, lacquers and polyurethane foam	use stopped end of the seventies	
PCDD/PCDF (polychlorinated dibenzo-p-dioxins and dibenzofurans)	harmful to environment; moderate toxicity; IARC classification as possible carcinogen to humans, endocrine disrupting effects	possible by-products from the production of certain chemicals and new formation in combustion and incineration processes (250-450°C)	no intentional production or use	[H7, but not applicable to all PCDD/PCDF]

Table 1-1: POP substances covered by the European POP regulation (2004/850/EC), their classification, use, bans, restrictions and hazardous properties

Due to their specific properties POP substances have been disseminated to the environment all over the world and entered the food chain, via transfer to plants from atmospheric deposition and soil and contamination of food from animal origin, which is especially high for fish and other sea food and is caused by the natural bioaccumulation in the food chain. However it can be aggravated by feeding of industrially manufactured contaminated feeding stuffs.

The latter may occur by the use of certain waste products concentrated in POPs which are used as by-products or recyclates in the production of compound feedingstuffs.

The exposure to POPs of humans is mainly by ingestion of contaminated foods so that all available measures should be taken to reduce the contamination level in food by maximum reduction of all possible emissions and remediation of environmental hot spots.

For an optimised approach to this objective all sectors in the life cycle of a product and of anthropogenic emission sources have to be addressed. In this framework the waste management is an essential sector for the control of POP releases into the environment.

While the waste sector potentially is a sector, where POP substances can be eliminated from the environment it can be as well – if improperly performed or if inadequate management

methods are used- be itself an important sector for release of POP substances to the environment.

Thus the comprehensive regulation of POP contamination in waste might have the potential to reduce POP presence in the environment.

In chapter 5 of this report summarised data on existing POP levels in the environment and on POP concentrations in human tissues are given as reference data for environmental background levels of POP substances currently observed in European countries and for the documentation of peak levels observed at hot spot sites.

1.3 Legal background

The legal situation in the European Union and at national level in the 25 member states as well as existing or planned limit values set up for the management of POP substances are described in detail in chapter 6.

With respect to the legal background of the project it is important to take into account the global dimension of the POP problem.

In the consequence two International Conventions and a protocol form the thematic basis of the European POP regulation which forms the direct legal background to this project:

- Stockholm Convention
- Basel Convention
- Aarhus Protocol to the UNECE Convention on long-range transboundary air pollution (CLRTAP)

Stockholm Convention

The major objective of the Stockholm Convention is the protection of human health and the environment from persistent organic pollutants by means of elimination from use or restriction to use for all POPs and the minimisation of unintentional production. The obligations include measures to reduce releases from stockpiles and wastes.

The Stockholm Convention differentiates between two categories of POPs:

- intentionally produced POPs where production and use are to be eliminated or restricted and
- unintentionally produced POPs where parties are required to take measures to reduce total releases from anthropogenic sources.

In Article 6 of the Convention provisions for waste consisting of, containing or contaminated with POPs related to environmental sound management (ESM) are set out:

Besides other wastes shall be disposed of in such a way

- that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or
- otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the persistent organic pollutant content is low.

In order to clarify which wastes would be classified as "waste consisting of, containing or contaminated with POPs" according to Article 6 (1a,ii) of the Stockholm Convention it is stated in Article 6 (2c) that the Conference of Parties shall cooperate closely with the appropriate bodies of the Basel Convention to inter alia establish, as appropriate, the concentration levels of POPs in order to define the low POP content referred to in paragraph 1 (d)(ii).

Furthermore the contracting parties shall take all necessary legal and administrative measures to ensure the implementation of the obligations under the convention. To this purpose national implementation plans (NIPs) will have to be established defining a programme for POP management including inventory, monitoring and control as well as collection, storage and final disposal of the substances in question.

Basel Convention

While the Stockholm Convention covers all aspects of POP management including monitoring, permitting and control, the Basel Convention concentrates on the transboundary movement of waste.

According to the Basel Convention export and import of waste is only permitted, when the movement itself as well as the disposal of the concerned waste is environmentally sound. POP wastes are referred to in this Convention due to their hazardous properties. The Convention contains categories of wastes to be controlled and a list of recovery and disposal operations allowed.

Aarhus Convention

The Aarhus Protocol to the UNECE Convention on Long-range transboundary Air Pollution is focussed on control, reduction of discharges, emissions and losses of persistent organic pollutants by elimination or restriction of substances from use. Besides the 12 Stockholm POPs the Protocol covers Chlordecone, HCH, HxBB and PAH which are not subject to the Stockholm Convention.

Technical Guidelines and low POP content

As discussed above limit values for POP have to be established under the Stockholm and Basel Convention in order to define a low POP content above which the environmentally sound management (ESM) of the wastes will require destruction or irreversible transformation of the POP content.

In the consequence technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants have been adopted at COP7 of the Basel Convention in October 2004¹.

These guidelines contain definitions for provisional low POP contents. These are for PCDD/PCDF of 15 µg/kg (15 ppb) and 50 mg/kg (50 ppm) for PCB and POP pesticides.

European Legislation

In the European POP regulation (2004/850/EC) the provisions of the above mentioned Conventions and the protocol have been implemented for the scope of the European Community.

The main objectives of the Regulation are the following:

- Production and use of hexachlorohexane (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 for stockpiles which consist of or are contaminated with persistent organic pollutants as soon as possible.
- 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
- Establish common concentration limits for POP substances and substance groups before 31 December 2005.

The concentration limits referred to in Annex IV of the Regulation shall define the limit concentration (LPCL) above which the POP content of a waste consisting of, containing or contaminated with the POP listed in Annex IV principally will have to be destroyed or irreversibly transformed by physico-chemical treatment (D9), incineration on land (D 10) or use as secondary fuel².

¹ <http://www.basel.int/meetings/sbc/workdoc/techdocs.html>

² According to Article 7 Paragraph 2 waste consisting of, containing or contaminated by any substance listed in Annex IV shall be disposed of or recovered, without undue delay and in accordance with Annex V, part 1 in such a way as to ensure that the persistent organic pollutant content is destroyed or irreversibly transformed so that the remaining waste and releases do not exhibit the characteristics of persistent organic pollutants.

However wastes listed in Annex V to the Regulation may be disposed of in hard rock formations, underground salt mines or at landfill sites for hazardous waste in exceptional cases provided that destruction or irreversible transformation do not represent the environmentally preferable option³.

However the alternative methods shall only be usable up to an additional set of specific upper concentration limits (MPCL) that have to be established for Annex V wastes.

To conclude, it can be stated that the lower limit values that have to be adopted under the European POP regulation follow the same principle as the limit values established under the Basel Convention. However they will take into account specific European aspects (e.g. technical standards, analytical and destruction capacity, economic impacts, environmental benefits) and therefore do not necessarily show the same results.

No limit corresponding to the upper limit for operations under Annex V has been considered at the international level so far.

National legislation

National legislation with respect to POPs in general has implemented the European legislation in the sectors of water protection, atmospheric pollution, chemicals classification, marketing and use, waste management and food and feed safety. In addition to Community legislation a number of countries have established provisions relating to POP mainly in the sectors of soil and water protection.

In the waste sector a number of countries have taken additional measures to restrict the disposal and recovery of waste on landfill sites, limit the recovery of waste oil and speed up the elimination of PCB containing equipment (for details see chapter 6). In general it can be stated that only few limit values related to waste management have been set up for POPs up to now.

1.4 Economic background

Some of the POPs have been produced on a commercial basis for long periods, some have never been produced intentionally (U-POPs) and some are still produced. However specific information on production periods and annual quantities are often not available, so that the figures given below can only be regarded as rough estimations.

Figures provided for the phasing out from use refer to the year of banning in European legislation. The de facto use stopped earlier in some Member States.

³ (b) a Member State ... may, in exceptional cases, allow wastes listed in Annex V, part 2 ... to be otherwise dealt ... with a method listed in Annex V, part 2 provided that: (i) destruction or irreversible transformation of the persistent organic pollutant content, performed in accordance with best environmental practice or best available techniques, does not represent the environmentally preferable option

POP substance	production/use
Aldrin	1950 - 1990
Dieldrin	1948 - 1979
Endrin	1950 - 1985; restricted 1985 - 1990
Chlordane	1945 - 1997
DDT	1940 - 1983; use restricted 1983 -1990; DDT production ongoing in IT
Heptachlor	? - 1985
Chlordecone	listed in the Aarhus Protocol as substance scheduled for elimination without any exception in production and use
Mirex	1950 - 1990 the substance has never been used in Mediterranean countries
Toxaphene (Camphechlor)	1949 – 1983 the substance has never been used in Mediterranean countries
HCH including Lindane	1940 - 1990; ongoing use in control of ectoparasites; production in France, Italy and Germany
HCB	1945 - 1979; derogation on use as intermediate in Poland ongoing production in Germany unintentional production in combustion processes and chemical production
PCB	around 1950-1980; derogation granted for specific applications in use unintentional production in combustion processes in the temperature range of 250-450°C
HxBB	1970 –1974 HxBB has been produced in the US only under the trade name Firemaster; In Europe octa- and decabromobiphenyl where produced. OBB in Germany until 1985 (Bromkal), DBB in the UK until 1977 and in France until 2000 (Adine).
PCDD/PCDF	unintentional production as by-product or in combustion processes in the temperature range of 250-450°C

Table 1-2: European production of POP substances (UNEP regional report Europe & Mediterranean, country reporting, COWI 2002)

Besides the economic aspects of production and use of POPs there are economic interests with respect to POP wastes:

In general European Member States have adopted taxes or fees for landfill of waste which motivate the producing industry to limit its waste output to a minimum and find recovery operations as far as possible. In the consequence investments have been taken in on-site recycling and reactivation of spent material as well as in the development of optimised secondary production processes for the recovery of metals or other valuable materials.

Besides the interests in disposal and recovery of POP wastes there is a market for measurement and monitoring activities with respect to POPs.

1.5 Technical background

It is obvious that mandatory regulations have to take existing technologies into consideration.

With respect to POP wastes technologies for treatment, disposal and destruction are of special importance. Currently classical and well known technologies for the management of the POP content in waste are incineration, underground disposal and landfilling. Other destruction technologies are less established in Europe. One example for these alternatives is the Na-Reduction Technology (Envio) and Autoclavation (Tredi) which is used for decontamination of PCB containing equipment. However incineration of eliminated liquid is in part required as second step.

Cement kiln co-incineration is a well established destruction method suitable for all wastes with remaining caloric value (e.g. waste oils, waste wood, plastics).

Another example is the base catalysed decomposition (BCD) that has been reported from the Czech Republic. The installation is operating in pilot and shall be used primarily for remediation purposes. It will address PCDD/PCDF contamination at the former pesticide factory at Spolana Neratovice. The technique however is applicable for all POPs. In situ thermal desorption and plasma arc processes are additional processes mainly for PCB and pesticide destruction. However they are not well established in Europe.

A comprehensive compilation of potential destruction methods is given in the General Technical Guideline on POPs prepared under the Basel Convention⁴ and adopted by COP7 in October 2004.

Physico-chemical methods (sorption, dewatering, pH adjustment, solvent washing with distillation, screening, shredding) are used for pre-treatment of POP wastes prior to final disposal mainly for reasons of mass reduction or increased caloric value. Another important domain of technology are processes which use POP containing wastes as input to a production process via recycling.

⁴ <http://www.basel.int/meetings/sbc/workdoc/techdocs.html>

The following recycling options are currently available for residues from different industrial and municipal POP relevant processes:

- use in construction (under construction, basement, asphalt filler)
- use in cement production (secondary fuel and raw material for clinker production)
- use as fertilizer (direct application as sewage, agrochemical production)
- use in secondary production in the metallurgical industry (secondary, aluminium, copper, zinc, lead and precious metal production)
- use as secondary fuel (cement production)

In addition measurement techniques and their applicability have to be considered. This issue is investigated in detail in chapter 7.

Under the Basel convention General Technical Guidelines on the environmental sound management of wastes consisting of, containing or contaminated with HCB [HCB Tech Guidelines 2005] and pesticides, as well as with POPs [UNEP GTGESM final 2005] and PCB [PCB Tech Guidelines 2005] have been elaborated:

- Draft technical guidelines on environmental sound management of wastes consisting of, containing or contaminated with HCB; (1 draft)
- Draft technical guidelines on environmental sound management of wastes consisting of, containing or contaminated with POP pesticides; (2 draft)
- General Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants to the Basel Convention; (final)
- Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Polychlorinated Biphenyls (PCBs), Polychlorinated Terphenyls (PCTs) or Polybrominated Biphenyls (PBBs); (final)

2 Sources of information

2.1 Structure of required information

First step for the collection of necessary data was the identification of required information. The developed structure follows the objectives of the project and is disaggregated in:

- information on occurrence and levels of POPs in different processes and waste categories
- information on existing legislation and corresponding policies on POPs, as well as concentration limits in different waste categories
- information and specifications to be taken into account by a methodology (or a process) and criteria that shall serve as a decision making tool for the question whether specific waste should be destroyed or irreversibly transformed or whether an environmentally more sound alternative should be chosen for the treatment of that waste
- information that enables to identify the most appropriate reference measurement methods for the determination of the 14 POPs substances and substance classes in waste
- further information needs such as links to additional relevant information or impact relevant information.

Based on this structure the concept of a questionnaire was developed and discussed in a kick off meeting with the Commission on 3rd September 2004.

As a result three different types of questionnaires were elaborated and sent

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

This was done to address the necessary questions as specifically as possible (see the questionnaires in annex).

The questions in the questionnaires also formed the basis for all other ways of information collection such as

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

2.2 Feedback to the questionnaire

Feedback has been provided from Member States, industry and scientific experts.

From Member States the following feedback is available:

country	contact (discussion, meeting)	questionnaire	questionnaire promised	remark
AT	2		1	
BE	2	1		
CY	2	1		
CZ	3	1		
DE	5	1		
DK	3	1		
EE	1	1		
ES	3	1		
FI	3	1		
FR	2	1		
GR	2		1	
HU	3	1		
IE	3	1		
IT	2		1	
LT		1		
LU	3	1		
LV	2	1		
MT	1	questionnaire not expected due to missing relevant industrial production		
NL	3		1	
PL		1		
PT		1		
SE	2	1		
SI	3	1		
SK		1		
UK	4	1		
sum	54	19	5	2

Table 2-1: Feedback to the questionnaire from Member States

As documented in Table 2-1 the project work was not limited to the evaluation of received questionnaires but included active discussions with competent officers. By this procedure two effects were achieved:

Firstly, the motivation to answer to the questionnaire could be stimulated. As Member States receive a large number of questionnaires from the European Commission the project team was sometimes informed that MS are only in a position to answer mandatory questionnaires and not voluntary ones. This difficulty has been overcome during the discussion so that sufficient feedback has been achieved.

Secondly, details could be discussed, additional and background information could be exchanged. For Malta the answers of the personal discussion were filled into the format of a questionnaire.

From the industry side the following feedback is available:

branch	contact (discussion, meeting)	questionnaire	response announced
waste incineration	4	7	
hazardous waste incineration	2	8	
landfill	1	3	
underground disposal	2	1	
non ferrous metal	5	9	
iron and steel	2	2	
paper	2	2	x
sewage sludge	1	1	x
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		answer promised
electro- and electronic industry	1		
sum	35	51	

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

What has been said for the personal discussions with Member States is also valid for the questionnaire feedback from industry. There have been 15 personal meetings, partly connected with visits of production sites.

From scientific and other institutions 21 questionnaires have been returned.

Based on the questionnaires, contacts, discussions and meetings appropriate information has been achieved so that finally more than 100 responses have been evaluated.

In the annex an Excel file is documented which contains all returned questionnaires.

2.3 European Commission

The project team received a high volume of documents and material available at the European Commission. These materials were investigated and used for the study. For the final report it will be discussed with the European Commission which documents can be mentioned as literature and which sources have to be quoted as "internal information".

2.4 Conferences

Members of the project team participated in three conferences in order to intensify contacts, discuss open issues and collect information:

1. *24th International Symposium on Halogenated Environmental Organic Pollutants and Persistent Organic Pollutants (POPs), September 6-10, 2004, Berlin*

The scope of the conference covered a wide range of items in the fields of sampling and analysis, industrial sources, toxicity and risk assessment, as well as environmental and human tissue levels with respect to chlorinated and brominated POPs and allowed an insight into the most recent stage of scientific knowledge.

2. *Pre-session consultation on the development of Technical Guidelines on POPs, 23-24 October 2004, Geneva*

The consultation has been held with the view of finalising draft documents for adoption by COP7. Major objectives have been the finalisation of the two draft documents: General Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants [UNEP GTGESM final 2005] and Specific Technical Guideline for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with PCB, PBBs and PCTs. Main points of discussion have been the definition of low POP contents and the definition of level of destruction and irreversible transformation.

Furthermore the draft Specific Technical Guideline for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with POP pesticides has been discussed.

3. *Joint Research Center – Workshop: Problems around soil and waste I – Horizontal aspects of leaching, Ispra, 14-15 February 2005*

The JRC co-organised with the European standardisation body CEN the Workshop "Problems around Soil and Waste I - Horizontal aspects of leaching" addressing the issue of greater harmonisation in the context of leaching (desorption of contaminants) test requirements from various Directives. A member of the project team participated at the meeting. Important information with respect to the development of appropriate measurement techniques could be derived.

4. *Expert workshop for stakeholders, 11 May 2005, Brussels.*

An expert workshop was organized by the Commission Services the 11 May 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.

5. *Meeting of the Committee for the Adaptation to scientific and technical Progress of EC-Legislation on Waste, 16 June 2005, Brussels*

Members of the project team participated in the meeting in order to present the results of draft final report. Member States have been invited to comment. Comments have been integrated as far as possible into the final report.

2.5 Statistics, data bases and literature

As a major source for activity data EuroStat statistics have been used.

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

- 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

For the elaboration of the results a large number of literature was checked. The literature used is listed in the table of references. This table will be further completed for the final report.

3 Overview on POP mass flows

3.1 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 we 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. Due to limited data it was not possible to derive medians, 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.

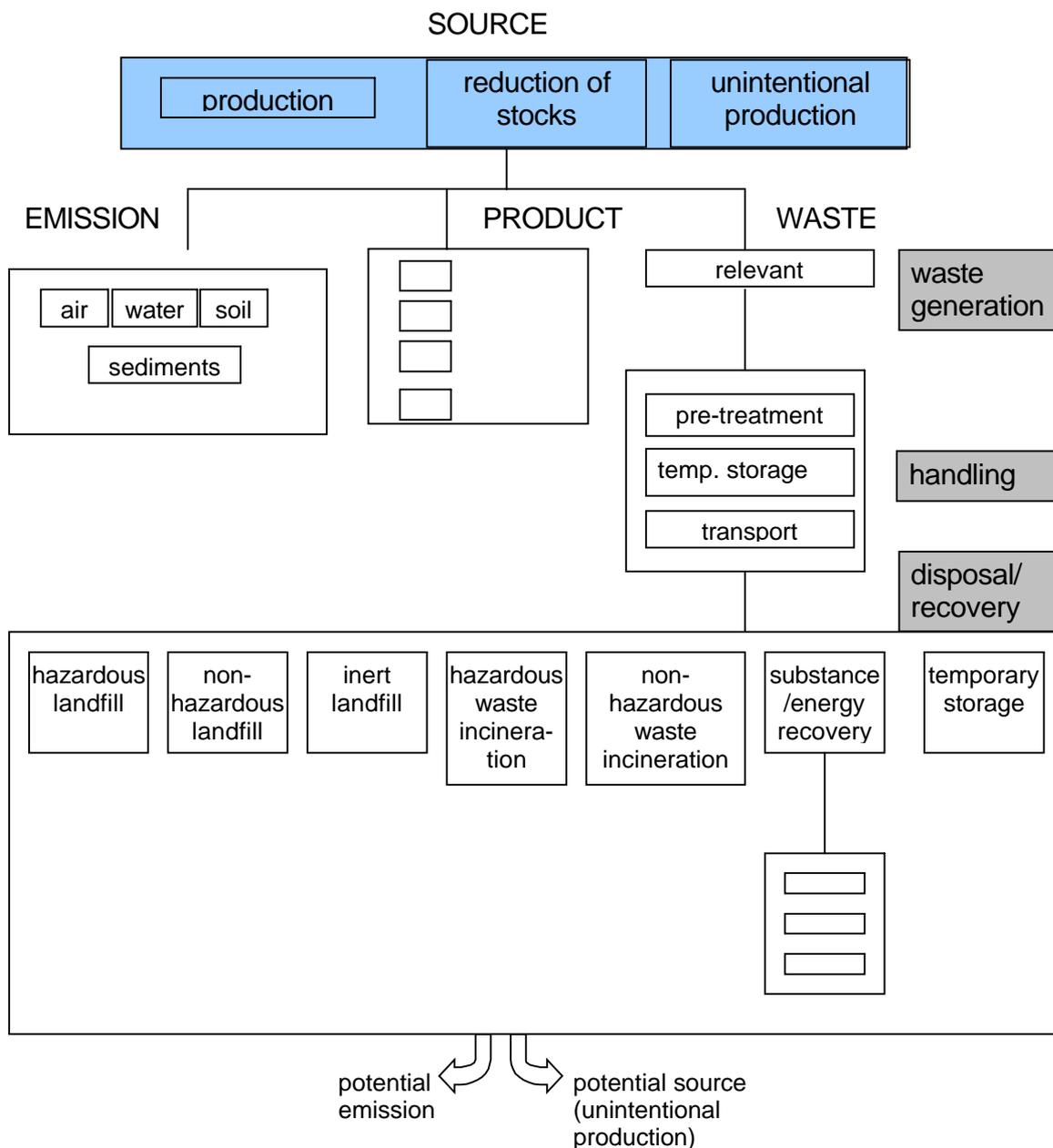


Figure 3-1: General structure of mass flow (macro dimension)

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 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.

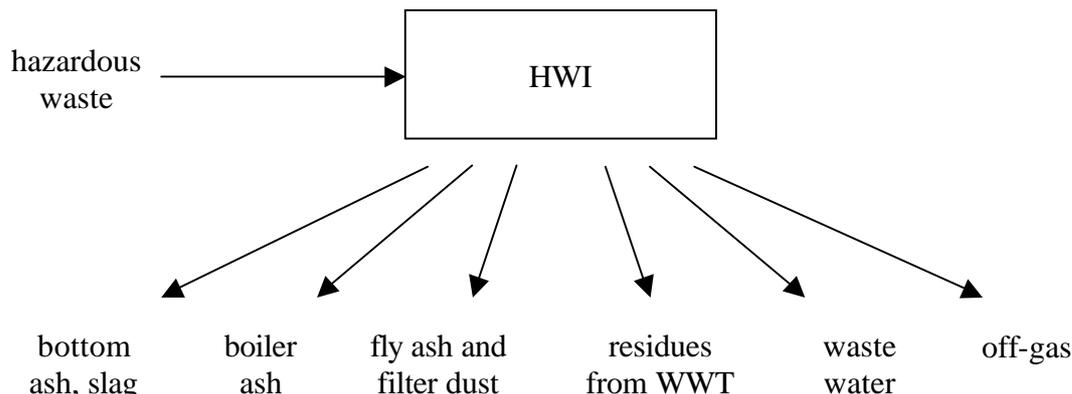
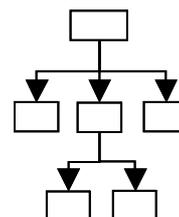


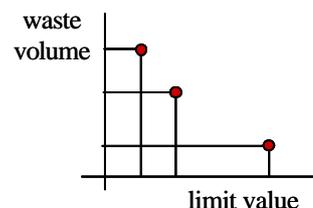
Figure 3-2: Example for process specific differentiation of residues and emissions in the mass flow (micro dimension)

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 consists of the following:

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



2. Volumes and management options for contaminated wastes (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 this 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 corresponding paragraphs of chapter 4.

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.

3.2 Sources for POP discharge to environment and waste

3.2.1 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 which will be discussed in chapter 8.

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 (see chapter 3.2) relevant sources according to literature and international discussions have been investigated.

All figures for PCDD/PCDF given in this 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 as discussed in paragraph 3.8 the related effect is negligible.

3.2.2 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 (national use ~40,000)	1955 up to 1980	[DEMEX]
Europe total	~700,000		

Table 3-1: 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. Information on related concentrations is compiled in chapter 3.7.

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 sheets⁵]. 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.

3.2.3 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. A compilation of reported amounts is presented in chapter (detailed mass flow POP pesticides).

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.

3.2.4 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/pcb/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, computer). 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 and no data about HxBB in wastes.

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

3.3 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 ubiquitous 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.

3.4 Total POP mass flows

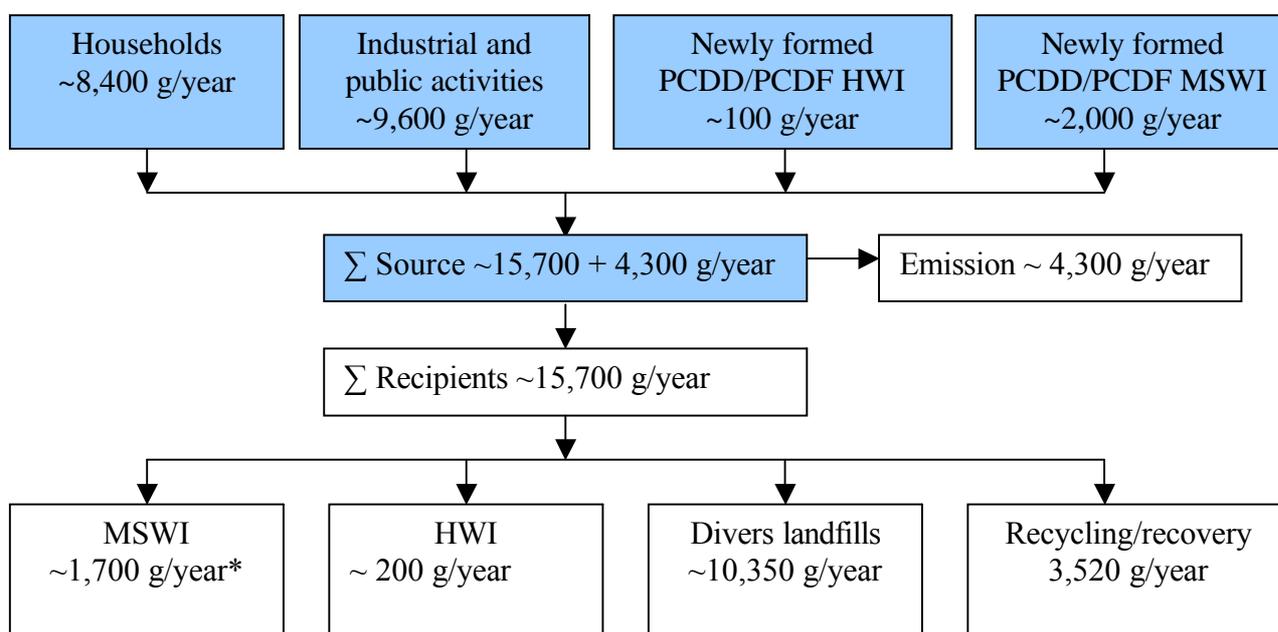
Total mass flows for the different POP substance groups to investigate are based on the results of the detailed mass flows in chapter 4. To give information on the relative importance of different disposal/recovery pathways they provide summarised information from all investigated "sources". Detailed information on the contribution of specific sectors to different disposal/recovery pathways is discussed in the corresponding paragraphs of chapter 4.

Sectors not included in the mass flow model due to low importance or insufficient data are discussed in chapter 3.7.1 "sectors not covered".

3.4.1 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 3-6 and are discussed for each activity in the corresponding detailed PCDD/PCDF flow (see chapter 4.1.1 to 4.1.18). Sectors not covered with respect to the PCDD/PCDF mass flow are discussed in chapter 3.7.1.

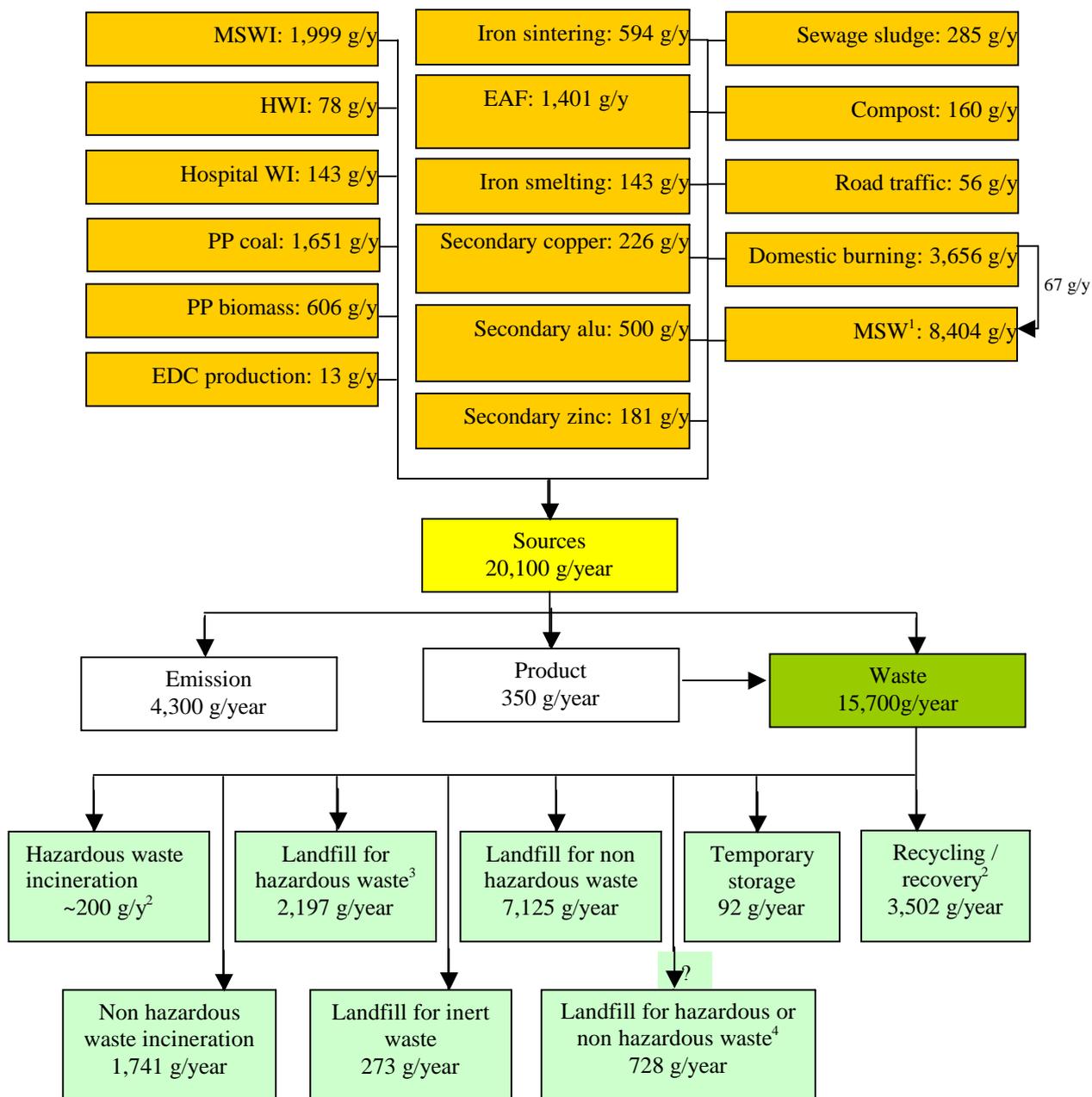
Based on the information presented in chapter 3.7 it can be stated that > 90% of the PCDD/PCDF in waste are covered in the total mass flow.



* plus 16 t PCB from MSW, plus other precursors

Figure 3-3: 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 3-4: Overall mass flow of PCDD/PCDF from sources to current disposal/recovery operations in investigated sectors in EU 25

As illustrated in Table 3-2 discharge of PCDD/PCDF from the investigated sources in Europe leads to a dimension of about 20 kg/y with an overall distribution of the discharge of about 25% to air and around 75% to solid process residues (waste).

country	emission [kg]	product [g]	waste [kg]	sum [kg]
EU 25	~4.3	~350	~15.4	~20

Table 3-2: Overall discharge of PCDD/PCDF to air and solid residues from all investigated sources in EU 25

In the following tables (Table 3-3 and Table 3-4) 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. As demonstrated in Table 3-2 discharge to waste significantly dominates the overall emissions in the industrial sectors. This observation clearly reflects the effect of a high standard flue gas treatment in the "old" Member States leading to increased absorption of pollutants to the filter material. The effect of less sophisticated flue gas treatment measures in the "new" Member States is illustrated by the relative high share of air emissions in EU 10.

Please note that - as the focus of the project has been the waste sector - PCDD/PCDF discharge to products (e.g. PVC, pesticides, textile, leather) has not been investigated in detail and therefore is not complete but includes only data from the production sectors investigated for reasons of relevant amounts of discharge to waste.

Sector/Activity	emission [g TEQ/y]	product [g TEQ/y]	waste [g TEQ/y]	sum [g TEQ/y]
municipal solid waste incineration EU 25	21.5	0	1,977	1,999
municipal solid waste incineration EU 15	21	0	1,940	1,961
municipal solid waste incineration EU 10	0.5	0	37	38
power production (coal) EU 25	38	0	1,613	1,651
power production (coal) EU 15	27	0	1,137	1,164
power production (coal) EU 10	11	0	476	487
FM EAF EU 25	167	0	1,234	1,401
FM EAF EU 15	156	0	1,152	1,308
FM EAF EU 10	11	0	82	93
FM sinter plants EU 25	525	0	70	595
FM sinter plants EU 15	295	0	59	354
FM sinter plants EU 10	230	0	11	241
Power production (biomass) EU 25	1.7	0	604	606
Power production (biomass) EU 15	1.4	0	487	488
Power production (biomass) EU 10	0.3	0	117	117
NFM secondary aluminium EU 25	58	0	443	500
NFM secondary aluminium EU 15	32	0	395	427
NFM secondary aluminium EU 10	26	0	47	73
NFM secondary copper EU 25	84	95	47	225
NFM secondary copper EU 15	45	0	129	174
NFM secondary copper EU 10	39	0	12	51
NFM secondary zinc EU 25	2.5	94	85	182
NFM secondary zinc EU 15	0.3	93	84	177
NFM secondary zinc EU 10	2.2	1.5	1	5
Hospital waste incineration EU 25	111	0	32	143
Hospital waste incineration EU 15	included in figures for hazardous waste incineration			
Hospital waste incineration EU 10	111	0	32	143

Sector/Activity	emission [g TEQ/y]	product [g TEQ/y]	waste [g TEQ/y]	sum [g TEQ/y]
FM iron smelting EU 25	21	0	122	143
FM iron smelting EU 15	19	0	111	130
FM iron smelting EU 10	2	0	11	13
hazardous waste incineration EU 25	2.3	0	76	78
hazardous waste incineration EU 15	2.1	0	68	70
hazardous waste incineration EU 10	0.2	0	8	8
Chem. Industry EU 25	8	0	1	9
Chem. Industry EU 15	7.7	0	0.8	8.5
Chem. Industry EU 10	0.3	0	0.03	0.33
Sum EU 25	1,039	190	6,308	7,531
Sum EU 15	606	188.5	5,563	6,357
Sum EU 10	433	1.5	834	1,268

Table 3-3 discharge of PCDD/PCDF to air and solid residues from industrial and public sectors in "old" and "new" MS

In contrary to the industrial sectors air emission from domestic burning is the dominating discharge in the domestic and public sectors. Due to a significantly higher share of single stove, private heating in the "new" Member States associated with a higher consumption of coal and derivatives instead of virgin wood the figures for this sector from EU 10 are dominating the overall emissions from the residential sector, while sewage sludge and ashes from wood combustion in EU 15 form the larger part of discharge to waste.

Uncontrolled fires also form a relevant source for air emissions of PCDD/PCDF and even increase the importance of non-industrial sectors for the overall air emissions, but due to incomplete data contamination in residues they has not been included in the investigation.

Sector/Activity	emission [g TEQ/y]	product [g TEQ/y]	waste [g/TEQ/y]	sum [g TEQ/y]
domestic burning fossil fuels EU 25	3,133	0	241	3,374
domestic burning fossil fuels EU 15	815	0	62	877
domestic burning fossil fuels EU 10	2,318	0	179	2,497
sewage sludge EU 25	0	0	297	297
sewage sludge EU 15	0	0	264	264
sewage sludge EU 10	0	0	33	33
domestic burning wood EU 25	125	0	157	282
domestic burning wood EU 15	95	0	119	214
domestic burning wood EU 10	30	0	38	68
compost EU 25	0	160	0	160
compost EU 15	0	131	0	131
compost EU 10	0	29	0	29
road traffic EU 25	56	0	0	56
road traffic EU 15	23	0	0	23
road traffic EU 10	33	0	0	33
Sum 25	3,314	160	695	4,169
Sum 15	933	131	445	1,509
Sum 10	2,381	29	250	2,660

Table 3-4 Emissions and discharge of PCDD/PCDF from non-industrial sources in EU 25

Sector/Activity	emission [g TEQ/y]	Product [g TEQ/y]	waste [g/TEQ/y]	sum [g TEQ/y]
MSW from household and commerce (including share of db) EU 25	0	0	8,404	8,404
MSW from household and commerce (including share of db) EU 15	0	0	7,325	7,325
MSW from household and commerce (including share of db) EU 10	0	0	1,079	1,079

Table 3-5: Discharge of PCDD/PCDF to waste via MSW from household and commerce in EU 25

To conclude it can be stated that (under BAT conditions) air emissions are dominated by non-industrial sources like domestic burning and other open fires, while the discharge to residues is dominated by MSW from household and commerce (including a share of waste from domestic burning), MSWI, power production from solid fossil fuels, and the iron & steel industry in terms of sinter plants and electric arc furnaces (EAF). The overall discharge from non-industrial sources is about two times as high as from investigated industrial sources. However it has to be noted that the assessment is focused on residues which are well controllable. Provided they are disposed of according to the provisions of the waste directive, solidly bound to other material or reused in thermal processes, they have a significantly smaller impact on the environment than emissions to air from incineration. Air emissions lead to an uncontrolled deposition of the pollutants on soil and water surfaces, thus directly affecting the food chain.

In order to illustrate the relative importance of different sectors on air emissions and discharge to waste, the shares of the investigated sectors are illustrated in the following pie charts.

As illustrated in

Figure 3-5 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.

PCDD/PCDF emissions to the environment

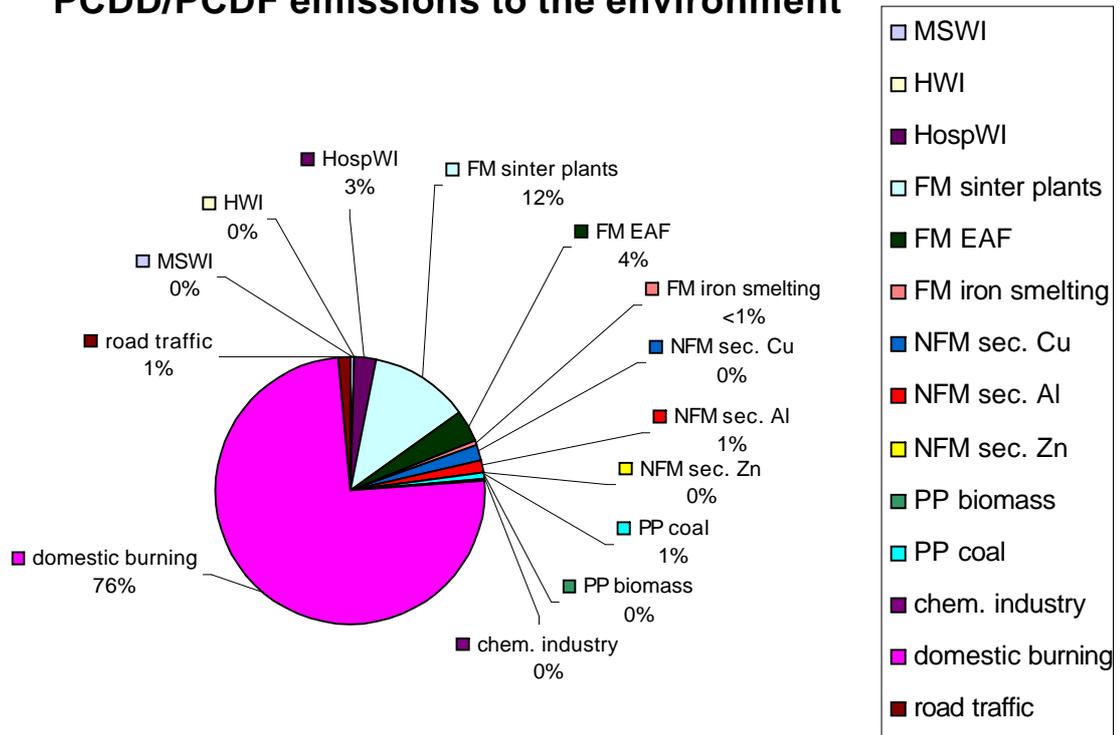


Figure 3-5: Relative distribution of air emissions from investigated sectors in EU 25

PCDD/PCDF discharge to waste

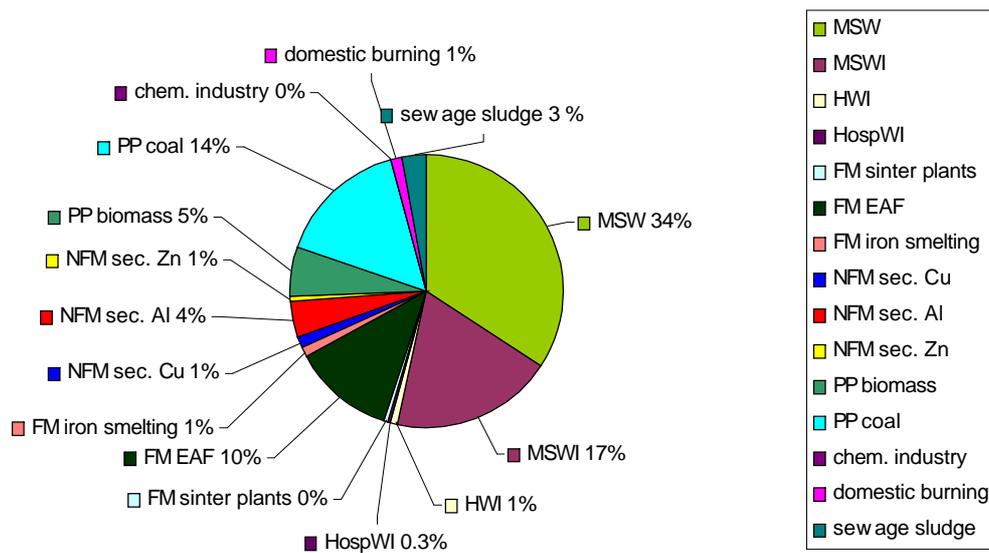


Figure 3-6: Relative distribution of discharge to waste from investigated sectors in EU 25

Unlike emissions to air discharges to waste show a more even distribution for the investigated sectors. Based on the results from the mass flows in chapter 4 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 3-6.

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 3-6 illustrates how the selected activities contribute to the PCDD/PCDF flow to specific disposal/recovery operations, whereas Figure 3-7 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		

Treatment / Activity	g TEQ/y	Comment
MSW	6,763	181 Mt (mean 0.04 ppb)
Domestic burning	289	
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 3-6: Quantitative contribution of PCDD/PCDF from different sectors to currently used

disposal/recovery operations in EU 25

Waste treatment

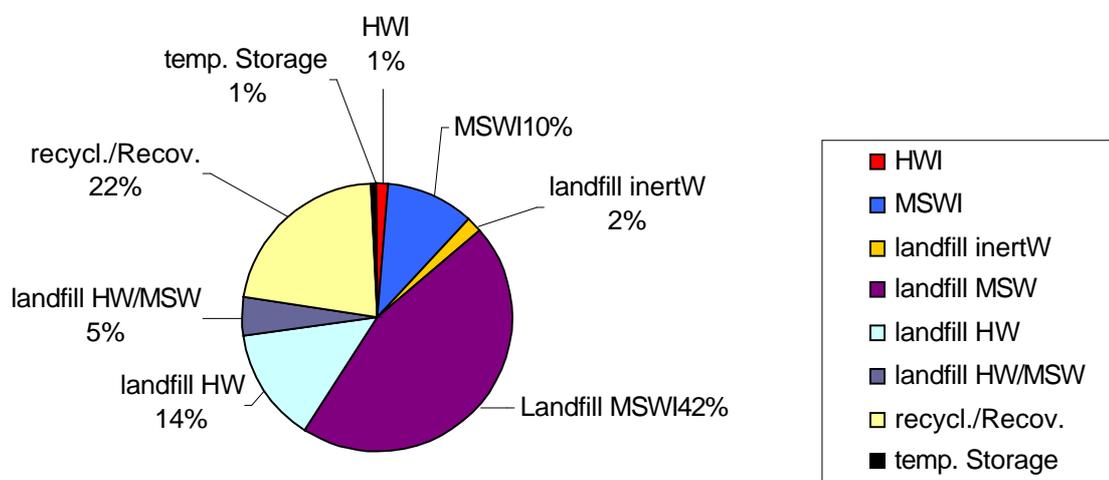


Figure 3-7: Relative importance of different waste treatment options with respect to the PCDD/PCDF mass flow in EU 25

3.4.2 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 chapter 4. 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.

Information concerning effects of proposed limit values is compiled and discussed in chapter 8.

	waste and product	annual generation	Contamination data [ng TEQ/g]			PCDD/PCDF (g/y)	share of total PCDD/PCDF to waste and products [%]
			[kt/y]	mean	min		
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 (g/y)	share of total PCDD/PCDF to waste and products [%]
			[kt/y]	mean	min		
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 3-7: 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 in chapter 4 and the contamination data compiled in Table 3-7 an overview on current levels of contamination as well as their corresponding ranges is illustrated in Figure 3-8 below.

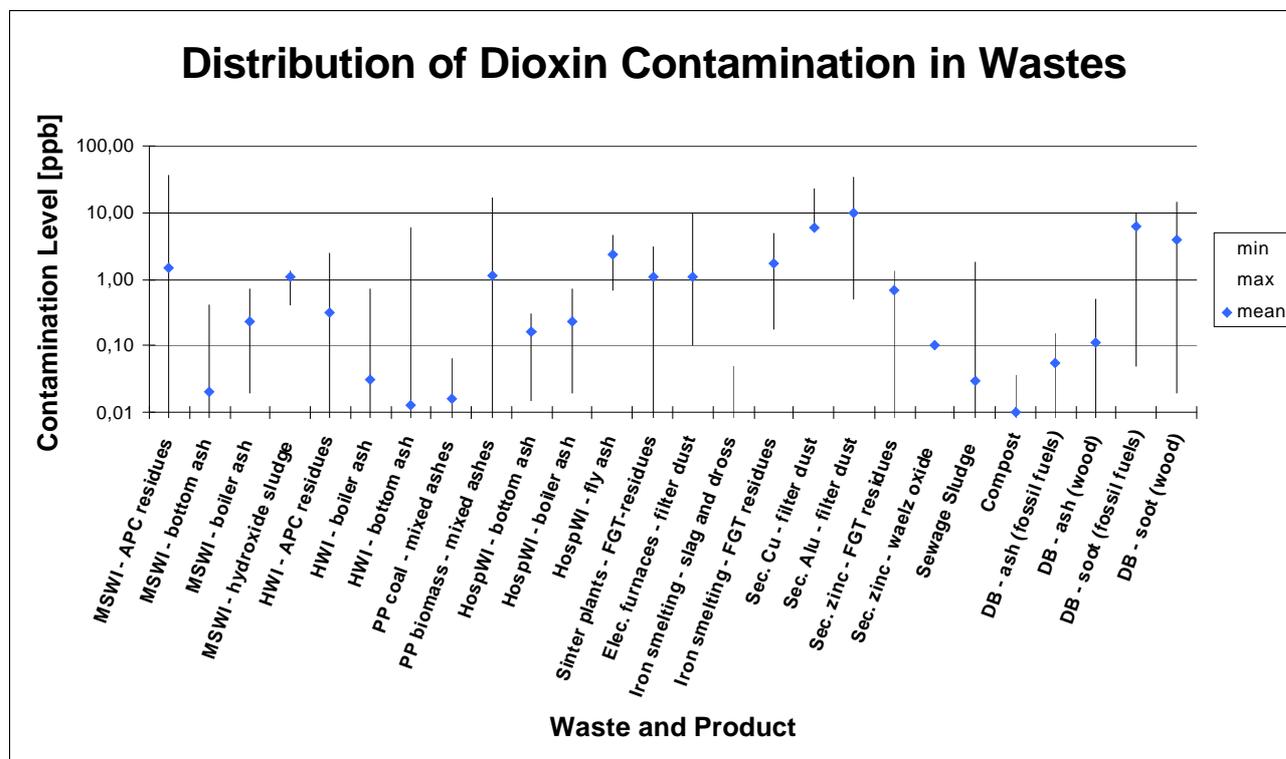


Figure 3-8: Means and ranges of recent PCDD/PCDF contamination in different waste types in EU 25

As shown in the figure and summarised in Table 3-7 (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.

3.4.3 Total PCB flow

The following figure shows the overall result of the detailed PCB mass flow analyses in chapter 4.2.1 to 4.2.6. The individual streams from each activity are listed in Table 3-9 and are discussed in detail for each activity in the corresponding paragraphs of the PCB mass flow in chapter 4.

Base on the information presented in chapter 3.7 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 (see chapter 4).

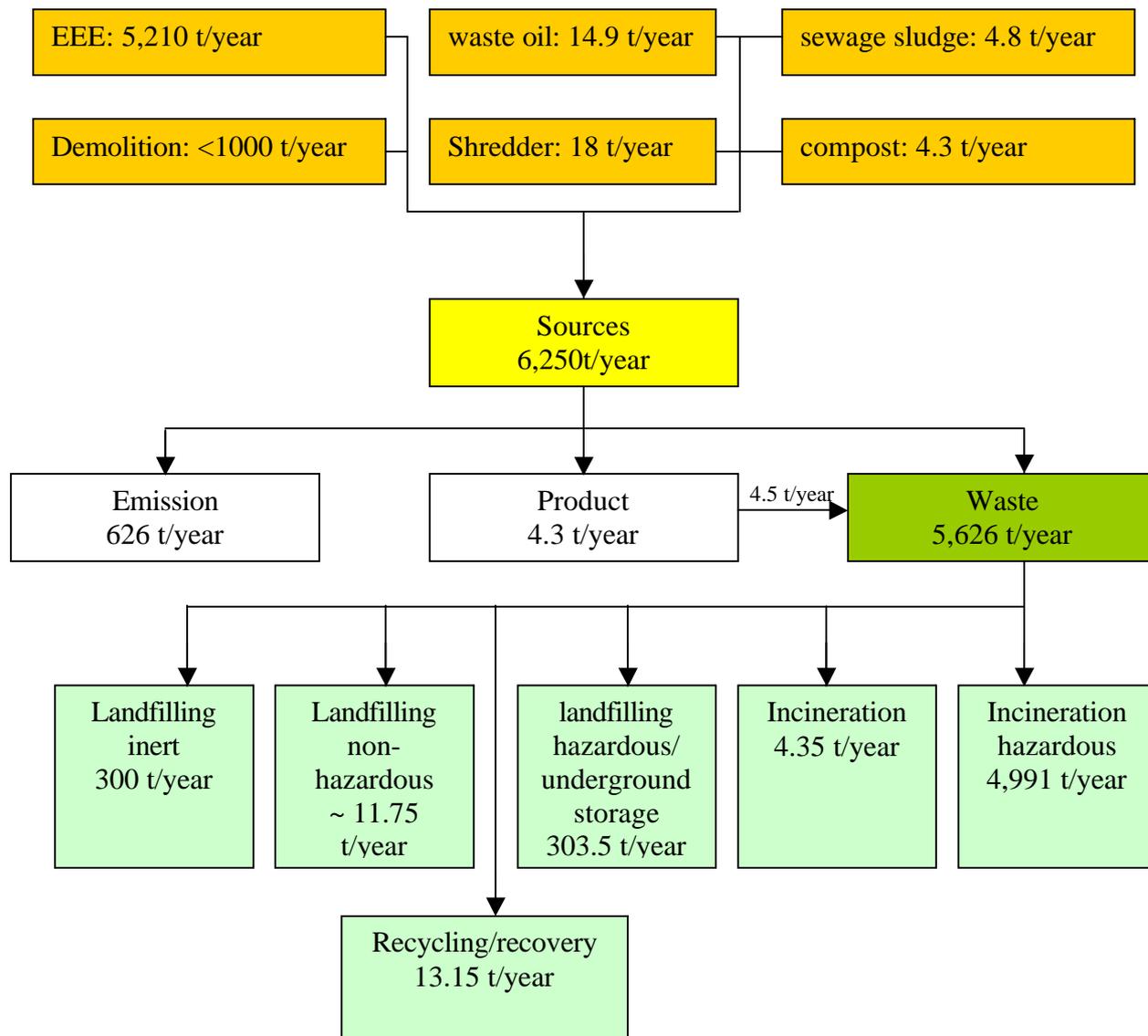


Figure 3-9: Overall mass flow of PCB from sources to current disposal/recovery operations in investigated sectors in EU 25

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 3-8) 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. More detailed information on country level can be found in the related paragraphs of chapter 4.

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 15	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 3-8: 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 (see chapter 3.7). 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 is the dominating source 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.

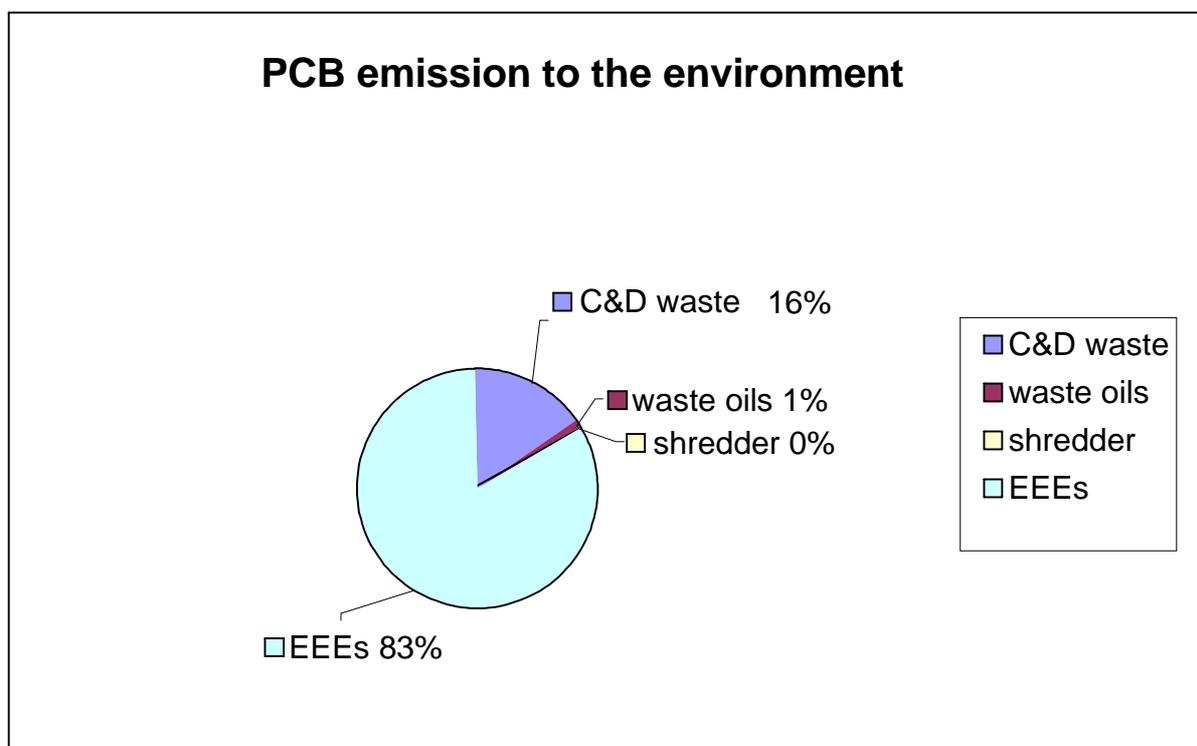


Figure 3-10: Relative distribution of environment emissions from investigated sectors in EU 25

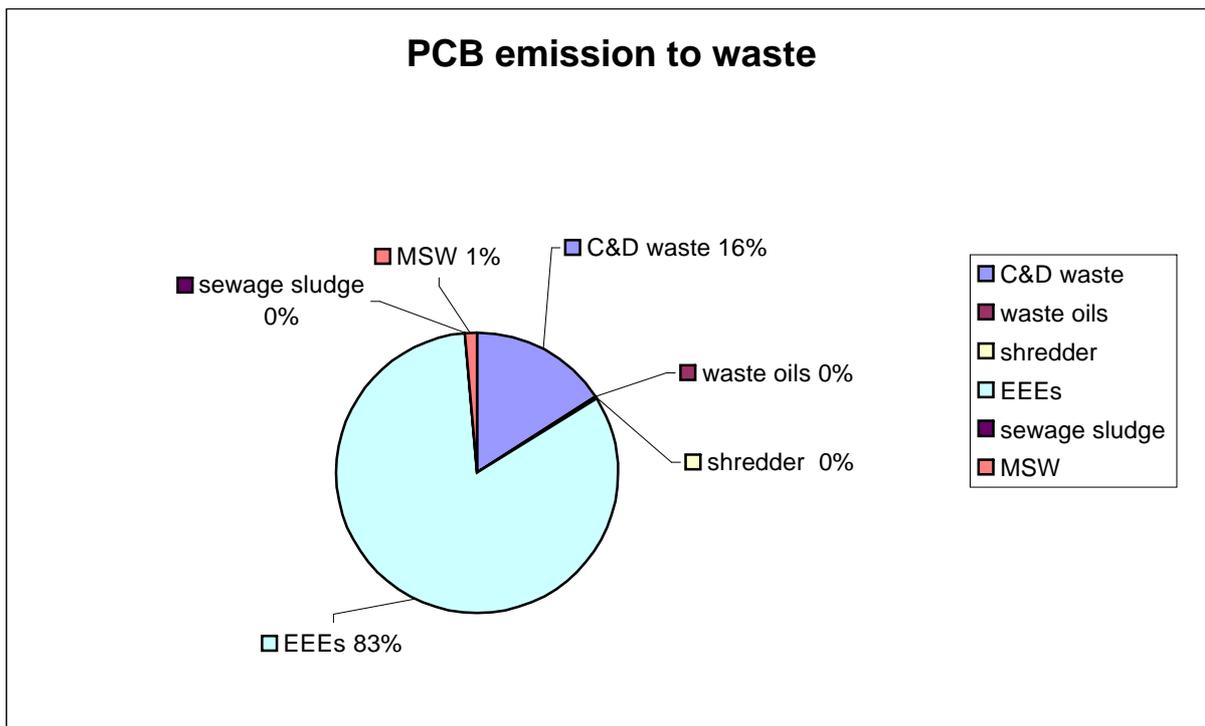


Figure 3-11: Relative distribution of discharge of PCB to waste from investigated sectors in EU 25

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		

Disposal/Recovery option	PCB tons/y	Comment
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
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); 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); 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); 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 3-9: 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
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respect to the PCB mass flow.

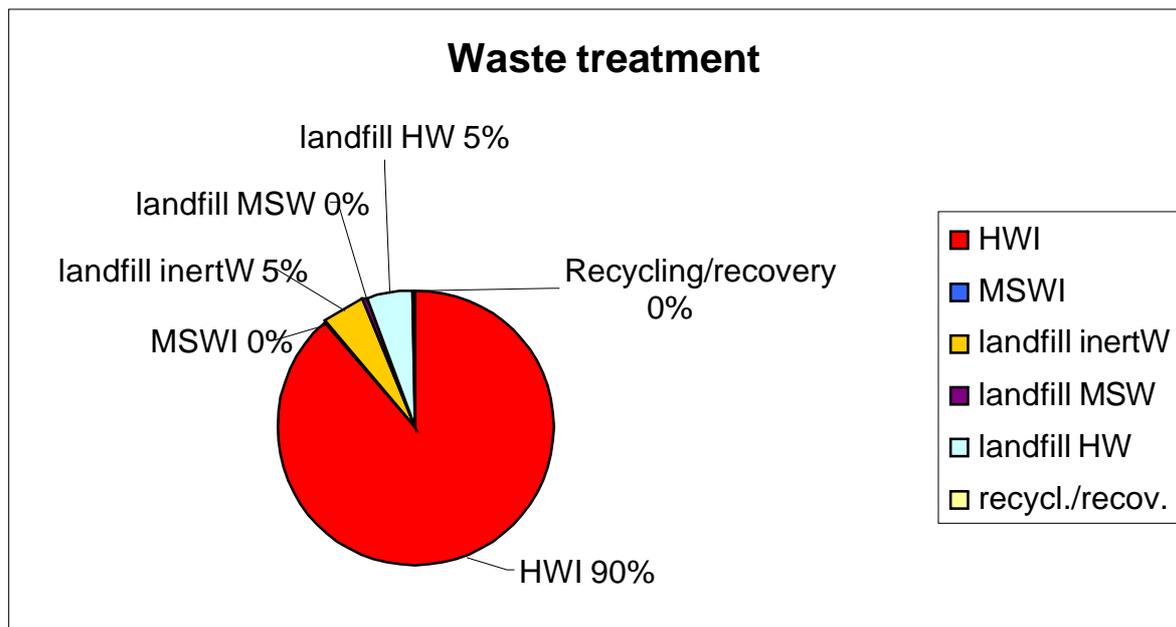


Figure 3-12: Relative importance of different waste treatment options for the PCB mass flow in EU 25

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 is currently directed to landfills for non-hazardous and inert waste from where PCB might be discharged to the surrounding environment.

3.4.4 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. As for the POP mass flows detailed information is contained in the corresponding paragraphs of chapter 4. 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.

Information concerning effects of proposed limit values is compiled and discussed in chapter 8.

	waste	amount [kt/y]	Contamination data (mg/kg)			PCB discharge (t/y)	PCB to waste & products (t/y)	share of total PCB to waste and products [%]
			mean	min	max			
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
	170106		70.0	0.01	6,135			0.0
	170204		0.1	0.02	3,086			0.0
	170503		27.5	0.0005	9,700			0.0
	170902		17,000	4.5	147,300			0.0
	170903		2,450	0.03	10,650			0.0
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 3-10: 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 chapter 4 and the contamination data compiled in Table 3-10 an overview on current levels of contamination as well as their corresponding ranges is illustrated in Figure 3-13 below.

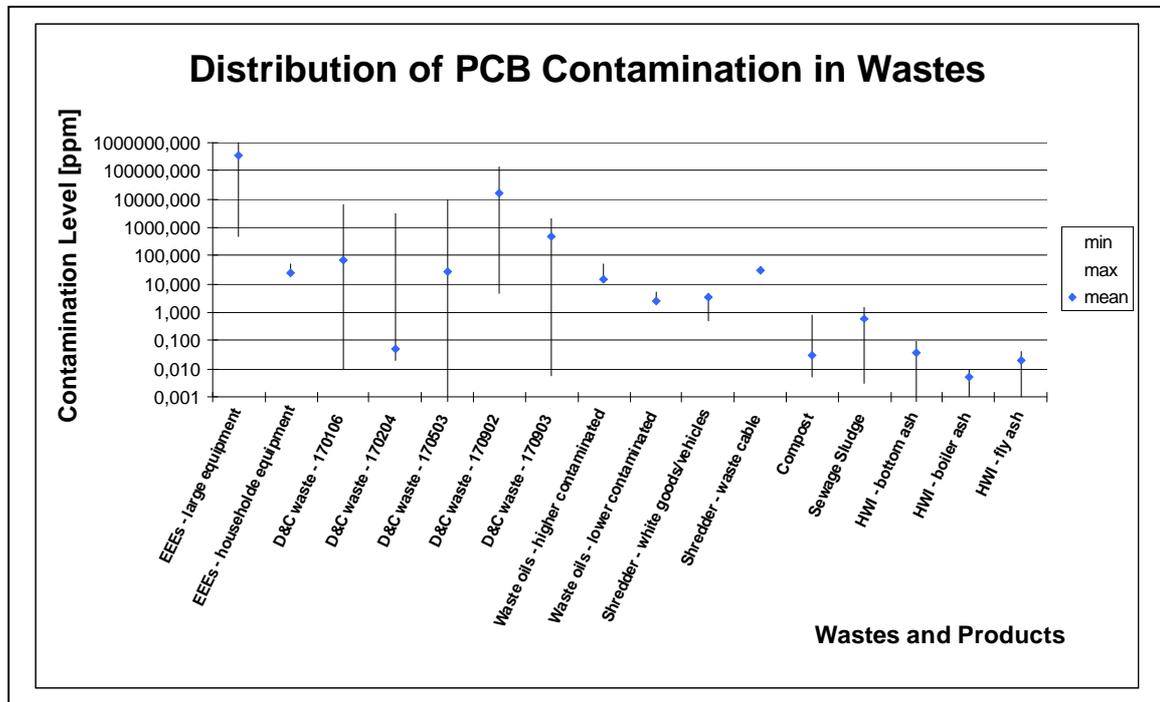


Figure 3-13: Means and ranges of recent PCB contamination in different waste types in EU 25

As shown in the figure and summarised in Table 3-10 (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.

3.4.5 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 chapter 4.3. 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.

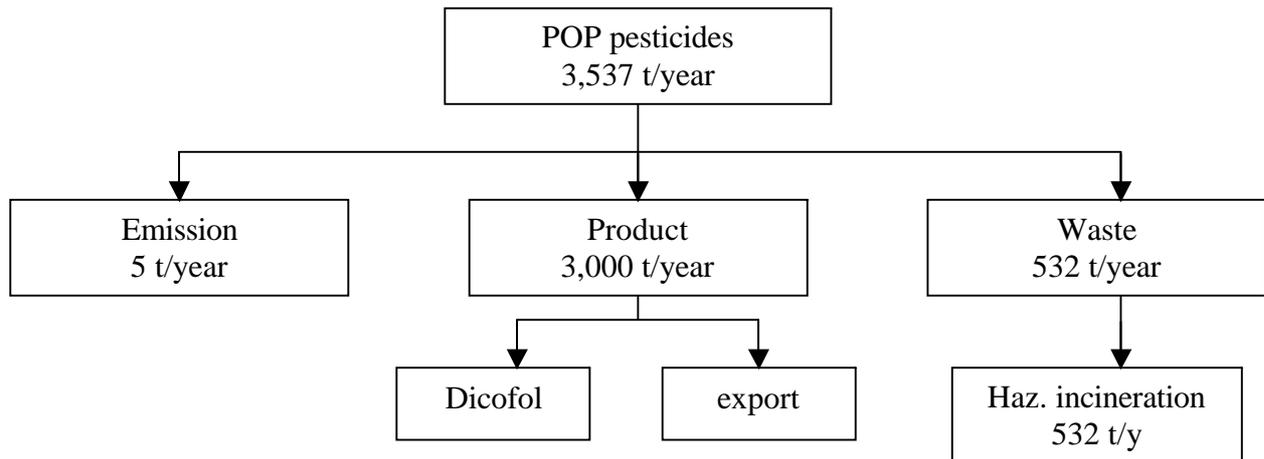


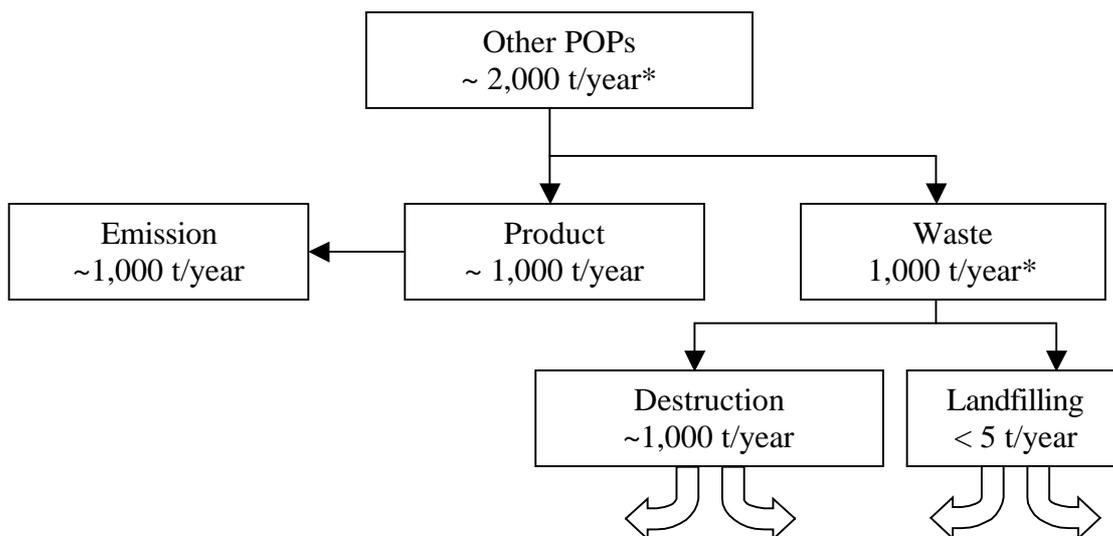
Figure 3-14: Total flow of POP pesticides

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.

3.4.6 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 chapter 4.4. 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; Landfilling refers to estimated HCB in combustion residues; destruction refers to stocks of production residues (HCH)

Figure 3-15: 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.

3.5 Overall flows and potential of regulation

New waste legislation covers only such parts of the mass flow which are related to production of waste and its management via recovery or disposal operations. It does not cover emissions and POP quantities already spread to the environment or already disposed of in former times.

In order to facilitate decisions on feasible limit values and measures to take in the waste sector with respect to POPs an evaluation of the investigated mass flows in view of existing environmental burdens and potential impacts of the regulation has been performed in this

paragraph to assess the relative importance of current waste streams and used disposal/recovery methods in relation to existing environmental burdens and in order to assess the environmental effects of the POP regulation.

As information on cumulated amounts in environment and landfills are limited the overall mass flow can not be more than a rough estimation. However it helps to identify the relative importance of different sectors and pathways and allows for conclusions on environmental effects of the POP regulation.

3.5.1 PCDD/PCDF

In order to assess the impact of the legislative measures considered, a first step is to identify those pollutant streams altered significantly with entry into force of the regulation. Their relative importance within the total pollutant flow is evaluated. In a second and third step, the same amount of pollutants is compared to those emissions which remain untouched by the limit value regulation, and to existing environmental loads. If the share of pollutant amounts affected by the regulation is high, the measure can be judged effective⁶.

To this end, a rough evaluation of the mass flow in view of points of control and of existing environmental burdens has been performed.

The emissions/discharges are reported on an annual basis, whereas the environmental load has been calculated as a minimum estimate on the basis of recent total emissions as modelled in the EMEP database. Taking into account that emissions were higher in former times while natural degradation processes slowly reduce the amounts in the soils, a minimum load of 200 kg PCDD/PCDF-TEQ has been calculated on the basis of emission estimations extrapolated for fifty years.

⁶ this has to be seen against the background that POPs are not only released from local sources but are subject to long-range transport (in particular long-range air transport)

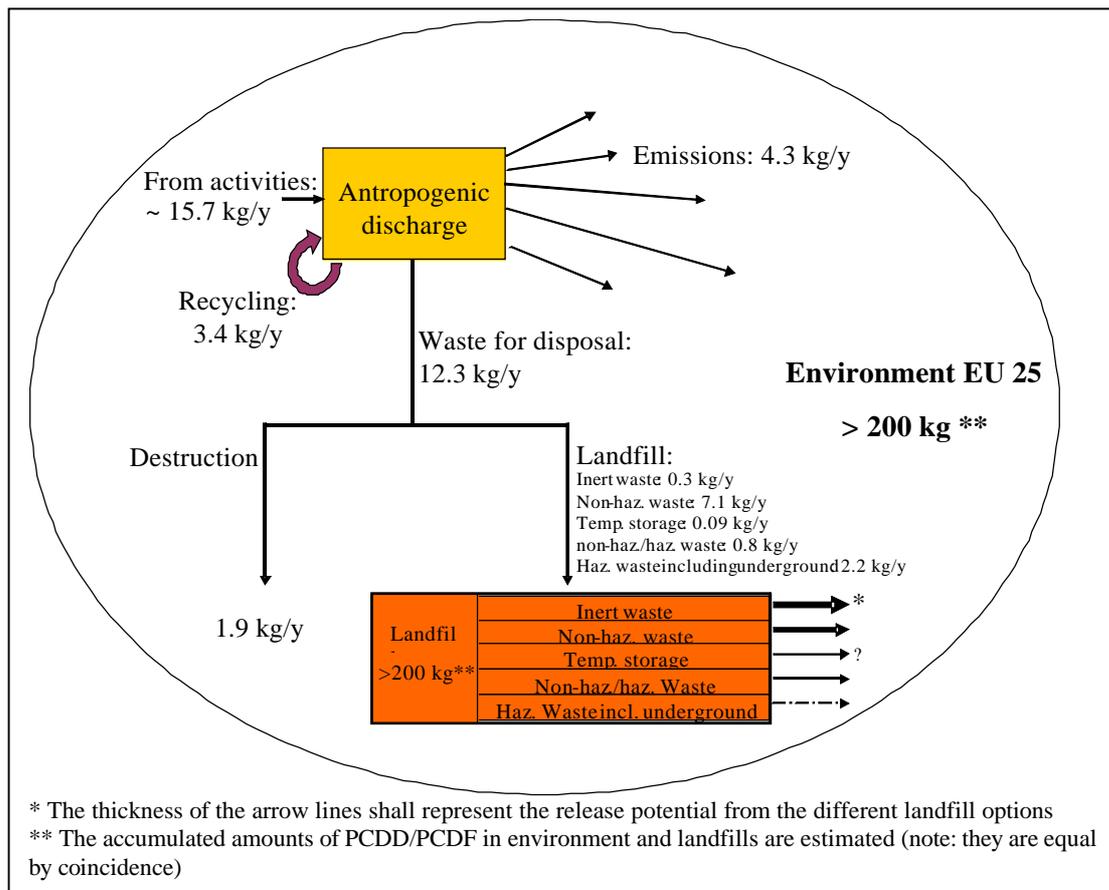


Figure 3-16: Major pathways and amounts of PCDD/PCDF distributed in EU 25

As illustrated in Figure 3-16 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. Together the waste sector would add annually 8% of the calculated environmental load to the total of 200 kg, whereas air emissions would add 1%.

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 are further reduced in the processes.

So while the waste sector is important for the overall discharge of PCDD/PCDF the major share of PCDD/PCDF discharge via waste is due to 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 and only 2 kg/y contained in wastes that may in part be disposed of or used as secondary construction material at non-hazardous waste landfills may be influenced by the POP regulation.

As the landfill directive (1999/31/EC) which prohibits the landfilling of untreated waste, and enhances incineration of all combustible fractions will show effects only after 2005 the importance 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. Furthermore secondary high temperature processes receive only a small fraction of the PCDD/PCDF discharged and 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.

3.5.2 PCB

Other than the PCDD/PCDF flow the overall PCB mass flow is still clearly dominated by remaining stocks from former production, which step by step have to be destroyed and so eliminated from the environment.

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.

Figures for PCB represent total PCB⁷ numbers. For large PCB containing equipment the figures have been calculated as pure PCB contained in the liquids.

⁷ Sum 6 congener multiplied by 5

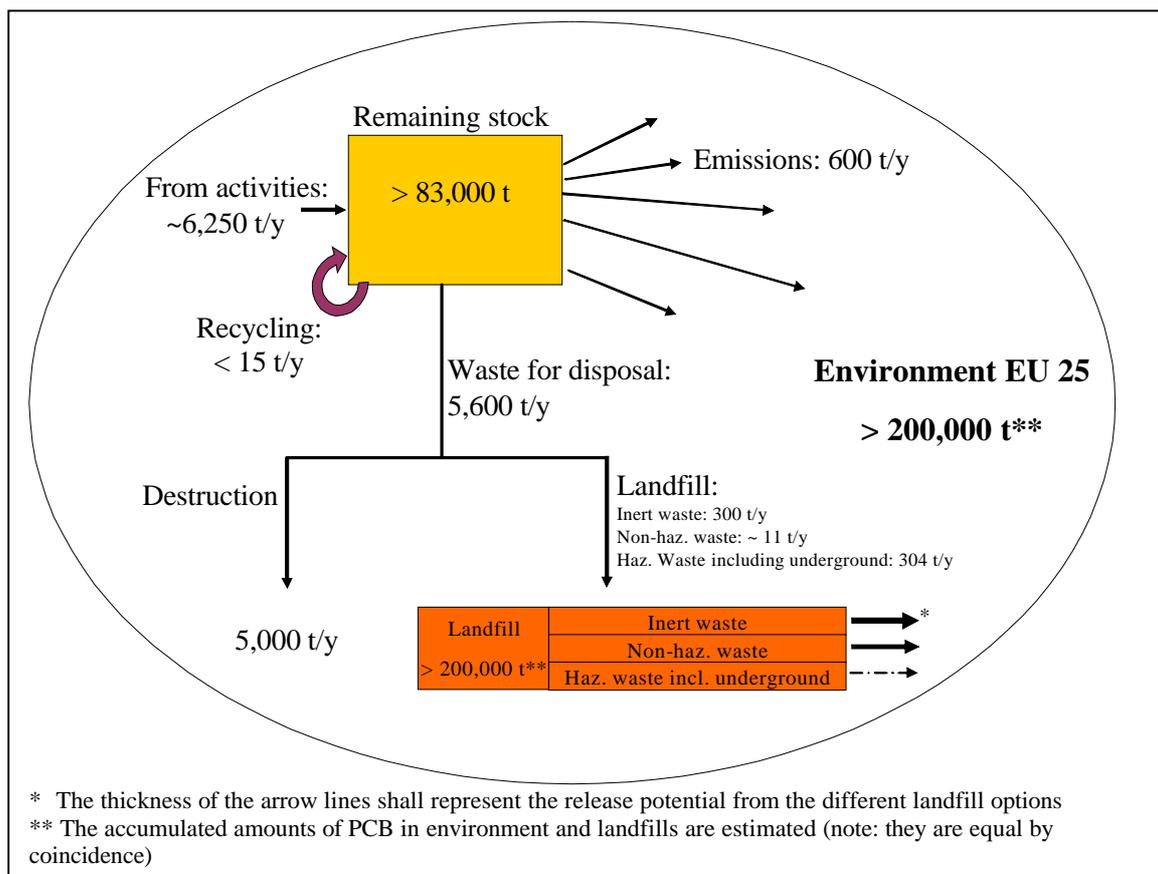


Figure 3-17: Major pathways and amounts of PCB distributed in EU

In relation to the remaining stocks recycling operations currently can not be regarded as of high importance as they account for only 0.2 ‰ of the total discharge, however they may get a higher importance when the stocks will be eliminated and they have a higher 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, so that there will be no additional benefit from the POP regulation. However the about 10% of annual PCB discharge directed to landfill via C&D waste could 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 take 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 – and 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 be increasingly be destroyed.

Contrary to the situation for PCDD/PCDF the overall flow of PCB is highly dominated by sectors already subject to regulation. The situation however may be different in Member States where large PCB containing equipment has already been decontaminated and 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.

3.5.3 POP Pesticides

As before, the judgement on the effectiveness of legislation depends on the relations between pollutant streams affected by the proposed limit values and those unaltered. The results of a rough evaluation of the mass flow in view of points of control and of existing environmental burdens are depicted in the figure below.

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 literature data [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 for "other POPs".

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

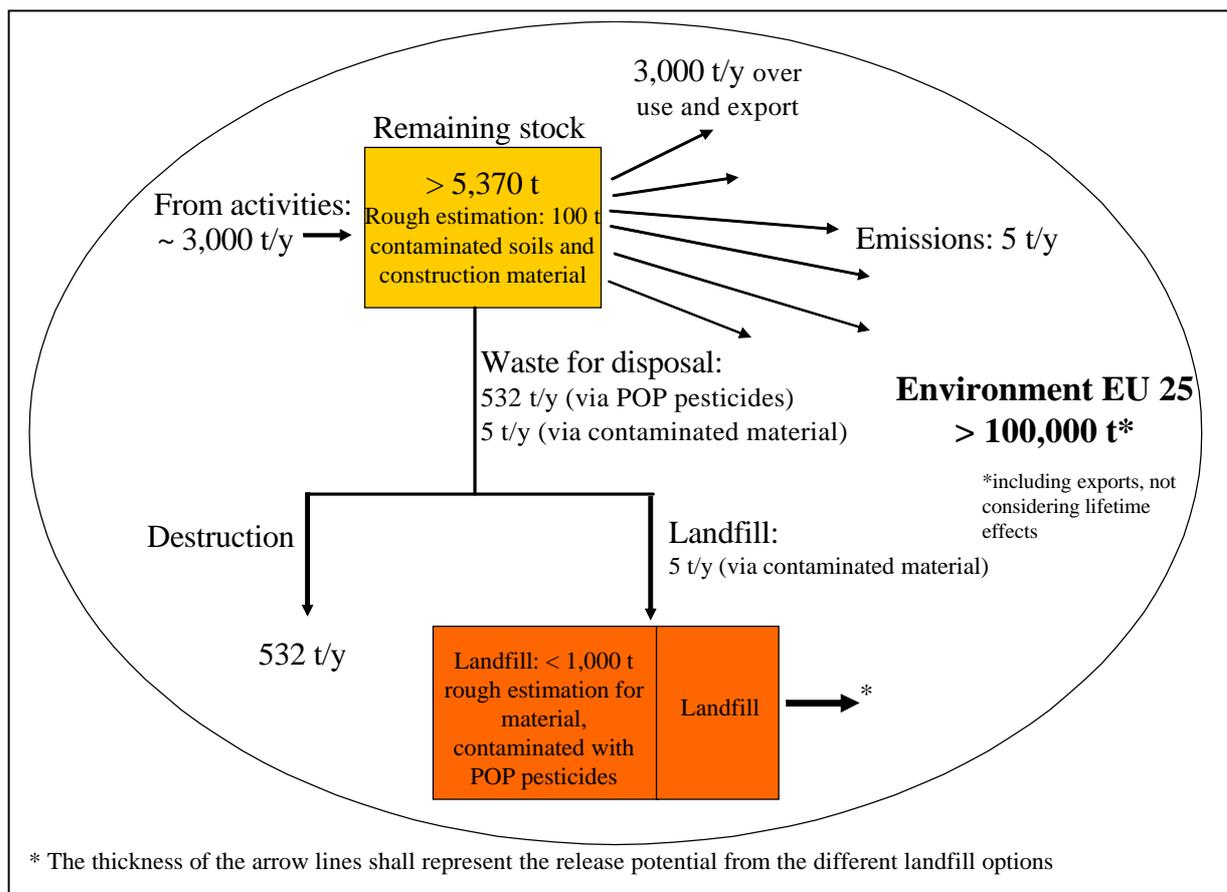


Figure 3-18: Major pathways and amounts of POP pesticides distributed in EU 25

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 Regulation⁸ 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 significant effects on both waste streams as levels can generally be assumed to lay above the low POP content limit.

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

3.5.4 Other POPs

As the mass flows for PCB and POP pesticides the reduction of remaining stocks play 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 literature data [COWI 2002, 6th Pesticides Forum, UNEP Mediterranean Regional report].

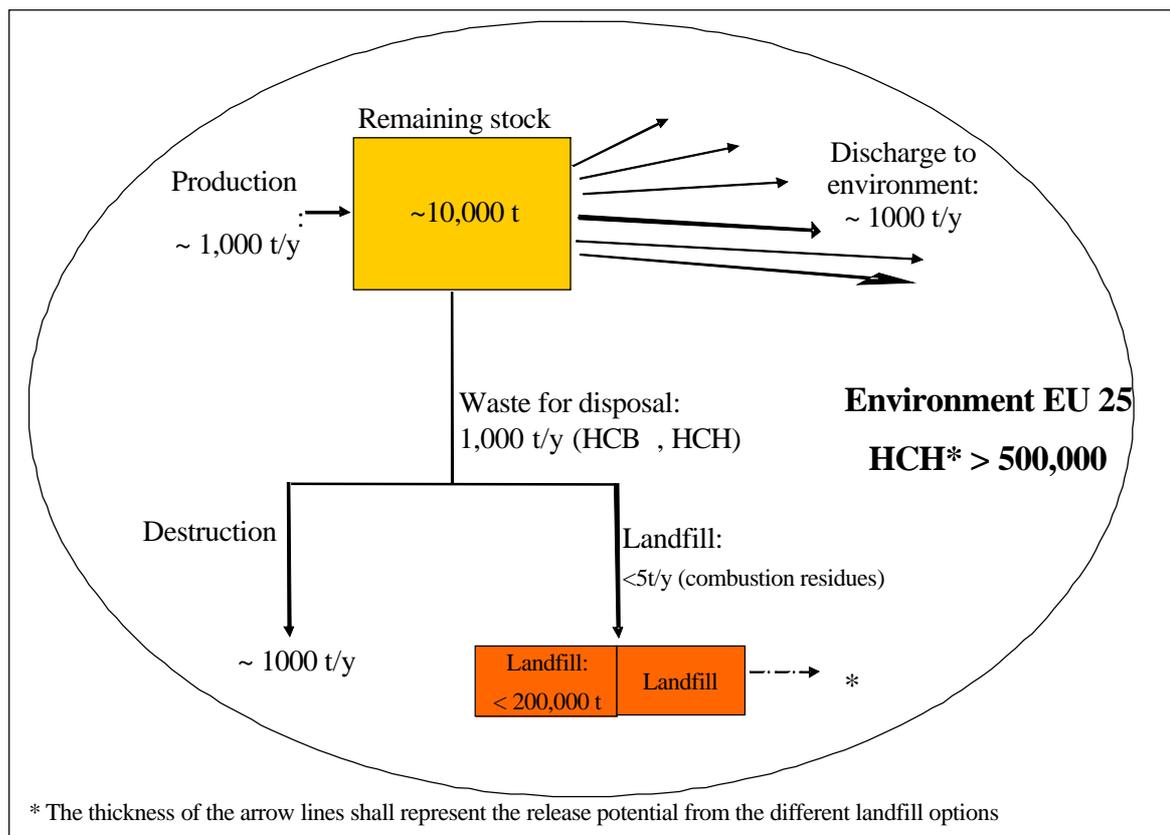


Figure 3-19: Major pathways and amounts of other POPs distributed in EU 25; HCH figures are sum figures for $\alpha, \beta, \gamma, \delta$ -isomers.

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.

3.6 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 (see chapter 3.2.)

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 3-11: Considerations on the eco-relevance of relevant waste treatment options

3.6.1 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 3-9), 532 t POP pesticides (see

Figure 3-14) and ~1,000 t other POPs (see Figure 3-15). 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.

3.6.2 *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 3-6) and 300 t PCB (see Table 3-9). 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.

3.6.3 *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 3-6). Additionally, about 5 tons of PCB (see Table 3-9) 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 3-6), 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 all⁹.

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.

3.6.4 *Landfills for inert waste*

Landfills for construction and demolition waste are relevant for yearly amounts of 273 g TEQ PCDD/PCDF (see Table 3-6) and 300 tons of PCB contained in construction and demolition waste (Table 3-9). 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.

⁹ BREF document on waste incineration

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 (see chapter 4.2.2).

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 Germany¹⁰, 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.

3.6.5 *Recycling / Recovery*

Recycling and recovery operations are relevant for yearly amounts of about 3.5 kg TEQ PCDD/PCDF (see Table 3-6), 13 t PCB (see Table 3-9) 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 amount of PCDD/PCDF.

¹⁰ Kreislaufwirtschafts- /Abfallgesetz

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. (For details see chapter 4.1.6 ff.)

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%)¹¹.

¹¹ BREF waste incineration

In the Netherlands and Belgium also fly ashes are currently recycled and recovered in the asphalt production in order to save the limited national resources of lime which would be needed as filling material in asphalt instead of the ashes. (For details see 4.1.1 f)

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 3-12 Treatment options for residues from 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. For details see chapter 4.1.4.

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 and Austria have set up stricter national rules for substance recovery in order to enhance to elimination of PCB from the environment. (For limit values see chapter 6.2.2.1.)

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. Further results are discussed in chapter 4.1.11.

3.6.6 *Temporary Storage*

Storage is relevant for yearly amounts of 92 g TEQ PCDD/PCDF (see Table 3-6). 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.

3.7 **Sectors not covered**

3.7.1 *Waste and product streams not covered by the PCDD/PCDF mass flow*

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.

These sectors comprise the following:

- pulp and paper
- leather, textile
- lead, precious metals, magnesium
- cement
- contaminated wood
- crematoria

Pulp and paper

Up to the beginning of the nineties the pulp and paper industry was an important sector for PCDD/PCDF emissions to water and caused heavy pollution of the aquatic environment. Emissions were mainly due to the use of chlorine bleaching causing high contamination levels in waste water and bleaching sludges. De-inking sludges were another source of PCDD/PCDF and HCB due to the use of these substances in the dyes and inks.

Meanwhile most pulp mills have changed the bleaching technology and stopped the use of molecular chlorine in favour of ECF and TCF techniques. With the new techniques the formation of PCDD/PCDF is considered to have virtually ceased [UNEP BAT-BEP 2004].

Furthermore the share of residues disposed of in landfills has constantly decreased in recent years. According to information from the European recovered pulp and paper association CEPI in 2002 only 20% of all residues were landfilled, while 50% were used for energy recovery on-site or in other industrial processes and 12% were used as soil improver and fertilisers in agricultural land.

As there has not been a systematic follow up of the PCDD/PCDF concentrations in sludges recent representative data are not available. However it is likely that new studies for the monitoring of POPs will be established in the Scandinavian countries, so that data will be available in the near future. A reassessment of the pulp and paper sector should then be taken into consideration.

Furthermore it has been reported [Baseline report TWG dioxin 2004] that some of the paper mills in the new Member States were still using chlorine bleaching, which would then be a source of PCDD/PCDF emissions. Unfortunately no data have been available on the situation following accession.

Leather and textiles

Leather and textiles have been reported to contain relatively high contamination levels of PCDD/PCDF in the past. These levels are most probably due to the use of biocides and chemicals for dyestuff not permitted anymore in the European Union, but may enter products via import of the material. According to a recent study [LFU 2003] textiles in municipal solid waste exhibit a PCDD/PCDF concentration around 0.01 ng I-TEQ/g (ppb) whereas other studies ([Abad 2000], [Abad 2002]) reported 0.16 ppb. For leather, cork and rubber, contaminations of about 0.09 ppb were measured in the German study [LFU 2003]. As in addition to low concentrations the contaminants are not found in production residues but in products which enter the MSW stream, the sector has not been further investigated.

Lead, precious metals, magnesium

Lead, primary aluminium, precious metal and magnesium production are thermal production processes which contain a certain risk for PCDD/PCDF formation in the flue gases, which could potentially lead to low contamination in the residues. However the processes are not regarded as important sources in the relevant BREF documents and in the UNEP Guidance document on BAT and BEP. Contamination data have neither been provided by the responsible industry associations, nor is information available from national authorities

Cement

proposal CEMBUREAU: Cement clinker production is a thermal process with the potential to form certain amounts of POPs (PCDD/PCDF) in the exhaust gases. However, this can be avoided by quick cooling of the exhaust gases, efficient dust filter equipment and maximum dust re-circulation into the thermal process.

In the rotary kiln and in the calcinatory POPs originating from the fuel are completely destroyed and there is no re-formation. Thus no chlororganic compounds are found in the clinker. However dust from the pre-heater may contain POPs. Most of this dust is recycled to the process however certain amounts have to be disposed of. According to the draft Stockholm BAT-BEP document [UNEP BAT-BEP 2004] reported concentrations in the dust range from 0.4-2.6 ppb.

Contaminated wood

Waste wood treated with PCP containing wood preservatives or painted with PCB based paints can form an important source for PCDD/PCDF emissions via evaporation from the product or as result of incineration processes. However contamination levels in investigated wood samples are not high. Contamination levels in untreated wood are at 0.0006 ppb whereas in waste wood levels up to 0.3 ppb can be reached [LFU 1998]. This however is so low that a further investigation of this sector has not been performed.

As waste wood is combustible, it is largely incinerated thus entering the mass flow of hazardous waste, MSW incineration and Biomass power production where the POPs can be captured and absorbed to the filter material.

Crematoria

As during other combustion processes PCDD/PCDF are newly formed in the off gases of crematoria. Relatively old data from some Member States indicate relatively high air emissions/Nm³, however due to a small capacity the overall emissions are not important (see Table 3-13).

<i>country</i>	<i>emission</i>	<i>reference</i>
<i>DE</i>	<i>8 ng TEQ/Nm³</i>	<i>[Dioxins 1997]</i>
<i>DK</i>	<i>0.16 g/y</i>	<i>[Dioxin and Furan Inventories 1999]</i>
<i>NL</i>	<i>1.6 to 3.3 ng I-TEQ/m³ corresponding to 0.2 g/y</i>	<i>[Dioxins 1997]</i>
<i>UK</i>	<i>61 ng I-TEQ/crematorium corresponding to 0.027 g/y</i>	<i>www.cheforhealth.org</i>

Table 3-13: PCDD/PCDF emissions into air from crematoria

According to COWI 2000, BAT/BEP a document about PCDD/PCDF [Dioxins 1997] there are 32 crematoria in Denmark which cremate about 40,000 bodies a year. In the Netherlands 43 crematoria exist, in which in 1991 about 60,000 bodies were cremated. From a study of two crematoria in 1994 it results that less than 0.02 g I-TEQ remain yearly in the residues of the cremations [Dioxins 1997]. Due to the small capacity of crematoria the output of PCDD/PCDF into air and residues is negligible.

3.7.2 Waste and product streams not covered by the PCB mass flow

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.

These sectors comprise the following:

- incineration and combustion processes
- municipal solid waste
- pulp and paper
- waste wood
- galvanic sludges

Incineration and combustion processes

During high temperature thermal processes not only PCDD/PCDF but also PCB and HCB may be formed by new formation. However the rate of reformation and the resulting amount of PCB and HCB in flue gas and solid residues is significantly less important than the amount of PCDD/PCDF. As up to date there is no reporting obligation on these substances, measurement data are rarely available. However some data have been reported for HWI and MSWI from EURITS and a German "Länder" database (see Table 3-14).

	sum 6 PCB (mg/kg)	total PCB (mg/kg)	Reference
bottom ash	0.05	0.25	Questionnaire NRW
bottom ash	0.02	0.10	Questionnaire NRW
bottom ash	0.045	0.23	[EURITS 2004]
mean for bottom ash:	0.04	0.19	
boiler ash	0.005	0.03	[EURITS 2004]
FGT	0.010	0.05	Questionnaire NRW
fly ash		0,0	[EURITS 2004]
mean for fly ash and FGT	0.02	0.1	

Table 3-14: contamination data for residues from hazardous waste incineration

Comparable ranges of contamination can be expected for other combustion/incineration processes.

As illustrated in Table 3-15 contamination levels of PCB in residues and emission factors are also low in domestic burning of coal and wood. Reported contaminations are even lower than the contamination in residues from hazardous waste incineration. Therefore they are not considered an important mass flow.

emissions	Burning of coal	Burning of wood and wood waste
PCB contamination in ash [mg/kg residue]:	0.008-0.025	0.01-0.02
PCB contamination in soot [mg/kg residue]:	0.04-0.055	0.03-0.11
PCB emission to air [m/kg input]:	0.001-0.005	0.008-0.016

Table 3-15: PCB contamination (sum 6 congeners x 5) in solid residues and emission factors for domestic burning (coal and wood) [Thanner 2002].

Based on these data a calculation for the dimension of the PCB mass flow from HWI can be performed as illustrated in Table 3-16 .

The resulting annual discharge of 175 kg total PCB /y from this sector are negligible in comparison to discharge from other sectors, so that it has not been further investigated.

country	hazardous waste incinerated (t/y)	PCB bottom ash (kg/y)	PCB boiler ash (kg/y)	PCB fly ash (kg/y)
AT	110,000	3.47	0.09	0.46
BE	135,000	4.25	0.11	0.57
CY	0	0.00	0.00	0.00
CZ	80,000	2.52	0.07	0.34
DE	850,000	26.78	0.70	3.59
DK	100,000	3.15	0.08	0.42
EE	10,267	0.32	0.01	0.04
ES	30,000	0.95	0.02	0.13
FI	100,000	3.15	0.08	0.42
FR	1,490,000	46.94	1.22	6.29
GR	77,000	2.43	0.06	0.33

country	hazardous waste incinerated (t/y)	PCB bottom ash (kg/y)	PCB boiler ash (kg/y)	PCB fly ash (kg/y)
HU	70,000	2.21	0.06	0.30
IE	30,000	0.95	0.02	0.13
IT	581,776	18.33	0.48	2.46
LT	41,905	1.32	0.03	0.18
LU	23,955	0.75	0.02	0.10
LV	7,033	0.22	0.01	0.03
MT	0	0.00	0.00	0.00
NL	310,000	9.77	0.25	1.31
PL	229,288	7.22	0.19	0.97
PT	153,999	4.85	0.13	0.65
SE	100,000	3.15	0.08	0.42
SI	4,278	0.13	0.00	0.02
SK	30,000	0.95	0.02	0.13
UK	240,000	7.56	0.20	1.01
EU-25	4,804,501	151.35	3.94	20.29
EU-15	4,331,730	136.46	3.55	18.29
EU-10	472,770	14.89	0.39	2.00

Table 3-16: PCB in residues from hazardous waste incineration

Provided comparable contamination levels do occur in all major combustion processes the overall mass flow from combustion residues would amount for 39 t/y (390 Mt of FGT residues x 0.1 ppm). This is less than 0.5 % of the current overall flow but will become more important when the large PCB containing equipment has been decontaminated and disposed of.

Municipal solid waste

PCB levels in municipal solid waste have been reported to account for 0.4 mg/kg ([LFU 2003], 5 x sum 6 congeners) and are thus in the range of contamination in sewage sludge (0.6 mg/kg) and compost (0.3 mg/kg) and far below the proposed low POP content limit. However as illustrated in Table 3-17 a yearly load of 87.7 tons is discharged via municipal solid waste due to the large amount of municipal solid waste produced annually in EU 25.

	amount of MSW (Mt/y)	contamination (mg/kg)	PCB (kg/y)
AT	1.3	0.4	506
BE	4.8	0.4	1,858
CY	0.5	0.4	206
CZ	4.2	0.4	1,608
DE	45.0	0.4	17,235
DK	3.1	0.4	1,195
EE	0.6	0.4	218
ES	17.0	0.4	6,511
FI	1.0	0.4	375
FR	48.0	0.4	18,576
GR	3.2	0.4	1,226
HU	5.0	0.4	1,915
IE	1.8	0.4	689
IT	25.4	0.4	9,728

	amount of MSW (Mt/y)	contamination (mg/kg)	PCB (kg/y)
LT	1.2	0.4	464
LU	0.3	0.4	115
LV	0.6	0.4	229
MT	0.22	0.4	84
NL	7.9	0.4	3,045
PL	12.3	0.4	4,717
PT	3.5	0.4	1,333
SE	4.2	0.4	1,598
SI	1.0	0.4	392
SK	3.7	0.4	1,425
UK	32.5	0.4	12,448
EU-25	229.0	0.4	87,695
EU-15	199.6	0.4	76,436
EU-10	29.4	0.4	11,968

Table 3-17: PCB contamination and amount in municipal solid waste

Using the average figures for incineration of MSWI of 14% (see chapter 4.1.1) and the contamination figures compiled in Table 3-16 about 2 tons total PCB/y would be discharged to solid FGT residues from MSWI, while 75.4 tons total PCB/y are directed to non-hazardous waste landfills or other treatment (e.g. MBT, composting, etc.).

Although this amount is not negligible in relation to shredder residues and waste oil it does only represent one per cent of the overall discharge of PCB to residues.

Pulp and paper

PCB contamination may occur in de-inking sludges from the pulp and paper industry mainly when waste paper is used as a secondary raw material. However contamination levels are low. Measurement data of < 0.5 mg/kg (Sum 7) or 0.09 - <0.3 mg/kg (Sum 6) have been reported for 1996 [UNEP draft 2001]. As more recent data shall be collected in follow-up studies in the Scandinavian countries in the near future, a re-evaluation may be interesting.

Waste wood

Waste wood treated with PCB based paints can form a source for PCDD/PCDF emissions as result of incineration processes, however only limited data are available. According to analysis data from Germany contamination levels with PCB in different waste wood fractions show average levels up to 2.5 ppm (Sum 6 congeners multiplied by 5) with peak concentrations of 5 ppm.

As waste wood is combustible it is largely incinerated thus entering the mass flow of hazardous waste, MSW incineration and biomass power production where the POPs is either destroyed or captured and absorbed to the filter material.

Galvanic sludges

Contamination data for galvanic sludges from surface treatment of metals and plastic have only been reported from Germany. However reported contamination levels with PCB are low with medians between 0.5 and 1.5 mg/kg total PCB (Sum 6 Congener x 5).

3.7.3 Waste and product streams not covered by the POP pesticide mass flow

Highly contaminated soils at historic production sites have not been assessed in the mass flow model because of high uncertainties with respect to concerned amounts. Based on limited information from Germany, Poland and Spain, contamination levels are in the range of several hundred mg/kg and thus high above the low POP content limit.

3.7.4 Waste and product streams not covered by the mass flow for other POPs

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.

These sectors comprise the following:

- contaminated soils
- combustion/incineration processes
- chemical production and use of pesticides
- shredder residues
- waste wood

Contaminated soils

Contaminated soils at historic production sites have not been assessed in the mass flow model because of high uncertainties with respect to concerned amounts. Based on limited information from Germany (Länder reporting) and Spain [6th Pesticide Forum] contamination levels are in the range of several hundred mg/kg and thus high above the low POP content limit.

Combustion/incineration processes

During high temperature thermal processes not only PCDD/PCDF but also PCB and HCB may be formed by several re-formation mechanisms. However the rate of reformation and the resulting amount of PCB and HCB in flue gas and solid residues is significantly less important than the amount of PCDD/PCDF. As up to date there is no reporting obligation on these substances in general measurement data are rarely available. According to EURITS [EURITS 2004] the concentration of HCB in residues (fly ash) of hazardous waste incineration is

between 0.02 and 0.06 mg/kg. With the average contamination data of 0.04 mg/kg an annual discharge of about 4 t HCB results from all high volume combustion sources (MSWI, HWI, PP biomass, PP coal, EAF filter dusts, domestic burning). In comparison with the total discharge to waste, this amount is less than 1 %.

Chemical and metallurgical production and use of pesticides

HCB occurs in the production process of chlorinated solvents. However the present day manufacture of chlorinated solvents only gives rise to very small quantities of HCB, which are treated as hazardous wastes by incineration in dedicated HWI on-site, so that no extra mass flow has to be drawn up.

HCB emissions may occur during electrolytic aluminium production and as by-product of the use of hexachloroethane as a degassing agent prior to aluminium casting as well as during production of magnesium especially if graphite anodes are used, however information from scarce data shows relatively low contamination levels. According to the latest UNEP draft guideline on BAT and BEP [UNEP2004] emission factors to land of <0.12 mg/kg have been reported for a European plant and even highest emission factors derived from measurements in a Canadian asbestos factory in the middle of the nineties are still < 3 mg/kg. Thus the process has not been further investigated.

Another sources of HCB emissions is the use of pesticides containing HCB as an impurity in concentrations below 0.05% (50ppm). As this flow is not related to the waste regime it is not further investigated.

Shredder residues

Due to the production and use of HxBB as a flame retardant up to the eighties in the USA. Thermoplastics in cars and electronic articles might in single cases be still contaminated which might lead to contamination of shredder residues. However this will probably not lead to any measurable contamination. Measurement data for HxBB have not been available.

Waste wood

Wood used in outdoor applications (e.g. railway sleepers) has largely been treated with Lindane (still permitted by Community legislation until 2006) in order to protect it against fungal destruction. This wood may present a source for Lindane emissions/discharge, although it is not expected to be of high importance compared to other sectors investigated in the mass flow. Contamination levels have only been reported from Germany, showing median contamination levels of 550 mg/kg (ppm) for railway sleepers and median contamination levels of 22 mg/kg in other waste wood fractions (mainly 170204*) classified as hazardous. As these wastes already have to be disposed of as hazardous waste mainly by incineration no separate waste flow has been established for this sector.

3.8 Assessment of uncertainty

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 chapter 2 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.

According to the availability of information, activity data are based on recent years. Most activity data represent the year 2001 or one of the following years. In most cases activity data are available at a country specific level. In several cases missing activity data for individual countries have been extrapolated (e.g. by means of an average generation factor per capita). E.g. the amount of compost generation has been identified for 13 countries (AT, BE, DE, DK, ES, FI, FR, IT, LU, NL, PT, SE and UK). The values for the other countries have been extrapolated on the basis of the average generation factor per capita determined in the countries with known compost generation. Generally the applied calculation system often enables to extrapolate data in those fields where no data are available.

Contamination levels are based on available information from analytical results. Where possible recent results have been used. The contamination levels should thus represent a good estimate of the actual situation having in mind that the contamination of outputs often depends on applied processes and technologies. In some cases the data background enables to apply country specific average contamination levels. Contamination levels often vary considerably according to the application of different processes and technologies. In reality contamination levels often show wide ranges. Frequently they are reported in different

ways and the way of reporting does not always enable to derive specific mean or median values or a specific range. The calculated figures shall represent the best estimate based on given or estimated averages. Therefore it has to be kept in mind that the estimated POP mass flows are related to a certain, more or less wide range (see Figure 3-20).

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.

The activity data, generation factors and contamination levels were correlated in calculation models. An MS-Excel calculation scheme allows to adjust the mass flows if new or improved data will become available. All applied activity data, contamination levels and generation factors are documented in the annex. Detailed information concerning specific mass flows is contained in chapter 4.

A compilation of estimated average contamination levels and corresponding ranges for the investigated mass flows is given for PCDD/PCDF and PCB in the figures below. Ranges represent process and infeed related variations as well as inter-country variations.

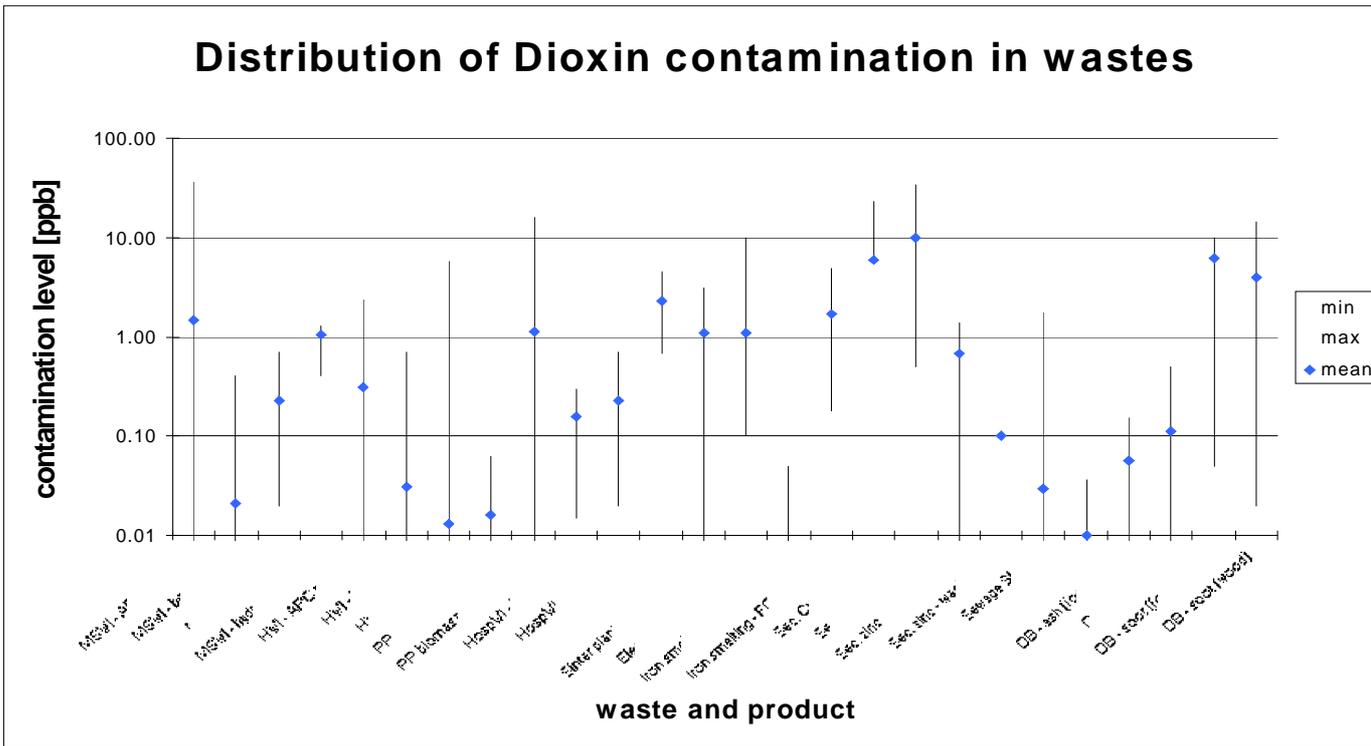


Figure 3-20: Distribution of PCDD/PCDF contamination in waste and products

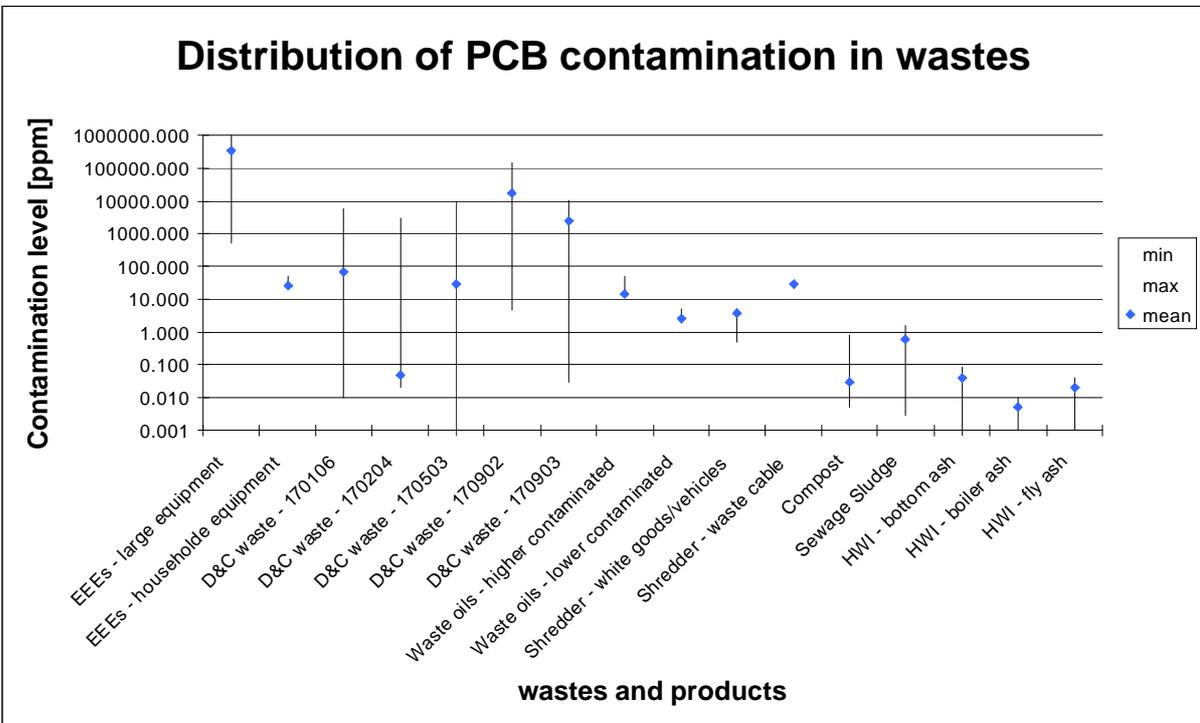


Figure 3-21: Distribution of PCB contamination in waste and products

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 3-18: Assessment of the uncertainty related to the different POP flows

4 Detailed mass flow analyses

The mass flows in this chapter follow a standardised structure to produce comparable results. Results are calculated on the basis of activity data, generation factors for emissions and residues and average contamination figures. A compilation of activity data, waste generation factors, air emissions and estimated contamination levels is given in the tables in Annex II.

4.1.1 *Municipal solid waste incineration*

(A) Background

The objective of waste incineration is to generate energy and to treat wastes so as to reduce their volume and hazard, whilst capturing (and thus concentrating) or destroying potentially harmful substances that may be released from incineration. Municipal solid waste as input material as well as residues resulting from the incineration process contain relevant amounts of PCDD/PCDF.

Operating conditions are laid down in Article 6 of the Waste Incineration Directive¹². The relevant processes and technical aspects in waste incineration are described in detail in the corresponding BAT reference document [WI BREF 2004]:

Basically, incineration is the chemical reaction (oxidation) of a combustible material with oxygen. Waste is generally a highly heterogeneous material, consisting essentially of organic substances, minerals, metals and water. During incineration, flue-gases are created that will contain the majority of the available fuel energy as heat. The organic fuel substances in the waste will burn when they have reached the necessary ignition temperature and come into contact with oxygen. The actual combustion process takes place in the gas phase within fractions of seconds and simultaneously releases energy. If the calorific value of the waste and oxygen supply is sufficient, it can lead to a thermal chain reaction and self-supporting combustion, i.e. there is no need for the addition of other fuels.

The main stages of incineration are:

1. drying and degassing – here, volatile content is evolved (e.g. hydrocarbons and water) at temperatures generally between 100 and 300 °C. The drying and degassing process does not require any oxidising agent and only depend on the supplied heat
2. pyrolysis and gasification – pyrolysis is the further decomposition of organic substances in the absence of an oxidising agent at approx. 400 – 700 °C. Gasification of the carbonaceous residues is the reaction of the residues with water vapour and CO₂ at temperatures, typically between 700 and 1000 °C, but can occur at even higher temperatures. Thus, solid organic matter is transferred to the gaseous phase. In addition to the temperature, water and steam support this reaction

¹² DIRECTIVE 2000/76/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 December 2000 on the incineration of waste

3. oxidation - the combustible gases created in the previous stages are oxidised, depending on the selected incineration method, at flue-gas temperatures generally between 850 and 1150 °C according to the Waste Incineration Directive.

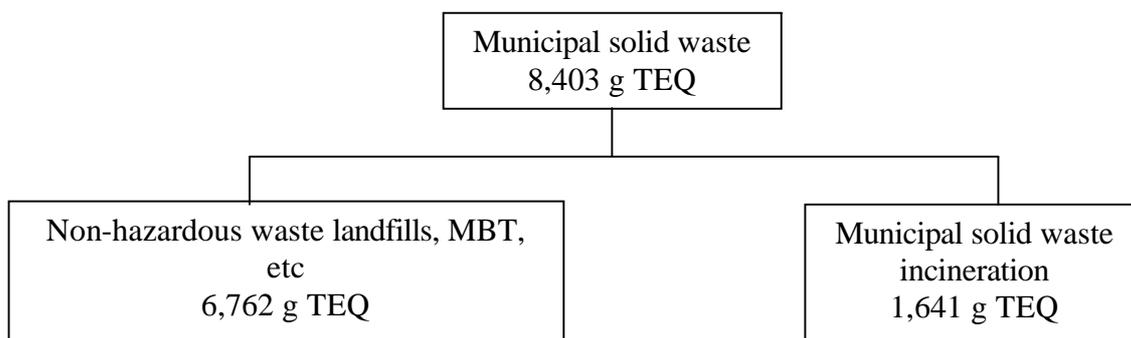
These individual stages generally overlap, meaning that spatial and temporal separation of these stages during waste incineration may only be possible to a limited extent. Indeed the processes partly occur in parallel and influence each other. It is possible, using in-furnace technical measures, to influence these processes so as to minimise polluting emissions.

Such measures include furnace design, air distribution and process control. With municipal solid waste incineration the main constituents of the flue-gas are: water vapour, nitrogen, carbon dioxide and oxygen. Depending on the composition of the material incinerated and on the operating conditions, small amounts of heavy metal compounds remain (among others) and CO, HCl, HF, NO_x, SO₂, VOCs, PCDD/PCDF and PCB are formed in off gases.

With appropriate combustion conditions organic compounds are almost completely destroyed during incineration, volatile heavy metals and inorganic compounds (e.g. salts) are totally or partly evaporated. These substances are transferred from the input waste to the flue-gas and are adsorbed to the fly ash it contains.

It has to be noted that municipal solid waste in Europe is either treated by municipal solid waste incineration or sent to other management options such as non-hazardous waste landfills, MBT or composting. Based on average figures for production of municipal solid waste (229 Mt/y) and an average contamination level of MSW of 0.037 ng PCDD/PCDF I-TEQ/g waste (average from several sources) the PCDD/PCDF input via waste accounts for roughly 8.4 kg TEQ/y.

Based on the average of waste incineration in EU 25 the following average flow for municipal solid waste has been calculated for EU 25:



Approximately 20% of the PCDD/PCDF in municipal waste are incinerated and about 80% are landfilled.

In the following, only the path to the municipal solid waste incineration is investigated.

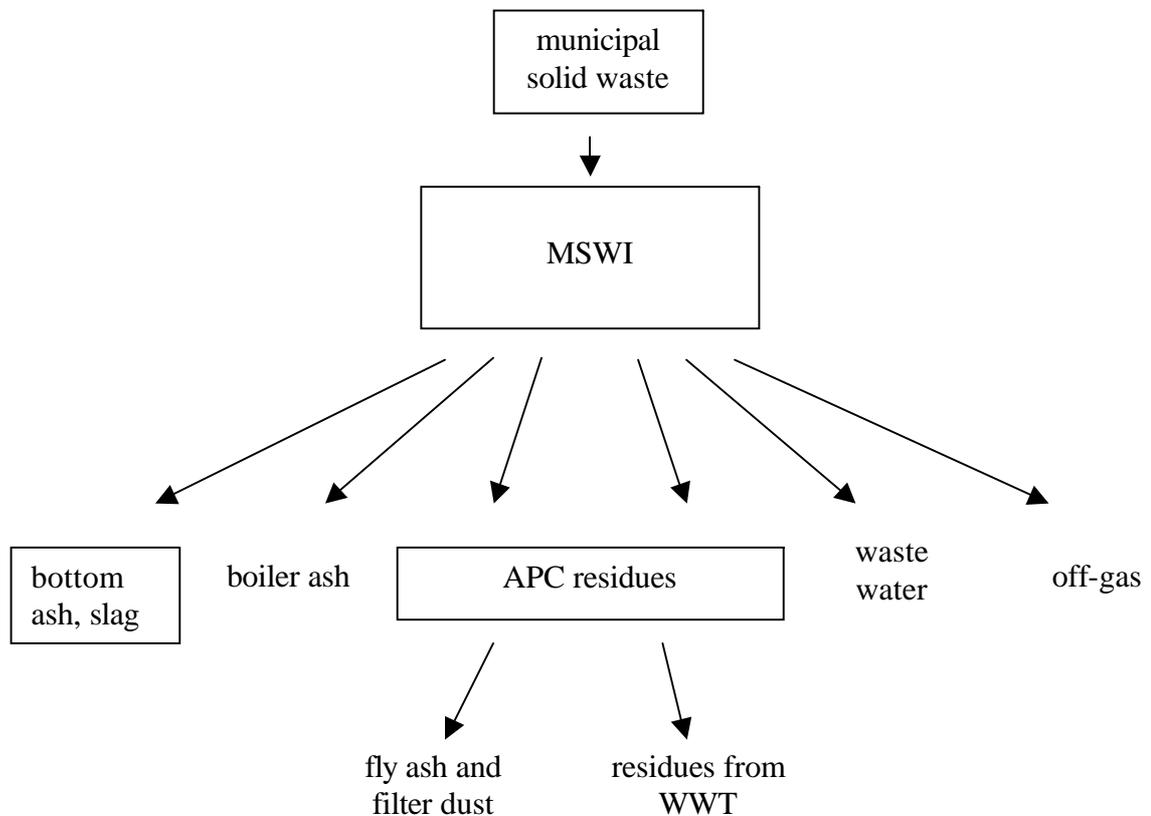
(B) Process input and output

Figure 4-1: Relevant input and output from municipal solid waste incineration

Input:

- Municipal solid waste. The precise determination of the composition of MSW for incineration is difficult. The composition of municipal waste is treated in sections 1.5 and 2.2.1 of the BAT reference document [WI BREF 2004].

Output:

- Bottom ash or slag (EWC 190111*, 190112) is a solid mineral residue that remains from the incineration process. It results from grate incineration of waste. Because of its large volume, this is an important type of residue
- Boiler ash (EWC 190115*, 190116) is collected in the boiler of waste incineration plants
- Fly ash (EWC 190113*, 190114) or dust and additives is a fraction of solid mineral residue (APC residues; EWC 190107*) that remains from the incineration and that ends up in solid residues from dust removal including solid additives such as lime and activated-carbon.

- Residues from flue gas treatment (FGT) also contain fly ash and therefore, also contain PCDD/PCDF. Residues from FGT are a mixture of calcium and/or sodium salts, mainly chlorides and sulphites/sulphates. There are also some fluorides and non-reacted reagent chemicals (e.g. lime or sodium carbonate). Residues from FGT also include filter cakes¹³ (EWC 190105*) from the physico-chemical treatment of waste water from wet flue-gas treatment. This material is characterised by a very high heavy metals content, but can also include insoluble salts and gypsum. These residues may contain PCCD/F and are therefore sometimes pre-treated before landfilling.
- Treated waste water contains no or very low concentrations of PCDD/PCDF
- Treated off-gas still contains traces of PCDD/PCDF

In practice boiler ash and APC residues from FGT are often mixed together and disposed of as one waste stream. In the PCDD/PCDF flow the fly ash and residues from FGT are assessed as one material flow because in literature, residues from dust removal steps and specific fractions of residues from FGT can not always be differentiated unambiguously. Both potentially contain PCDD/PCDF and are relevant with respect to the PCDD/PCDF flow.

(C) Generation factors for relevant waste and other output (air, water)

The proportions of solid residue vary greatly with the waste type and detailed process design. The following figures indicate typical amounts reported for outputs related to the incineration of 1 tonne of municipal solid waste:

Bottom ash 233 kg/t MW (range from 185 to 275)

Boiler ash 3 kg/t MW (range from 2 to 4)

APC residues: 38 kg/t MW (range from 10 to 80)

a) Fly ash and filter dust

The most relevant fraction of APC residues are fly ashes and filter dusts. According to the BREF on waste incineration amounts of dust from boiler and de-dusting range from 20 to 40 kg/t MSW. Taking into account that thereof approximately 3 kg are boiler ash, an average of approximately 27 kg can be assumed. According to other information fly ash amounts range from 15 to 20 kg/t.

→ Based on these values an estimated average of 22.5 kg fly ash has been used for the calculation of the PCDD/PCDF flow within fly ashes and filter dust.

b) Hydroxide sludge

The remaining fractions of APC residues amount to approximately 15 kg/t MW. These remaining APC fractions among others contain

¹³ In literature the term "filter cake" is used as well for filter cakes from dust removal via fabric filter as well for filter cakes from wet FGT systems.

hydroxide sludge which amounts to approximately 3 kg/t MSW.
→ This figure has been taken as a basis for calculation of the PCDD/PCDF mass flow.

Off gas The average exhaust air volume per tonne incinerated waste is approximately 6,000 Nm³/t MSW

(D) Contamination data

Municipal solid waste Due to the heterogeneous composition of municipal solid waste it is difficult to estimate an average contamination. Reported values range from 0.002 to 0.255 ng TEQ/g. An estimated average contamination is 0.037 ng TEQ/g. It has to be kept in mind that values from more recent measurements (e.g. from Abad et al., 2002 or LFU 2003) are in the lower range of reported values (usually below 10 ng TEQ/g), whereas measurements from the 1980ies showed values around 0.050 to 0.060 ng TEQ/g (see LFU 2003). Since then the components of municipal solid waste have changed and the contamination level of 0.037 used for the PCDD/PCDF flow assessment may therefore be overestimated with respect to the actual contamination of municipal solid waste. In addition other precursors e.g. 16 t of PCB enter the process via MSW.

Bottom ash Reported values range from 0.0006 to 0.4 ng TEQ/g. The PCDD/PCDF flow is calculated on the basis of an estimated average of 0.021 ng TEQ/g.

Boiler ash Reported values range from 0.02 to 0.7 ng TEQ/g. The PCDD/PCDF flow is calculated on the basis of an estimated average of 0.23 ng TEQ/g.

APC residues: Documentation and reporting on fly ashes and other APC residues is not consistent throughout the countries. While in some cases fly ashes are reported separately, the mixed fraction of APC residues (fly ash, additives) is measured in others. Thus reported contamination data can not be compared directly in all cases.

According to information from CEWEP extended investigations on contamination levels have been conducted in Sweden and Germany resulting in median contamination levels of 0.7 ng TEQ/g in both countries for the whole fraction of APC residues (which amount to ~38 kg/t MSW). Average contamination levels of 0.7 ng TEQ/g

are generally achievable in MSWI installations applying BAT.

For the calculation of the PCDD/PCDF flow a differentiation between "fly ashes and filter dust" (~ 22.5 kg/t MSW) and hydroxide sludge as relevant contaminated fractions of the remaining APC residues (~ 3 kg/t MSW) has been made:

a) Fly ash and filter dust:

It is difficult to clearly separate reported values for APC residues as a whole and for fly ashes and filter dusts. The range of reported values indicate that reported values are related to fly ashes and filter dusts.

The values reported for APC as a whole and for fly ashes and filter dusts range from 0.0008 to 35 ng TEQ/g.

Reported values for filter cakes range from 0.0013 to 66 ng TEQ/g with an estimated average of 9.33.

The PCDD/PCDF flow is calculated with an estimated average of 1.46 ng TEQ/g which is based on reported values for fly ash and filter dust and APC residues.

b) Hydroxide sludge

Contamination levels of hydroxide sludge range from 0,409 o 1,304 ng TEQ/g d.w.

The PCDD/PCDF flow is calculated with an average of 1.062 ng TEQ/g d.w.

Off gas

Measured contamination levels range from 0.0002 to 0.1 ng TEQ/Nm³. The PCDD/PCDF flow is calculated on the basis of an average contamination of 0.08 ng TEQ/Nm³ [BREF WI 2004].

(E) Activity data

Data on municipal solid waste are mainly derived from European statistics. Data for new Member States are either derived from national inventories, answers to questionnaires or from the report on PCDD/PCDF emissions in Candidate Countries [TNO 2005].

It has to be taken into account that the reporting is not always consistent, so that reported amounts may be either household waste only, while in a few cases residues from the commercial sector incinerated in MSWI may be included. The following table shows amounts of municipal solid waste incinerated in Europe according to different sources:

country	MSW [mio t]	amount of MSW incinerated [mio t]	reference year	reference for amount of MSW incinerated
AT	1.32	0.46	1999	[BREF waste incineration]
BE	4.85	1.70	1997	[BREF waste incineration]
CY	0.54	0.00		[TNO 2005]
CZ	4.20	0.37		[TNO 2005]
DE	45.00	13.05	2000	[BREF waste incineration]
DK	3.12	3.29	2003	Questionnaire DK
EE	0.57	0.00		[TNO 2005]
ES	17.00	0.10	1997	[BREF waste incineration]
FI	0.98	0.02	1997	[BREF waste incineration]
FR	48.50	12.61	2000	[BREF waste incineration]
GR	3.20	0.00	1993	[BREF waste incineration]
HU	5.00	0.35	2000	Questionnaire HU
IE	1.80	0.00	1999	[BREF waste incineration]
IT	25.40	2.03	1995	[BREF waste incineration]
LT	1.21	0.00		[TNO 2005]
LU	0.30	0.14	1995	[BREF waste incineration]
LV	0.60	0.00		[TNO 2005]
MT	0.22	0.00		[TNO 2005]
NL	7.95	4.93	1997	[BREF waste incineration]
PL	12.32	0.00		[TNO 2005]
PT	3.48	0.87	1999	[BREF waste incineration]
SE	4.17	1.68	2002	[CEWEP country report Sweden, September 2004]
SI	1.02	0.00		[TNO 2005]
SK	3.72	0.18	2003	[COHEM 2003]
UK	32.50	2.93		[ISWA, international waste information]
EU-25	228.97	44.70		
EU-15	199.57	43.80		
EU-10	29.40	0.90		

Table 4-1: Quantities of MSW and amounts of MSW incinerated in EU 25

(F) Waste treatment

The high mineral content of incineration ash residues can make them suitable for use as road or other construction material. Use is possible if the material complies with a set of environmental and technical criteria.

This requires an optimisation of the ash quality through primary (e.g. optimised combustion process) or secondary measures. Due to its large production volume, treatment for recycling is mainly applied to MSW bottom ash. Bottom ash use is promoted in the Netherlands (>90% used), Denmark (90%), Germany (80%), France (>70%). Recovery of bottom ash in Belgium and the UK is 21% (Source WI BREF 2004: [Vehlow, 2002], [Vrancken, 2001], [56, UK Environmental Agency, 2002], [64, TWG Comments, 2003]).

Based on these figures it is assumed that more than 50% of bottom ash is used for construction. The remainder is usually directly land filled or land filled after certain treatment.

Bottom ash is not mixed with APC residues and is used as secondary raw material in a number of processes.

Filter and boiler ash treatment is performed in only a few installations in Europe.

According to the BAT reference document on waste incineration [WI BREF 2004], the following measures are available for pre-treatment improving waste characteristics prior to disposal or recovery:

- solidification
- thermal treatment (vitrification, melting, sintering)
- extraction and separation
- chemical stabilisation
- other methods

The treatment shall improve the leaching properties or reduce the contamination level in the residues. After pre-treatment the residues are normally disposed of at landfills for hazardous waste or are stored underground.

The most important pre-treatment method for wastes intended for landfilling is solidification. Solidification can principally be achieved by addition of several, mostly inorganic, binder reagents (cement, lime and other pozzolanic materials such as fly ash from coal fired power plants, blast furnace bottom ash or cement kiln dust) or organic binders such as bitumen/asphalt, paraffin and polyethylene. However immobilisation in cement blocks is the prevalent technique.

No information is available concerning the relevance of the other different treatment options. It can be expected that the bulk of the PCDD/PCDF contained in the FGT residues is finally landfilled as hazardous waste or stored underground.

In the Netherlands about 36% of fly ash is recovered in asphalt production. In Latvia residues from waste incineration are temporarily stored until an appropriate landfill will be completed in 2007.

(G) PCDD/PCDF flow

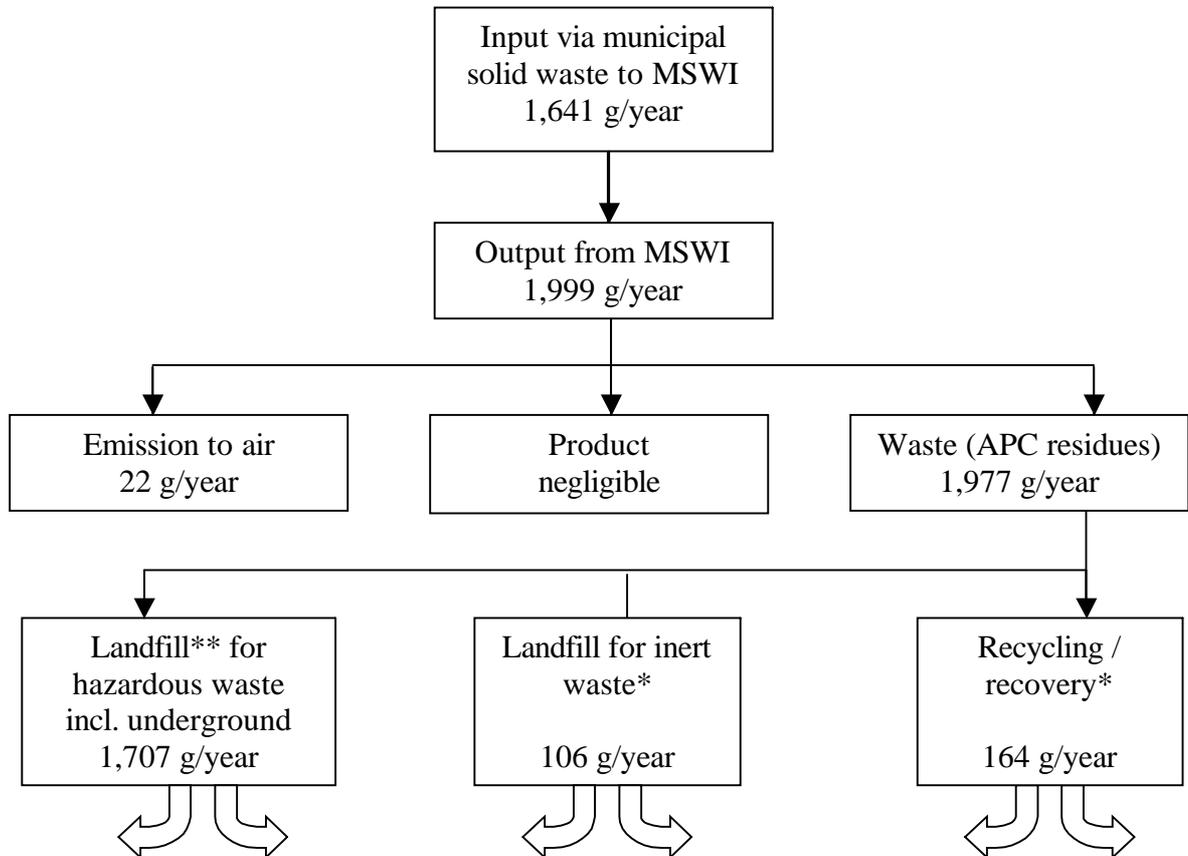
The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and discharge to waste via exhaust air and solid residues resulting from MSWI. The following table shows a country specific estimation on emitted amounts:

country	amount of MSW incinerated [mio t]	air [g TEQ/y]	bottom ash [g TEQ/y]	boiler ash [g TEQ/y]	fly ash and filter dust [g TEQ/y]	hydroxide sludge [g TEQ/y]	total to waste [g TEQ/y]
AT	0.5	0.2	2.2	0.3	15.1	1.6	19.2
BE	1.7	0.8	8.2	1.2	55.3	5.8	70.5
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CZ	0.4	0.2	1.8	0.3	12.1	1.3	15.5
DE	13.1	6.3	62.8	8.8	425.2	44.3	541.1
DK	3.3	1.6	13.3	7.7	79.3	57.5	157.8
EE	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ES	0.1	0.0	0.5	0.1	3.3	0.3	4.2
FI	0.02	0.0	0.1	0.0	0.6	0.1	0.8
FR	12.6	6.1	60.7	8.5	410.9	42.9	523.0
GR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.4	0.2	1.7	0.2	11.4	1.2	14.5
IE	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IT	2.0	1.0	9.8	1.4	66.2	6.9	84.3
LT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LU	0.1	0.1	0.7	0.1	4.7	0.5	6.0
LV	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	4.9	2.4	23.7	3.3	160.6	16.8	204.4
PL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PT	0.9	0.4	4.2	0.6	28.3	3.0	36.1
SE	1.7	0.8	8.1	1.1	156.7	5.7	171.6
SI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SK	0.2	0.1	0.9	0.1	5.9	0.6	7.5
UK	2.9	1.4	14.1	2.0	95.3	9.9	121.3
EU-25	44.7	21.5	212.6	35.7	1,530.8	198.2	1,977.8
EU-15	43.8	21.0	208.3	35.1	1,501.5	195.2	1,940.3
EU-10	0.9	0.4	4.3	0.6	29.3	3.1	37.5

Table 4-2: PCDD/PCDF mass flow for MSWI in EU 25

At a European scale the estimated emissions amount to ~ 1,999 g TEQ/y. Thereof ~22 g are emitted to air and ~ 1,977 g are emitted to waste. This is related to an estimated input of ~ 1,641 g TEQ/y. The bulk of the PCDD/PCDF freight (~ 1,977 g) is concentrated in the waste fraction. Thereof approximately 1,700 g are disposed of in landfill for hazardous waste including underground disposal (see Figure 4-2) and has as a consequence no or low relevance for the ecosystem.

The following PCDD/PCDF flow results:



- * more than 50% of bottom ash is used for construction; 36% of Dutch fly ash is used in asphalt production
 ** prevalent treatment is solidification and subsequent landfill; other options are thermal treatment, chemical stabilisation, extraction and separation or other treatment including recovery in underground.

Figure 4-2: Assessment of the PCDD/PCDF flow related to municipal solid waste incineration

(H) MSWI waste flow

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

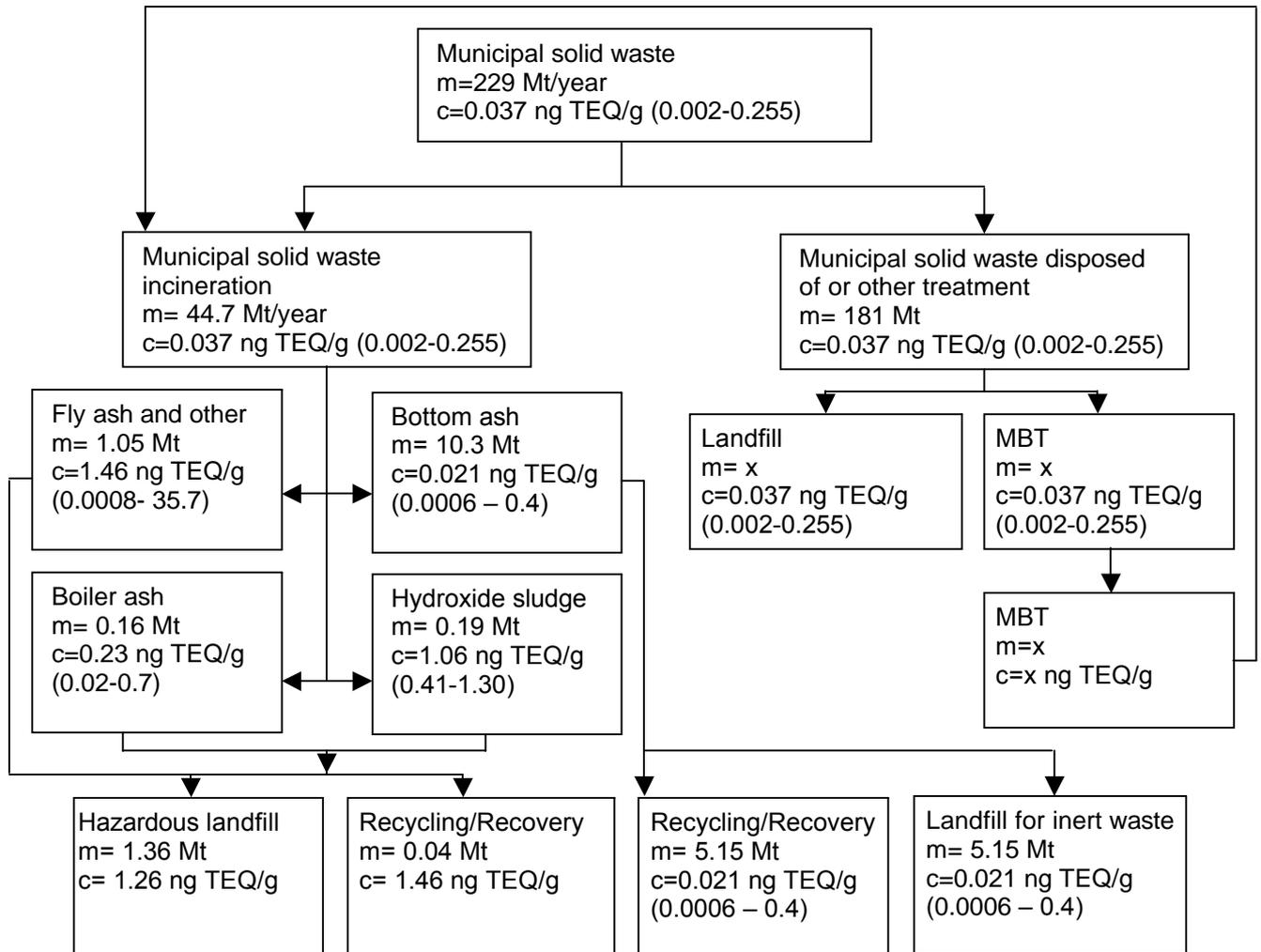


Figure 4-3: Detailed waste flow for MSWI in EU 25

The relevant data and their origin are listed in tables 1.1.1 - 1.1.5 in the Annex.

4.1.2 Hazardous waste incineration

(A) Background

In contrast to Municipal solid waste incineration, hazardous waste incineration is usually carried out in rotary kiln incinerators or in static furnaces. The relevant processes and aspects of waste incineration are described in detail in the corresponding BAT reference document [WI BREF 2004].

(B) Process input and output

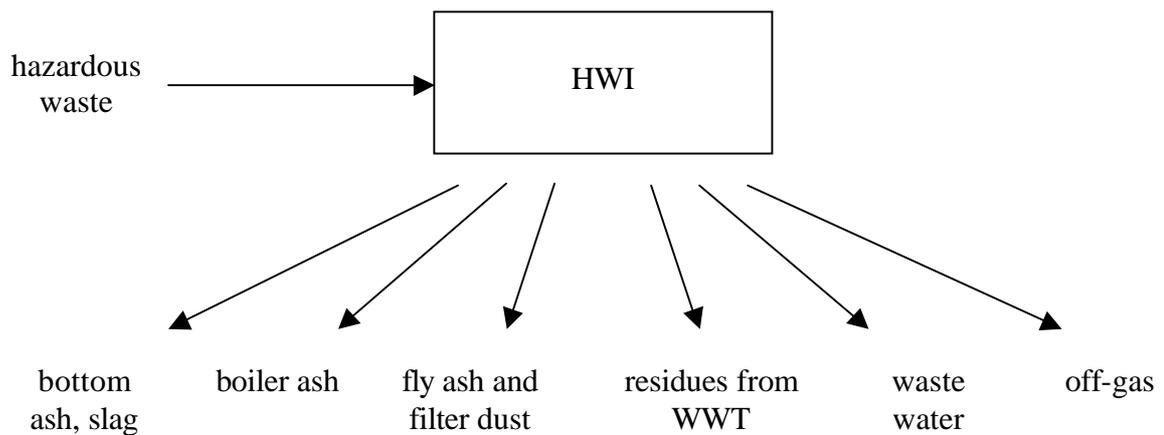


Figure 4-4: Relevant input and output of hazardous waste incineration

Input:

- Hazardous waste (estimated input 200 g/y)

Output:

The output from hazardous waste incineration is not fundamentally different from that from municipal solid waste incineration with generally higher content of heavy metals. The outputs are

Fly ash

- Bottom ash and slag 190111*, 190112
- Boiler ash 190115*, 190116
- Fly ash or dust and other residues from flue gas treatment (FGT) 190113*, 190114, 190107*

- Treated waste water
- Treated off-gas

(C) Generation factors for relevant waste and other output (air, water)

The proportions of solid residue vary greatly according to the waste type and detailed process design. According to information compiled in the BREF document on waste incineration or provided from EURITS the following figures indicate typical amounts reported for outputs related to the incineration of 1 tonne of hazardous waste:

Bottom ash	~ 140 kg/t HW (range from 83 to 246)
Boiler ash	~ 29 kg/t HW (range from 12 to 68)
Fly ash and residues from FGT:	~45 kg/t HW (range from 20 to 109)
Off gas	The assumed average exhaust air volume is approximately 6,000 Nm ³ /t HW (assumption analogue to MSWI)
Waste water	estimated average: 10000 l/t HW (range from 200 to 20000)

(D) Contamination data

Hazardous waste	Due to the heterogeneous composition of hazardous waste an average contamination is not assumed. Reported values range from 0.01 to 10 ng TEQ/g.
Bottom ash	Reported values range from 0.0001 to 5.83 ng TEQ/g. The PCDD/PCDF flow is calculated on the basis of the 50% percentile of 0.013 ng TEQ/g.
Boiler ash	Reported values range from 0.003 to 0.7 ng TEQ/g. The PCDD/PCDF flow is calculated on the basis of the 50% percentile of 0.031 ng TEQ/g.
Fly ash and residues from FGT:	Reported values range from 0.0002 to 2.4 ng TEQ/g. The PCDD/PCDF flow is calculated on the basis of the 50% percentile of 0.312 ng TEQ/g.
Off gas	The PCDD/PCDF flow is calculated on the basis of an average contamination of 0.08 ng TEQ/Nm ³ .
Treated waste water	Reported values range from 0.0002 to 0.005 ng TEQ/g. The PCDD/PCDF flow is calculated on the basis of an estimated average of 0.025 ng TEQ/l.

(E) Activity data

The following table shows amounts of municipal solid waste incinerated in Europe according to different sources:

country	amount of hazardous waste incinerated [mio t]	reference year	reference
AT	0.11	1999	[BREF waste incineration]
BE	0.14	2001	[WMCN 2004]
CY	0.00	2000	
CZ	0.08	2003	[CHMI, 2003 emission inventory]
DE	0.85	2001	[WMCN 2004]
DK	0.10	1996	[BREF waste incineration]
EE	0.01	1999	[BREF waste incineration]
ES	0.03	1997	[BREF waste incineration]
FI	0.10	1997	[BREF waste incineration]
FR	1.49	2001	[WMCN 2004]
GR	0.08	1993	[BREF waste incineration]
HU	0.07	2000	Questionnaire. [2000 Emission inventory]
IE	0.03	1995	[BREF waste incineration]
IT	0.58	1995	[BREF waste incineration]
LT	0.04	1999	[BREF waste incineration]
LU	0.02	1995	[BREF waste incineration]
LV	0.01	1998	[BREF waste incineration]
MT	0.00		
NL	0.31	1997	[BREF waste incineration]
PL	0.23	1999	[BREF waste incineration]
PT	0.15	1996	[BREF waste incineration]
SE	0.10	1999	[BREF waste incineration]
SI	0.00	1995	[BREF waste incineration]
SK	0.03	2003	[COHEM 2003]
UK	0.24	2001	[ISWA international waste information]
EU-25	4.80		
EU-15	4.33		
EU-10	0.47		

Table 4-3: Amount of hazardous waste incinerated in EU 25

The German figure includes in-house plants of chemical industry.

(F) Waste treatment

Treatment and recycling of solid residues from HWI follows the same principles as treatment of residues from MSWI. More than 50% of bottom ash is used for construction purposes. Boiler ash and fly ash and other reaction products are usually mixed together and the bulk of these FGT residues is either directly landfilled or landfilled after further treatment. Slag is usually disposed of in landfills without further treatment or it is recycled.

(G) PCDD/PCDF flow

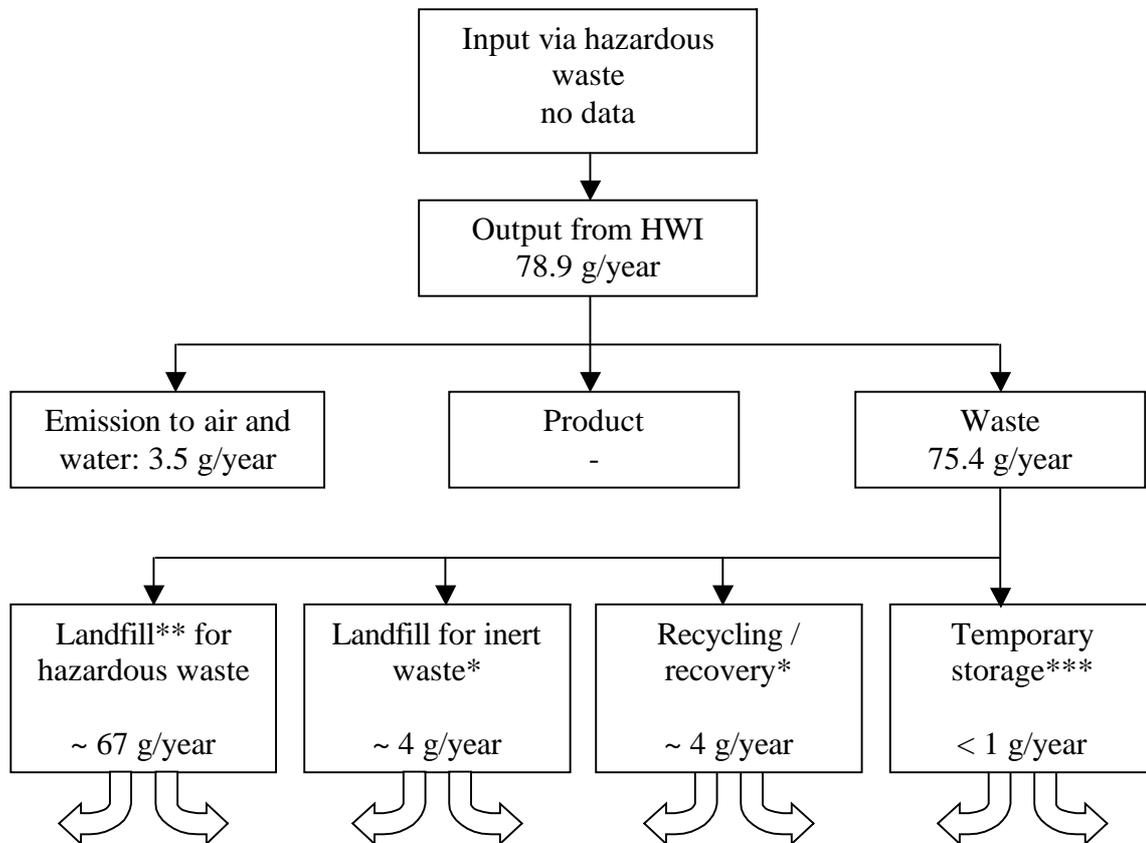
The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via exhaust air and solid residues resulting from HWI. The following table shows a country specific estimation on emitted amounts:

country	amount of hazardous waste incinerated [mio t]	air [g TEQ/y]	water [g TEQ/y]	bottom ash [g TEQ/y]	boiler ash [g TEQ/y]	fly ash and residues from FGT [g TEQ/y]	total to waste [g TEQ/y]
AT	0.1	0.1	0.03	0.2	0.1	1.4	1.7
BE	0.1	0.1	0.03	0.2	0.1	1.7	2.0
CY	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CZ	0.1	0.04	0.02	0.1	0.1	1.0	1.2
DE	0.9	0.4	0.2	1.5	0.9	10.9	13.3
DK	0.1	0.1	0.03	0.2	0.1	1.3	1.6
EE	0.01	0.0	0.0	0.0	0.0	0.1	0.1
ES	0.03	0.01	0.01	0.1	0.0	0.4	0.5
FI	0.1	0.1	0.03	0.2	0.1	1.3	1.6
FR	1.5	0.7	0.4	2.7	1.5	19.2	23.4
GR	0.1	0.04	0.02	0.1	0.1	1.0	1.2
HU	0.1	0.03	0.02	0.1	0.1	0.9	1.1
IE	0.03	0.01	0.01	0.1	0.0	0.4	0.5
IT	0.6	0.3	0.2	1.1	0.6	7.5	9.2
LT	0.04	0.02	0.01	0.1	0.0	0.5	0.6
LU	0.02	0.01	0.01	0.0	0.0	0.3	0.3
LV	0.01	0.0	0.0	0.0	0.0	0.1	0.1
MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NL	0.3	0.2	0.1	0.6	0.3	4.0	4.9
PL	0.2	0.1	0.1	0.4	0.2	2.9	3.5
PT	0.2	0.1	0.04	0.3	0.2	2.0	2.5
SE	0.1	0.1	0.03	0.2	0.1	1.3	1.6
SI	0.004	0.0	0.0	0.0	0.0	0.1	0.1
SK	0.03	0.01	0.01	0.1	0.0	0.4	0.5
UK	0.2	0.1	0.1	0.4	0.2	3.1	3.7
EU-25	4.8	2.3	1.2	8.7	4.9	61.8	75.4
EU-15	4.3	2.1	1.1	7.9	4.4	55.7	68.0
EU-10	0.5	0.2	0.1	0.9	0.5	6.1	7.4

Table 4-4: (G) PCDD/PCDF mass flow from hazardous waste incineration (HWI) in EU 25

At a European scale the estimated emissions amount to ~ 79 g TEQ/y. Thereof ~3.5 g are emitted to air (2.3) and water (1.2) and ~ 75 g are emitted to waste. Due to the heterogeneity of the input waste an estimation of the PCDD/PCDF input quantities is not possible.

The following PCDD/PCDF flow results:



* more than 50% of bottom ash is used for construction, the remainder is disposed of

** by far prevalent treatment is solidification and subsequent landfill; other options are thermal treatment, chemical stabilisation, extraction and separation or other treatment

*** solid residues from WI are temporarily stored in Latvia

Figure 4-5: Assessment of the PCDD/PCDF flow related to hazardous waste incineration

(H) HWI waste flow

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

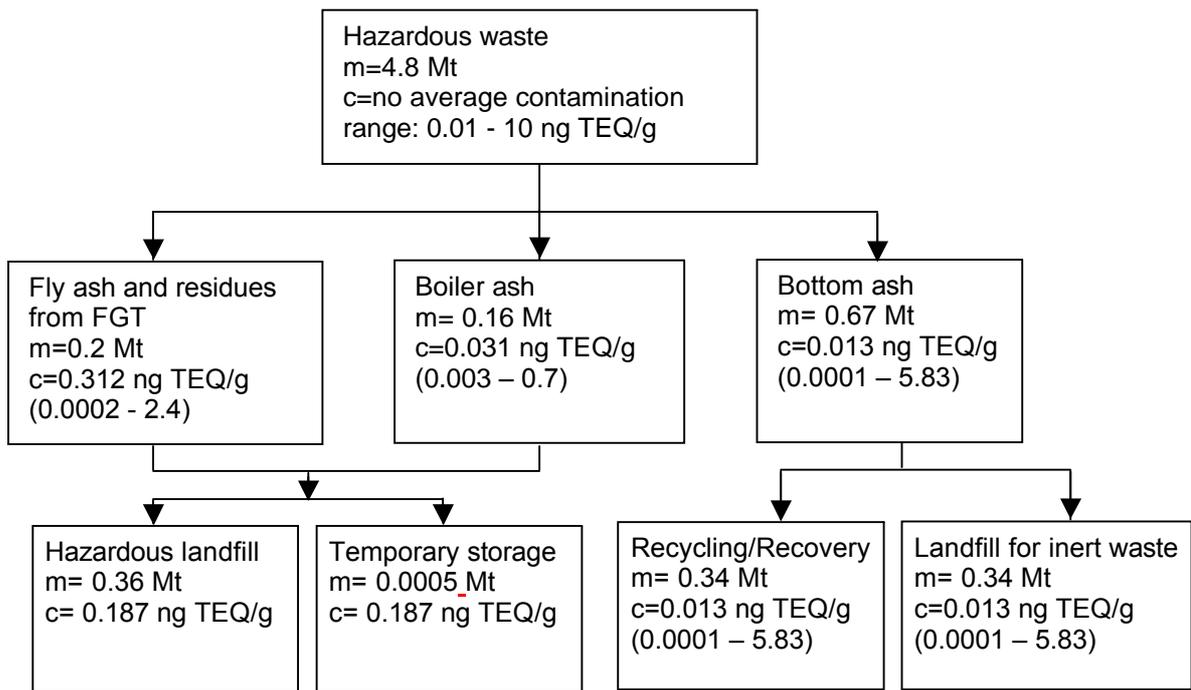


Figure 4-6: Detailed waste flow for hazardous waste incineration (HWI) in EU 25

The relevant data and sources are listed in tables 1.2.1 - 1.2.4 in the Annex.

4.1.3 Hospital waste incineration

(A) Background

The relevant processes and aspects in clinical waste incineration are described in detail in the corresponding BAT reference document [BREF WI 2004]. For incineration of medical waste rotary kilns are most commonly used, but grate incinerators (including co-firing with other wastes) are also sometimes applied. Clinical waste is also incinerated together with municipal solid waste. National regulations sometimes limit the ratio of clinical waste that may be treated in combined incineration (e.g. in France <10% thermal load). Dedicated incineration of hospital waste occurs mainly among the new Member States.

(B) Process input and output

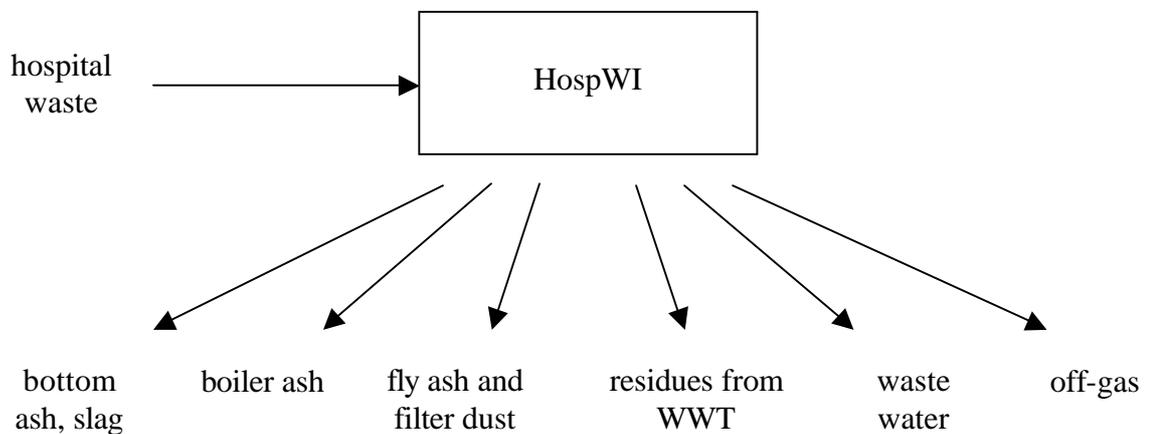


Figure 4-7: Relevant input and output of hospital waste incineration

Input:

Similar to hazardous wastes, the composition of specific hospital or clinical wastes varies greatly. According to the BREF on waste incineration clinical [BREF WI 2004] waste may include to varying degrees infectious agents, contaminated clothing/wipes and swabs, pharmaceutical substances, sharp materials such as hypodermic needles, veterinary wastes, body parts, used medical equipment, packaging materials, laboratory wastes and also radioactive contaminated materials. In some cases a distinction is made between the incineration routes for pathological (potentially infectious waste) and non-pathological waste. The treatment of pathological waste is sometimes restricted to dedicated incinerators, while non-pathological waste is, in some cases, incinerated with other wastes in non-dedicated incinerators e.g. MSWI. Clinical waste is also incinerated in hazardous waste incineration plants.

Output:

The output from hospital waste incineration is not fundamentally different from that from municipal solid waste incineration or hazardous waste incineration (see above).

(C) Generation factors for relevant waste and other output (air, water)

Waste generation factors are not fundamentally different from those in MSWI. For the PCDD/PCDF flow assessment analogue values as in MSWI have been applied.

(D) Contamination data

If no specific values for hospital waste incineration were available, analogue values as in MSWI have been applied for the PCDD/PCDF flow assessment.

Contamination of residues from clinical waste incineration flue gas treatment ranges from 0.68 to 4.5 ng TEQ/g. For the PCDD/PCDF flow a weighted average of 2.3 ng TEQ/g has been applied.

Contamination levels for bottom ash from clinical waste range from 0.015 to 0.03 ng TEQ/g. For the PCDD/PCDF flow an average of 0.16 ng TEQ/g has been applied.

Off gas contamination from clinical waste incineration ranges from 0.002 to 0.05 ng TEQ/Nm³ [WI BREF 2004]. For the PCDD/PCDF flow the emission factors according to a recent study on PCDD/PCDF emissions in the new Member States [TNO 2005] have been applied (HU: 5 µg/t; CZ: 14 µg/t; PL: 450 µg/t; SK 815 µg/t; CY, LT, LV, MT, SI: 3,000 µg/t; EE: 14,000 µg/t).

(E) Activity data

Dedicated incineration of hospital waste occurs mainly in the new Member States. According to the EU dioxin inventory from 1999 dedicated incineration of hospital waste was also carried out in Greece, Italy, Portugal and Spain. Information on actual amounts incinerated in these countries are not available. The following table shows amounts of municipal solid waste incinerated in EU 10 according to different sources:

country	amount of clinical waste incinerated (t/y)	reference
CY	1,080	[TNO 2005]
CZ	6,000	[CHMI emission inventory]
EE	2,100	[TNO 2005]
HU	7,000	Questionnaire
LT	5,250	[TNO 2005]
LV	3,600	[TNO 2005]
MT	585	[TNO 2005]
PL	58,500	[TNO 2005]
SI	3,000	[TNO 2005]
SK	18,000	[COHEM 2003]
EU-10	105,115	

Table 4-5: Amount of hospital waste incinerated in EU-10

(F) Waste treatment

It is assumed that treatment and recycling of solid residues from follows the same principles as treatment of residues from MSWI. More than 50% of bottom ash is used for construction purposes. Boiler ash and fly ash and other reaction products are usually mixed together and the bulk of these FGT residues is either directly land filled or land filled after further treatment. Slag is usually disposed of in landfills without further treatment or it is recycled.

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via exhaust air and solid residues resulting from dedicated clinical waste incineration. The following table shows a country specific estimation of emitted amounts:

country	amount of clinical waste incinerated (t/y)	air [g TEQ/y]	bottom ash [g TEQ/y]	boiler ash [g TEQ/y]	fly ash and FGT residues [g TEQ/y]	Total to waste [g TEQ/y]
AT						
BE						
CY	1,080	3.2	0.0	0.0	0.3	0.3
CZ	6,000	0.1	0.1	0.0	1.7	1.8
DE						
DK						
EE	2,100	29.4	0.0	0.0	0.6	0.6
ES						
FI						
FR						
GR						
HU	7,000	0.04	0.2	0.0	1.9	2.1
IE						
IT						
LT	5,250	15.6	0.1	0.0	1.5	1.6
LU						
LV	3,600	10.8	0.1	0.0	1.0	1.1
MT	585	1.8	0.0	0.0	0.2	0.2
NL						
PL	58,500	26.3	1.4	0.03	16.2	17.6
PT						
SE						
SI	3,000	9.0	0.1	0.0	0.8	0.9
SK	18,000	14.7	0.4	0.01	5.0	5.4
UK						
EU-25	105,115	111.1	2.5	0.06	29.1	31.7
EU-15						
EU-10	105,115	111.1	2.5	0.06	29.1	31.7

Table 4-6: PCDD/PCDF mass flow from hospital waste incineration (HospWI) in EU 10

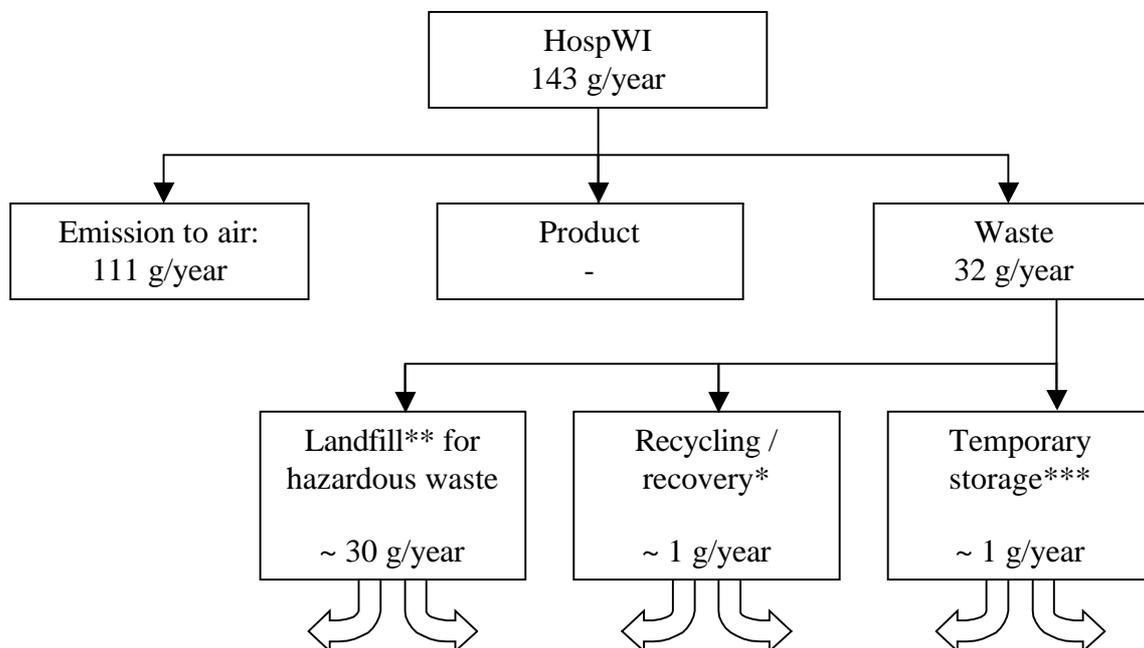
According to this estimation the emissions amount to ~ 143 g TEQ/y. Thereof ~ 111 g are emitted to air and ~ 32 g are emitted to waste. Due to the heterogeneity of the input waste an estimation of the PCDD/PCDF input quantities is not possible.

According to recent emission inventories carried out in Lithuania and Latvia the PCDD/PCDF emissions to air and residues from hospital waste incineration are estimated as follows:

country	emissions to air [g TEQ/y]	emissions to residues [g TEQ/y]	reference
LT	0.12	0.64	[COWI 2002]
LV	0.93	0.007	[COWI 2002]

In particular the emissions to air are far below those estimated on the basis of the emission factors applied for the above mentioned emission assessment for EU 15. The estimations have partly been confirmed by measurements of the Latvian EPA that have been performed in the framework of the national implementation plan of the Stockholm Convention (which result in emissions to air from medical waste incineration in Latvia amounting to 0.57 g TEQ/y). These considerations indicate that the assessment of PCDD/PCDF emissions to air from hospital waste incineration in EU 10 amounting to 111 g TEQ/y are overestimated.

The following PCDD/PCDF flow results:



- * more than 50% of bottom ash is used for construction, the remainder is disposed of
- ** by far prevalent treatment is solidification and subsequent landfill; other options are thermal treatment, chemical stabilisation, extraction and separation or other treatment
- *** solid residues from WI are temporarily stored in Latvia

Figure 4-8: Assessment of the PCDD/PCDF flow related to hospital waste

(H) HospWI waste flow

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

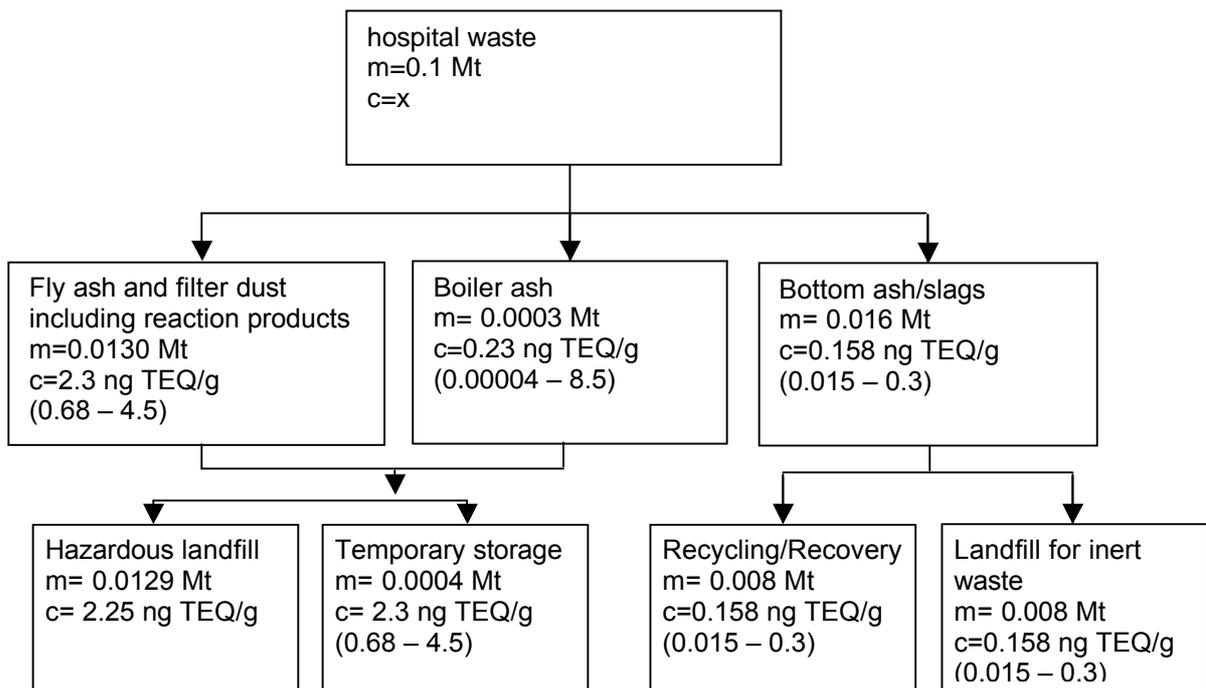


Figure 4-9: Detailed waste flow for hospital waste incineration in EU 10

The relevant data and their origin are listed in tables 1.3.1 - 1.3.4 in the Annex.

4.1.4 Power production (coal)

(A) Background

Besides the combustion of fossil fuels and biomass (EWC 1001), power production can be based on incineration of municipal or other waste with energy recovery. These activities are discussed separately in the mass flows on waste incineration.

The relevant processes and aspects related to the combustion of conventional fuels (such as coal, lignite, peat, liquid and gaseous fuels) including co-combustion of waste and recovered fuel are described in detail in the corresponding BAT reference document [LCP BREF 2004].

(B) Process input and output

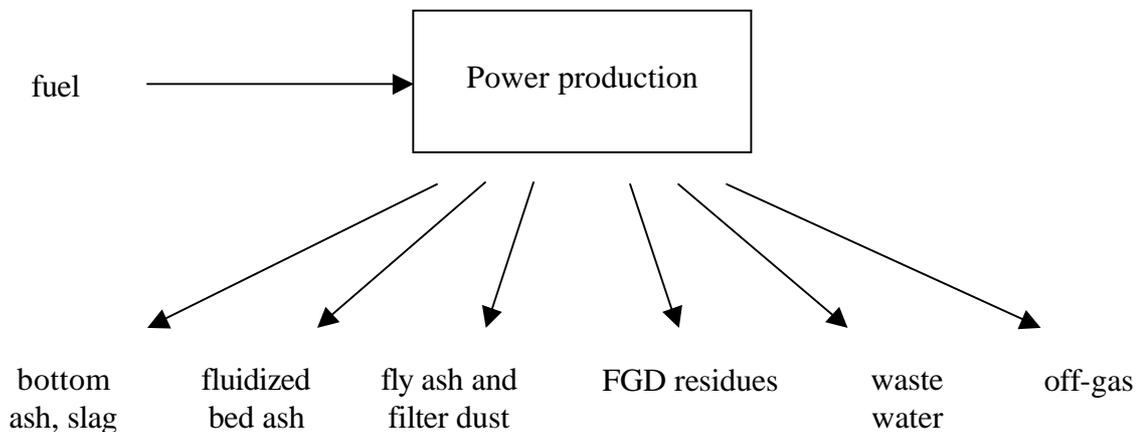


Figure 4-10: Relevant input and output of power production

Input:

- Fuel

Output:

Residues directly related to the process of combustion of fossil fuels are ashes (fly and bottom ash) and residues that are generated by the desulphurisation of flue-gases

- Bottom ash and/or boiler slag (EWC 100101, 100115): Bottom ash is non-combustible material that settles to the bottom of the boiler and remains in the form of unconsolidated ash. If combustion temperatures exceed the ash fusion temperature, the ash remains as slag in a molten state until it is drained from the bottom of the boiler as boiler slag

(D) Contamination data

Ash from coal incineration contamination values for ashes from coal incineration range from 0.00005 to 0.063 ng/g. The PCDD/PCDF flow is calculated on the basis of an estimated average of 0.0162 ng TEQ/g

Off gas Average emission levels of exhaust air from combustion of different fuels are in dimensions ranging from 0.001 to 0.01 ng TEQ/Nm³. Average emission of exhaust air from coal combustion is ~ 0.002 ng TEQ/Nm³.

(E) Activity data

The following table shows amounts of coal and lignite and its derivatives incinerated in Europe according to EUROSTAT statistics for conventional thermal power production, public thermal power production and auto producer power production (EUROSTAT, Annual PRODCOM, data for 2001):

country	coal [kt/y]	lignite and derivatives [kt/y]	total solid fuels [kt/y]
AT	3,346	2,998	6,344
BE	7,562	0	7,562
CY	0	0	0
CZ	89,504	996	90,500
DE	105,188	331,798	436,986
DK	13,200	0	13,200
EE	0	21,334	21,334
ES	55,490	17,542	73,032
FI	8,480	12,846	21,326
FR	15,036	524	15,560
GR	4	133,480	133,484
HU	60	26,278	26,338
IE	4,952	5,908	10,860
IT	22,438	6	22,444
LT	0	0	0
LU	0	0	0
LV	0	216	216
MT	0	0	92
NL	18,312	0	18,312
PL	88,484	118,254	206,738
PT	9,576	0	9,576
SE	1,012	1,100	2,112
SI	2,842	7,020	9,862
SK	804	9,414	10,218
UK	101,856	0	101,856
EU-25	548,146	689,714	1,237,952
EU-15	366,452	506,202	872,654
EU-10	181,694	183,512	365,298

Table 4-7: Annual consumption of solid fuels for power production (reference: 2001) in the EU

(F) Waste treatment

Ash and FGT residues are by far the largest quantities of waste from power production. These residues are partly discharged to a landfill or can be used for different purposes such as an additive in cement and concrete production; an aggregate in concrete, asphalt, mine reclamation or waste stabilisation; and as an ingredient in many other products. Gypsum, a by-product from the desulphurisation plant, is largely used in the production of gypsum board [BREF LPC 2004].

Solid residues from power production are used in construction industry and underground (~56%), restoration of open cast mines, quarries and pits (~33%), landfill (~9%) and temporary stockpiles (~2%) [BREF LPC 2004, figures 4.47].

The fate of the different fractions in the year 1999 for EU 15 is shown in the following table:

residue	construction, underground mining	restoration of mines, quarries, pits	land filling	temporary stockpile
bottom ash	~42	~38	~19	~1
boiler slag	100			
fluidised bed ash	~43	~40	~17	
fly ash and APC residues	~45	~43	~10	~2
gypsum and SDA product	~90	5-10	1-2	

Table 4-8: Treatment of solid residues from power production in EU 15 in 1999 [BREF LPC 2004]

Being well aware of the fact that construction is a recycling/recovery treatment but underground mining has to be considered a disposal treatment, these activities should be separated. As this is not possible on the basis of the available data background, construction and underground mining as well as restoration of mines, quarries and pits is allocated to the treatment category "recycling, recovery". Residues that are land-filled are either disposed as hazardous waste or as non-hazardous waste (assumption: relation hazardous : non-hazardous ~ 1 : 10).

(G) PCDD/PCDF flow for power production from coal and lignite

The available data and assumptions allow an estimation of PCDD/PCDF emissions to solid residues (general estimation for ashes: bottom ash, fluidised bed ash, fly ash including FGT residues) resulting from power production from coal and lignite. The following table shows a country specific estimation on emitted amounts in the year 2001:

country	total solid fuels [kt/y]	emission to air [g TEQ/y]	discharge to ashes [g TEQ/y]
AT	6,344	0.19	8.3
BE	7,562	0.23	9.9
CY	0	0.00	0.0
CZ	90,500	2.77	117.9
DE	436,986	13.37	569.4
DK	13,200	0.40	17.2
EE	21,334	0.65	27.8
ES	73,032	2.23	95.2
FI	21,326	0.65	27.8
FR	15,560	0.48	20.3
GR	133,484	4.08	173.9
HU	26,338	0.81	34.3
IE	10,860	0.33	14.2
IT	22,444	0.69	29.2
LT	0	0.00	0.0
LU	0	0.00	0.0
LV	216	0.01	0.3
MT	92	0.00	0.1
NL	18,312	0.56	23.9
PL	206,738	6.33	269.4
PT	9,576	0.29	12.5
SE	2,112	0.06	2.8
SI	9,862	0.30	12.9
SK	10,218	0.31	13.3
UK	101,856	3.12	132.7
EU-25	1,237,952	37.87	1,613.1
EU-15	872,654	26.70	1,137.1
EU-10	365,298	11.18	476.0

Table 4-9: PCDD/PCDF mass flow from Power production via coal, lignite and derivatives in EU 25 (reference year: 2001)

At a European scale the estimated emissions amount to ~ 1,651 g TEQ/y. Thereof approximately 38 g are emitted to air and 1,613 g are part of the ashes.

The following PCDD/PCDF flow results:

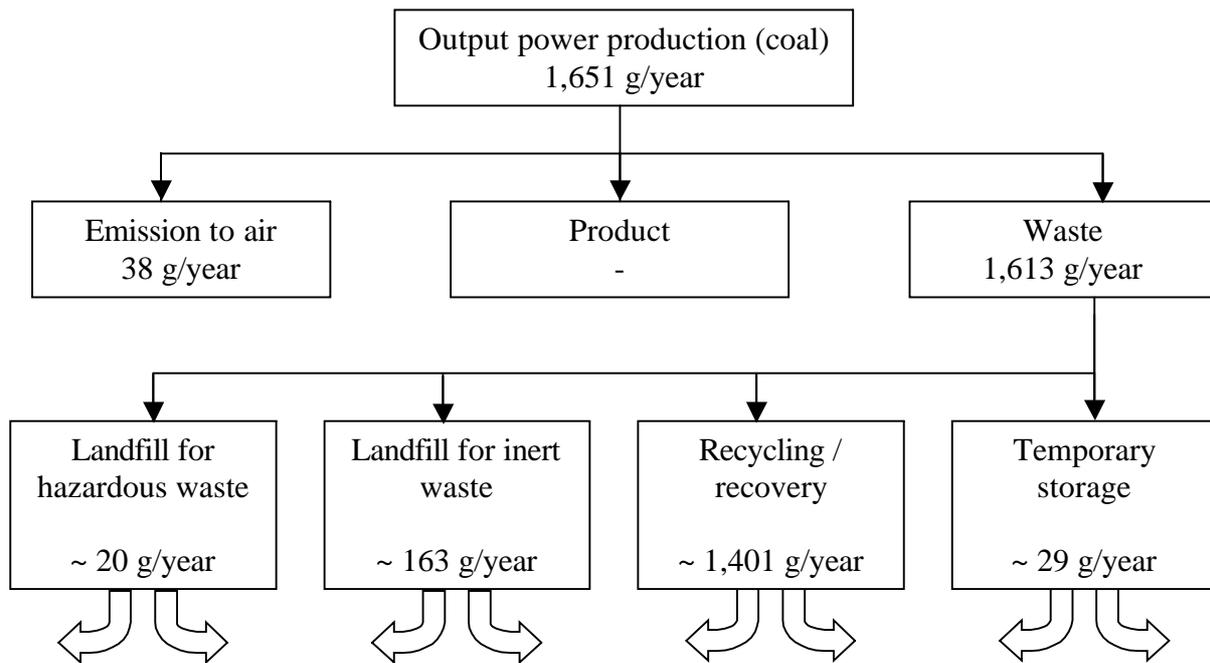


Figure 4-11: Assessment of the PCDD/PCDF flow related to power production from coal and lignite

(H) Waste flow for power production from coal

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

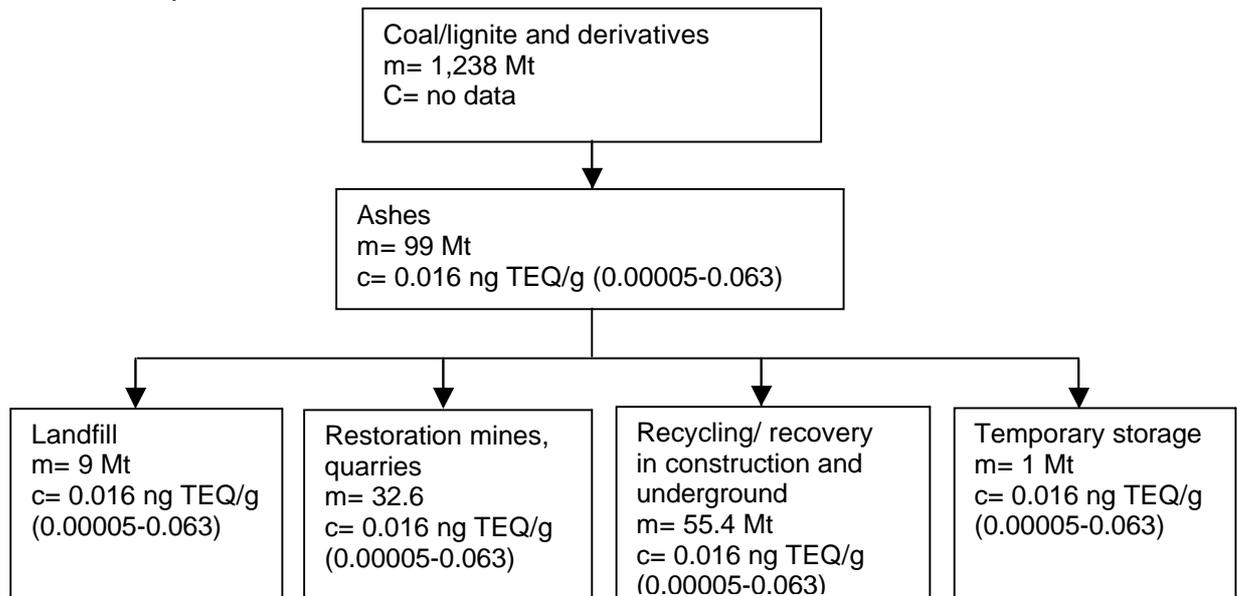


Figure 4-12: Detailed waste flow for coal fired power plants (PP coal) in EU 25

Relevant data and their origin are listed in tables 1.4.1 - 1.4.2 in the Annex.

4.1.5 Power production (biomass)

(A) Background

The relevant processes and aspects related to the combustion of biomass (such as wood and straw) including co-combustion of wood waste and wood residues are described in detail in the corresponding BAT reference document [LCP BREF 2004].

(B) Process input and output

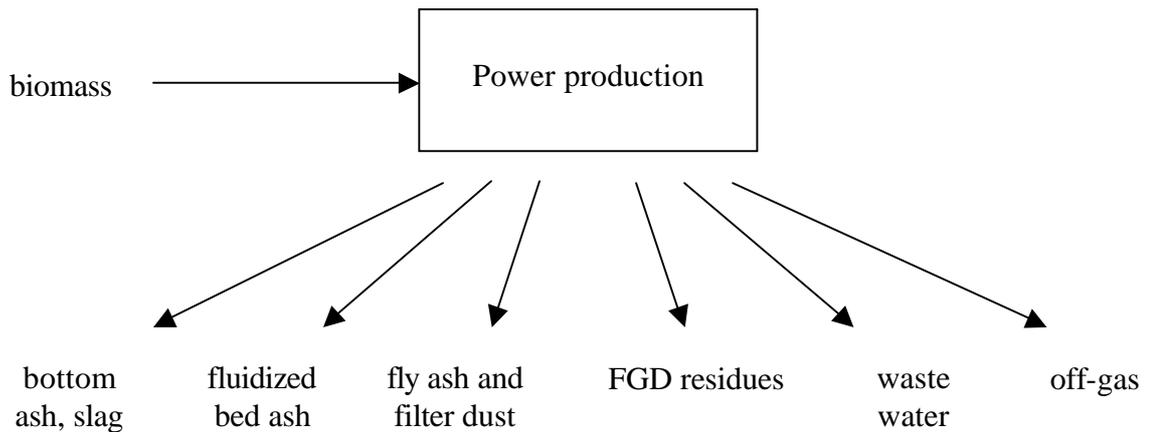


Figure 4-13: Relevant input and output of power production

Input:

- Biomass

Output:

- Bottom ash and/or boiler slag (EWC 100101, 100115)
- Fluidised bed ash: The operation of a fluidised bed combustion installation for burning biomass is related to the generation of ash, which is a composition of spent bed material and fuel ash
- Fly ash (EWC 100102, 100116*)
- Treated off-gas

(C) Generation factors

According to the ECB report [ECB 2003] the amount of resulting ashes from incineration of biomass depends on the type of furnace. Data of <2%, <5% and <50% are reported. No generation factors for the different types of ashes are available. Therefore an assumed average value of 100 kg ash (no differentiation of ashes) per tonne biomass has been taken as basis for the calculation of the PCDD/PCDF flow into waste.

For exhaust gas resulting from the incineration of biomass no generation factor is available. Therefore the generation factor of 6000 for municipal solid waste is used for calculation.

(D) Contamination data

Ash and other solid residues: Contamination values for ashes from biomass incineration range from 0.001 to 16.186 ng/g. The PCDD/PCDF flow is calculated on the basis of an estimated average of 1.1348 ng TEQ/g

Exhaust gas Several data for contamination in exhaust gas are reported [ECB 2003]. According to [Rösch 2001] most of the biomass used for power production in Europe is wood. The data for wood range between 0.004 and 0.88 ng/g. Therefore a value for wood achieved with appropriate technology of 0.052 ng TEQ/Nm³ is used for calculation.

(E) Activity data

The following table shows amounts of biomass incinerated in Europe according to EuroStat and data of the country specific submission for 2004 by Annex I Parties to the UNFCCC. Where no data are available the amount of biomass burnt has been estimated on a per capita basis.

country	biomass (t/y)	reference
AT	22,000	[ESTAT 2001]
BE	378,654	extrapolated
CY	28,335	extrapolated
CZ	71,000	[ESTAT 2001]
DE	275,294	[UNFCC CRF 2004]
DK	197,974	extrapolated
EE	51,885	extrapolated
ES	107,153	[UNFCC CRF 2004]
FI	1,884,706	[UNFCC CRF 2004]
FR	105,882	[UNFCC CRF 2004]
GR	392,637	extrapolated
HU	369,822	extrapolated
IE	144,249	extrapolated
IT	127,059	[UNFCC CRF 2004]
LT	132,474	extrapolated
LU	16,559	extrapolated
LV	86,476	extrapolated

country	biomass (t/y)	reference
MT	14,719	extrapolated
NL	21,176	[UNFCC CRF 2004]
PL	8,471	[UNFCC CRF 2004]
PT	5,506	[UNFCC CRF 2004]
SE	487,059	[UNFCC CRF 2004]
SI	71,389	extrapolated
SK	199,814	extrapolated
UK	127,059	[UNFCC CRF 2004]
EU-25	5,327,352	
EU-15	4,292,967	
EU-10	1,034,384	

Table 4-10: Annual consumption of biomass for power production in EU 25

(F) Waste treatment

Ash and FGT residues are by far the largest quantities of waste from power production. These residues are partly discharged to a landfill or can be used for different purposes such as an additive in cement and concrete production; an aggregate in concrete, asphalt, mine reclamation or waste stabilisation; and as an ingredient in many other products. Gypsum, a by-product from the desulphurisation plant, is largely used in the production of gypsum board [BREF LPC 2004].

According to information from a natural wood incineration plant about 83% of the residues are used in construction industry and underground and about 17% are now land filled in an inert land fill with the view to apply it on land in near future. In other incineration plants where treated wood is used for incineration also residues for hazardous landfill are produced. The share for hazardous and inert landfill is not available. These data are similar with the data for the treatment of residues from power production coal, therefore they are used for calculation. No other data are available for the treatment of residues from biomass incineration.

(G) PCDD/PCDF flow for power production from biomass

The available data and assumptions allow an estimation of PCDD/PCDF emissions to solid residues (general estimation for ashes: bottom ash, fluidised bed ash, fly ash including FGT residues) resulting from power production from biomass. The following table shows a country specific estimation on emitted amounts of PCDD/PCDF:

country	amount of biomass burnt (t/y)	discharge to ashes [g TEQ/y]	emission to air [g TEQ/y]
AT	22,000	2.50	0.01
BE	378,654	42.97	0.12
CY	28,335	3.22	0.01
CZ	71,000	8.06	0.02
DE	275,294	31.24	0.09
DK	197,974	22.47	0.06
EE	51,885	5.89	0.02
ES	107,153	12.16	0.03

country	amount of biomass burnt (t/y)	discharge to ashes [g TEQ/y]	emission to air [g TEQ/y]
FI	1,884,706	213.87	0.59
FR	105,882	12.02	0.03
GR	392,637	44.56	0.12
HU	369,822	41.97	0.12
IE	144,249	16.37	0.05
IT	127,059	14.42	0.04
LT	132,474	15.03	0.04
LU	16,559	1.88	0.01
LV	86,476	9.81	0.03
MT	14,719	1.67	0.01
NL	21,176	2.40	0.01
PL	8,471	0.96	0.003
PT	5,506	0.62	0.002
SE	487,059	55.27	0.15
SI	71,389	8.10	0.02
SK	199,814	22.67	0.06
UK	127,059	14.42	0.04
EU-25	5,327,352	604.54	1.66
EU-15	4,292,967	487.16	1.34
EU-10	1,034,384	117.38	0.32

Table 4-11: PCDD/PCDF mass flow for power production from biomass in EU 25

At a European scale the estimated emissions amount to ~ 606 g TEQ/y. Thereof approximately 1.7 g are emitted to air and 604.5 g are contained in the ashes.

The following PCDD/PCDF flow results:

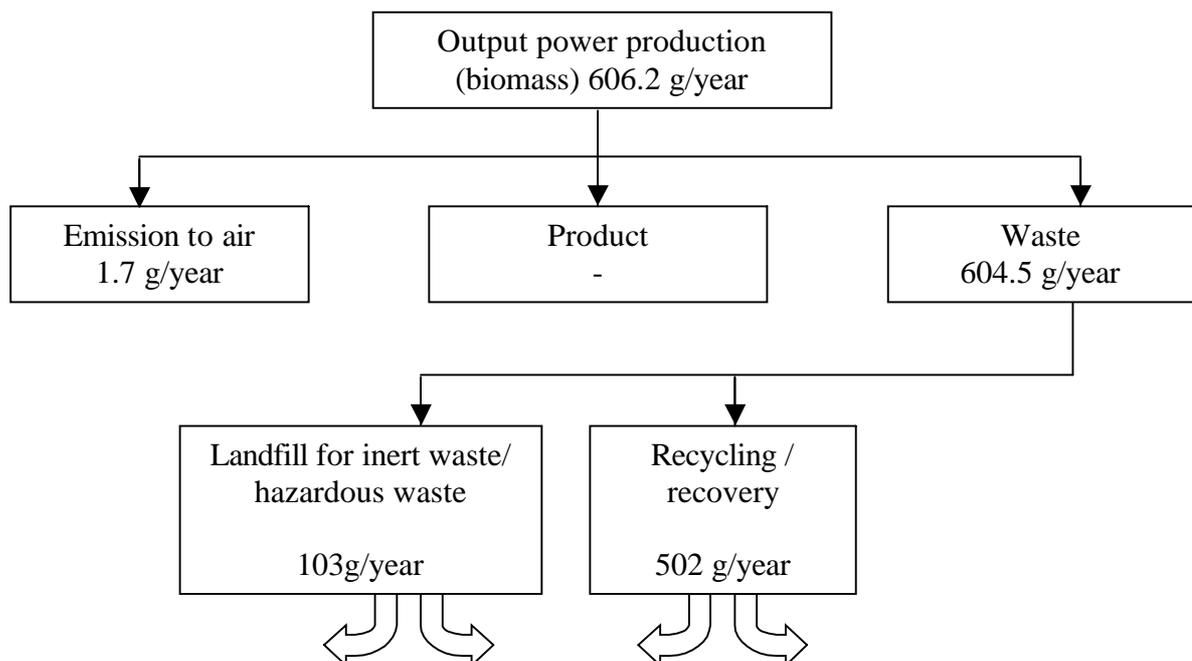


Figure 4-14: Assessment of the PCDD/PCDF flow related to power production from biomass

(H) Waste flow for power production from biomass

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

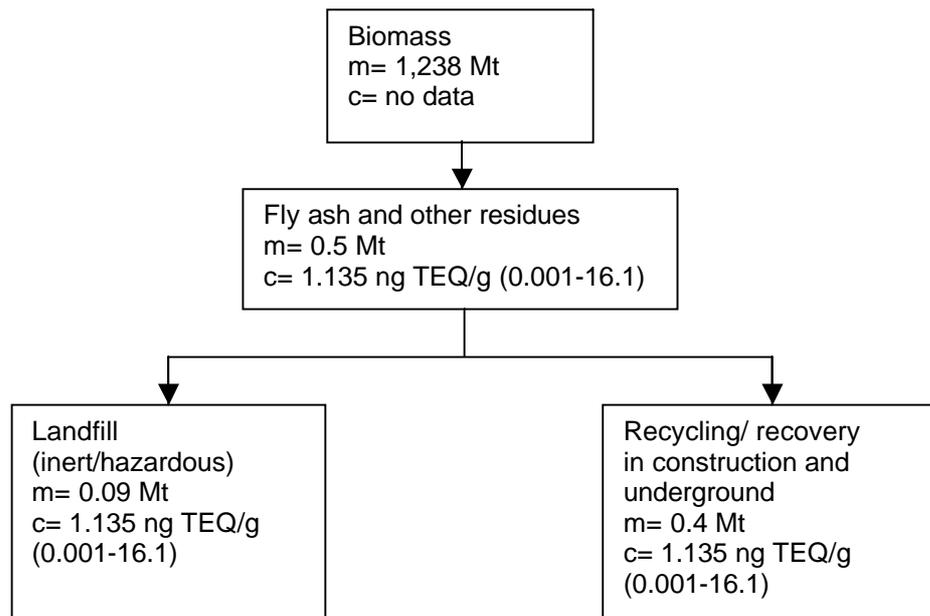


Figure 4-15: Detailed waste flow for power production from biomass in EU 25

The relevant data and their origin are listed in tables 1.5.1 - 1.5.2 in the Annex.

4.1.6 Iron and steel production – Sinter plants

Four routes are currently used for the production of steel: the classic blast furnace/basic-oxygen furnace route, direct melting of scrap (electric arc furnace), smelting reduction and direct reduction.

In 2003 EU steel production was based on the blast furnace/ basic-oxygen route (approximately 62%) and the electric arc furnace (EAF) route (approximately 38%) [EUROFER steel statistics for 2003]. In Europe smelting reduction and direct reduction are of very limited importance [IS BREF 2001]. Consequently the relevant emissions from European iron and steel production originate from the blast furnace/basic oxygen route and electric arc furnace.

(A) Background

In integrated steelworks applying the blast furnace/basic oxygen route, sinter plants dominate the overall emissions for atmospheric pollutants including significant emissions of PCDD/PCDF and PCB. Consequently, sinter, as a product of an agglomeration process of iron-containing materials, represents a major part of the emissions from blast furnaces. The most relevant environmental issues are exhaust air from the sinter strand, which contains a wide range of pollutants including PCDD/PCDF and PCB and emissions via solid waste, in particular PCDD/PCDF contaminated dust resulting from filtering processes.

The relevant processes and technical aspects in iron sintering are described in detail in the corresponding BAT reference document [IS BREF 2001].

(B) Process input (raw material) and output (waste, air, water, product)

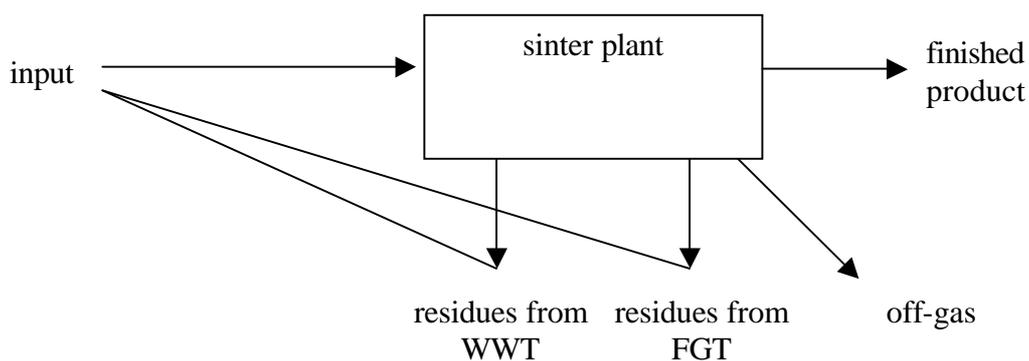


Figure 4-16: Relevant input and output of the iron sintering process (dotted lines: internal recycling possible)

Solid residues management in an integrated steelwork aims at extracting value from the various types of slag and recycling of most of the residues in the sinter plant, which can be considered the 'digester of an integrated steelworks' [IS BREF 2001]. Thus, besides the

sintering process itself, the sinter plant plays this important role of recycling residues for which no adequate alternatives exist.

Only small parts of the overall quantity of residues are landfilled. These often consist of fine dust from blast-furnace gas cleaning, rubble, fine dust from basic oxygen furnace gas scrubbing (if wet cleaning is used) and, in some cases, the high alkali chlorides and heavy metal chlorides from the last field of electrostatic precipitators treating the off-gas from sinter strands.

Input:

- Main input are iron ores, other iron materials, lime and limestone, additives, dust from blast furnace process, recycled materials and internally recycled sinter

Output:

- Sludges from waste water treatment (EWC 100213*, 100214) result if a fine scrubber system is used for flue gas treatment. Consequently the generated waste water contains dust from flue gas treatment with potential PCDD/PCDF contamination. The resulting solid residues are covered under residues from FGT.
- Residues from FGT (EWC 100207*, 100208): residues from flue gas treatment are internally recycled to a large degree. However a certain share of dust has to be disposed of. This is in particular dust from the last field of electrostatic precipitators and, if a fine scrubber system is applied, sludges from flue gas treatment.
- Treated off-gas may still contain certain amounts of PCDD/PCDF
- Product: sinter

(C) Generation factors for relevant waste and other output (air, water)

Residues from FGT: Dust amounts that arise in a sinter plant range from 0.9 to 15 kg/t liquid steel. According to the BREF for iron and steel production, most European sinter plants are operated with fully closed dust cycles. However, some plants exclude fine dust from the last field of the ESP. This dust mainly consists of alkali and other metal chlorides. This so-called partly open filter dust cycle is carried out in order to improve the operation of ESP or (in one case) of the bag filter, or to reduce alkali and metal chloride emissions.

According to information from EUROFER (personal communication Anna Utsi) 0.2 to 0.5 kg/t liquid steel is disposed of to landfills. An average of 0.5 kg/t liquid steel is assumed for the calculation of the PCDD/PCDF flow.

If relevant, sludge from fine scrubber systems amounts to 0.3 kg/t liquid steel. In 2001 only 2 plants in Europe were operating a wet FGT system, so that sludges have not been taken into consideration in the calculation.

Off gas The average exhaust air volume per tonne liquid steel is approximately 2,300 Nm³.

(D) Contamination data for output (and input)

Residues from FGT No specific values for externally disposed filter dust or sludge from scrubber systems from sinter plants have been reported. For filter dust from the ferrous metal industry two values are available from a Belgian inventory from 1997 0.1 ng/g for filter dust and 1.1 ng TEQ/g for filter dust which is externally treated or used. Additional values are available from German iron and steel industry for solid wastes from gas treatment containing dangerous substances (ranging from 0.0001 to 3.1 ng TEQ/g) and for sludge and filter cakes from gas treatment containing dangerous substances (ranging from 0.01 to 0.18). According to EUROFER levels can raise up to 20 ppb in mixtures of dust and absorbance from de-dusting systems used for minimisation of air emissions. For the PCDD/PCDF flow to waste, the fine dust which is not recycled is relevant. Accordingly, for the calculation of the PCDD/PCDF flow, an average of 1.1 ng TEQ/g is applied (range <0.01-20 ppb).

Off gas Reported values for off gas from sinter strands range from < 0.1 to 5 ng TEQ/Nm³. Optimised process conditions allow emissions in the lower dimension of this range, although even optimised processes show emission values ranging between 2 and 3 ng TEQ/Nm³. For the assessment of the PCDD/PCDF emissions to air a calculated mean value of 1.2 ng TEQ/Nm³ is assumed. On the basis of emission factors used for some of the new Member states in a recent study [TNO 2005] average contamination levels for off gas have been calculated and applied for individual countries (CZ: 8.73 ng TEQ/Nm³; HU: 2.18 ng TEQ/Nm³; PL: 0.66 ng TEQ/Nm³; SI: 8.73. ng TEQ/Nm³; SK: 8.73 ng TEQ/Nm³). The effect on the estimation of the corresponding annual European emissions to air is an increase from 351 to 524 g TEQ/y.

(E) Activity data

The following table shows the current capacity for sinter production in Europe [sources: personal communication from EUROFER; TNO 2005]:

country	production of crude steel (oxygen) [kt/y]	reference
AT	3,700	[source: EUROFER] * steel production in Slovenia according to [TNO 2005]
BE	15,300	
CY		
CZ	6,330	
DE	28,950	
DK		
EE		
ES	5,400	
FI	2,700	
FR	21,550	
GR		
HU	900	
IE		
IT	11,500	
LT		
LU		
LV		
MT		
NL	4,400	
PL	9,000	
PT		
SE		
SI	250	
SK	4,000	
UK	13,800	
EU-25	127,780	
EU-15	107,300	
EU-10	20,480	

Table 4-12: Production of crude steel in EU 25 in 2003 via the blast furnace/basic oxygen route

(F) Waste treatment

Residues from flue gas treatment are internally recycled to a large degree. However a certain share of dust has to be disposed of. This is in particular fine dust from the last field of electrostatic precipitators and, if a fine scrubber system is applied, sludge from flue gas treatment. It is assumed that all dust and sludge which is not internally recycled is externally disposed of. The share of disposal of hazardous and non-hazardous FGT residues (EWC numbers 10 02 07* and 10 02 08) is not known.

In the case of sludge only 0.3 kg arise per tonne liquid steel, and wet FGT systems are only applied in two plants in Europe. So this flow is neglected in the PCDD/PCDF flow assessment.

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via exhaust air and filter dusts resulting from flue gas treatment. The following table shows a country specific estimation on emitted amounts in the year 2003:

country	production of crude steel (oxygen) [kt/y]	emission to air [g TEQ/y]	discharge to FGT residues [g TEQ/y]
AT	3,700	10.2	2.0
BE	15,300	42.0	8.4
CY		0.0	0.0
CZ	6,330	126.6	3.5
DE	28,950	79.5	15.9
DK		0.0	0.0
EE		0.0	0.0
ES	5,400	14.8	3.0
FI	2,700	7.4	1.5
FR	21,550	59.2	11.9
GR		0.0	0.0
HU	900	4.5	0.5
IE		0.0	0.0
IT	11,500	31.6	6.3
LT		0.0	0.0
LU		0.0	0.0
LV		0.0	0.0
MT		0.0	0.0
NL	4,400	12.1	2.4
PL	9,000	13.5	5.0
PT		0.0	0.0
SE		0.0	0.0
SI	250	5.0	0.1
SK	4,000	80.0	2.2
UK	13,800	37.9	7.6
EU-25	127,780	524.4	70.3
EU-15	107,300	294.8	59.0
EU-10	20,480	229.6	11.3

Table 4-13: PCDD/PCDF mass flow for iron sintering in EU 25 (reference year: 2003)

At a European scale the estimated emissions amount to ~ 595 g TEQ/y. Thereof ~525 g are emitted to air and ~ 70 g are emitted to waste. The latter figure depends to a high degree on the average contamination of filter dusts that can not be recycled. The value of 1.1 ng TEQ/g used here should be verified. Based on the assumption that filter dusts not internally recycled are disposed of, the following picture results:

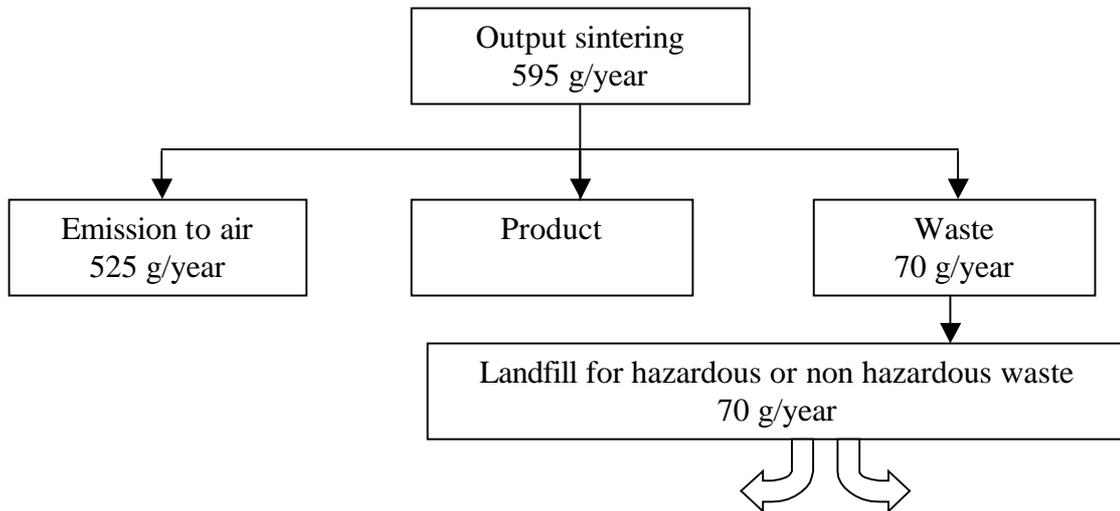


Figure 4-17: Assessment of the PCDD/PCDF flow related to iron ore sintering

(H) Waste flow for iron sintering

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

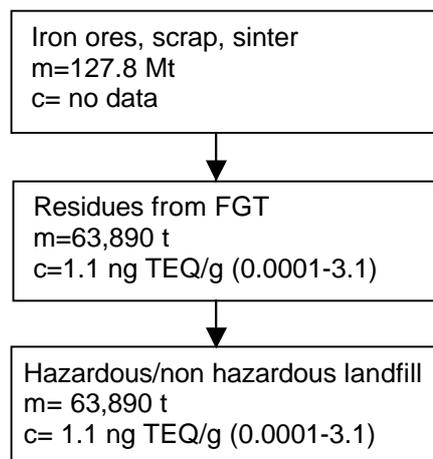


Figure 4-18: Detailed waste flow for sinter plants in EU 25

The relevant data and their origin are listed in tables 1.6.1 - 1.6.2 in the Annex.

4.1.7 Iron and steel production – electric arc furnaces

(A) Background

The activity „Iron and steel electric arc furnaces“ is related to the melting of iron containing materials (mainly scrap) in electric arc furnaces.

Depending on the process conditions and the composition of the feed material favourable conditions for PCDD/PCDF formation can occur. The major paths for emission of PCDD/PCDF are the air pathway and emissions in the form of solid waste, in particular slag and filter dust.

The electric arc furnace process includes raw material handling and storage, furnace charging with or without scrap preheating, EAF scrap melting, steel and slag tapping, ladle furnace treatments for quality adjustment, slag handling and continuous casting.

Emission of PCDD/PCDF and PCB is relevant for the Furnace and the preheating process.

Scrap preheating may result in higher emissions of aromatic organohalogen compounds such as polychlorinated dibenzo-p-dioxins and -furans (PCDD/PCDF), chloro-benzenes, polychlorinated biphenyls (PCB) as well as polycyclic aromatic hydrocarbons (PAH) and other partial combustion products from scrap which is contaminated with paints, plastics, lubricants or other organic compounds. This formation can be minimised by post-combustion within the furnace by additional oxygen burners. They have been developed in order to (post-)combust CO (and hydrocarbons). Thus the chemical heat from this combustion can also be used for scrap preheating [Knapp, 1996]. But such a post-combustion is different from a post-combustion after the EAF in order to reduce emissions of organic compounds like PCDD/PCDF etc. Such a post combustion requires a considerable quantity of energy [IS BREF 2001].

The relevant processes and technical aspects in ferrous metal founding are described in detail in the corresponding BAT reference document [IS BREF 2001].

(B) Process input (raw material) and output (waste, air, water, product)

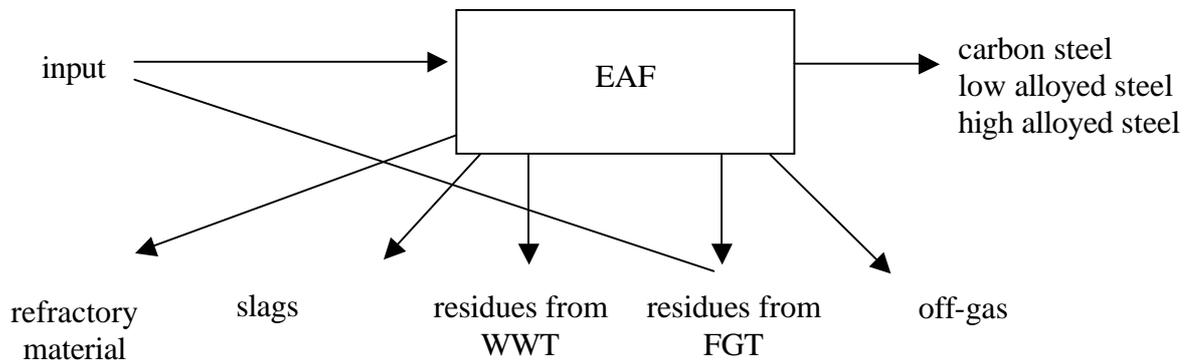


Figure 4-19: Relevant input and output of the electric arc furnace process (dotted lines: internal recycling possible)

Input:

- Main input is metal containing scrap, lime, coal, iron sponge and auxiliaries such as alloying metals, graphite electrodes and linings. In particular cases hot melted metal, pig iron or direct reduced iron are also used as feed materials.

Output:

- Refractory bricks (EWC 161101*, 161102, 161103*, 161104)
- As in the blast oxygen furnace, slags (EWC 100202, 100201) are formed from lime to collect undesirable components from the steel. Slags are generated during the melting stage and from the ladle. They are removed and screened for metal recovery before they are crushed. The residues are either re-used or disposed of.
- Sludges from waste water treatment (EWC 100213*, 100214): result from the drainage of the scrap yard, continuous casting and, in exceptional cases from off gas scrubbing. The latter fraction consists of dust from flue gas treatment and contains PCDD/PCDF.
- Residues from FGT (EWC 100207*, 100208): Airborne emissions contain among other dust and PCDD/PCDF. Off gases are collected and treated by different systems [IS BREF 2001]. Particulate matter is removed from collected combustion gases and results in filter dust.
- Treated off-gas may still contain certain amounts of PCDD/PCDF.
- Product: carbon steel, low alloyed steel, high alloyed steel. Approximately 85% of European production is carbon steel and low alloyed steel (according to an EC study from 1996; [IS BREF 2001])

(C) Generation factors for waste and other output (air, water)

Refractory bricks: 2 to 8 kg/t liquid steel

Slag: carbon steel/low alloyed steel:
slag from furnace: ~125 kg/t liquid steel (range 100 to 150)
slag from ladle: ~ 20 kg/t liquid steel (range 10 to 30)
total amount: ~145 kg /t liquid steel (range 110 to 180)

high alloyed steel:
slag from furnace: ~117.5 kg/t liquid steel (range 100 to 135)
slag from ladle: ~ 35 kg/t liquid steel (range 30 to 40)
total amount: ~152.5 kg /t liquid steel (range 130 to 175)

As ~ 85% of EU steel production from EAF is carbon steel and low alloyed steel a waste generation factor of 145 kg/t liquid steel has been taken as a basis for the calculation of the PCDD/PCDF flow.

Residues from WWT Only in exceptional cases EAF is related to waste water treatment. In the calculation of the mass flow all EAFs are regarded as furnished with dry flue gas treatment. This has no considerable effect on the PCDD/PCDF mass flow.

Residues from FGT Dust from EAF amounts to 14 to 20 kg/tonne liquid steel (carbon steel/low alloyed steel) and to 6 to 15 kg/tonne liquid steel (high alloyed steel). Taking into account that 85% of EU production is carbon steel/low alloyed steel, a weighted mean value of 16 kg/tonne is taken as basis for the calculation of the PCDD/PCDF flow.

Off gas The exhaust air volume varies considerably among different EAF plants. In practice the specific flow can vary considerably from 6,000 to 16,000 Nm³/t liquid steel. According to the iron and steel BREF document emissions are calculated with an average of 8,000 Nm³/t liquid steel.

(D) Contamination data for output (and input)

Refractory bricks: No contamination expected

Slag: From Belgium an average contamination of slag from the ferrous metal industry of 0.0002 ng TEQ/g is reported. According to TNO 2005 contamination of slag from EAF ranges from 0.0004 to 0.003 ng TEQ/g. An average contamination value of 0.001 has been assumed for the calculation of the PCDD/PCDF flow.

Residues from FGT For the PCDD/PCDF flow assessment the same contamination figure as above (1.1 ng TEQ/g) is assumed for filter dust for external treatment (cf. chapter 4.1.6 (D)).

Off gas On the basis of emission factors reported for several plants an average contamination of 0.3 ng/Nm³ (range <0.1 to 0.5 ng/Nm³) has been calculated as a basis for the PCDD/PCDF flow assessment.

(E) Activity data

EAF steel production is carried out in nearly 250 electric arc furnaces in Europe. The following table shows European production data for crude steel via direct melting in electric arc furnaces in 2003:

country	production of crude steel (electric) [kt/y]	reference
AT	555	[EUROFER steel statistics, reference year 2003]
BE	2,805	
CY	0	
CZ	464	
DE	13,432	
DK	0	
EE	0	
ES	12,529	
FI	1,358	
FR	7,770	
GR	1,701	
HU	349	
IE	0	
IT	16,898	
LT	0	
LU	2,675	
LV	0	
MT	0	
NL	120	
PL	3,037	
PT	722	
SE	1,792	
SI	543	
SK	229	
UK	2,499	
EU-25	69,478	
EU-15	64,856	
EU-10	4,622	

Table 4-14: European production of crude steel via direct melting in electric arc furnaces in 2003

(F) Waste treatment

Refractory bricks are usually put to landfill.

Slags from EAF plants are internally recycled, externally used, sold or landfilled and stored. The following figure gives an overview on the importance of the relevant treatments according to an EC study from 1996:

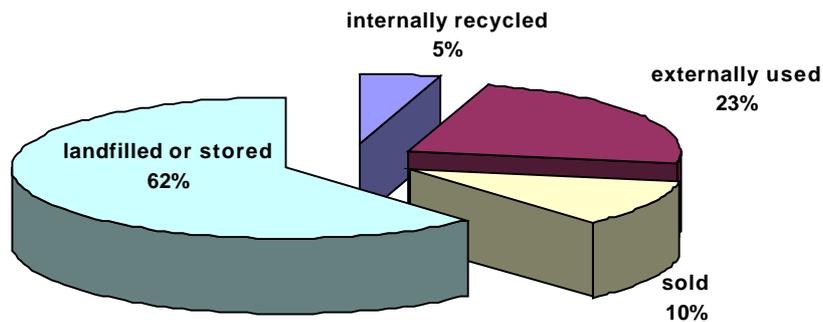


Figure 4-20: Treatment of slags from EAF [IS BREF 2001, Table 9.5]

The share of recycling (e.g. in hydraulic engineering, road construction etc.) is increasing. To this end the slag has to be crushed, screened and sized for use. With respect to the treatment of filter dust, three options for dust treatment are generally possible:

- chemical stabilisation or vitrification
- internal recycling of dusts by returning them to the EAF (which is only possible to a certain degree due to plant specific technical problems; see [IS BREF 2001 section 9, EP.5 EAF dust recycling])
- hydrometallurgical and pyrometallurgical processes for zinc recovery and recovery or removal of other heavy metals (see [IS BREF 2001 section 9, EP.5 EAF dust recycling])

The above mentioned EC study from 1996 reports on the fate of filter dust collected from primary and secondary off-gases from electric arc furnaces as demonstrated in the following figure:

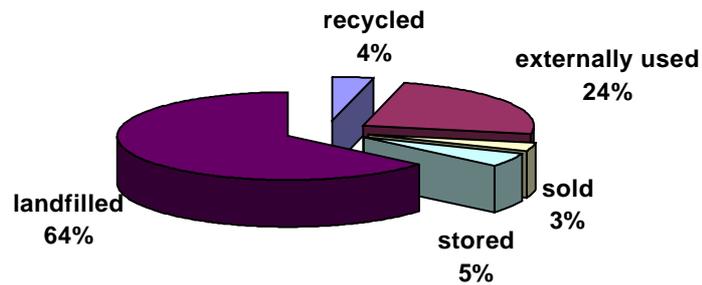


Figure 4-21: The fate of filter dust collected from primary and secondary off-gases from electric arc furnaces

The data show that approximately 70% of filter dust from EAF have been stored or landfilled. More recent data show that, according to efforts to re-use the filter dusts, significantly lower amounts are stored or land filled. Approximately 45% are recycled within the waelz process (see secondary zinc production). The following table shows the treatment of filter dust from EAF (carbon steel and low alloyed steel) for selected EU countries and regions:

country	recycling of filter dust in the waelz process (external use) [%]	share with other fate [%]	fate of residual amount of dust
AT and CH	83	17	Landfill
BeNeLux	85	15	Landfill
DK	100	0	n.a.
FR	33	67	Landfill
DE	70	30	landfill, filling of mines
IT	44	56	landfill and external recycling
Scandinavia	33	67	landfill and storage for recycling in the future
ES and PT	20	80	Landfill
UK	0	100	Landfill
Total	45	55	see above

Table 4-15: Fate of filter dust from EAF (carbon steel and low alloyed steel) for selected EU countries and regions [IS BREF, table 9.7 according to Hoffmann, 1997]

Recent data provided from EUROFER show significant effects of recent efforts made to reduce the amount of waste and increase recovery of metal compounds.

As illustrated in Table 4-16 recycling rates for Germany, Benelux and Spain have increase since the mid nineties to an actual high level in important producer countries.

country	recycling of filter dust in the waelz process (external use) [%]	share with other fate [%]	fate of residual amount of dust
BeNeLux	100	0	Landfill
DE	98	2	landfill, filling of mines
ES	45	55	Landfill
SE	55	45	Landfill

Table 4-16: Fate of filter dust from EAF (carbon steel and low alloyed steel) for selected EU countries (EUROFER 2005)

Based on the activity data it can be stated that DE, IT and ES each represent about 20% of the overall EAF activity in EU 25. Thus an average can be derived from the reported recycling rates covering 60% of the overall production in Europe.

Against this background the following shares for the actual treatment of filter dust from EAF are used for the PCDD/PCDF flow assessment:

- sold, externally or internally used and recycled: min. 60%
- stored 5%
- landfilled 35%

The share of disposal as hazardous or non-hazardous waste according to hazardous and non-hazardous FGT residues (EWC numbers 10 02 07* and 10 02 08) is not known.

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via slag and filter dust resulting from flue gas treatment.

The following tables show a country specific estimation on emitted amounts in the year 2002:

country	production of crude steel (electric) [kt/y]	air [g TEQ/y]	FGT residues [g TEQ/y]	slag [g TEQ/y]	total to waste [g TEQ/y]
AT	555	1.33	9.78	0.08	9.86
BE	2,805	6.73	49.45	0.39	49.84
CY	0	0.00	0.00	0.00	0.00
CZ	464	1.11	8.18	0.06	8.24
DE	13,432	32.24	236.77	1.85	238.62
DK	0	0.00	0.00	0.00	0.00
EE	0	0.00	0.00	0.00	0.00
ES	12,529	30.07	220.85	1.73	222.58
FI	1,358	3.26	23.94	0.19	24.13
FR	7,770	18.65	136.97	1.07	138.04
GR	1,701	4.08	29.98	0.23	30.21
HU	349	0.84	6.15	0.05	6.20

country	production of crude steel (electric) [kt/y]	air [g TEQ/y]	FGT residues [g TEQ/y]	slag [g TEQ/y]	total to waste [g TEQ/y]
IE	0	0.00	0.00	0.00	0.00
IT	16,898	40.56	297.87	2.33	300.20
LT	0	0.00	0.00	0.00	0.00
LU	2,675	6.42	47.15	0.37	48.52
LV	0	0.00	0.00	0.00	0.00
MT	0	0.00	0.00	0.00	0.00
NL	120	0.29	2.12	0.02	2.14
PL	3,037	7.29	53.53	0.42	53.95
PT	722	1.73	12.73	0.10	12.83
SE	1,792	4.30	31.59	0.25	31.84
SI	543	1.30	9.57	0.07	9.64
SK	229	0.55	4.04	0.03	4.07
UK	2,499	6.00	44.05	0.34	44.39
EU-25	69,478	166.75	1,224.72	9.57	1234.29
EU-15	64,856	155.65	1,143.25	8.93	1152.18
EU-10	4,622	11.09	81.47	0.64	82.11

Table 4-17: PCDD/PCDF mass flow for EAF steel production in EU 25 (reference year: 2002)

At a European scale the estimated emissions amount to 1,401 g TEQ/y. Thereof 167 g are emitted to air and 1,234 g are emitted to waste.

The following table shows the PCDD/PCDF flow taking into account the assumed handling of filter dust from EAF:

treatment	recovered. recycled	stored	landfilled
share%	0.6	0.05	0.35
g TEQ in filter dust	612.4	61.2	551.1

The following table shows the PCDD/PCDF flow taking into account the assumed handling of slag from EAF:

treatment	internally recycled	externally recycled	sold	landfilled or stored
share%	0.05	0.23	0.1	0.62
g TEQ in slag	0.48	2.20	0.96	5.93

Taking into account the waste treatment, the following PCDD/PCDF flow results (in g TEQ/y):

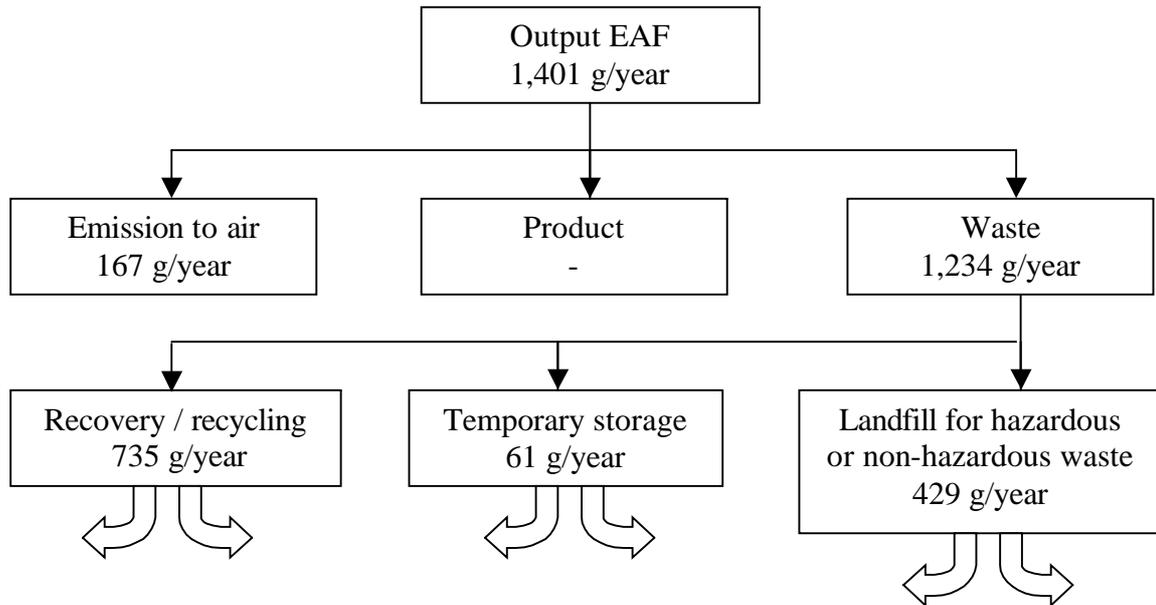


Figure 4-22: Assessment of the PCDD/PCDF flow related to electric arc furnaces

(H) EAF waste flow

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

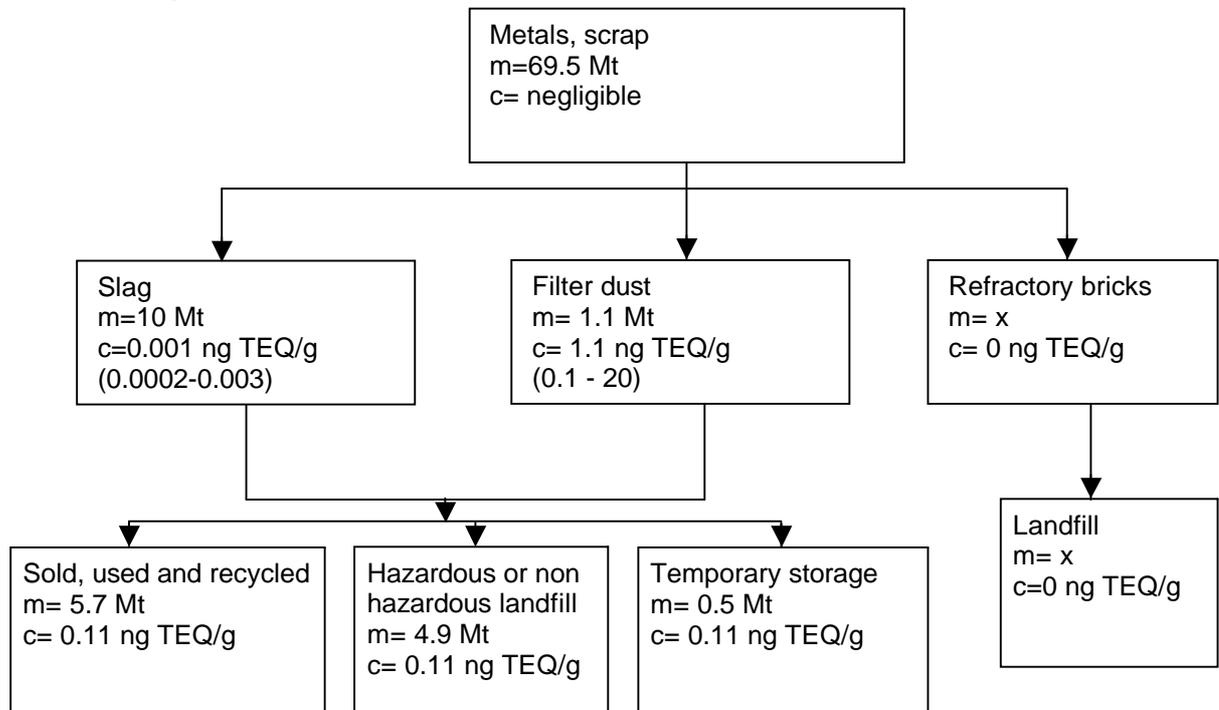


Figure 4-23: Detailed waste flow for electric arc furnaces (EAF) in EU 25

The relevant data and their origin are listed in tables 1.7.1 - 1.7.3 in the Annex.

4.1.8 Iron and steel production – Iron smelting

(A) Background

The activity "iron smelting" is carried out at ferrous metal foundries. Depending on the furnace type and metal load several conditions for PCDD/PCDF formation can occur. Such conditions are in particular contamination of scrap and other input used for smelting with chloride and/or organic carbon and thermal operations with temperatures that are critical for PCDD/PCDF formation. Considering the high temperatures in the melting furnace, PCDD/PCDF emission will mainly generate from de-novo synthesis [SF BREF 2004].

The ferrous metal foundry process includes melting, casting and finishing. Melting is carried out in different furnace types (cupola furnace, electric arc furnace, induction furnace, rotary furnace). The relevant processes and aspects in ferrous metal founding are described in detail in the corresponding BAT reference document [SF BREF 2004].

(B) Process input (raw material) and output (waste, air, water, product)

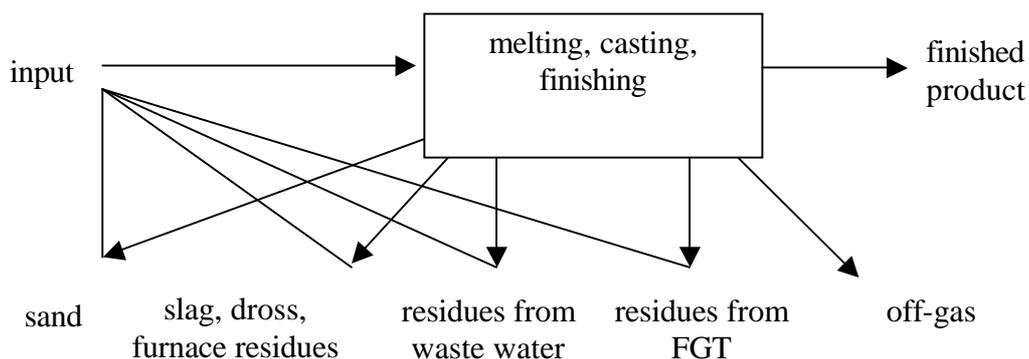


Figure 4-24: Relevant input and output of the iron smelting process (dotted lines: internal recycling possible)

Input:

- Main input are metal, binders, chemicals, sand and water. The input may be contaminated with chlorine and organic materials

Output:

- Slag (EWC 100202, 100201), drosses and eventually furnace residues are generated during the melting stage and are removed as impurities. They are either re-used or disposed of.
- Casting may involve huge amounts of sand for molding. Used sand can be regenerated, re-used or disposed of.

- Sludges from waste water treatment (EWC 100213*, 100214): Foundries may have a high water consumption e.g. for cooling and quenching operations. The major part of the water evaporates. The water is generally used in the cooling systems of electric or cupola furnaces. Usually the waste water volume is very small. Nevertheless, when wet dedusting techniques are used, the generated waste water contains dust from flue gas treatment with potential PCDD/PCDF contamination. The resulting solid residues are covered under “residues from FGT”.
- Residues from FGT: Airborne emissions contain, among others, dust and metal compounds and organic carbon compounds including PCDD/PCDF. According to BAT, particulate matter is removed from collected combustion gases. Filter dusts can partly be used as an input for internal or external uses.
- Treated off-gas may contain significant amounts of PCDD/PCDF
- Product: casted iron

The most relevant material flows with respect to the PCDD/PCDF flow are in particular filter dust and off-gas.

(C) Generation factors for waste and other output (air, water)

Slag and dross:	No specific information available for ferrous foundries;
Sand	Sand to liquid metal ratios are in the range from 1:1 up to 20:1. Used sand can be regenerated, re-used or be disposed of. The amount of sand needed is process specific. In the example of a Dutch green sand foundry 424 kg of sand are required for the foundry process. 354 kg are internally recycled. 70 kg have to be disposed of or to be used externally. This figure is taken as a basis for the mass flow assessment.
Residues from FGT	Dust amounts from cupola melting of cast iron can be above 10 kg/tonne iron. Reported mean values range from 4.5 to 8.2 kg/tonne iron. The calculated average over the reported values (6.175 kg/tonne iron) is used for the PCDD/PCDF flow assessment.
Off gas	The exhaust air volume depends on the furnace type used in the iron melting process. Reported mean values are ~ 1,600 Nm ³ / tonne iron (hot blast cupola), ~ 3,700 Nm ³ / tonne iron (cold blast cupola), ~ 7,600 Nm ³ / tonne iron (rotary furnace) and ~ 10,700 Nm ³ / tonne iron (induction furnace). The mean from all used furnace types (3,850 Nm ³ /tonne iron) is used for the mass flow assessment.

(D) Contamination data for output (and input)

- Slag and dross: No or very low contamination expected; For a Belgium inventory contamination values of 0.005 ng TEQ/g for slag and furnace residues from foundries and 0.007 ng TEQ/g for salt slag from foundries and 0.05 ng TEQ/g dross have been used for the year 1997. For the assessment 0.005 ng TEQ/g can be taken as a basis.
- Sand No or very low contamination expected; in the mentioned Belgian inventory contamination values of 0.005 ng TEQ/g have been reported for sand from foundries. This value has been taken as the basis for the PCDD/PCDF flow assessment.
- Residues from FGT In the mentioned Belgian inventory an average contamination of 1 ng TEQ/g filter dust has been assumed. The value used for filter dust that is not internally recycled is 1.1 ng TEQ/g. Other reported values for filter dust from iron foundries in Germany are 4.85 and 0.96 ng TEQ/g for cold blast cupola furnaces and 0.18 and 1.4 ng TEQ/g for hot blast cupola furnaces. The mean value of 1.7 ng TEQ/g for dusts collected from iron foundries is the basis for the PCDD/PCDF flow assessment.
- Off gas Reported contamination levels for exhaust air from cast iron industry are approximately 0.5 (mean cold blast cupola 0.54, hot blast cupola 0.75, induction furnace 0.01 and rotary furnace 0.27 ng TEQ/Nm³; mean of reported values in [SF BREF 2004] 0.53 ng TEQ/g, which is taken as a basis for the PCDD/PCDF flow assessment). Taking into account the specific exhaust air volumes specific PCDD/PCDF emission factors can be calculated. The mean emission to air per tonne produced iron is 1.82 µg TEQ. Specific values calculated on the basis of the values reported in the reference document on BAT [SF BREF 2004] are 3.04 µg for cold blast furnaces, 1.06 for hot blast furnaces, 0.03 for induction furnaces and 2.06 µg for rotary furnaces.

(E) Activity data

The following table shows European production data for ferrous castings in 2002 [SF BREF 2004]:

country	production of ferrous castings [t]	reference
AT	181,200	[SF BREF 2004]
BE	143,700	[SF BREF 2004]
CY	0	[SF BREF 2004]
CZ	381,600	[SF BREF 2004]
DE	3,749,700	[SF BREF 2004]
DK	87,300	[SF BREF 2004]
EE	1,100	[SF BREF 2004]
ES	992,900	[SF BREF 2004]
FI	112,500	[SF BREF 2004]
FR	2,128,600	[SF BREF 2004]
GR	0	[SF BREF 2004]
HU	67,900	[SF BREF 2004]
IE	0	[SF BREF 2004]
IT	1,460,900	[SF BREF 2004]
LT	0	[SF BREF 2004]
LU	0	[SF BREF 2004]
LV	0	[SF BREF 2004]
MT	0	[SF BREF 2004]
NL	123,700	[SF BREF 2004]
PL	598,000	[SF BREF 2004]
PT	96,700	[SF BREF 2004]
SE	234,600	[SF BREF 2004]
SI	0	[SF BREF 2004]
SK	0	[SF BREF 2004]
UK	886,300	[SF BREF 2004]
EU-25	11,246,700	
EU-15	10,198,100	
EU-10	1,048,600	

Table 4-18: European production data for ferrous castings in 2002 [SF BREF 2004]

(F) Waste treatment

Sand can be disposed of or be used externally. External use is mainly the use as a raw material in cement production and in the construction sector. It is assumed that most of the used sand is externally used. It is assumed that residues from flue gas treatment that can not be internally recycled any further are usually disposed of. The share of disposal of hazardous and non-hazardous FGT residues (EWC numbers 10 02 07* and 10 02 08) is not known.

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via used sand and filter dusts resulting from flue gas treatment. Emissions to slag, drosses and furnace residues are not assessed due to missing data on amounts occurring. However, emissions via these waste categories are expected to be comparatively low. As mentioned, the most relevant PCDD/PCDF flows are emitted via air and residues from flue gas treatment. The following tables show a country specific estimation on emitted amounts in the year 2002:

country	production of ferrous castings [t]	air [g TEQ/y]	FGT residues [g TEQ/y]	used sand [g TEQ/y]	total to waste [g TEQ/y]
AT	181,200	0.3	1.9	0.1	2.0
BE	143,700	0.3	1.5	0.1	1.6
CY	0	0.0	0.0	0.0	0.0
CZ	381,600	0.7	4.0	0.1	4.1
DE	3,749,700	7.1	39.3	1.3	40.6
DK	87,300	0.2	0.9	0.03	0.9
EE	1,100	0.0	0.0	0.0	0.0
ES	992,900	1.9	10.4	0.4	10.8
FI	112,500	0.2	1.2	0.04	1.2
FR	2,128,600	4.0	22.3	0.8	23.1
GR	0	0.0	0.0	0.0	0.0
HU	67,900	0.1	0.7	0.02	0.7
IE	0	0.0	0.0	0.0	0.0
IT	1,460,900	2.8	15.3	0.5	15.8
LT	0	0.0	0.0	0.0	0.0
LU	0	0.0	0.0	0.0	0.0
LV	0	0.0	0.0	0.0	0.0
MT	0	0.0	0.0	0.0	0.0
NL	123,700	0.2	1.3	0.0	1.3
PL	598,000	1.1	6.3	0.2	6.5
PT	96,700	0.2	1.0	0.03	1.0
SE	234,600	0.4	2.5	0.1	2.6
SI	0	0.0	0.0	0.0	0.0
SK	0	0.0	0.0	0.0	0.0
UK	886,300	1.7	9.3	0.3	9.6
EU-25	11,246,700	21.4	117.9	3.9	121.8
EU-15	10,198,100	19.4	106.9	3.6	110.5
EU-10	1,048,600	2.0	11.0	0.4	11.4

Table 4-19: PCDD/PCDF mass flow for ferrous metal smelting in EU 25 (reference year: 2002)

At a European scale the estimated emissions amount to ~ 143 g TEQ/y. Thereof ~21 are emitted to air and ~ 122 are emitted to waste. Based on the assumption that used sand is externally used and residues from FGT are disposed of the following overall picture results:

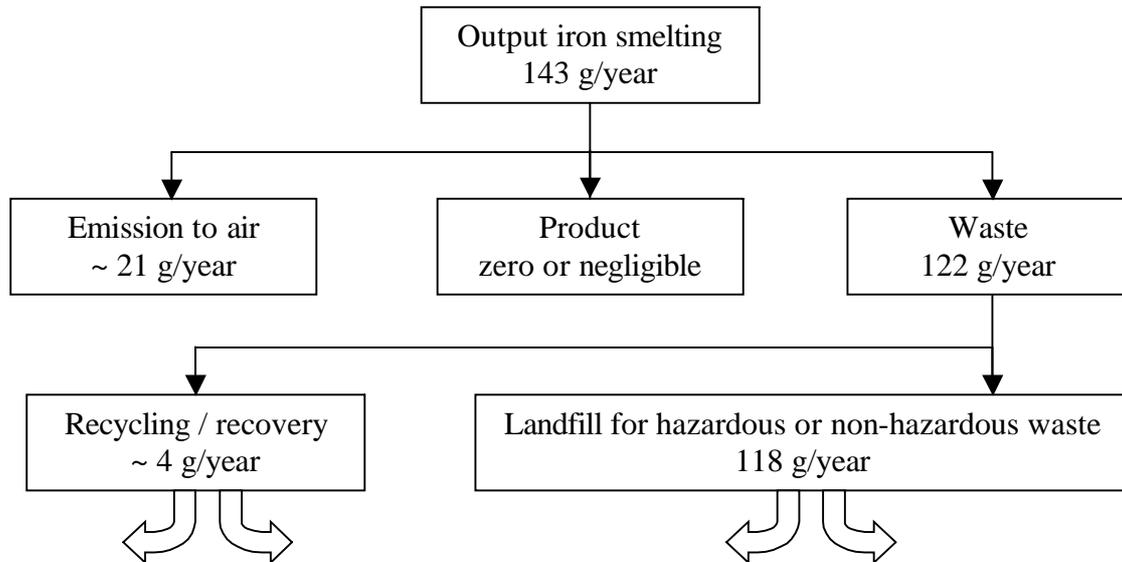


Figure 4-25: Assessment of the PCDD/PCDF flow related to ferrous metal melting

(H) Waste flow for Iron smelting

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

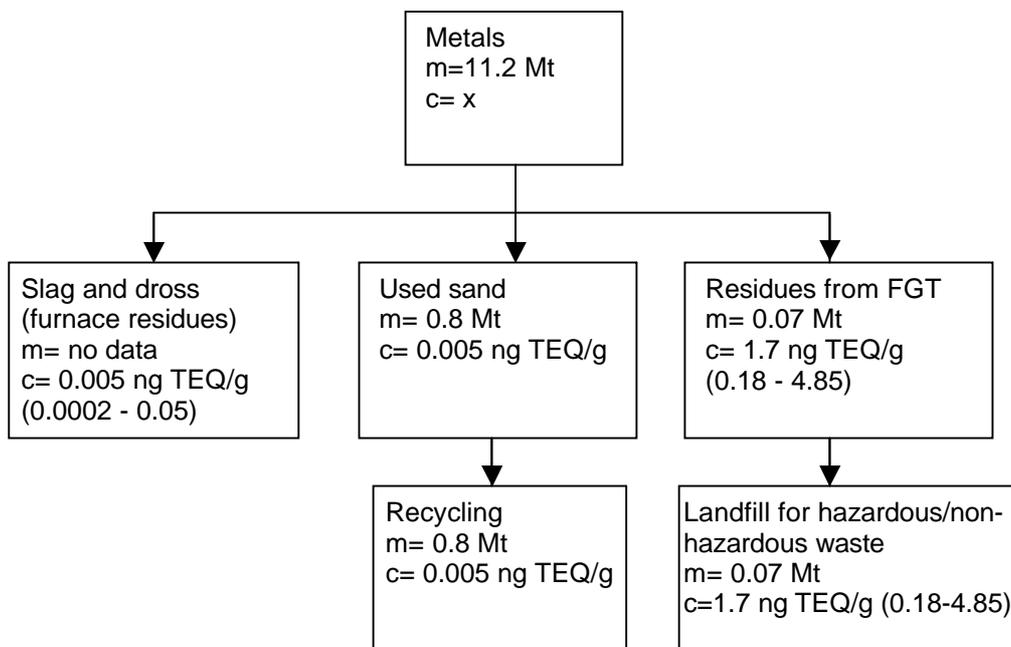


Figure 4-26: Detailed waste flow for iron smelting in EU 25

The relevant data and their origin are listed in tables 1.8.1 - 1.8.3 in the Annex.

4.1.9 *Non-ferrous metal industry –Secondary copper production*

(A) Background

Potential emissions from secondary copper production (EWC 1006) are of particular concern as copper is the most efficient metal to catalyse PCDD/PCDF formation. The formation is due to the presence of chlorine from plastics and trace oils in the feed material. The relevant processes and aspects in secondary copper production are described in [NFM BREF 2001] and [UNEP BAT-BEP 2004].

Secondary copper production is divided into 4 separate operations: scrap pre-treatment, smelting, alloying, and casting. Pre-treatment includes the cleaning and consolidation of scrap in preparation for smelting. Smelting consists of heating and treating the scrap for separation and purification of specific metals. Alloying involves the addition of 1 or more other metals to copper to obtain desirable qualities characteristic of the combination of metals.

Scrap pre-treatment may be achieved through manual, mechanical, pyrometallurgical, or hydrometallurgical methods. Manual and mechanical methods include sorting, stripping, shredding, and magnetic separation. Pyrometallurgical pre-treatment may include sweating (the separation of different metals by slowly staging furnace air temperatures to liquefy each metal separately), burning insulation from copper wire, and drying in rotary kilns to volatilise oil and other organic compounds. Hydrometallurgical pre-treatment methods include flotation and leaching to recover copper from slag. Leaching with sulphuric acid is used to recover copper from slime, a by-product of electrolytic refining.

Smelting of low-grade copper scrap begins with melting in either a blast or a rotary furnace, resulting in slag and impure copper. If a blast furnace is used, this copper is charged to a converter, where the purity is increased to about 80 to 90 percent, and then to a reverberatory furnace, where copper of about 99 percent purity is obtained. In these fire-refining furnaces, flux is added to the copper and air is blown upward through the mixture to oxidize impurities. These impurities are then removed as slag. Then, by reducing the furnace atmosphere, cuprous oxide (CuO) is converted to copper. Fire-refined copper is cast into anodes, which are used during electrolysis. The anodes are submerged in a sulphuric acid solution containing copper sulphate. As copper is dissolved from the anodes, it deposits on the cathode. Then the cathode copper, which is as much as 99.99 percent pure, is extracted and recast. The blast furnace and converter may be omitted from the process if average copper content of the scrap being used is greater than about 90 percent.

In alloying, copper-containing scrap is charged to a melting furnace along with 1 or more other metals such as tin, zinc, silver, lead, aluminium, or nickel. Fluxes are added to remove impurities and to protect the melt against oxidation by air. Air or pure oxygen may be blown through the melt to adjust the composition by oxidizing excess zinc. The alloying process is, to some extent, mutually exclusive of the smelting and refining processes described above that lead to relatively pure copper.

The final recovery process step is the casting of alloyed or refined metal products. The molten metal is poured into moulds from ladles or small pots serving as surge hoppers and flow regulators. The resulting products include shot, wire bar, anodes, cathodes, ingots, or other cast shapes.

(B) Process input (raw material) and output (waste, air, water, product)

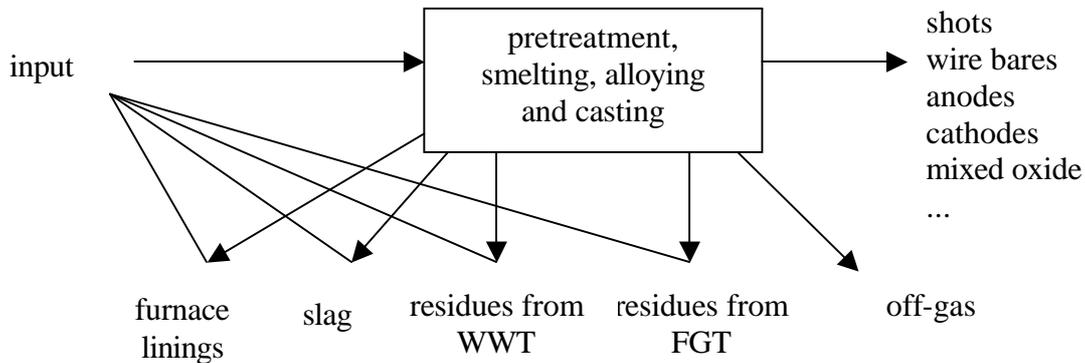


Figure 4-27: Relevant input and output of secondary copper production (dotted lines: internal recycling possible)

Input:

- Feed sources are copper scrap, sludge, computer scrap, drosses from refineries and semi-finished products and internally recycled materials such as dusts, ashes, drosses or sludge. These materials may contain organic matter like coatings or oil, and installations take this into account by using de-oiling and de-coating methods or in an appropriate design of the furnace and abatement system.

Output:

- Final slag (EWC 100601): In fire-refining furnaces, slags are partly recycled within the smelting process. Not recyclable “final slag” is used for road construction. Due to production conditions (~ 1,200°C) slags are virtually free from PCDD/PCDF or other POPs (source: questionnaire NA Lünen).
- Sludges from waste water treatment (EWC 100607*): Depending on the site specific production process, waste water may arise. Process, surface and cooling water can be contaminated by suspended solids, metal compounds and oils. Most process and cooling water is recycled. By-products and residues from waste water treatment are recycled in the process as these contain recoverable quantities of copper and other non-ferrous metals. If waste arises, it generally consists of acid sludge which is disposed of.
- Furnace linings (EWC 161101*, 161102, 161103*, 161104) are removed in intervals (e.g. each 14 to 15 months) from the inner surface of involved furnaces.

In processing the linings are exposed to high temperature and a contamination with PCDD/PCDF is not expected. If at all, the surface of the linings may be contaminated with PCDD/PCDF.

- Residues from FGT (EWC 100603*, 100606*): Airborne emissions contain among other dust and metal compounds and organic carbon compounds including PCDD/PCDF. Particulate matter is removed from collected and cooled combustion gases by electrostatic precipitators (ESPs) or fabric filters. Filter dusts are partly used as input for secondary production (see “products”), partly internally recycled and partly disposed of (due to their high content of arsenic).
- Off-gas may contain significant amounts of PCDD/PCDF
- Products: shot, wire bar, anodes, cathodes, ingots, or other cast shapes. Specific filter dust from flue gas treatment consist of zinc/lead mixed oxide (“furnace-oxide”) which is used as raw material for secondary zinc and lead production.

The relevant material flows with respect to the PCDD/PCDF flow are in particular input and output filter dust and off-gas.

(C) Generation factors for waste and other output (air, water)

Emission per tonne of pure copper produced:

- filter dusts from other metal industry sectors are used as up to 10% of the input; for the PCDD/PCDF flow assessment an input of 10% has been calculated
- output filter dust: ~ 6 kg
- furnace linings: ~ 6 kg
- WWT residues (acid sludge): no information available
- Furnace-oxide: ~ 96 kg
- Slag: ~ 620 kg

(D) Contamination data for output (and input)

Typical contamination

- filter dust: up to 23 ng TEQ/g, estimated average: 6 ng TEQ/g
- furnace-oxide: 1 ng TEQ/g
- off-gas: 0.01 to 0.1 ng TEQ/Nm³; estimated average 0.05 ng TEQ/Nm³. For the assessment of the emissions to air the emission factor of 50 µg/t product (UNEP toolkit emission factor for well controlled technology) has been applied for the bulk

of the Member States. Only for Poland and Slovakia the emission factor for uncontrolled technology (800 µg/t product) has been used in line with a recent study on PCDD/PCDF emissions in the new Member States. As a consequence the estimated corresponding annual PCDD/PCDF emissions to air increase from ~ 50 to ~ 80 g TEQ.

- Slag: No specific values are reported for slag from secondary copper production. From Belgium an average contamination of slag from the non ferrous metal industry of 0.02 ng TEQ/g is reported. It is not specified, to which type of slag this value refers. The most common type of slag in secondary copper production is iron silicate slag that is produced at temperatures ranging from 1200 to 1300°C. Consequently. The occurrence of dioxins at these temperature is quite improbable. However, the value of 0.02 ng TEQ/g has been taken for the calculation of the PCDD/PCDF flow.
- Refractory bricks: No specific values are reported for furnace linings from secondary copper production. From Belgium an average contamination of furnace residues of 0.01 ng TEQ/g is reported. However, as the furnace linings are only contaminated at the surface, only very low contamination levels are expected.
- filter cakes from waste water treatment in secondary copper production showed contamination levels ranging from 0.01 to 4.2 ng TEQ/g. A calculated average of 1.58 ng TEQ/g could be taken as a basis for the calculation of the PCDD/PCDF flow (if a waste generation factor was available).

(E) Activity data

The following table shows production data of secondary copper for the old member states for 1997 and for selected new Member States according to a recent study on PCDD/PCDF emissions in new the new Member States [TNO 2005].

country	production of secondary copper [t]
AT	77,000
BE	183,000
CY	0
CZ	12,000
DE	378,000
DK	0
EE	0
ES	63,000
FI	0
FR	29,000
GR	0
HU	30,000
IE	0
IT	80,000
LT	0
LU	0

country	production of secondary copper [t]
LV	0
MT	0
NL	0
PL	29,000
PT	0
SE	34,000
SI	0
SK	17,000
UK	58,000
EU-25	990,000
EU-15	902,000
EU-10	88,000

Table 4-20: European production of secondary copper for 1997 (source: [NFM BREF 2001])

(F) Waste treatment

Filter dust is partly internally recycled (up to 100%) and partly disposed of as hazardous waste (due to its high content of arsenic). The relation between recycling and disposal is not available.

“Furnace-oxide” is used as a raw material for secondary zinc and lead production.

Furnace linings may be partly recycled externally or internally, or disposed of. The relation between recycling and disposal is not available. Acid sludge is usually disposed of on site. Slag is used for road construction. Treated off gas is released to the atmosphere.

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via slag, filter dust, and furnace oxide. The following tables show a country specific estimation on emitted amounts based on the above mentioned activity data.

country	production of secondary copper [t]	air [g TEQ/y]	furnace oxide [g TEQ/y]	slag [g TEQ/y]	filter dust [g TEQ/y]	total to waste [g TEQ/y]
AT	77,000	3.9	7.4	0.9	2.8	3.7
BE	183,000	9.2	17.5	2.2	6.6	8.8
CY	0	0.0	0.0	0.0	0.0	0.0
CZ	12,000	0.6	1.1	0.1	0.4	0.5
DE	378,000	18.9	36.1	4.6	13.5	18.1
DK	0	0.0	0.0	0.0	0.0	0.0
EE	0	0.0	0.0	0.0	0.0	0.0
ES	63,000	3.15	6.0	0.8	2.3	3.1
FI	0	0.0	0.0	0.0	0.0	0.0
FR	29,000	1.5	2.8	0.4	1.0	1.4
GR	0	0.0	0.0	0.0	0.0	0.0
HU	30,000	1.5	2.9	0.4	1.1	1.5
IE	0	0.0	0.0	0.0	0.0	0.0

country	production of secondary copper [t]	air [g TEQ/y]	furnace oxide [g TEQ/y]	slag [g TEQ/y]	filter dust [g TEQ/y]	total to waste [g TEQ/y]
IT	80,000	4.0	7.6	1.0	2.9	3.9
LT	0	0.0	0.0	0.0	0.0	0.0
LU	0	0.0	0.0	0.0	0.0	0.0
LV	0	0.0	0.0	0.0	0.0	0.0
MT	0	0.0	0.0	0.0	0.0	0.0
NL	0	0.0	0.0	0.0	0.0	0.0
PL	29,000	23.2	2.8	0.4	1.0	1.4
PT	0	0	0.0	0.0	0.0	0.0
SE	34,000	1.7	3.2	0.4	1.2	1.6
SI	0	0.0	0.0	0.0	0.0	0.0
SK	17,000	13.6	1.6	0.2	0.6	0.8
UK	58,000	2.9	5.5	0.7	2.1	2.8
EU-25	990,000	84.0	94.6	12.0	35.5	47.5
EU-15	902,000	45.1	86.2	10.9	32.3	43.2
EU-10	88,000	38.9	8.4	1.1	3.2	4.3

Table 4-21: PCDD/PCDF mass flow for secondary copper production in EU 25

At a European scale the estimated emissions amount to 226 g TEQ/y. Thereof 84 g are emitted to air, 95 g are emitted to products and 47 g are emitted to waste. The following overall picture results:

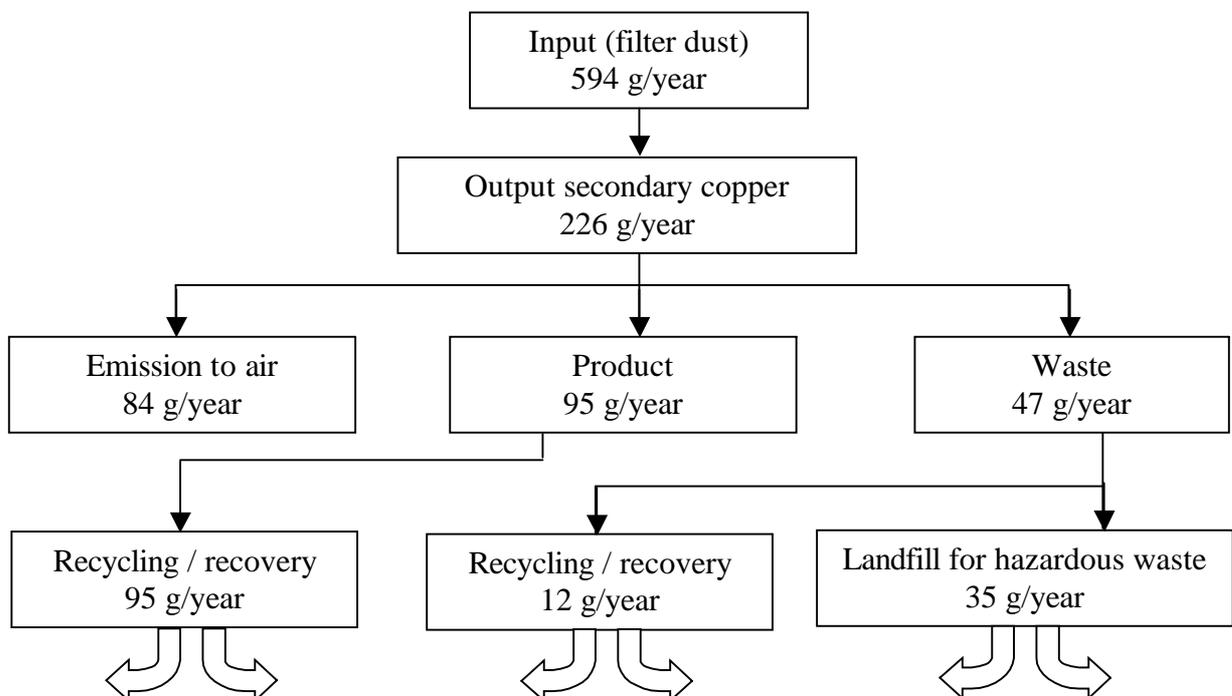


Figure 4-28: Assessment of the PCDD/PCDF flow related to secondary copper production

(H) Waste flow for secondary copper production

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

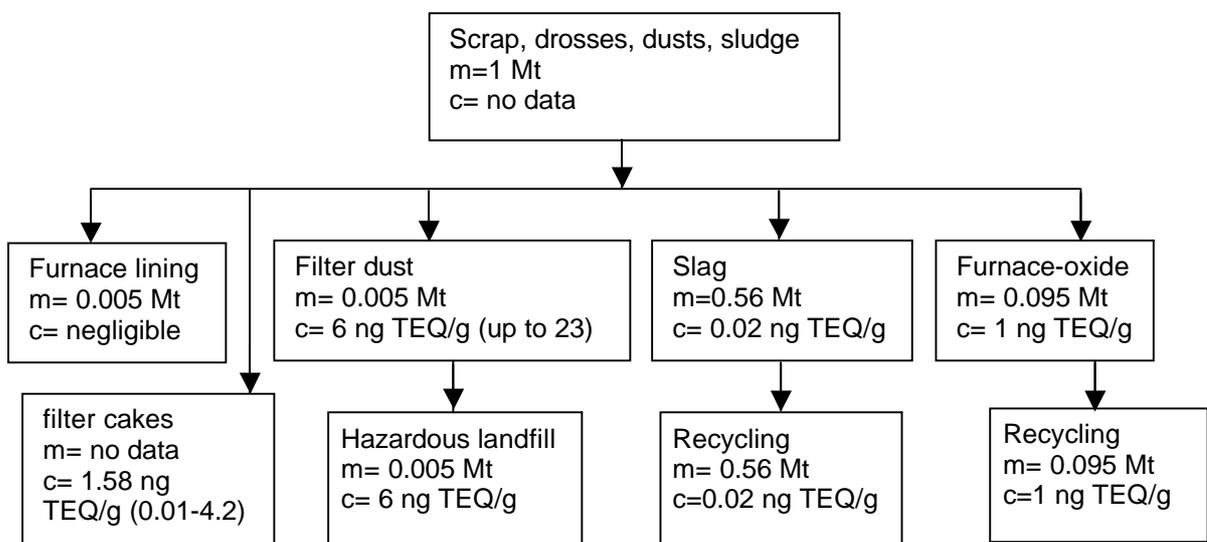


Figure 4-29: Detailed waste flow secondary copper production in EU 25

The relevant data and their origin are listed in tables 1.9.1 - 1.9.4 in the Annex.

4.1.10 Non-ferrous metal industry –Secondary aluminium production

(A) Background

Potential emissions from secondary aluminium production are due to the presence of organic contaminants and plastics in the feed material with the addition of chlorine and chlorides during the smelting process.

The relevant processes and technical aspects in secondary aluminium production are described in [NFM BREF 2001] and [UNEP BAT-BEP 2004].

(B) Process input (raw material) and output (waste, air, water, product)

The important inputs and outputs are illustrated in the following schematic flow chart.

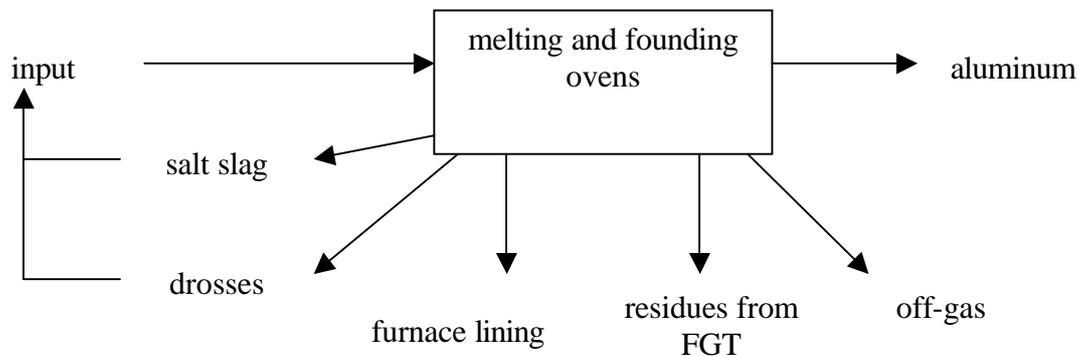


Figure 4-30: Relevant input and output of secondary aluminium production

Input:

- input: aluminium scrap, drosses, solid metal, alloy metals, adjuvants (melting salt, azote-chlorine mixture)

Output:

- salt slag (EWC 100308*) and drosses (100309*) are internally recycled and re-used as input for the production process
- furnace linings (EWC 161101*, 161102, 161103*, 161104)
- dry and wet residues from flue gas treatment (EWC 100323*, 100324, 100325*, 100326): filter dust (EWC 100319*); (containing PCDD/PCDF)
- off-gas (containing dust and PCDD/PCDF)

The relevant material flows with respect to the PCDD/PCDF flow are in particular filter dust and off-gas.

(C) Generation factors for waste and other output (air, water)

Emissions per tonne aluminium produced:

- furnace linings: 4.7 kg (range 3.6 to 7.7)
- filter dust: 20.9 kg (range 18 to 47)
- sludge from WWT 2.7 kg (range 1,0 to 3.6)
- salt slag 310 kg (range 152 to 444)
- off-gas ~ 3,500 Nm³

(D) Contamination data for output (and input)

Contamination levels:

- furnace linings: no data; low contamination expected
- filter dust: 10.00 ng TEQ/g (range 0.5 to 33.8)
- sludge from WWT no data available; for the PCDD/PCDF flow assessment the contamination value from secondary copper production (1.58 ng TEQ/g) has been applied
- salt slag no data; no or low contamination expected
- off-gas For the assessment of the PCDD/PCDF emissions to air a calculated mean value of 0.23 ng TEQ/Nm³, derived from a German secondary aluminium production site, is assumed. On the basis of emission factors used for some of the new Member states in a recent study [TNO 2005], average contamination levels for off gas have been calculated and applied for individual countries (CZ: 10.2 ng TEQ/Nm³; HU, PL and SK: 101.5 ng TEQ/Nm³). The effect on the assessment of the corresponding annual European emissions to air is an increase from 2 to 58 g TEQ/y.

(E) Activity data

Production data are based on NFM BREF for the year 1997. According to the OEV at present 481,705 tonnes of aluminium are annually produced in secondary aluminium production in AT, DE, DK NL and SE.

country	production of secondary aluminium [t]	reference
AT	98,000	[NFM BREF 2001]
BE	0	[NFM BREF 2001]
CY	0	
CZ	35,000	[TNO 2005]
DE	433,000	[NFM BREF 2001]
DK	14,000	[NFM BREF 2001]
EE	0	
ES	154,000	[NFM BREF 2001]
FI	33,000	[NFM BREF 2001]
FR	233,000	[NFM BREF 2001]
GR	10,000	[NFM BREF 2001]
HU	32,761	[ESTAT, PRODCOM data]
IE	0	[NFM BREF 2001]
IT	443,000	[NFM BREF 2001]
LT	0	
LU	0	[NFM BREF 2001]
LV	28,138	[ESTAT, PRODCOM data]
MT	0	
NL	150,000	[NFM BREF 2001]
PL	123,000	[TNO 2005]
PT	3,000	[NFM BREF 2001]
SE	26,000	[NFM BREF 2001]
SI	0	
SK	1,400	[TNO 2005]
UK	257,000	[NFM BREF 2001]
EU-25	2,074,299	
EU-15	1,854,000	
EU-10	220,299	

Table 4-22: European production of secondary aluminium (reference years: [NFM BREF 2001] for 1997 and EUROSTAT, annual PRODCOM for 2001)

(F) Waste treatment

Salt slag and drosses are internally recycled and re-used as a process input. Filter dust and furnace linings are treated for further use.

Disposal or recycling operations for filter dust according to the OEV (particular situation in Germany) include 18% mine filling, 53% underground disposal and 29% re-use as building material (cover of above ground landfills).

Off gas including remaining dust is emitted after flue gas treatment

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and to waste via slag, filter dust, furnace oxide and air. The following tables show a country specific estimation on emitted amounts based on the above mentioned activity data.

country	production of secondary aluminium [t]	air [g TEQ/y]	filter dust [g TEQ/y]	WWT residues [g TEQ/y]	total to waste [g TEQ/y]
AT	98,000	0.08	20.49	0.42	20.91
BE	0	0.00	0.00	0.00	0.00
CY	0	0.00	0.00	0.00	0.00
CZ	35,000	1.23	7.32	0.15	7.47
DE	433,000	0.34	90.55	1.84	92.39
DK	14,000	0.01	2.93	0.06	2.99
EE	0	0.00	0.00	0.00	0.00
ES	154,000	0.12	32.21	0.66	32.87
FI	33,000	0.03	6.90	0.14	7.04
FR	233,000	0.18	48.73	0.99	49.72
GR	10,000	0.01	2.09	0.04	2.13
HU	32,761	11.47	6.85	0.14	6.99
IE	0	0.00	0.00	0.00	0.00
IT	443,000	0.35	92.65	1.89	94.54
LT	0	0.00	0.00	0.00	0.00
LU	0	0.00	0.00	0.00	0.00
LV	28,138	0.02	5.88	0.12	6.00
MT	0	0.00	0.00	0.00	0.00
NL	150,000	0.12	31.37	0.64	32.01
PL	123,000	43.05	25.72	0.52	26.24
PT	3,000	0.00	0.63	0.01	0.64
SE	26,000	0.02	5.44	0.11	5.55
SI	0	0.00	0.00	0.00	0.00
SK	1,400	0.49	0.29	0.01	0.30
UK	257,000	0.20	53.75	1.09	54.84
EU-25	2,074,299	57.72	433.80	8.83	442.63
EU-15	1,854,000	1.47	387.73	7.90	395.63
EU-10	220,299	56.25	46.07	0.94	47.01

Table 4-23: PCDD/PCDF mass flow for secondary aluminium production in EU 25

At a European scale the estimated emissions amount to ~ 500 g TEQ/y. Thereof ~ 58 g is emitted to air and ~ 443 g are emitted to waste. The following overall picture results:

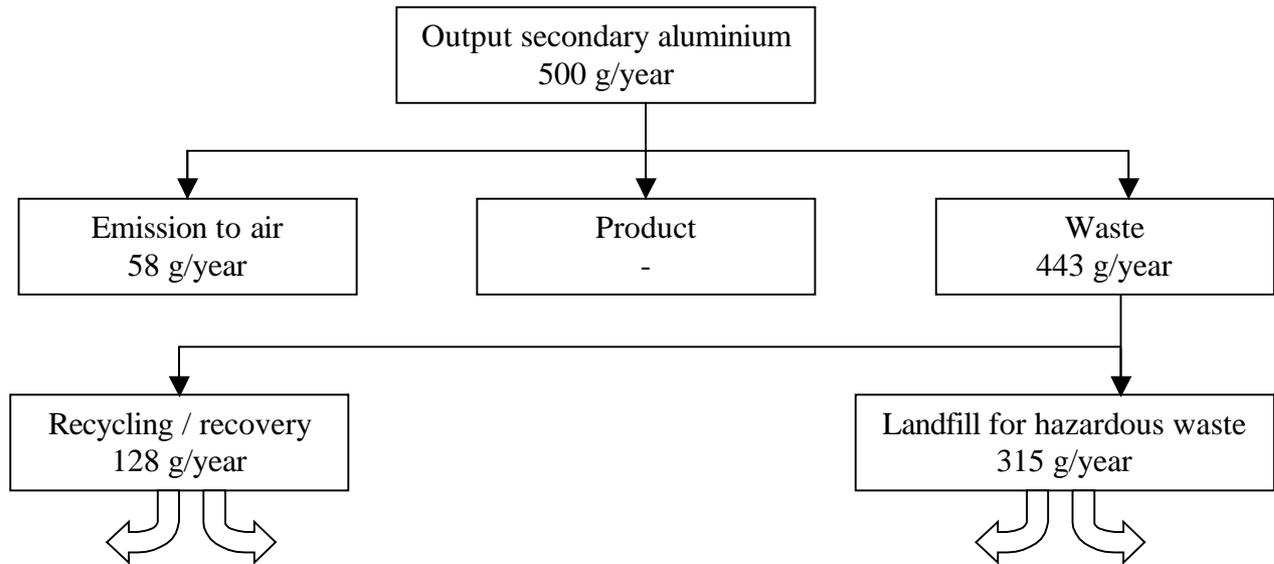


Figure 4-31: Assessment of the PCDD/PCDF flow related to secondary aluminium production

(H) Waste flow for secondary aluminium production

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

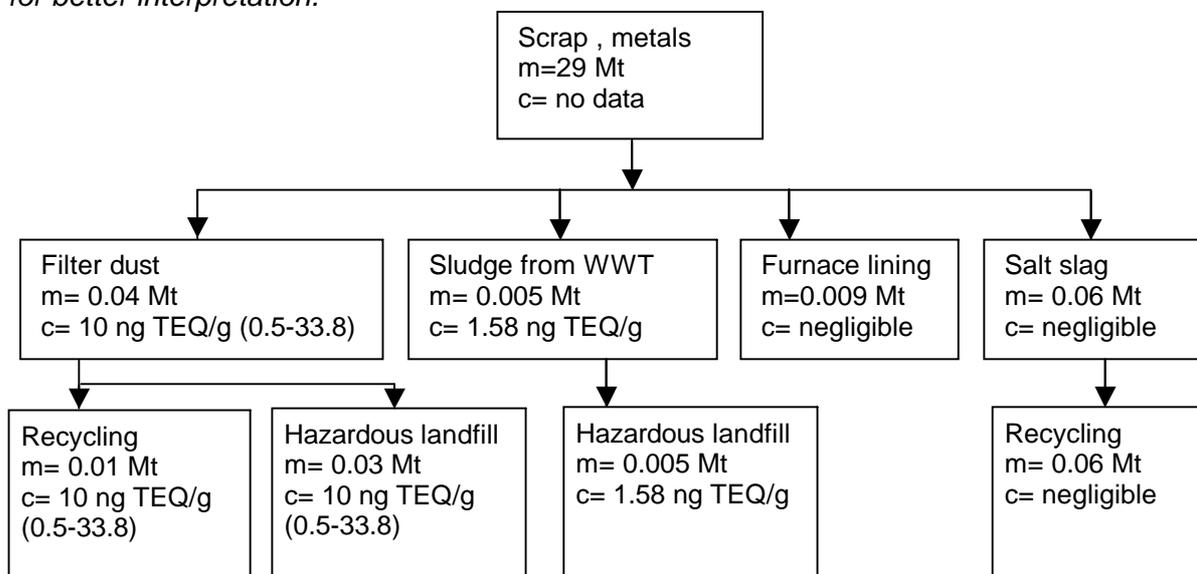


Figure 4-32: Detailed waste flow secondary aluminium production in EU 25

The relevant data and their origin are listed in tables 1.10.1 - 1.10.3 in the Annex.

4.1.11 Non-ferrous metal industry –Secondary zinc production

(A) Background

Potential emissions from secondary zinc production are due to impurities in the process input and comparatively low temperatures around 250 to 500°C involved in zinc melting. The addition of chloride fluxes provides a chlorine source. Formation of PCDD/PCDF is possible in the combustion zone by incomplete combustion of organic compounds and in the off-gas treatment cooling section through new formation. PCDD/PCDF can be discharged to the environment through air emissions, wastewater and residue disposal.

The relevant processes and aspects in secondary zinc production are described in [NFM BREF 2001] and [UNEP BAT-BEP 2004]. General processes are the following:

Physical separation, melting and other high temperature treatment techniques are used. Chlorides are removed and the residues are used to produce zinc metal or alloys for re-use, impure metal or oxide, which will be refined further in the primary zinc processes. Alternatively they can be further treated to produce commercial grades zinc oxide, powders or dust [NFM BREF 2001 citation: tm 120 TU Aachen 1999; tm 206 TGI 1999].

Process details are very often confidential but some examples of these specific treatments can be given.

- Galvaniser ashes which arise during galvanisation of pieces, wire and tubes are essentially a mixture of zinc metal and zinc oxide, contaminated with ammonium and zinc chloride. They are ball-milled to liberate the phases. Separation is accomplished by sweeping the mill with a stream of air to entrain the non-metallic components, which are then collected by a fabric filter. Alternatively, a screen is incorporated into the mill, which passes the fine non-metallic fraction, but retains the coarse metallic fraction. In either case, the metallic fraction is discharged from the mill, melted and cast into ingots for sale, re-use or further treatment.
- Bottom dross (also called hard zinc or spelter) is a zinc iron alloy, also containing some lead, which forms and accumulates in holding furnaces and tanks used for batch galvanising. Blockages may result and automatic removal systems are used. Top dross is zinc-iron-aluminium alloy generated from continuous hot dip galvanising. Drosses or skimmings and other residues from the die-cast industry contain a mixture of zinc metal and zinc oxide, with little or no chlorides. The treatment schemes summarised above are all applied to these materials. The same applies to old roofing and other sheet materials as well as to residues from the chemical uses of zinc or zinc products.

- Processing scrap vehicles in a series of mills produces shredder residue. After the removal of the non-metallic fraction, the non-ferrous fraction is separated from other steel-based products by magnetic separation. Heavy media separation and other techniques are then used to treat the metallic fraction. They are followed by selective melting to recover zinc. The residue is melted in two stages in a gas-fired reverberatory furnace. In the first stage lead is melted at 340 °C and is tapped and cast into ingots. In the second stage, the temperature is raised to 440 °C and zinc is melted, tapped and cast into ingots. An alternative process uses an indirectly fired rotary kiln with a perforated inner lining. Zinc melts and flows out through the liner into a holding furnace from where it is cast into ingots. Further refining is always necessary.
- Zinc oxide is also produced from residues, in particular the dust from electric arc steel making furnaces. Waelz kilns and slag fuming furnaces can be used.

(B) Process input and output

The important inputs and outputs are illustrated in the following schematic flow chart.

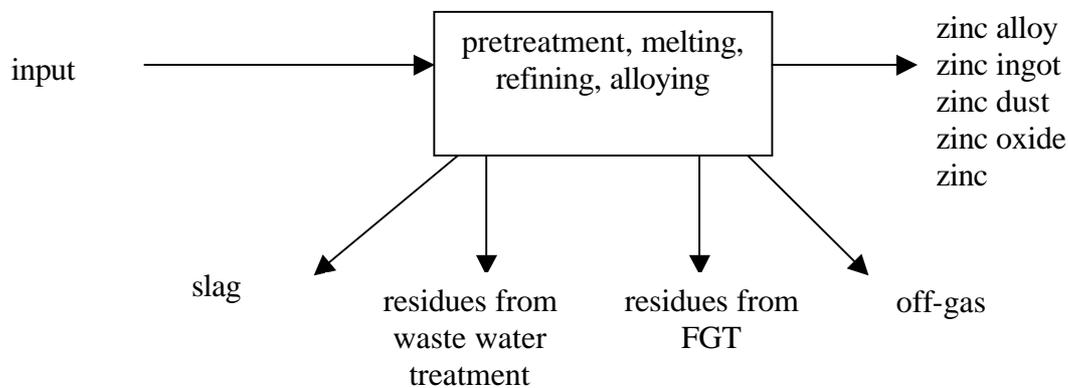


Figure 4-33 : Relevant input and output of secondary zinc production

The in- and outputs can shortly be characterised:

- raw material input: the feed material may be contaminated with PCDD/PCDF (e.g. dusts from electric arc steel making); If additional plastics and oils are present in the input material, impurities increase the risk of PCDD/PCDF formation. Input materials include
 - dust from copper alloy making
 - residues from the die casting industry

- waelz oxide: < 0.2 ng TEQ/g; for the calculation an average contamination of 0.1ng TEQ/g is assumed.
- absorbent and filter material: 0.68 ng TEQ/g (range 0.002 to 1.36 ng TEQ/g)
- slag no specific values are reported for slag from secondary zinc production. From Belgium an average contamination of slag from the non ferrous metal industry of 0.0195 ng TEQ/g is reported. This value has been taken for the calculation of the PCDD/PCDF flow.
- air: For the assessment of the PCDD/PCDF emissions to air a calculated mean value derived from German secondary zinc production site of 0.008 ng TEQ/Nm³ (range 0.003 to 0.01) is assumed. On the basis of emission factors used for some of the new Member states in a recent study [TNO 2005] average contamination levels for off gas have been calculated and applied for individual countries (CZ, PL and SK: 3.93 ng TEQ/Nm³). The effect on the assessment of the corresponding annual European emissions to air is an increase from 0.27 to 2.52 g TEQ/y.

(E) Activity data (amount zinc produced)

Production data on secondary zinc production in 1994 in Table 4-24 are based on [LUA NRW 1997], more recent values are available from [TNO 2005] and on actual production data of European top producers [personal communication B.U.S. Freiberg].

country	production of secondary zinc [t]	reference
AT	2,000	[LUA NRW 1997] for 1994 and [TNO 2005] and [personal communication B.U.S. Freiberg] for actual production amounts
BE	20,000	
CY		
CZ	1,000	
DE	460,000	
DK		
EE		
ES	130,000	
FI		
FR	120,000	
GR		
HU		
IE	300	
IT	150,000	
LT		
LU		
LV		
MT		
NL		

country	production of secondary zinc [t]	reference
PL	13,000	
PT		
SE	500	
SI		
SK	1,000	
UK	47,000	
EU-25	944,800	
EU-15	929,800	
EU-10	15,000	

Table 4-24: European production of secondary zinc in 1994

(F) Waste treatment

The secondary production of 1 tonne waelz oxide generates 200 to 300 kg of used absorbent and filter dust, which is mainly recycled. About 2.5 kg of the absorption and filter material has to be disposed of.

Slag is used for road construction or has to be disposed of due to contamination with heavy metals. E.g. 64% of the waelz slag from a German production site is used for road construction and 36% are disposed of.

(G) PCDD/PCDF flow

The input of PCDD/PCDF in dusts from ferrous metal industry amounts to approximately 7 kg.

The available data and assumptions allow an estimation of PCDD/PCDF output to air, to residues and to waelz oxide as a product. The following tables show a country specific estimation on emitted amounts based on the above mentioned activity data.

country	production of secondary zinc [t]	air [g TEQ/y]	waelz oxide [g TEQ/y]	slag [g TEQ/y]	absorption and filter material [g TEQ/y]	total to waste [g TEQ/y]
AT	2,000	0.00	0.20	0.18	0.00	0.18
BE	20,000	0.01	2.00	1.76	0.03	1.79
CY						
CZ	1,000	0.15	0.10	0.09	0.00	0.09
DE	460,000	0.13	46.00	40.46	0.78	41.24
DK						
EE						
ES	130,000	0.04	13.00	11.43	0.22	11.65
FI						
FR	120,000	0.04	12.00	10.55	0.20	10.75
GR						
HU						
IE	300	0.00	0.03	0.03	0.00	0.03
IT	150,000	0.04	15.00	13.19	0.26	13.45
LT						
LU						
LV						

country	production of secondary zinc [t]	air [g TEQ/y]	waelz oxide [g TEQ/y]	slag [g TEQ/y]	absorption and filter material [g TEQ/y]	total to waste [g TEQ/y]
MT						
NL						
PL	13,000	1.95	1.30	1.14	0.02	1.16
PT						
SE	500	0.00	0.05	0.04	0.00	0.04
SI						
SK	1,000	0.15	0.10	0.09	0.00	0.09
UK	47,000	0.01	4.70	4.13	0.08	4.21
EU-25	944,800	2.52	94.48	83.10	1.61	84.71
EU-15	929,800	0.27	92.98	81.78	1.58	83.36
EU-10	15,000	2.25	1.5	1.32	0.03	1.35

Table 4-25: PCDD/PCDF mass flow for secondary zinc production in EU 25

At a European scale the estimated total discharge amounts to ~ 181 g TEQ/y. Thereof ~ 94 g is emitted to the product zinc oxide and ~ 85 g are emitted to waste, while ~ 7,000 g TEQ/y enters the process via PCDD/PCDF containing of dusts from EAF-steelworks. Thus secondary zinc production under BAT standards can be regarded as significant sink for PCDD/PCDF.

The following overall picture results:

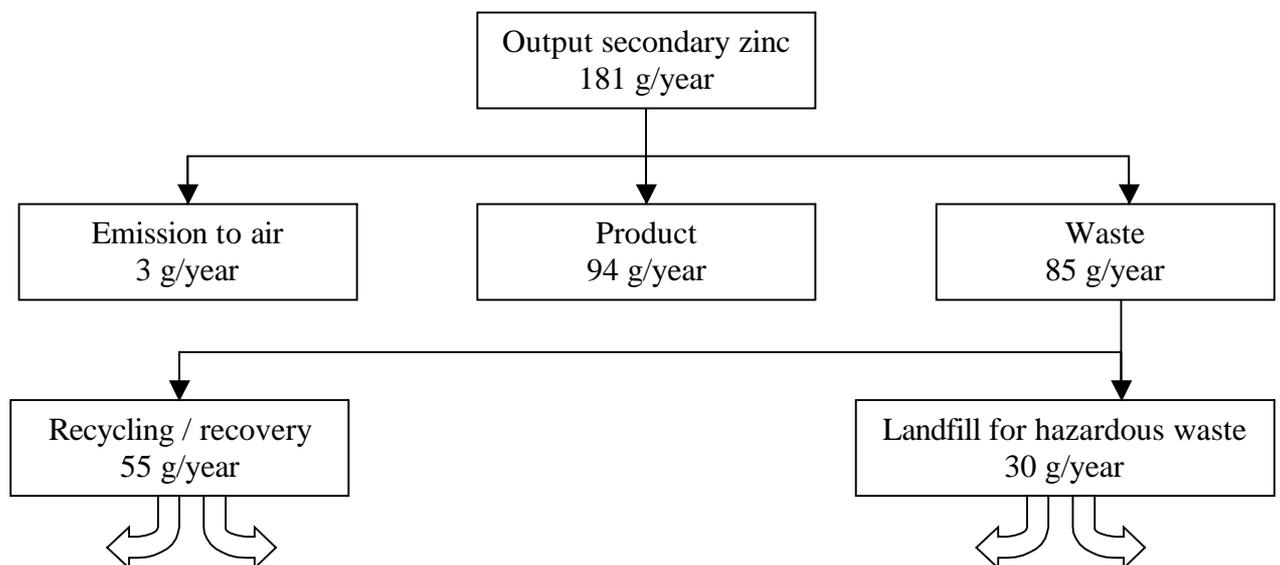


Figure 4-34: Assessment of the PCDD/PCDF flow related to secondary zinc production

H) Waste flow for secondary zinc production

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

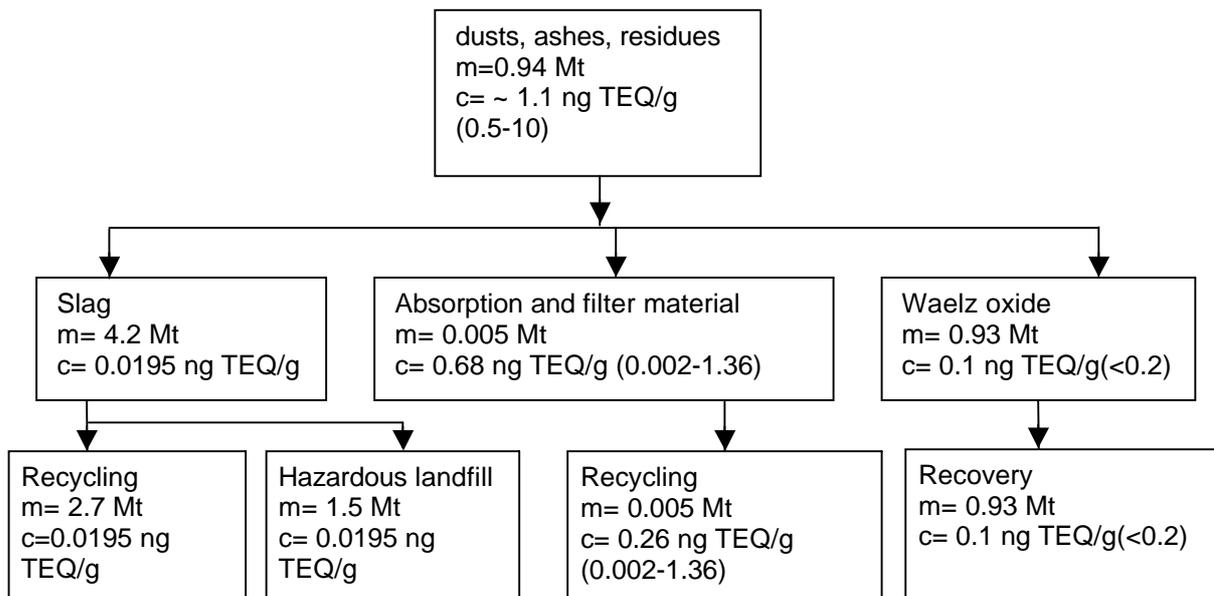


Figure 4-35: Detailed waste flow for secondary zinc production in EU 25

The relevant data and their origin are listed in tables 1.11.1 - 1.11.4 in the Annex.

4.1.12 Mechanical biological treatment

(A) Background

According to the European thematic strategy on prevention and recycling of waste only pre-treated municipal solid waste can be disposed of at landfills. One possibility for pre-treatment is Mechanical biological treatment (MBT).

MBT is used to mechanically separate municipal solid waste into several streams for separate treatment and to reduce the mass of waste. About 20% of the incoming waste is separated in the mechanical treatment as the light fraction for thermal treatment. About 5% of metals are separated and the so called heavy fraction is biologically treated, whereby the mass will be reduced to about 58%. The biologically treated waste can be landfilled with reduced impacts on the environment [WMO 2001].

The WMO report on "Waste management options and climate change 2001" [WMO 2001] is related to a research programme launched by the German Federal Research Ministry. The results indicate that MBT is a suitable pre-treatment for waste prior to landfill and considerably reduces the environmental impacts of landfilling. According to the report, the results of a series of detailed experiments using landfill simulation reactors showed that MBT reduces the landfill gas emission potential by 90% compared to untreated MSW. As a consequence of the low infiltration of water, leachate production is minimised.

The emission standards of a mechanical biological treatment plant are the same as for an incineration plant.

According to the WMO report MBT is deployed mostly in Germany and Austria so far. Therefore the PCDD/PCDF flow is calculated for Germany and Austria, based on available data.

(B) Process input and output

The important inputs and outputs are illustrated in the following schematic flow chart.

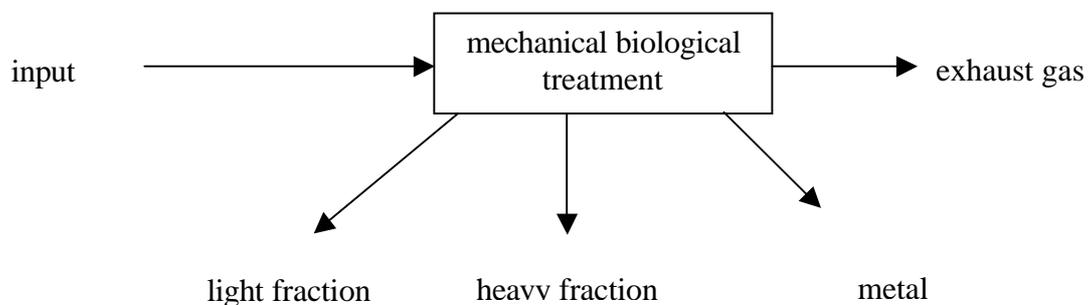


Figure 4-36: Relevant input and output of MBT

Input:

- municipal solid waste

output:

- light fraction for thermal treatment
- metal
- heavy fraction for biological treatment
- exhaust gas

(C) Generation factors for relevant waste and other output

The generation factor for exhaust gas amounts to 7,000. According to Baumgartner [Baumgartner 2005], the generation factor for the heavy fraction amounts to 0.58. For the light fraction no generation factor exists. The calculation of the metal fraction is neglected because no contamination data are available.

(D) Contamination data for output (and input)

exhaust gas: 0.0008 ng TEQ/g (0.0005 – 0.001)

light fraction: According to Baumgartner [Baumgartner 2005], the percentage of POPs in the light and the heavy fraction is the same. In this case, the average value used for calculation is 0.057 ng TEQ/g (0.006 -0.25).

heavy fraction: The absolute contamination in the heavy fraction is higher because of the evaporation of 42% of the mass. It is about 0.074 ng TEQ/g (0.014 – 0.330).

(E) Activity data

The activity data for Austria and Germany are given in Table 4-26

country	treated amount of waste (t/y)
AT	300,000
DE	5,034,000

Table 4-26: Amounts of MSW treated in MBT plants in Austria and Germany

(F) Waste treatment

The light fraction goes to municipal solid waste incineration, the heavy fraction is landfilled.

(G) PCDD/PCDF flow

country	total amount (t/y)	exhaust air [g TEQ/y]	light fraction [g TEQ/y]	heavy fraction [g TEQ/y]
AT	300,000	0.001	0.7	7.3
DE	5,0000,00	0.02	11.4	122.1

Table 4-27: PCDD/PCDF mass flow for MBT in Austria and Germany

The light fraction is treated in municipal solid waste incineration. It is therefore not considered in the mass flow, but is included in the municipal solid waste incineration flow.

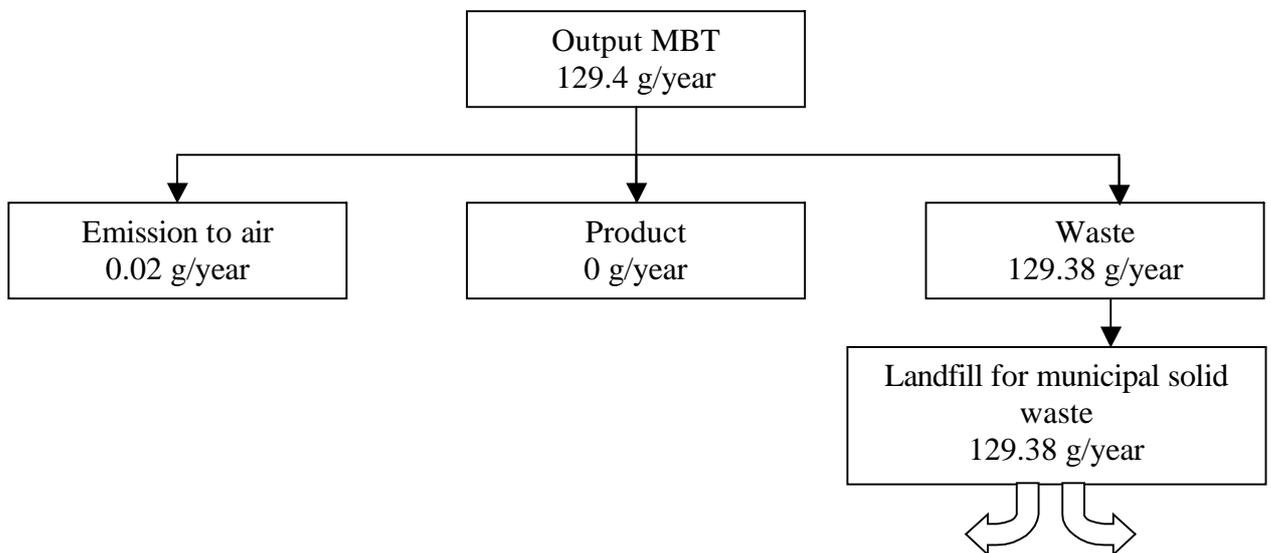


Figure 4-37: Assessment of the PCDD/PCDF flow related to mechanical biological treatment

4.1.13 Agriculture

A study has been launched by the European Commission (Directorate-General Environment) to evaluate the current data situation concerning PCDD/PCDF and other POPs in wastes and their fluxes into feedingstuffs [Fiedler et al 2000]. The study identified the most relevant wastes and by-products from agriculture and the feed and food processing industry potentially containing PCDD/PCDF and PCB. In a follow up study [EC 2002] the mass flow for PCDD/PCDF and dioxin-like PCB of the four waste streams identified as most relevant, originating from the processing of olives, used oils and fats, agricultural wastes with a high fibre content and animal waste have been estimated, as well as some other potentially relevant waste streams.

As a result the following overall estimation has been reported for the flow of PCDD/PCDF and dioxin-like PCB:

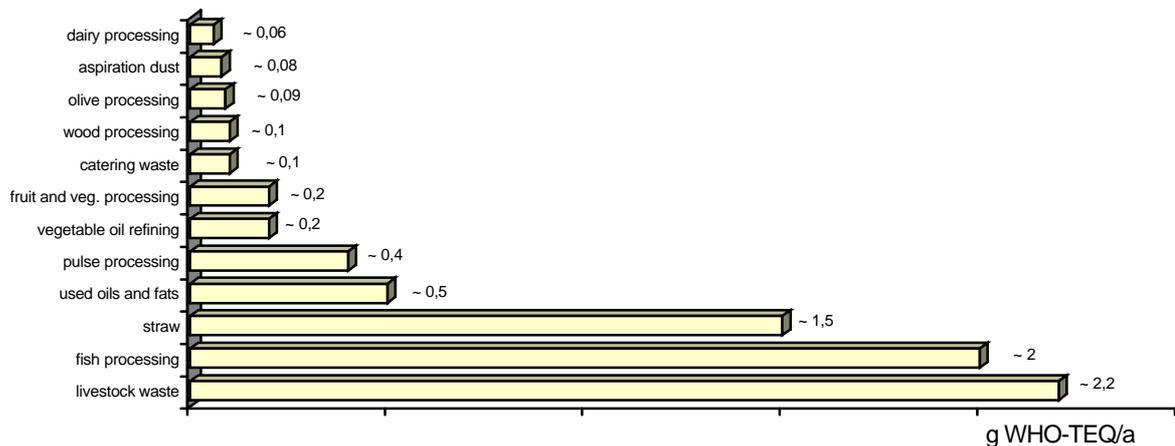


Figure 4-38: Estimations for WHO-TEQ flows for PCDD/PCDF and dioxin-like PCB for specific wastes and by-products from agriculture and feed and food processing

It can be concluded that an annual PCDD/PCDF and PCB WHO-TEQ load up to ~10 g may result from the recovery of wastes, by-products and recyclates from agriculture and feed and food processing. These flows are upper boundary estimations for the background pollution.

The most relevant flows are related to processing of livestock waste, fish waste and high fibre content materials (e.g. straw, pulses, etc.). Based on the assumption that the major part of the relevant wastes and by-products is recycled, the mass flow of PCDD/PCDF into residues related to these waste or by-product streams is less than 10 g TEQ/y.

4.1.14 Chemical industry

(A) Background

Chemical production has been deemed to be one of the most important PCDD/PCDF sources in the past. The production of chemicals has been estimated to account for 34% of the total emissions of PCDD/PCDF with a strong decreasing trend [LUA NRW 2000]. Certainly chemical production has been an important emitter of PCDD/PCDF in the past. However, under modern conditions of operation these processes are typically not a major source of PCDD/PCDF emissions [UNEP BAT-BEP 2004]. For example the US EPA estimates the emissions from EDC/Vinyl chloride production to air, land and water for the year 1995 to amount to 12.36 g TEQ/a, which is a small share of the total emission estimate of ~ 3.25 kg [US EPA 2004].

Specific priority areas in chemical production involving chlorinated chemicals may still be relevant regarding emission of PCDD/PCDF, in particular in the form of unintentional by-products or due to formation during thermal treatment of production waste.

(B) Process input and output

The following flow chart shows schematically where PCDD/PCDF may arise in chemical production processes.

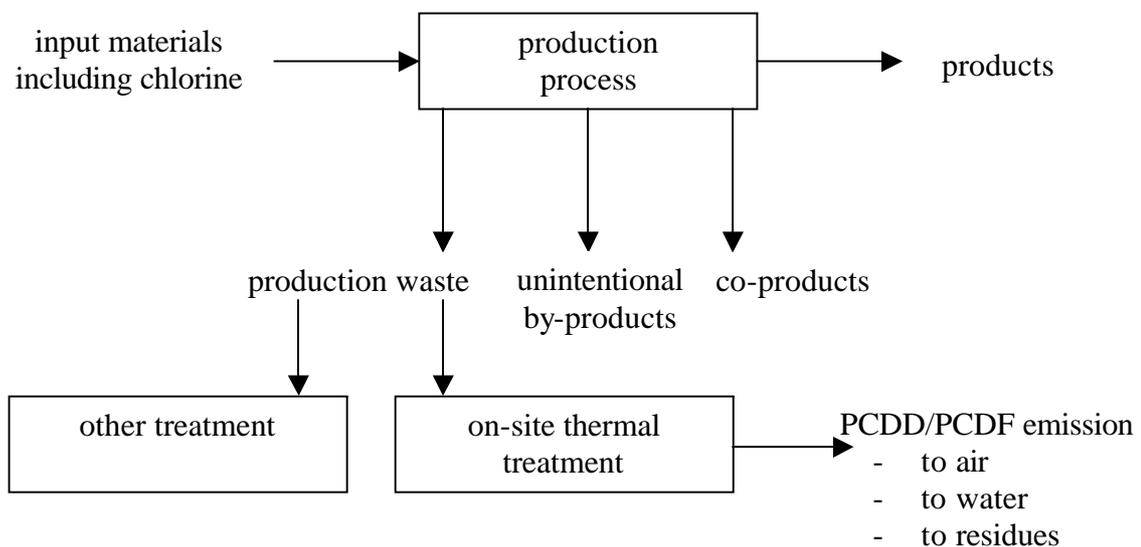


Figure 4-39: Input and output scheme for chemical industry

The release of PCDD/PCDF from thermal treatment, which is usually carried out on the production site, can be controlled by the use of appropriate combustion technologies and exhaust gas treatment. As a consequence, the PCDD/PCDF emissions from the incineration of chemical production waste have been strongly reduced. PCDD/PCDF are emitted to air (stack gas), water (treated waste water) and residues (sludge from flue gas treatment, spent absorbent, spent catalyst). The residues are usually incinerated as hazardous waste in in-

house plants of the chemical industry. The application of BAT leads to air contamination levels ranging from 0.05 to 0.07 ng PCDD/PCDF TEQ/m³. In the PCDD/PCDF mass flow the emissions from the incineration of chemical production waste are already taken account of with the incineration of hazardous waste.

Relevant technologies for waste water and waste gas treatment are described in the BREF documents on Best Available Techniques in “Common Waste Water and Waste Gas Treatment / Management Systems in the Chemical Sector” [BREF WWCS 2003] and in the Large Volume Organic Chemical Industry [BREF LVOC 2003].

Output directly resulting from production processes which is not incinerated as hazardous waste is expected to be very low. The formation of PCDD/PCDF as unintentional by-products is very limited under modern production conditions. A description of the relevant chemical production processes in the light of the potential formation and release of POPs including PCDD/PCDF can be found in the Guidelines on Best Available Techniques and Guidance on Best Environmental Practice relevant to the provisions of Article 5 and Annex C of the Stockholm Convention [UNEP BAT-BEP 2004].

Production of ethylene dichloride (EDC) shall be mentioned here as an example due to its large production volumes and potential relevance for the release of PCDD/PCDF.

The production of EDC is carried out by oxychlorination. Ethylene reacts with dry HCl and oxygen in a heterogeneous catalytic reaction to form EDC and water ($C_2H_4 + 2HCl + \frac{1}{2}O_2 \rightarrow C_2H_4Cl_2 + H_2O$). The reaction is carried out in the vapour phase over a modified Deacon catalyst. The catalyst, which is essential for an efficient production of EDC, typically contains cupric chloride ($CuCl_2$) as the primary active ingredient, impregnated on a porous support such as alumina, and may also contain numerous other additives. While there is an effective minimum temperature for the reactions, excessively higher reactor temperatures lead to more by-products, mainly through increased ethylene oxidation to carbon oxides and increased EDC cracking. Excessive temperatures (>300°C) can also deactivate the catalyst through increased sublimation of $CuCl_2$. As a consequence there is a strong commercial incentive to avoid overheating which would also increase the potential to lead to the production of polychlorinated by-products. The two types of catalyst systems used in oxychlorination (fixed bed and fluid bed) are described in [UNEP BAT-BEP 2004].

The presence of heat, elemental chlorine, copper chloride catalyst and organic material makes the oxychlorination process a potential source of by-product POPs. Aromatics may be generated in high temperature processes and may also be present in feed materials, including HCl or air. Conditions in an oxychlorination reactor are in some ways similar to conditions in the areas of an incinerator downstream of the combustion zone, but may or may not contain similar amounts of soot-like elemental carbon or PAH's, which may contribute to de novo formation of PCDF. OSPAR data for two different plants showed a total formation of PCDD/PCDF in the internal process of 6 g/y for a fluid bed and 40 g/y for a fixed bed reactor [BREF LVOC 2003].

After the oxychlorination EDC is purified by distillation. Distillation and high purity are essential in order to fulfil the final product requirements. Distillation systems can be designed to effect separation of materials of closely- or widely-separated boiling points. The boiling points of chemical products of direct chlorination and the boiling points of competing impurities allow for their practical separation. Their boiling points are also sufficiently different from those of the unintentional POPs that virtually complete separation can be accomplished. By-product POPs can be virtually completely removed from the product and isolated in high-boiling materials (heavy ends) as a result of the distillation process. Correspondingly, purified EDC and oxychlorination process off-gas do not contain significant amounts of PCDD/PCDF compounds [LVOC BREF 2003]. Resulting medium boilers which may contain POPs are recycled within the process. The high boilers contain a mixture of heavies (e.g. chlorinated cyclic or aromatic compounds including PCDD/PCDF-related components, predominantly the octo-chlorodibenzofuran congener from oxychlorination) with suspended iron salts from catalysts. These are thermally destroyed.

Some by-product POPs will adhere to particles of catalyst. In the case of fixed bed systems, they can be a part of the spent catalyst that is removed from service. The dry spent catalyst can be treated thermally to destroy adsorbed organics, or placed in a secure landfill. In reactors, fluidised bed catalyst particles undergo size attrition and can become entrained in the vapour stream.

These particles eventually show up in solid waste or in the biological solids removed at the end of waste water treatment. The remaining sludge contains about 100 fg TEQ/t EDC. After separation of the suspended solids (catalyst) a concentration of about 500 fg TEQ per kg is measured.

As a result the following output fractions are potentially relevant for the PCDD/PCDF flow:

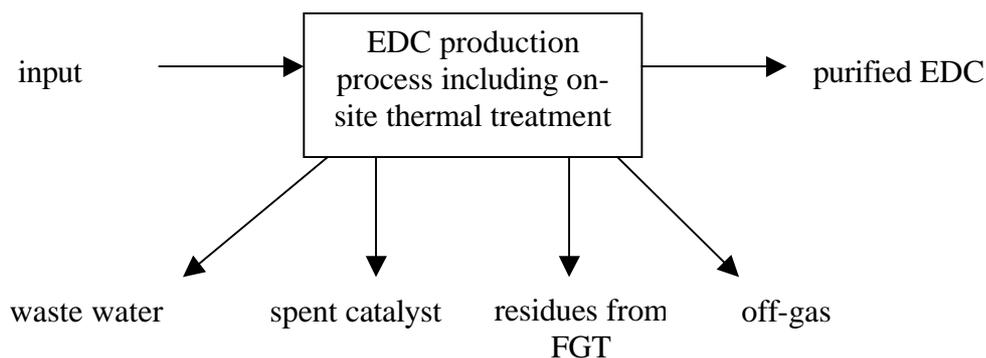


Figure 4-40: Relevant input and output of EDC production

Output:

- spent catalyst from fixed bed systems (usually incinerated on-site as hazardous waste)

- residues from flue gas treatment (from hazardous waste incineration)
- off-gas (from hazardous waste incineration)
- waste water and residues from waste water treatment

(C) Generation factors for waste and other output (air, water)

The amount of dry spent catalyst is in the range of 10 to 200 g/tonne VCM [BREF LVOC 2003]. This corresponds to ~ 6 to 120 g/t EDC. For the PCDD/PCDF flow assessment an estimated average of 60 g/t has been applied.

(D) Contamination data for output (and input)

Performance standards can be set locally in individual plant permits, and will vary. By-product PCDD/PCDF emission is mentioned in the ECVM Charter, and reflected in the OSPAR process via Decision 98/4 and adoption of BAT via PARCOM Recommendation 96/2. That standard is 1 µg TEQ/ton oxychlorination capacity release to water. Air emission limits in the ECVM Charter are 0.1 ng TEQ/Nm. This limit corresponds to the EU regulatory limit for emissions of PCDD/PCDF to air from incinerators. Limits in other regions/countries will typically be congruent with hazardous waste combustor regulations in local areas [UNEP BAT-BEP 2004].

The official BAT for effluent final treatment is biological treatment to achieve 0.1 ng I-TEQ/l PCDD/PCDF in treated water [BREF LVOC 2003].

The remaining sludge from flue gas waste water treatment contains about 100 fg TEQ/t EDC. After separation of the suspended solids (catalyst) a concentration about 500 fg TEQ per kg is measured. This corresponds to 0.5 ng TEQ/g.

(E) Activity data

Production of EDC in Germany, which is the most important producer of EDC in Europe, in 2001 was 2,902 kt tones [VCI 2004]. The corresponding figure for EU 15 in 1998 is 8,563 kt [EuroChlor 2000]. The following table gives an overview on the 32 EDC production sites in Europe:

ID	Company	Town	Country
4	BASF Antwerpen N. V.	Antwerpen 4	BELGIUM
21	Limburgse Vinyl Maatschappij	Tessenderlo	BELGIUM
27	Solvay S.A.	Bruxelles	BELGIUM
2	Atochem	Paris la Defense	FRANCE
24	Shell Chimie	Rueil Malmaison	France
25	Shell	Rueil Malmaison	FRANCE
3	BASF AG	Ludwigshafen	GERMANY
5	Bayer AG	Leverkusen	GERMANY
6	Celanese GmbH	Frankfurt am Main	GERMANY

ID	Company	Town	Country
7	Chemie GmbH Bitterfeld-Wolfen	Wolfen	GERMANY
8	DOW Deutschland Inc., Werk Stade	Stade	GERMANY
9	Degussa-Hüls AG	Frankfurt am Main	GERMANY
10	EVC (Deutschland) GmbH	Frankfurt/Main	GERMANY
16	Hoechst AG	Frankfurt/Main	GERMANY
17	Huels AG	Marl	GERMANY
26	Solvay Alkali GmbH	Solingen	GERMANY
28	VINTRON GmbH	Hürth-Knapsack	GERMANY
30	Vinnolit Monomer GmbH	Burgkirchen	GERMANY
31	Wacker - Chemie GmbH	Burghausen	GERMANY
33	Production site in Greece	City in Greece	GREECE
11	EVC (Italia) SpA	Venezia	ITALY
13	Enichem S.p.A.	Milan	ITALY
32	Wyeth Lederle	Catania	ITALY
1	Akzo Nobel Chemicals b.v.	Amersfoort	NETHERLANDS
15	Eurobrom B.V.	Rijswijk	NETHERLANDS
23	Petrasol B.V.	Gorinchem	NETHERLANDS
29	Viniclor S.A.	Madrid	SPAIN
18	Hydro Plast AB	Steenungsund	SWEDEN
12	EVC (UK) Limited	Runcorn, Cheshire	UK
14	Ethyl Petroleum Additives International	Bracknell, Berkshire	UK
19	ICI Chemicals & Polymers Limited	Runcorn Cheshire	UK
20	ICI Chemicals & Polymers Limited	Runcorn, Cheshire	UK

Table 4-28: EDC production sites in Europe Source: ECB, ESIS accessed December 8, 2008

No information was found for production sites in the new Member States. Based on the figure of 8,563 kt annual production an average production of approximately 268 kt per production site can be calculated. Where no EUROSTAT data on EDC production amounts were available (i.e. BE, FR, ES, GR, NL, SE and the UK), an average annual production of 268 kt has been assumed as the output per production site. An estimated European annual EDC production of 7,756 kt results. The production is most likely underestimated to a certain degree, as production sites in the new member states are not taken into consideration.

country	EDC production 2001 [source: ESTAT] [kg]	no of sites	estimated EDC production [kt/y]
AT	0	0	0
BE	n.d., confidential	3	803 ¹⁾
CY	n.d.		0
CZ	0	0	0
DE	2,597,093,120	13	2,597
DK	n.d.	0	0
EE	0	0	0
ES	n.d., confidential	1	268 ¹⁾
FI	0	0	0
FR	n.d., confidential	3	803 ¹⁾
GR	0	1	268 ¹⁾
HU	n.d., confidential		0
IE	0	0	0
IT	982,691,968	3	983
LT	0	0	0
LU	0	0	0

country	EDC production 2001 [source: ESTAT] [kg]	no of sites	estimated EDC production [kt/y]
LV	0	0	0
MT	n.d.		0
NL	0	3	803 ¹⁾
PL	n.d.		0
PT	0		0
SE	162,051,008	1	162
SI	n.d. confidential		0
SK	0	0	0
UK	0	4	1,070 ¹⁾
EU-25	3,741,836,096	32	7,756 ¹⁾

Table 4-29: Estimation of EDC production in EU 25 (Sources: ESTAT annual PRODCOM, VCI 2004, EuroChlor 2000; ¹⁾ extrapolation)

(F) Waste treatment

The residues from flue gas treatment are incinerated as hazardous waste.

(G) PCDD/PCDF flow

The emissions to water can be based on the existing emission standard of 1 µg TEQ/ton oxychlorination capacity release to water. Assuming that the average emission is half of the standard (i.e. 0.5 µg TEQ/ton oxychlorination capacity), the corresponding estimated emission is 3.8 g/y.

Emissions to air can be based on the UNEP toolkit emission factor to air for modern plants which is 0.95 µg/tonne product. Based on the above activity data this leads to an estimated PCDD/PCDF emission to air of 7.69 g TEQ/y.

Emissions to sludge from flue gas treatment based on a contamination of 0.5 ng TEQ/g in sludge and a generation of 200 g sludge per tonne EDC are approximately 0.8 g/y (no contamination data are available for spent catalyst). Therefore the extrapolation is based on the simplification that all EDC is produced in fluidised bed systems. This mass flow is already covered in the section of hazardous waste incineration.

To conclude the estimated emission from European EDC production is 12.5 g TEQ/y. Thereof about 8 g are emitted to air, 4 g are emitted to water and about <1 g enters the waste path.

It is not feasible to assess all relevant chemical production, but the example discussed here indicates its limited relevance.

4.1.15 Sewage sludge

(A) Background

As PCDD/PCDF tend to adsorb on particles the PCDD/PCDF content of waste water is concentrated in sewage sludge after the waste water treatment. The sewage sludge mentioned in this report is municipal sewage sludge. (Sludge from industrial processes is not taken into account.)

(B) Process input (raw material) and output (waste, air, water, product)

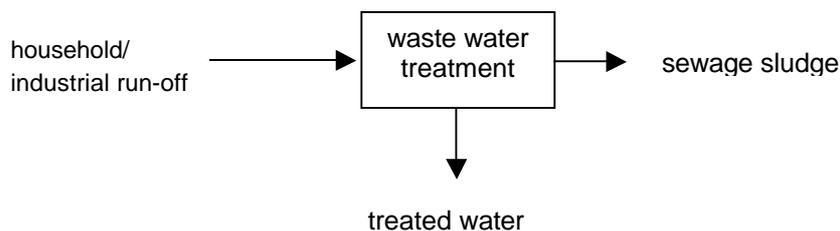


Figure 4-41: Relevant input and output of waste water treatment

Input:

- waste water

Output:

- sewage sludge
- treated water

(C) Generation factors for waste and other output (air, water)

No generation factor is used because the amount of sewage sludge produced from the wastewater depends on the composition. Following the low solubility of PCDD/PCDF in water the waste water is not taken into further account

(D) Contamination data for output (and input)

Sewage sludge: Several contamination data are reported. In Table 4-30 data are given which are used for estimation in this report. For countries where no data are available, an average value of 0.03 ng/g d.w. (0.00002-1.77) is assumed that is calculated from accessible information.

country	concentration [ng TEQ/kg d.w.]
AT	0.02
DE	0.03
DK	0.02
ES	0.06
PL	0.05
SE	0.02
UK	0.06

Table 4-30: Given concentrations of PCDD/PCDF in sewage sludge

(E) Activity data

In all 25 Member States a total amount of approximately 8 million tons of sewage sludge from municipal waste water treatment is estimated. The amounts for the countries are given in Table 4-31.

country	amount of sewage sludge [t]	reference
AT	401,867	[COM 2003]
BE	98,936	[COM 2003]
CY	20,000	[Sludge use acceptance report 2001]
CZ	175,000	[Sludge use acceptance report 2001]
DE	2,297,460	[COM 2003]
DK	155,621	[COM 2003]
EE	50,000	[Sludge use acceptance report 2001]
ES	703,482	[COM 2003]
FI	160,000	[COM 2003]
FR	853,482	[COM 2003]
GR	66,335	[COM 2003]
HU	30,000	[Sludge use acceptance report 2001]
IE	35,039	[COM 2003]
IT	779,220	[COM 2003]
LT	25,000	[Sludge use acceptance report 2001]
LU	7,000	[COM 2003]
LV	25,000	[Sludge use acceptance report 2001]
MT	400	[Sludge use acceptance report 2001]
NL	242,000	[COM 2003]
PL	330,000	[Sludge use acceptance report 2001]
PT	238,680	[COM 2003]
SE	220,000	[COM 2003]
SI	100,000	[Sludge use acceptance report 2001]

country	amount of sewage sludge [t]	reference
SK	95,000	[Sludge use acceptance report 2001]
UK	1,066,176	[COM 2003]
EU 25	8,155,698	
EU 15	7,225,298	
EU 10	850,400	

Table 4-31: Annual amount of sewage sludge in the EU

(F) Waste treatment

The relevant treatment of sewage sludge includes application on land, land filling and incineration. The amount of sewage sludge undergoing the different treatments is specific for each country. In Table 4-32 available data for the treatment of sewage sludge are given for specific countries. For the other countries average values of 33% for application on land, 37% for incineration and 29% for landfilling are taken as a basis for calculation.

country	land fill [%]	incineration [%]	application to land [%]	reference
AT	58	32	10	[Sludge use acceptance report 2001]
DK	4	42	53	[Affaldsstatistik 2003]
ES	25	19	56	[Dioxin Congress 2003]
FR	25	15	60	[Sludge use acceptance report 2001]
NL	25	60	15	[ISWA: international waste information 2003]
PL	42	43	15	[Country Report Poland 2002]
UK	8	37	55	[AEA 2002]
EU average	29	37	33	extrapolated

Table 4-32: Treatment of sewage sludge

(G) PCDD/PCDF flow

With the available data the amount of PCDD/PCDF transferred to the different treatment stations can be estimated. The values are given in Table 4-33.

country	generation sewage sludge [t d.m./y]	landfilled [g TEQ/y]	incineration [g TEQ/y]	applied to land [g TEQ/y]	total [g TEQ/y]
AT	401,867	3.38	1.86	0.58	5.83
BE	98,936	0.88	1.11	1.00	2.98
CY	20,000	0.18	0.22	0.20	0.60
CZ	175,000	1.55	1.96	1.76	5.27
DE	2,297,460	16.64	21.03	18.91	56.57
DK	155,621	0.09	1.00	1.28	2.37
EE	50,000	0.44	0.56	0.50	1.51
ES	703,482	10.5	8.01	23.6	42.2
FI	160,000	1.42	1.79	1.61	4.82
FR	853,482	6.42	4.88	14.39	25.69
GR	66,335	0.59	0.74	0.67	2.00

country	generation sewage sludge [t d.m./y]	landfilled [g TEQ/y]	incineration [g TEQ/y]	applied to land [g TEQ/y]	total [g TEQ/y]
HU	30,000	0.27	0.34	0.30	0.90
IE	35,039	0.31	0.39	0.35	1.05
IT	779,220	6.90	8.72	7.84	23.46
LT	25,000	0.22	0.28	0.25	0.75
LU	7,000	0.06	0.08	0.07	0.21
LV	25,000	0.22	0.28	0.25	0.75
MT	400	0.00	0.00	0.00	0.01
NL	242,000	2.14	4.37	1.09	7.29
PL	330,000	7.42	7.59	2.65	17.66
PT	238,680	2.11	2.67	2.40	7.19
SE	220,000	1.28	1.62	1.46	4.36
SI	100,000	0.89	1.12	1.01	3.01
SK	95,000	0.84	1.06	0.96	2.86
UK	1,066,176	5.20	24.06	35.77	65.04
EU-25	8,155,698	69.96	95.21	119.39	284.56
EU-15	7,225,298	57.94	81.8	111.51	251.2
EU-10	850,400	12.02	13.41	7.89	33.32

Table 4-33: PCDD/PCDF mass flow for sewage sludge in EU 25

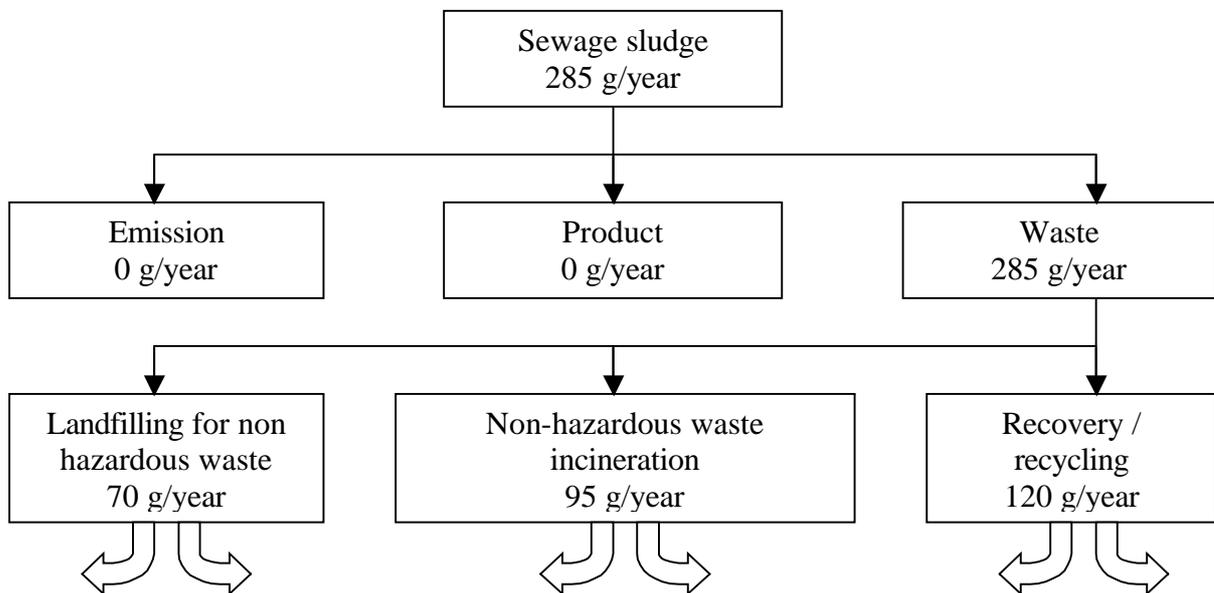


Figure 4-42: Assessment of the PCDD/PCDF flow related to sewage sludge

(H) Waste flow for sewage sludge

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

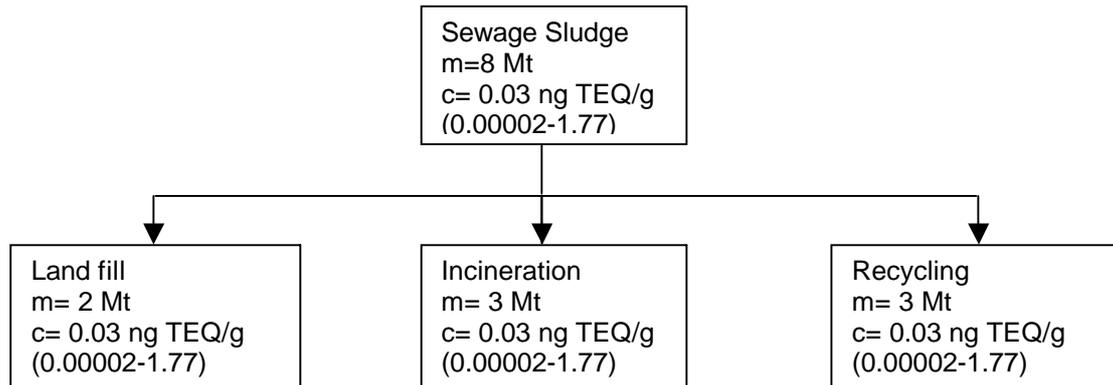


Figure 4-43: Waste flow for sewage sludge in EU 25

The relevant data and their origin are listed in tables 1.12.1 - 1.12.3 in the Annex.

4.1.16 Compost

(A) Background

The compost which is mentioned in this report includes bio compost and green compost. The potential recoverable amount of bio waste and green waste in EU 15 counts for about 49 million tons. Currently about 17 million tons bio waste and green waste are collected separately what results in a compost production of around 9 million tons in Europe [ECN 2002].

(B) Process input (raw material) and output (waste, air, water, product)



Figure 4-44: Relevant input and output of composting

Input:

- bio waste
- green waste

Output:

- compost

(C) Generation factors for waste and other output (air, water)

According to the ECN report 9 million tons of compost result from 17 million t of bio and green wastes. Therefore a generation factor of, 0.53 can be estimated.

(D) Contamination data for output (and input)

compost: Several contamination data for Germany are reported. The value which is used for estimation in this report is 0.01 ng TEQ/g d.w. (0.0008-0.036).
In the American compost report [CQS&G report 2000] an amount of 0.01 ng TEQ/g d.w. is mentioned.

(E) Activity data

In the 25 Member States a total amount of approximately 27,334,579 tons of bio and green waste and a resulting amount of 14,487,327 tons of compost is annually produced. The amounts for the countries are given in Table 4-34. The amount of bio and green waste for AT, BE, DK, FI, FR, LU, NL, PT, SE und UK are given in the above-mentioned ECN report. Data for ES and IT are extracted from the ISWA country reports [ISWA country report Spain], [ISWA country report Italy]. The value for DE is based on the BMU report 2002 [BMU report 2002].

The values for the other countries, mainly those for the new Member States, are extrapolated on a per capita basis. It can be assumed that for the new Member States the extrapolated values are slightly overestimated because the amount (per capita) of compost in these countries is usually lower compared to the old Member States. The extrapolation of the values on the basis of per capita production in PT, GR and ES would result in amounts that are closer to the situation in the new MS. However there is no considerable difference to the extrapolation carried out.

country	amount of bio and green waste [t]	amount of compost [t]	reference
AT	650,000	344,500	[ECN 2002]
BE	850,000	450,500	[ECN 2002]
CY	50,552	26,793	extrapolated
CZ	672,932	356,654	extrapolated
DE	7,575,000	4,014,750	[BMU 2002]
DK	687,000	364,110	[ECN 2002]
EE	92,569	49,062	extrapolated
ES	2,759,645	1,462,612	[ISWA 2004]
FI	100,000	53,000	[ECN 2002]
FR	1,550,000	821,500	[ECN 2002]
GR	700,505	371,268	extrapolated
HU	659,801	349,695	extrapolated
IE	257,355	136,398	extrapolated
IT	2,824,000	1,496,720	[ISWA 2004]
LT	236,347	125,264	extrapolated
LU	30,000	15,900	[ECN 2002]
LV	154,282	81,769	extrapolated
MT	26,261	13,918	extrapolated
NL	3,100,000	1,643,000	[ECN 2002]
PL	2,535,475	1,343,802	extrapolated
PT	10,000	5,300	[ECN 2002]
SE	290,000	153,700	[ECN 2002]
SI	127,365	67,503	extrapolated
SK	356,490	188,940	extrapolated
UK	1,039,000	550,670	[ECN 2002]
EU-25	27,334,579	14,487,327	
EU-15	22,422,506	11,883,928	
EU-10	4,912,073	2,603,399	

Table 4-34: Annual amount of bio and green wastes and the resulting amount of compost in the EU

(F) Waste treatment

Compost is reused as fertilizer for soil improvement.

(G) PCDD/PCDF flow

With the available data the amount of PCDD/PCDF in compost can be estimated. The estimated amount of PCDD/PCDF in compost in Europe is 160 g/y. For each single country the value is given in Table 4-35.

country	generation bio and green waste (t/y)	generation compost (t/y)	PCDD/PCDF in compost [g TEQ/y]
AT	650	344.5	3.81
BE	850	450.5	4.98
CY	50,552	26,793	0.30
CZ	672,932	356,654	3.94
DE	7,575,000	4,014,750	44.35
DK	687	364.11	4.02
EE	92,569	49,062	0.54
ES	2,759,645	1,462,612	16.16
FI	100	53	0.59
FR	1,550,000	821,500	9.08
GR	700,505	371,268	4.10
HU	659,801	349,695	3.86
IE	257,355	136,398	1.51
IT	2,824,000	1,496,720	16.54
LT	236,347	125,264	1.38
LU	30	15.9	0.18
LV	154,282	81,769	0.90
MT	26,261	13,918	0.15
NL	3,100,000	1,643,000	18.15
PL	2,535,475	1,343,802	14.85
PT	10	5.3	0.06
SE	290	153.7	1.70
SI	127,365	67,503	0.75
SK	356.49	188.94	2.09
UK	1,039,000	550,670	6.08
EU-25	27,334,579	14,487,327	160.05
EU-15	22,422,506	11,883,928	131.29
EU-10	4,912,073	2,603,399	28.76

Table 4-35: PCDD/PCDF mass flow for compost in EU 25

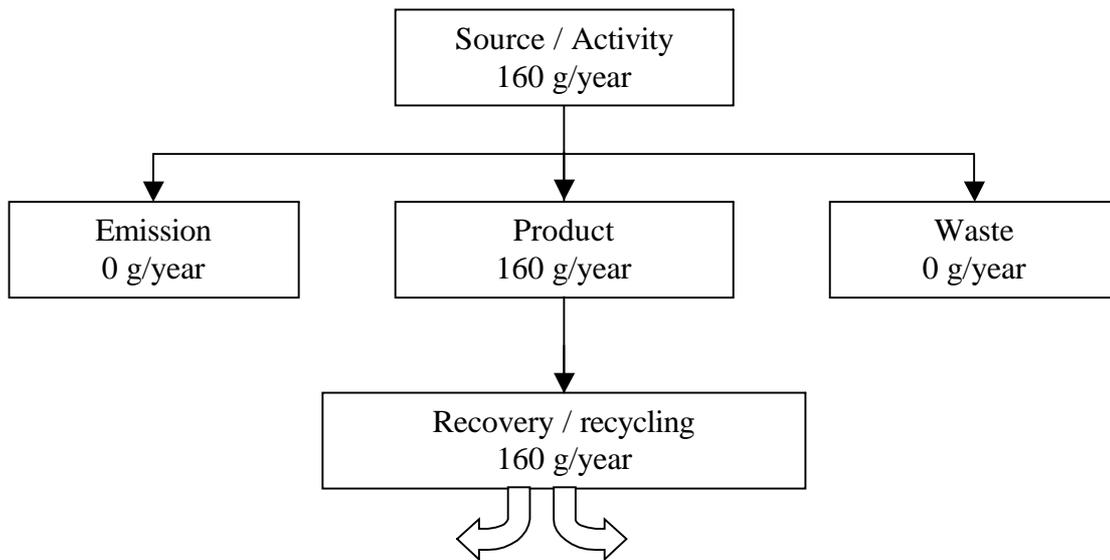


Figure 4-45: Assessment of the PCDD/PCDF flow related to composting

(H) Waste flow for compost

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

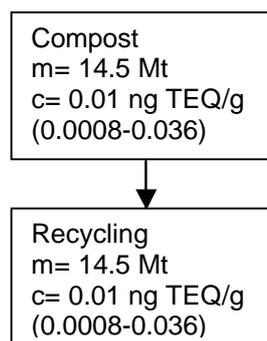


Figure 4-46: waste flow for compost in EU 25

The relevant data and their origin are listed in table 1.13 in the Annex.

4.1.17 Road Traffic

(A) Background

Incineration of fuels in engines releases PCDD/PCDF. Since leaded was substituted, the amount of PCDD/PCDF has decreased but there are still emissions of PCDD/PCDF to air.

(B) Process input (raw material) and output (waste, air, water, product)

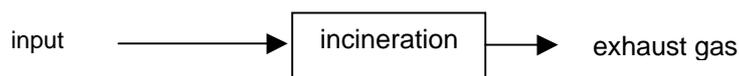


Figure 4-47: Relevant input and output of incineration of fuels in road traffic

Input:

- Gasoline
- Diesel Oil
- Natural Gas
- Biomass
- Other Fuels

Output:

- exhaust gas

(C) Generation factors for waste and other output (air, water)

Generation factors for the exhaust air are not available.

(D) Contamination data for output (and input)

Contamination data for PCDD/PCDF in exhaust air resulting from road traffic are not available.

(E) Activity data

In 25 Member States an estimated amount of almost 278 million tons of fuels are used in road traffic. The amounts for the countries are given in Table 4-36.

country	Fossil fuel consumption (t/y)	reference
AT	6,350,000	[Eurostat 2001]
BE	7,986,000	[Eurostat 2001]
CY	584,000	[Eurostat 2001]
CZ	4,669,000	[Eurostat 2001]
DE	54,980,000	[Eurostat 2001]
DK	3,749,000	[Eurostat 2001]
EE	588,000	[Eurostat 2001]
ES	28,101,000	[Eurostat 2001]
FI	3,806,000	[Eurostat 2001]
FR	42,840,000	[Eurostat 2001]
GR	5,642,000	[Eurostat 2001]
HU	3,039,641	[Eurostat 2001]
IE	3,542,000	[Eurostat 2001]
IT	38,096,000	[Eurostat 2001]
LT	1,074,000	[Eurostat 2001]
LU	1,740,000	[Eurostat 2001]
LV	762,000	[Eurostat 2001]
MT	173,000	[Eurostat 2001]
NL	10,705,000	[Eurostat 2001]
PL	8,026,000	[Eurostat 2001]
PT	6,225,000	[Eurostat 2001]
SE	6,823,000	[Eurostat 2001]
SI	1,314,000	[Eurostat 2001]
SK	1,681,000	[Eurostat 2001]
UK	39,063,000	[Eurostat 2001]
EU 25	281,558,641	
EU 15	259,648,000	
EU 10	21,910,641	

Table 4-36: Fossil fuel consumption in road traffic in EU 25 in 2001

(F) Waste treatment

No waste treatment is possible.

(G) PCDD/PCDF flow

For some countries data on the PCDD/PCDF concentrations in exhaust gas resulting from road traffic are reported. The corresponding average value is used as the PCDD/PCDF concentration for the other countries. The values are given in Table 4-37. The total PCDD/PCDF emissions into air for EU 25 is about 56 g TEQ/y.

country	Fuel consumption (t/y)	emission to air [g TEQ/y]
AT	6,350,000	0.89
BE	7,986,000	1.40
CY	584,000	1.40
CZ	4,669,000	22.41
DE	54,980,000	1.40
DK	3,749,000	1.50
EE	588,000	0.04
ES	28,101,000	1.40
FI	3,806,000	2.57
FR	42,840,000	3.09
GR	5,642,000	1.40
HU	3,039,641	3.78
IE	3,542,000	0.19
IT	38,096,000	1.40
LT	1,074,000	0.07
LU	1,740,000	1.40
LV	762,000	0.05
MT	173,000	1.40
NL	10,705,000	1.40
PL	8,026,000	1.45
PT	6,225,000	1.40
SE	6,823,000	0.57
SI	1,314,000	1.40
SK	1,681,000	0.52
UK	39,063,000	3.45
EU 25	281,558,641	55.96
EU 15	259,648,000	23.44
EU 10	21,910,641	32.52

Table 4-37: PCDD/PCDF mass flow for road traffic in EU 25 (air emissions)

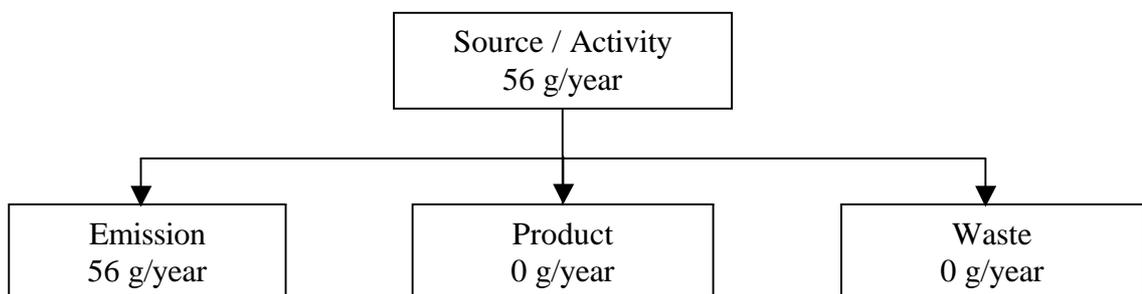


Figure 4-48: PCDD/PCDF flow related to road traffic in EU 25

The relevant data and their origin are listed in table 1.14 in the Annex.

4.1.18 Domestic Burning

(A) Background

Domestic burning of wood and fossil fuels counts to private burning in single stoves or open burning places. Domestic burning is associated with high air emissions as flue gas treatment is not performed. In addition process conditions can strongly vary due to specific oven characteristics and the properties of the used fuel. As a consequence measured contamination and emission data and derived emission factor are highly inhomogeneous to a large range of possible results. In general it can be stated that emissions by far exceed the discharge via residues and that burning of treated wood or co-combustion of waste significantly increases formation and discharge of PCDD/PCDF.

(B) Process input (raw material) and output (waste, air, water, product)

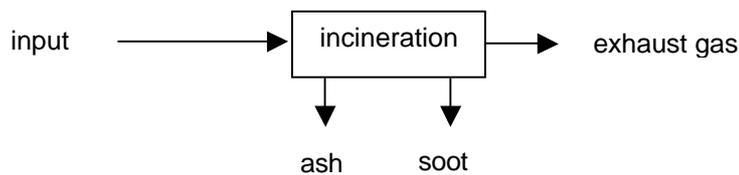


Figure 4-49: Relevant input and output of domestic burning

Input:

- Wood and wood waste
- Fossil fuels
- Mixed fuels or waste

Output:

- exhaust gas
- ash
- soot

(C) Generation factors for waste and other output (air, water)

Exhaust gas: Generation factors for the amount of resulting exhaust gas are not available. Given contaminations are specific for the materials burned.

Ash: For coal, the waste generation factor is 0.1 (ton ash/ton coal), for wood it amounts to 0.017.

Soot: The generation factor for soot is 0.0003 for wood, and 0.0006 for coal.

(D) Contamination data for output (and input)

Exhaust gas:

Coal & derivatives: According to the draft final report on PCDD/PCDF emissions in candidate countries [TNO 2005] contamination in exhaust air ranges from 0.001-0.002 ng TEQ/g. In other reports [UBA 2002], [UNEP BAT-BEP 2004] higher values of 0.2, 0.3 ng TEQ/g are reported. Thus an average value of 0.116 ng TEQ/g (range 0.0003 to 0.57) is used the calculation.

Wood: The value used for calculation amounts to 0.002 ng TEQ/g. Values between 0.0003 and 0.01 are given in several reports.

According to a number of studies [e.g. UNEP BAT-BEP 2004] concentrations of PCDD/PCDF are much higher when waste is co-combusted.

Ash:

Fossil fuels: For fossil fuels the contamination data depend on the type of fuel. In the TNO report values from 0.00022 to 0.00041 ng TEQ/g are given, while the UNEP reports contamination data of 0.15 ng TEQ/g.

The average value used for calculation is 0.056 (0.00022 – 0.15) ng TEQ/g.

Wood: According to the TNO report contamination amounts to 0.3 ng TEQ/g for untreated wood. On the other hand a contamination of 0.0016 is reported from an Austrian study [Thanner 2002] which is supported by a value of 0.0006 ng TEQ/g reported for virgin wood in the latest draft to the UNEP BAT-BEP report [UNEP BAT-BEP 2004]. Significantly higher values are reported in the UNEP report for contaminated wood (0.06 ng TEQ/g) and in the TNO report for treated wood (0.5 ng TEQ/g).

An average value of 0.11 ng TEQ/g (0.0001-0.5) is used for calculation.

Soot:

Fossil fuels: The value used for calculation is 6.15 ng TEQ/g. Reported values range from 0.05 to 10 ng TEQ/g.

Wood: The value used for calculation is 3.99 ng TEQ/g. Data between 0.02 and 14.4 ng TEQ/g are reported.

(E) Activity data

Fossil fuels: Activity data for the old Member States are derived from the IEA statistics [IEA energy statistics]. For the new Member States data are given in the draft final report to the project on PCDD/PCDF emissions in candidate countries [TNO 2005].

Wood: For some old Member States data from several sources are used (see Table 4-38). For the others activity data are calculated relying on the population. Activity data for new Member States are reported in the TNO report [TNO 2004].

The estimated annual amount of fossil fuels used in Europe (EU 25) is about 27 million tons. For wood and waste wood the value amounts to 51 million tons.

country	fossil fuels		wood	
	amount (t/y)	reference	amount (t/y)	reference
AT	425,000	IEA energy statistics 2001	300,000	[UBA 2000]
BE	341,000	IEA energy statistics 2001	660,000	[LUA NRW 2000]
CY	1,633,333	TNO 2004	166,667	[TNO 2004]
CZ	4,800,000	TNO 2004	2,583,333	[TNO 2004]
DE	1,604,000	IEA energy statistics 2001	4,806,512	[LUA NRW 2000]
DK	2,000	IEA energy statistics 2001	753,750	[COWI 2000]
EE	123,333	TNO 2004	1,000,000	[TNO 2004]
ES	90,000	IEA energy statistics 2001	2,273,524	extrapolated (MS 15)
FI	56,000	IEA energy statistics 2001	10,535,450	[Statistics Finland 2002]
FR	86,900	IEA energy statistics 2001	3,401,807	extrapolated (MS 15)
GR	64,000	IEA energy statistics 2001	603,145	extrapolated (MS 15)
HU	1,333,333	TNO 2004	2,666,667	[TNO 2004]
IE	1,220,000	IEA energy statistics 2001	221,587	extrapolated (MS 15)
IT	107,000	IEA energy statistics 2001	3,278,578	extrapolated (MS 15)
LT	47,500	TNO 2004	916,667	[TNO 2004]
LU	2,000	IEA energy statistics 2001	25,437	extrapolated (MS 15)
LV	146,667	TNO 2004	666,667	[TNO 2004]
MT	0	TNO 2004	83,333	[TNO 2004]
NL	7,000	IEA energy statistics 2001	403,500	[Statistics Netherlands 2002]
PL	10,000,000	TNO 2004	3,000,000	[TNO 2004]
PT	0	IEA energy statistics 2001	570,925	extrapolated (MS 15)
SE	0	IEA energy statistics 2001	10,201,189	[Statistics Sweden 2002]

country	fossil fuels		wood	
	amount (t/y)	reference	amount (t/y)	reference
SI	23,333	TNO 2004	500,000	[TNO 2004]
SK	1,956,667	TNO 2004	666,667	[TNO 2004]
UK	3,051,000	IEA energy statistics 2001	900,000	[LUA NRW 2000]
EU-25	27,120,067		51,185,403	
EU-15	7,055,900		38,935,403	
EU-10	20,064,167		12,250,000	

Table 4-38: Annual consumption of fossil fuels and wood for domestic burning in EU 25

(F) Waste treatment

There is no official information available on the further treatment of the solid residues from domestic burning. However according to experience and expert information it can be assumed that the residues are either added to the municipal solid waste or applied to land. As a first approach a share of application to land : municipal solid waste = 0,25 : 0,75 has been assumed. According to chimney sweeper information removed soot is completely disposed of with municipal solid waste. Based on the data from the mass flow on MSWI (see chapter 4.1.1) a distribution of 14% directed to MSWI and 86% disposed of at non-hazardous waste landfills can be used as European average for the calculation of the mass flow.

(G) PCDD/PCDF flow

The available data and assumptions allow an estimation of PCDD/PCDF emissions to air and discharge to ashes and soot. The following table shows a country specific estimation on emitted amounts:

Country	fuel consumption (t/y)		emission to air [g TEQ/y]		discharge to ash [g TEQ/y]		discharge to soot [g TEQ/y]		total to waste [g/TEQ/y]
	fossil fuels	wood	fossil fuels	wood	fossil fuels	wood	fossil fuels	wood	fossil fuels and wood
AT	425,000	300,000	49.10	0.74	2.38	0.56	1.57	0.36	4.87
BE	341,000	660,000	39.40	1.62	1.91	1.24	1.26	0.79	5.20
CY	1,633,333	166,667	188.70	0.41	9.16	0.31	6.03	0.20	15.70
CZ	4,800,000	2,583,333	554.54	6.33	26.93	4.84	17.71	3.09	52.57
DE	1,604,000	4,806,512	185.31	11.78	9.00	9.00	5.92	5.75	29.67
DK	2,000	753,750	0.23	1.85	0.01	1.41	0.01	0.90	2.33
EE	123,333	1,000,000	14.25	2.45	0.69	1.87	0.46	1.20	4.22
ES	90,000	2,273,524	10.40	5.57	0.50	4.26	0.33	2.72	7.81
FI	56,000	10,535,450	6.47	25.81	0.31	19.73	0.21	12.60	32.85
FR	86,900	3,401,807	10.04	8.33	0.49	6.37	0.32	4.07	11.25
GR	64,000	603,145	7.39	1.48	0.36	1.13	0.24	0.72	2.45
HU	1,333,333	2,666,667	154.04	6.53	7.48	4.99	4.92	3.19	20.58
IE	1,220,000	221,587	140.95	0.54	6.84	0.41	4.50	0.27	12.02
IT	107,000	3,278,578	12.36	8.03	0.60	6.14	0.39	3.92	11.05
LT	47,500	916,667	5.49	2.25	0.27	1.72	0.18	1.10	3.27

Country	fuel consumption (t/y)		emission to air [g TEQ/y]		discharge to ash [g TEQ/y]		discharge to soot [g TEQ/y]		total to waste [g/TEQ/y]
	fossil fuels	wood	fossil fuels	wood	fossil fuels	wood	fossil fuels	wood	fossil fuels and wood
LU	2,000	25,437	0.23	0.06	0.01	0.05	0.01	0.03	0.10
LV	146,667	666,667	16.94	1.63	0.82	1.25	0.54	0.80	3.41
MT	0	83,333	0.00	0.20	0.00	0.16	0.00	0.10	0.26
NL	7,000	403,500	0.81	0.99	0.04	0.76	0.03	0.48	1.31
PL	10,000,000	3,000,000	1155.30	7.35	56.10	5.62	36.89	3.59	102.20
PT	0	570,925	0.00	1.40	0.00	0.76	0.00	0.68	1.44
SE	0	10,201,189	0.00	24.99	0.00	19.10	0.00	12.20	31.30
SI	23,333	500,000	2.70	1.23	0.13	0.94	0.09	0.60	1.76
SK	1,956,667	666,667	226.05	1.63	10.98	1.25	0.00	0.80	13.03
UK	3,051,000	900,000	352.48	2.21	17.12	1.69	7.22	1.08	27.11
EU-25	27,120,067	51,185,403	3,133.18	125.40	152.14	95.54	88.80	61.22	397.76
EU-15	7,055,900	38,935,403	815.17	95.39	39.58	72.60	19.17	46.57	177.92
EU-10	20,064,167	12,250,000	2,318.01	30.01	112.56	22.94	66.80	14.65	216.95

Table 4-39: PCDD/PCDF mass flow for domestic burning of wood and solid fossil fuels in EU 25

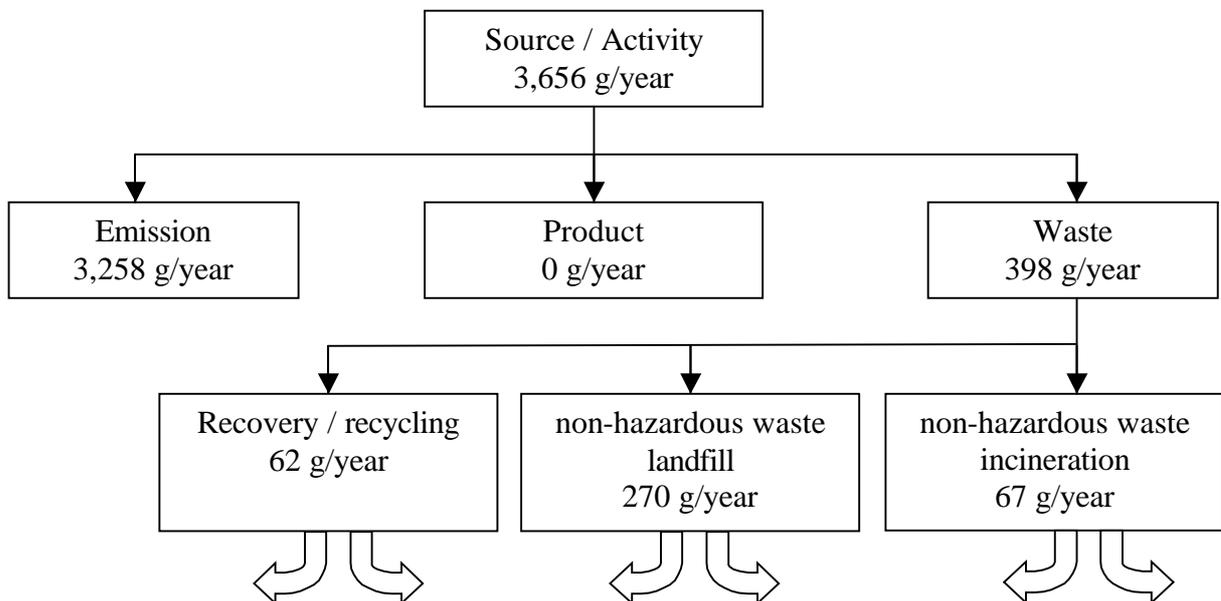


Figure 4-50: Assessment of the PCDD/PCDF flow related to domestic burning

(H) Waste flow for domestic burning of wood and fossil fuels

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

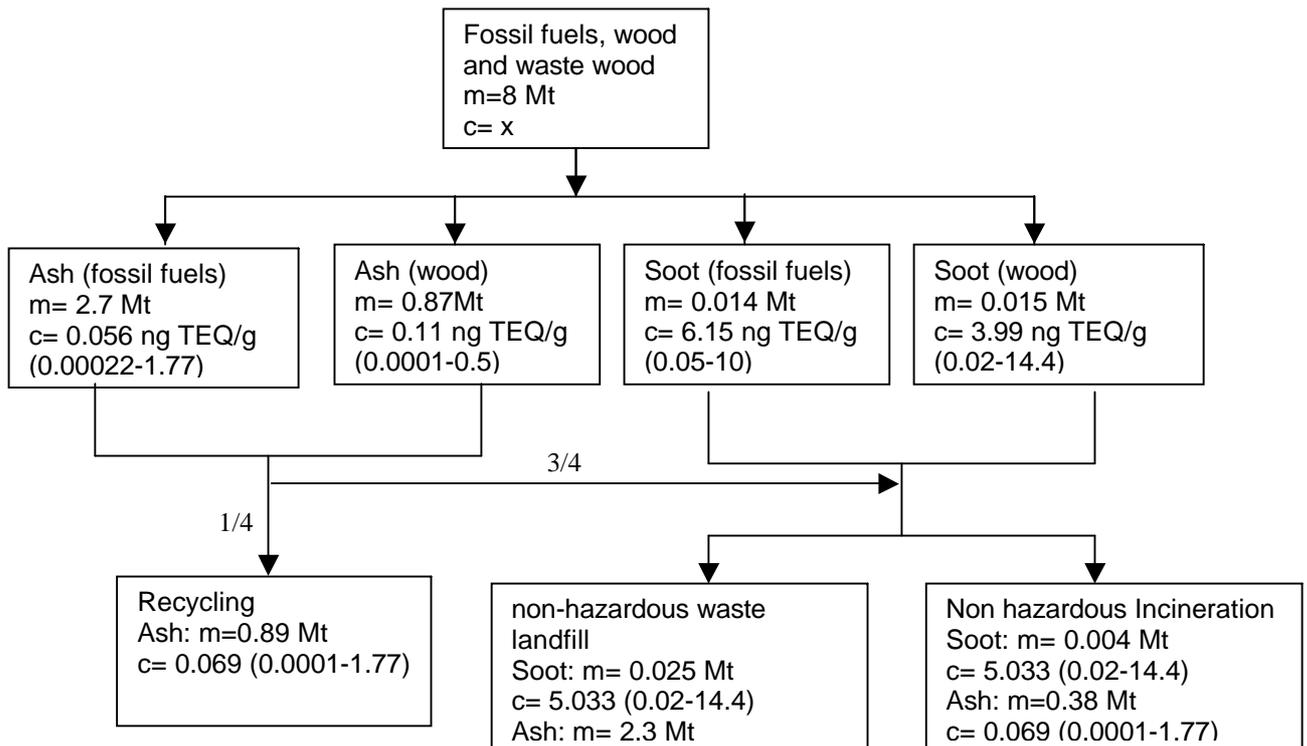


Figure 4-51: Detailed waste flow for domestic burning of wood and solid fossil fuels (coal and derivatives) in EU 25

The relevant data and their origin are listed in tables 1.15.1 - 1.15.6 in the Annex.

4.1.19 Uncontrolled Fires

(A) Background

A high contribution to PCDD/PCDF release is expected from uncontrolled fires, because no gas treatment exists. Uncontrolled fires include landfill fires, biomass burning, uncontrolled waste burning, open burning of waste wood, open burning of agricultural waste, on-field burning of stubble and straw, grassland and moor fires, forest fires, wood-cutting residue burning and accidental fires in vehicles and houses.

(B) Process input (raw material) and output (waste, air, water, product)

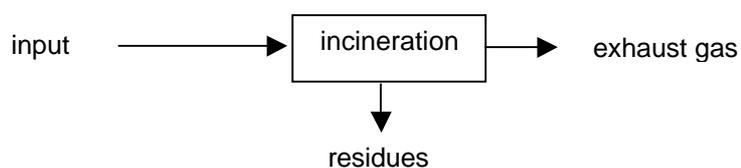


Figure 4-52: Relevant input and output of uncontrolled fires

Input:

- biomass
- waste
- wood
- vehicles and buildings

Output:

- exhaust gas
- residues

(C) Generation factors for waste and other output (air, water)

No generation factors for the amount of resulting exhaust gas and residues are available.

(D) Contamination data for output

Contamination data are only available for Estonia and Slovakia, and only for a part of the sources of uncontrolled fires. In the Estonian PCB inventory [COWI 2001] contamination for biomass burning amounts to 0,005 ng TEQ/g, 0,3 ng TEQ/g for uncontrolled waste burning, 0,025 ng TEQ/g for open burning of waste wood, and 1 ng TEQ/g for landfill fires. In the

Questionnaire from Slovakia an amount of 0,005 ng TEQ/g for forest fires and wood cutting residue burning is reported.

(E) Activity data

Activity data are available for the same sources of uncontrolled fires mentioned above, from Estonia and Slovakia. In an inventory of persistent organic pollutants in Poland [IEP, Stockholm Convention Focal Point, Warsaw, Poland; inventory of persistent organic pollutants in Poland] an amount of 438 t/y is reported for open burning of agricultural waste, on-field burning of stubble and straw, forest fires, landfill fires, vehicle and houses fires. For other countries no activity data are available.

(F) Waste treatment

There are no statements available on how the waste is treated. It is assumed that the residues remain in the soil.

(G) PCDD/PCDF flow

The available data are considered insufficient to establish a reliable PCDD/PCDF mass flow.

4.2 PCB flows

4.2.1 *Electrical and Electronic Equipment*

(A) Background

Before the use of PCB was banned by the Directive 76/769/EEC on restrictions in marketing and use of certain dangerous substances they were produced for a wide range of applications in open (e.g. plasticisers in sealants, paints, lacquers, floor coatings, etc.) and closed uses (i.e. liquids (oils) in large electrical equipment like transformers, condensers/capacitors and hydraulic machinery and in small capacitors, which are contained in household equipment (e.g. washing machines, fluorescent lamps, motor vehicles).

While the usage of PCB was completely banned in new closed circuits from 1986 existing equipment was allowed to be kept in use. These installations are subject to the PCB disposal directive (1996/59/EC) which requires inventorisation and final phasing out of all equipment containing liquids with PCB >500 mg/kg until 2010. A deadline for disposal in 2000 has been recommended for northern and middle European Member States by means of a PARCOM decision. Equipment between 50 and 500 ppm may stay in use until its life-time expires however shall be included in the inventories.

Small equipment with liquids containing PCB in amounts below 50 mg/kg has only recently been subjected to separate collection by the ELV (2000/53/EC) and the WEEE directive (2002/69/EC). Recovery of such liquids for substance and energy recovery is not limited by European legislation.

(B) Process input (raw material) and output (waste, air, water, product)

The process output is nearly equal to the process input.

(C) Generation factors for product/waste and other output (air, water)

The generation factor can be assumed as 1, because input and output are considered equal.

(D) Contamination data for output (and input)

For the PCB contents in liquids of existing equipment only a categorisation (no specific contamination data) is available. In general equipment and liquids containing >50 mg/kg PCB have to be disposed of by means of incineration or other safe disposal options. This category can be further disaggregated into a category of liquids with a PCB concentration >500 mg/kg, which have to be removed from use immediately, and liquids with PCB concentrations of 50-500 mg/kg, which are allowed for use till the end of life of the equipment. Only in Spain PCB containing liquid with a concentration between 50 and 500 mg/kg is not yet disposed of, this amount is calculated with 275 mg/kg.

According to expert information PCB containing liquids have to be regarded as "pure" PCB in the majority of cases. In Belgium a concentration of 2 g/kg is reported, for Italy it is clear that pure PCB is meant. In most of the reports it is often unclear whether the liquids are pure PCB

or PCB containing liquid. Furthermore capacitors, which are sealed after construction and thus can not be emptied and refilled have always to be calculated as containing “pure” PCB. As exact data on specific contamination levels are missing in most cases and reporting from Member States is not consistent with respect to reported parameter a minimum estimate with a concentration of 500 mg/kg and one a maximum estimate with an assumed concentration of 100% PCB/liquid have been calculated.

The concentration of PCB in small electronic and electrical equipment not subject to the PCB directive ranges from 0 mg/kg to 50 mg/kg. Therefore the mass flow for this category has been calculated with a mean contamination of 25 mg/kg. This estimation can be regarded as an upper bound estimation as there is certainly many equipment with almost no PCB in it.

(E) Activity data

Each EU Member State has to report its remaining PCB stocks to the European Commission in a national PCB inventory. Reports that have been available for the purpose of this study generally refer to stocks from 1999 till 2002. It has to be stated that the reporting has not been provided in standardised format and is not always complete. Furthermore no specification of the amount of liquid but only the number and type of installations have been provided by a number of countries. Thus extrapolations on the liquid content per tons of equipment have been made in a number of cases. According to information given in several reports it is estimated that one transformer contains 500 kg of PCB containing liquid and one capacitor contains 10 kg of PCB containing liquid. When only the weight of a transformer is reported, 15% of the weight are estimated to be PCB containing liquid, for capacitors it is estimated to be one third. Based on this data – and postulated that the elimination of existing stocks will be equally distributed over the coming 5 years and was equally distributed in the last approximately 5 years and will be finalised until 2010 – an annual amount of about 15,000 tons of PCB containing liquids (sum of all available data from the countries) is estimated as the relevant amount for EU 25.

Inventory information on remaining stocks and equipment in use has been reported by Member States and has been used as basis for the calculation of the PCB mass flow from large PCB containing equipment (e.g. transformer, capacitors, hydraulic machinery). A compilation of the available information is given in Table 4-40.

country	liquids amount [t]	liquids amount [t]	liquids amount [t]	liquids amount [t]	equipment amount [t]	item of equipment	reference and year
	all	Capacitors	Transformers	other	all	all	
AT	0	0	0				national PCB inventory 2000
BE (WL ⁶)	2,430	30 ³	2,400 ²	x ⁵		7,866 ¹	national PCB inventory 2001
BE (FL ⁷)	5,098	48 ³	5,050 ²	x ⁵		14,946 ¹	national PCB inventory 2001
CY							
CZ	4,059	2,702	325	1,000		20,833	national PCB inventory

country	liquids amount [t]	liquids amount [t]	liquids amount [t]	liquids amount [t]	equipment amount [t]	item of equipment	reference and year
DE	60						national PCB inventory 2002
DK	0	0	0				national PCB inventory 2001
EE	50						national PCB inventory 2004
ES	90,150				141,000		national PCB inventory 2001
FI	1					100	national PCB inventory 1999
FR	33,462 ⁴					545,610	national PCB inventory 2002
GR	65	58	7	x ⁵		13,185 ¹	national PCB inventory 2001
HU	56	56			546	12,436	national PCB inventory (2002)
IE	0.325		0.325				national PCB inventory 1999
IT	4 ⁴					3	national PCB inventory 2004
LT	138	51	87				national PCB inventory 2004
LU	150						national PCB inventory 2003
LV	206	138	68			4,299	national PCB inventory
MT							
NL	0						national PCB inventory 2000
PL	6,790	2,960	3,830		7,620	251,000	national PCB inventory
PT	466					855	national PCB inventory 2002
SE	0						national PCB inventory 2000
SI							
SK	500	300 ³	200 ²	x ⁵		31,261	national PCB inventory (2003)
UK	1,000						national PCB inventory 2001

1: BE (WI):7,866 items of equipment, thereof 4,801 transformers and 2,967 capacitors

BE (FI): 14,946 items of equipment, thereof 10,100 transformers and 4,774 capacitors

GR: 13,185 items of equipment, thereof 497 transformers and 12,631 capacitors

2: liquid amount of capacitors estimated on the assumption that one item of equipment contains in the average 10 kg of liquid.

3: liquid amount of transformers estimated on the assumption that one item of equipment contains in the average 500 kg of liquid

4: liquid is pure PCB

5: no estimation possible

6: WI = Wallonia

7: FI = Flamen

Table 4-40: Inventorised data on PCB containing equipment in use or stocked in EU 25

For the use of small capacitors in domestic equipment only Italy and the UK have made estimations. Based on the assumption that a comparable per capita amount of PCB containing domestic equipment exists in the majority of Member States, a total annual amount of about 609 tons PCB containing liquids (with an estimated average PCB content of 25 mg/kg) in domestic equipments is used for the calculation of the mass flow of PCB from this waste category.

(F) Waste treatment

Large equipment with a PCB contamination >50 mg/kg has to be decontaminated and disposed of according to the provisions of the PCB directive. This means the liquid is destroyed by means of hazardous waste incineration and equipment is decontaminated and recovered or disposed of underground. PCB from so called "white goods" from domestic and commercial use are either used for energy and substance recovery in the waste oil industry or are landfilled (including uncontrolled disposal).

For the mass flow it is assumed that only a share of the PCB containing liquids of the domestic equipment, which represents a small fraction of the total PCB in electronic and electrical waste, is incinerated in domestic incineration plants or landfilled, while liquids subject to the PCB directive, which represent the large fraction of the total annual PCB in this sector, are incinerated in hazardous waste incineration plants. So far there are no data for the specific amount of PCB incinerated or landfilled. Therefore an amount of 4,700 t/y is assumed to go into the hazardous waste incineration, the other two treatment options are expected to be of low importance.

(G) PCB flow

According to the PCB directive, PCB containing equipment with a PCB concentration above 500 mg/kg has to be disposed of by 2010 at the latest (in a few countries stricter regulations exist). The other PCB containing liquids have to be disposed of at the end of life. It can be assumed that in 2010 almost all PCB containing liquids will have been disposed of.

Calculated over the time period from 2000 (an estimated average of the inventories) to 2010 an annual amount of 5,210 tons of PCB in large equipments (see Table 4-41) and an annual amount of 0.015 tons of PCB from white goods (see Table 4-42) will be disposed of.

With respect to emissions of PCB from WEEE an overall maximum of 10% is assumed for the purpose of the mass flow. This means that <520 t/y are emitted and about 4,690 tons of PCB are disposed of.

country	liquid PCB stocks [t]	PCB containing liquid (t/y)	minimum estimate (kg/y)	maximum estimate (kg/y)	best estimate (kg/y)
AT	0	0	0	0	0
BE	7,528	753	376	752,800	376,588
CY	0	0	0	0	0
CZ	4,059	406	203	405,900	203,051
DE	60	6	3	6,000	3,002

country	liquid PCB stocks [t]	PCB containing liquid (t/y)	minimum estimate (kg/y)	maximum estimate (kg/y)	best estimate (kg/y)
DK	0	0	0	0	0
EE	50	5	3	5,000	2,501
ES	90,150	9,015	4,508	4,971,000	2,487,754
FI	1	0,1	0	100	50
FR	33,462	3,346*	1,673	3,346,200	1,673,937
GR	65	7	3	6,500	3,252
HU	56	6	3	5,600	2,801
IE	0	0,03	0	33	16
IT	4	0,4*	400	400	400
LT	138	14*	7	13,800	6,903
LU	150	15	32	32	32
LV	206	21	10	20,600	10,305
MT	0	0	0	0	0
NL	0	0	0	0	0
PL	6,790	679	340	679,000	339,670
PT	466	47	23	46,600	23,312
SE	0	0	0	0	0
SI	0	0	0	0	0
SK	500	50	25	50,000	25,013
UK	1,000	100	50	100,000	50,025
EU-25	144,690	14,469	7,659	10,409,565	5,208,612
EU-15	154,036	13,289	7,069	9,229,665	4,618,366
EU-10	11,799	1,180	590	1,179,900	590,245

Table 4-41: PCB mass flow for large PCB containing equipment (transformers, capacitors, etc) in EU 25

* pure PCB

country	amount (t/y)	PCB (kg/y)
EU 25	608.5	15.2

Table 4-42: Annual discharge of PCB via small PCB containing equipment in vehicles and white goods

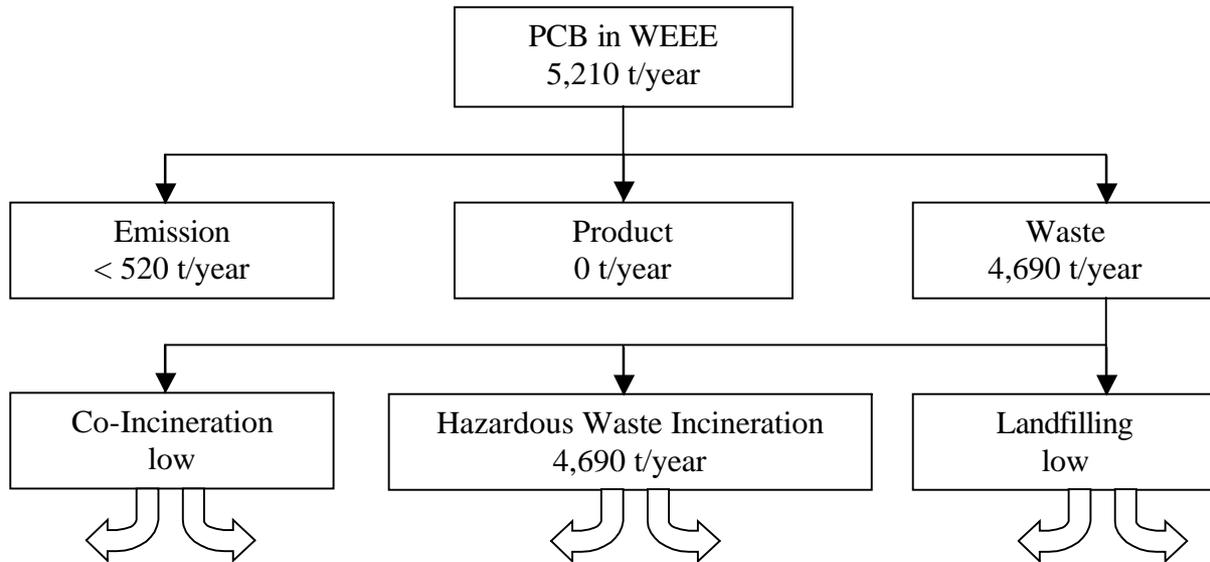


Figure 4-53: Total PCB mass flow for large PCB containing equipment and white goods in EU 25

(H) Waste flow for WEEEs

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

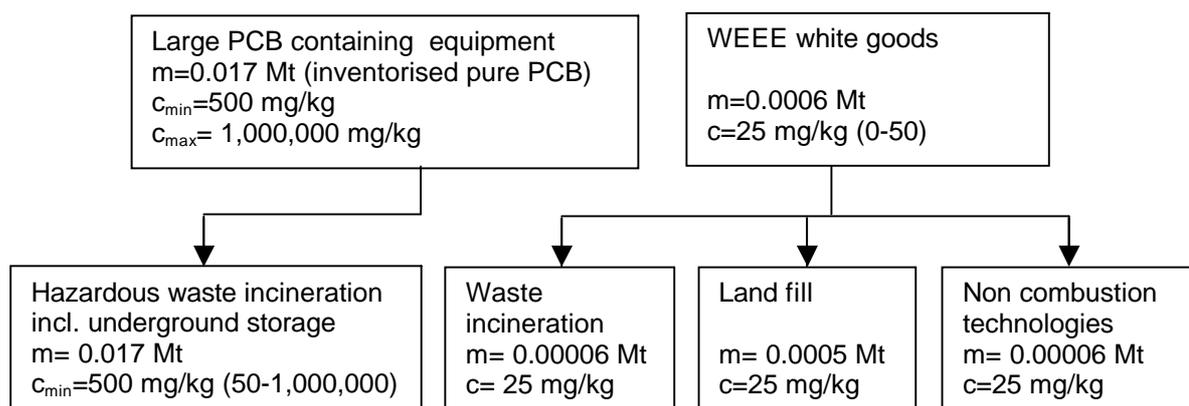


Figure 4-54: Detailed material flow for large PCB containing equipment and white goods in EU 25

The relevant data and their origin are listed in tables 2.1.1 - 2.1.3 in the Annex.

4.2.2 *Demolition and construction waste*

(A) Background

Before the use of PCB was banned for open applications by Directive 76/769/EEC on restrictions in marketing and use of certain dangerous substances, they were used in materials like double-glazing units, sealants, paints, adhesives and floor coating for construction. Based on information from a number of Member States it can be assumed that about 40% of the total consumption in old Member States was in open application in the building sector. Due to the longevity of buildings (reconstruction cycle 35-50 years), a relatively high amount of this material can still be assumed to remain in buildings and thus will flow into construction and demolition waste.

(B) Process input (raw material) and output (waste, air, water, product)

With respect to construction and demolition waste the amount of PCB in process output is regarded as equal to the process input.

(C) Generation factors for waste and other output (air, water)

The generation factor can be assumed as 1, because input and output are considered equal.

(D) Contamination data for output (and input)

Contamination data are not given in the PCB country reports. In an analysis of building materials in Sweden [PCB network 1999] an amount of 19 t PCB in construction and demolition waste is reported for the year 1998. Based on the assumption that a comparable per capita amount of PCB has been used in the majority of the Member States, the average annual amount of PCB in construction and demolition waste for Europe with a population of about 455 million (Sweden 9 mio) is extrapolated to a total of about 960 t PCB. It has to be taken into account that this is a rather rough estimation. Cross checks with data from the UK confirm the dimension of <1000 tons/y.

Based on data on annual amounts of construction and demolition waste in Member States [ISWA 2004] a total of 680 million tons of demolition waste per year is used as a calculation basis for the mass flow. However it has to be taken into account that only specific fractions of the total demolition waste have the potential to be contaminated with PCB. Based on data from Germany [3. Monitoring Bericht Baubranche] it can be assumed that about 30% (204 million tons) of the annual total may be contaminated (excavated soils and residues from road demolition, which amount to 70% of the total, are most likely not contaminated).

Provided that the 960 tons PCB estimated as European annual total are equally distributed over the 204 million tons of potentially contaminated waste, an overall contamination of 4.7 mg/kg results for the fractions of mixed and hazardous construction and demolition waste. Compared to existing analysis data for PCB contamination in building materials [PCB network 1999] this value sounds reasonable thus confirming the figure of 960 t as valid for the calculation of the mass flow.

According to information of the federal states from Germany, the following contamination data for PCB (sum 6) are given for different waste codes:

- 170106*¹⁵: 14 ppm (0.002 – 1,227)
- 170204*¹⁶: 10000 ppm (0.2 – 81,000), 0.32 ppm
- 170503*¹⁷: 5.5 ppm (0.0001 – 1,940)
- 170603*¹⁸: 9445 ppm (0.01 – 81,000)
- 170801*¹⁹: 27 ppm
- 170902*²⁰: 3400 ppm (0.9 – 29,460), >50 ppm
- 170903*²¹: 490 ppm (0.006 – 2,130)

EWC 170503 represents the largest fraction of C&D wastes in questions, so that the estimation of 4.7 ppm as average contamination in the potentially contaminated waste fractions based on the Swedish data does not seem to be disproportionate and is further used for calculation.

(E) Activity data

Data for AT, DE, DK, EE, IT, LT, NL and UK from 2001 are given in the ISWA report [ISWA report 2004]. For Sweden a value is given by the PCB network [PCB network 1999]. Based on this data the annual amount of wastes is extrapolated for the other countries resulting in an average per capita figure of 1 t/y.

According to information from Germany [3. Monitoring Bericht Baubranche] about 30% of the total waste is assumed to be contaminated. These values are important for further calculations.

¹⁵ mixtures of, or separate fraction of concrete, bricks, tiles and ceramics containing dangerous substances

¹⁶ glass, plastic and wood containing or contaminated with dangerous substances

¹⁷ soil and stones containing dangerous substances

¹⁸ other insulation materials consisting of or containing dangerous substances

¹⁹ gypsum based construction materials contaminated with dangerous substances

²⁰ construction and demolition wastes containing PCB (e.g. sealants, floorings, glazing units, capacitors)

²¹ other construction and demolition wastes (including mixed wastes) containing dangerous substances

country	demolition waste (t/y)	potentially contaminated fraction (t/y)	reference
AT	7,500,000	2,250,000	[ISWA 2004]
BE	10,548,168	3,164,451	extrapolated
CY	789,319	236,796	extrapolated
CZ	10,507,165	3,152,149	extrapolated
DE	250,790,000	75,237,000	[ISWA 2004]
DK	4,044,000	1,213,200	[ISWA 2004]
EE	1,262	378	[ISWA 2004]
ES	41,229,090	12,368,727	extrapolated
FI	1,400,000	420,000	extrapolated
FR	61,689,871	18,506,961	extrapolated
GR	10,937,702	3,281,311	extrapolated
HU	10,302,147	3,090,644	extrapolated
IE	4,018,350	1,205,505	extrapolated
IT	30,954,000	9,286,200	[ISWA 2004]
LT	14,800	4,440	[ISWA 2004]
LU	461,290	138,387	extrapolated
LV	2,408,960	722,688	extrapolated
MT	410,036	123,011	extrapolated
NL	19,550,000	5,865,000	[ISWA 2004]
PL	39,588,947	11,876,684	extrapolated
PT	10,353,401	3,106,020	extrapolated
SE	9,102,793	2,730,838	[PCB Network 2002]
SI	1,988,673	596,602	extrapolated
SK	5,566,235	1,669,870	extrapolated
UK	150,000,000	45,000,000	[ISWA 2004]
EU 25	684,156,208	205,123,852	
EU 15	612,578,666	183,773,600	
EU 10	71,577,542	21,113,456	

Table 4-43: Annual amount of demolition waste and its share potentially contaminated with PCB in the EU 25

(F) Waste treatment

According to European legislation, waste with a contamination level <50 ppm is not regarded as hazardous waste and thus can be recovered, disposed of or if combustible may be incinerated in MSWI plants. However an additional limitation has been set in Council Decision 2003/33/EC on acceptance criteria for inert landfills. By this means the acceptable PCB content in wastes intended for disposal is limited to 1 mg/kg. No limitation regarding PCB content has been set for disposal at non-hazardous or hazardous waste landfills.

In consequence of this, different options do exist for the treatment of construction and demolition waste. An unknown but probably large share of the building waste is landfilled at different landfill categories according to the specific contamination.

Combustible waste that is higher contaminated has to be incinerated. Currently no specific information on the amount of waste undergoing each type of treatment is available.

Wastes with expected PCB >50 ppm will be sent to incineration in either MSWI or HWI plants.

Therefore it is assumed that 30% are incinerated, 30% are disposed of in inert landfills (low or unknown PCB contamination) and 30% are disposed of in hazardous waste landfills or underground disposal (incombustible fractions classified as hazardous).

(G) PCB flow

The PCB flow is calculated on a European scale and is not differentiated by Member States. Because it is a rough estimation, it is calculated with <1,000 t/y for the mass flow. With respect to emissions of PCB from construction and demolition waste, an overall maximum of 10% is assumed for the purpose of the mass flow. This means that an amount of <100 t/y is annually emitted and at about 900 tons of PCB have to be annually disposed of.

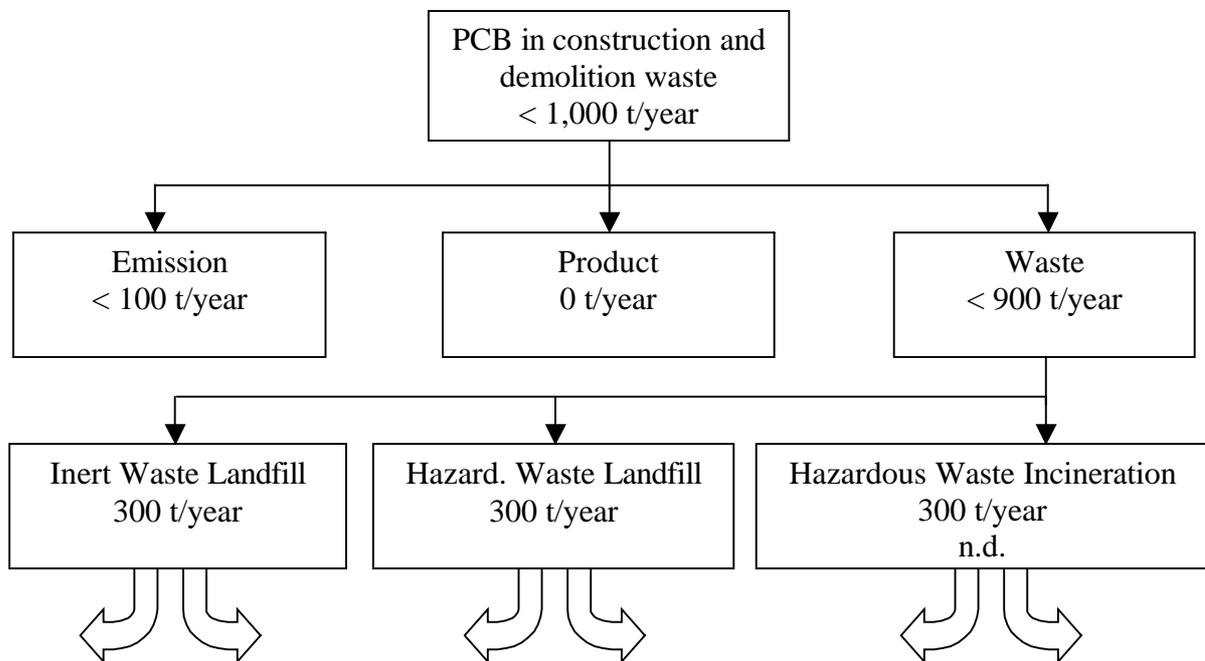


Figure 4-55: PCB mass flow for construction and demolition waste in EU 25

(H) Waste flow for C&D waste

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

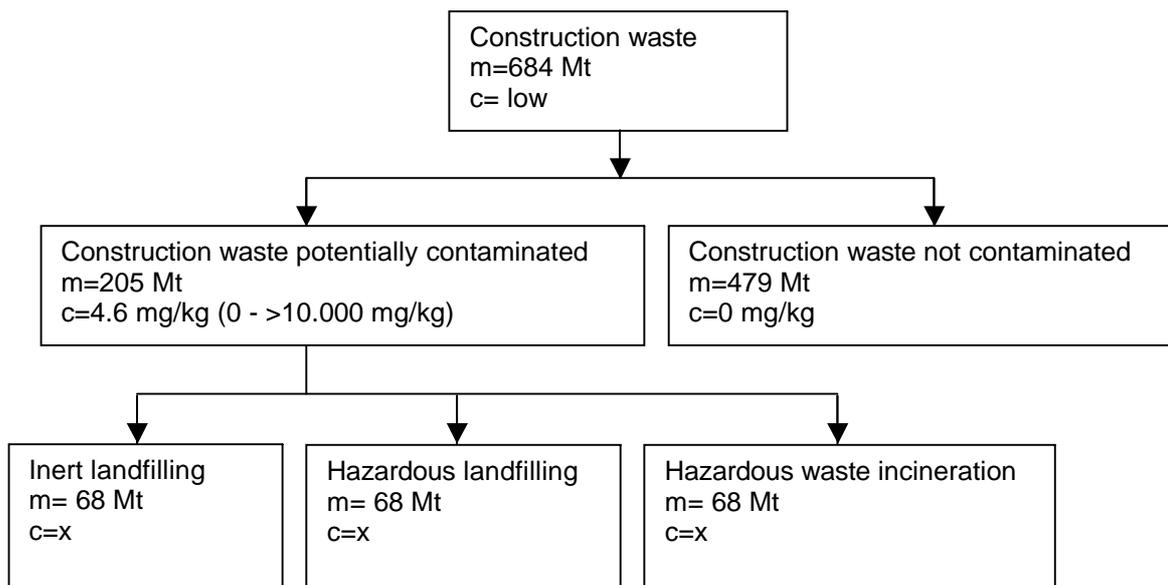


Figure 4-56: Waste flow for Construction & Demolition waste (C&D waste) in EU 25

The relevant data and their origin are listed in table 2.2 in the Annex.

4.2.3 Waste oil

(A) Background

Liquids containing less than 50 mg/kg PCB may be collected as waste oils according to the European Waste Oil Directive 75/439/EEC. At Community level no additional limit has been set for substance recovery. However some Member States have established stricter limits for substance recovery in their national legislation (Germany: 20 mg/kg, Sweden: 10 mg/kg, Finland: 2 mg/kg). Waste oils with PCB concentrations above those stricter limits can only be used for energy recovery.

According to a study of the Umweltbundesamt [UBA 2000] a great part of the consumed waste oils is used as lubricating grease, anticorrosive, mould release agent or aggregates in products and therefore is not collectable as waste oils. A smaller part is burned as fuels in engines and about 10% get lost through drip loss and leakage. Further losses from adhesion to materials, the oil remaining in vehicles etc. Therefore only about half of the waste oils can be collected.

(B) Process input (raw material) and output (waste, air, water, product)

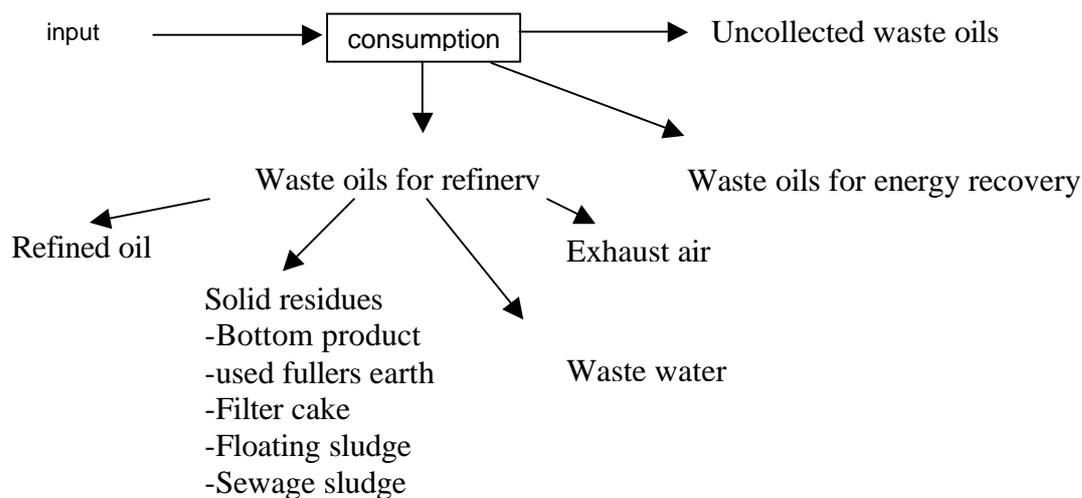


Figure 4-57: Relevant input and output of oil consumption and waste oil refinery

Input:

- industrial oil (hydraulic oil, engine lubricant, etc.)
- transformer oil
- anticorrosive
- lubricating grease
- ...

Output:

- oil for energy recovery
- uncollected waste oils
- waste oils for refinery
 - o refined oil
 - o exhaust air
 - o solid residues
 - bottom product
 - used fullers earth
 - sewage sludge
 - floating sludge
 - filter cake
 - o exhaust air

(C) Generation factors for waste and other output (air, water)

The generation factor for the higher contaminated waste oils amounts to 0.005 because it is assumed that 10% of the category III oils, which account for 0.5% of all waste oils, are higher contaminated.

The rest of the waste oils, which is considered to have a low contamination, amounts to 99.5%, therefore the amount of lower contaminated waste oils is calculated with a generation factor of 0.995 for the lower contaminated waste oil.

(D) Contamination data for output (and input)

According to German information PCB concentrations above 20 mg/kg were only found in category III oils. Other categories exhibit low concentrations. Oils with PCB concentrations exceeding 50 mg/kg have to be collected and treated separately. According to expert information about 10% of the category III oils are contaminated with about 15 mg/kg. This value is used for the higher contaminated waste oils (0.5% of all waste oils).

The refinery Dollbergen recycles waste oils with concentrations below 5 or 2 mg/kg. Contaminations reported from NRW amount to about 2.5 mg/kg. Therefore for the lower contaminated waste oils (99.5%) a contamination of 2.5 mg/kg is assumed.

(E) Activity data

For the old MS, activity data are reported in a statistic by GEIR for consumed, collectable and collected waste oils. For the new MS no activity data for the consumption are available. Therefore a rough estimation is made relying on the population. In a report of Hungary it is

mentioned that about 20,000 t of waste oils are currently collected annually [Hungarian NIP 2003]. In relation to the estimated annual oil consumption this leads to a collection factor of 0.15 which has been used as a first approach for all “new” Member States. A compilation of data is given in Table 4-44.

country	oil consumption (t/y)	collectable [%]	collected [%]	collected (t/y)	reference
AT	109,000	0.49	0.31	33,500	[GEIR 2002]
BE	173,100	0.36	0.35	60,000	[GEIR 2002]
CY	10,308		0.15	1,532	extrapolated
CZ	137,223		0.15	20,398	extrapolated
DE	1,032,361	0.45	0.45	460,000	[GEIR 2002]
DK	71,718	0.65	0.49	35,000	[GEIR 2002]
EE	18,877	0.50	0.15	2,806	extrapolated
ES	510,980		0.31	160,000	[GEIR 2002]
FI	88,809	0.56	0.45	39,677	[GEIR 2002]
FR	841,356	0.50	0.29	242,500	[GEIR 2002]
GR	87,800	0.46	0.25	22,000	[GEIR 2002]
HU	134,546		0.15	20,000	[Country report 2003]
IE	38,900	0.46	0.39	15,303	[GEIR 2002]
IT	617,594	0.32	0.31	189,595	[GEIR 2002]
LT	48,195		0.15	7,164	extrapolated
LU	10,170	0.46	0.45	4,564	[GEIR 2002]
LV	31,461		0.15	4,677	extrapolated
MT	5,355		0.15	796	extrapolated
NL	152,694	0.44	0.39	60,000	[GEIR 2002]
PL	517,030		0.15	76,856	extrapolated
PT	102,000	0.52	0.39	39,620	[GEIR 2002]
SE	142,814	0.54	0.43	61,786	[GEIR 2002]
SI	25,972		0.15	3,861	extrapolated
SK	72,695		0.15	10,806	extrapolated
UK	840,834	0.48	0.42	352,500	[GEIR 2002]
EU 25	5,821,792			1,924,941	
EU 15	4,820,130			1,776,045	
EU 10	1,001,662			148,896	

Table 4-44: Annual oil consumption and shares of collectable and collected waste oil in EU 25

(F) Waste Treatment

According to the waste oil directive, the aim is to recover as much as possible. Therefore the recycling rate increases more and more. According to information from the national authority [BMU 2003] as well as from the national industry association in Germany, 100% of the collected waste oils are reused for recycling or energy recovery. In other MS treatment options other than incineration and recycling are not practised.

Oils containing PCB >20 mg/kg (waste codes 130101, 130301) in Germany may only be used for energy recovery. Even stricter limits are applied e.g. in Sweden and Finland. However there are other Member States where oils with a PCB concentration up to 50 mg/kg can be used for substance recovery according to European legislation.

Data from Germany with 100% recovery of collected oils are used in the mass flow as a best case estimation. According to a report of the UBA [UBA 2000] about 50% of the collected waste oils are used for substance recovery in refineries and about 50% are used for energy recovery. According to information from the national authority [BMU 2003] as well as from the national industry association in Germany the collecting rate increases every year and in 2003 75% of the collected waste oils were recycled (collection category I; low contamination expected) 25% were used for energy recovery (category II and III) in Germany. In other MS treatment options other than incineration and recycling are not known. For the mass flow the data from the UBA report are used.

In the refinery process besides refined oil solid residues such as bottom products, used fullers earth, filter cake, sewage sludge and floating sludge are generated in the production. Bottom products, used fullers earth and filter cake are co-incinerated in the steel or cement industry, sewage sludge is used in agriculture, floating sludge is disposed of in a hazardous incineration plant. According to the UBA report [UBA 2000] it is assumed that a high amount of PCB remains in the bottom products of the flash distillation. In a report of the BMU [BMU 2001] it is told that with the flash distillation most of the PCB pass into the product whereas with ground distillation most of the PCB remain in the bottom products.

According to statistics from the European waste oil association [GEIR 2002] the average collected amount of waste oils in Europe [EU 15] is less than half (40%) of the whole oil consumption. The collected amount of waste oils in the new Member States is estimated to be 15% of the total consumed oils. On average 29% of waste oils are collected in the EU. The remaining 71% are uncollectible (about 50%) or just not separately collected. The non collected waste oils are emitted to the environment, most probably incinerated or landfilled as part of municipal solid waste. Data on the share of incineration and landfilling for non collectable and non collected waste oils are not available. It is assumed that half of the amount is incinerated and the other part is landfilled.

(G) PCB flow

According to information from the German Altölverband the waste oils collected in Germany are separated into 3 categories. 5% of the waste oils belong to category III, which includes the waste codes for oils containing or contaminated with PCB (130101*, 1301301*). Besides those two waste codes, category III also includes chlorinated oils, which are widely used in industry and therefore account for the major part of category III. As specific information about the actual contribution of 130101*, 1301301* is not available so far, the amount of PCB containing waste oils in category III is estimated to be 10%. Based on the information from the refinery Dollbergen the contamination of these oils is about 15 ppm. Calculations based on the above mentioned information show that a share of 0.005% of the annually consumed oil can be assumed to be contaminated with PCB up to 50 ppm. The rest of the waste oils is contaminated with about 2.5 ppm. This results in a total amount of about 14 t PCB/y as the source of the PCB mass flow from waste oils.

For the mass flow we estimate that the non collected fractions have on average the same contamination as the collected fractions and therefore contain about 10 tons of PCB. The collected waste oils, which contain about 4 tons of PCB, are recovered in waste oil refineries (50%) and used for energy recovery (50%). According to a rough estimation PCB from non collected waste oils enter to about 50% the waste path whereas the fate of the remaining share is unclear and enters partly the environment via air, water and soil or is treated in another way (e.g. storage in stockpiles).

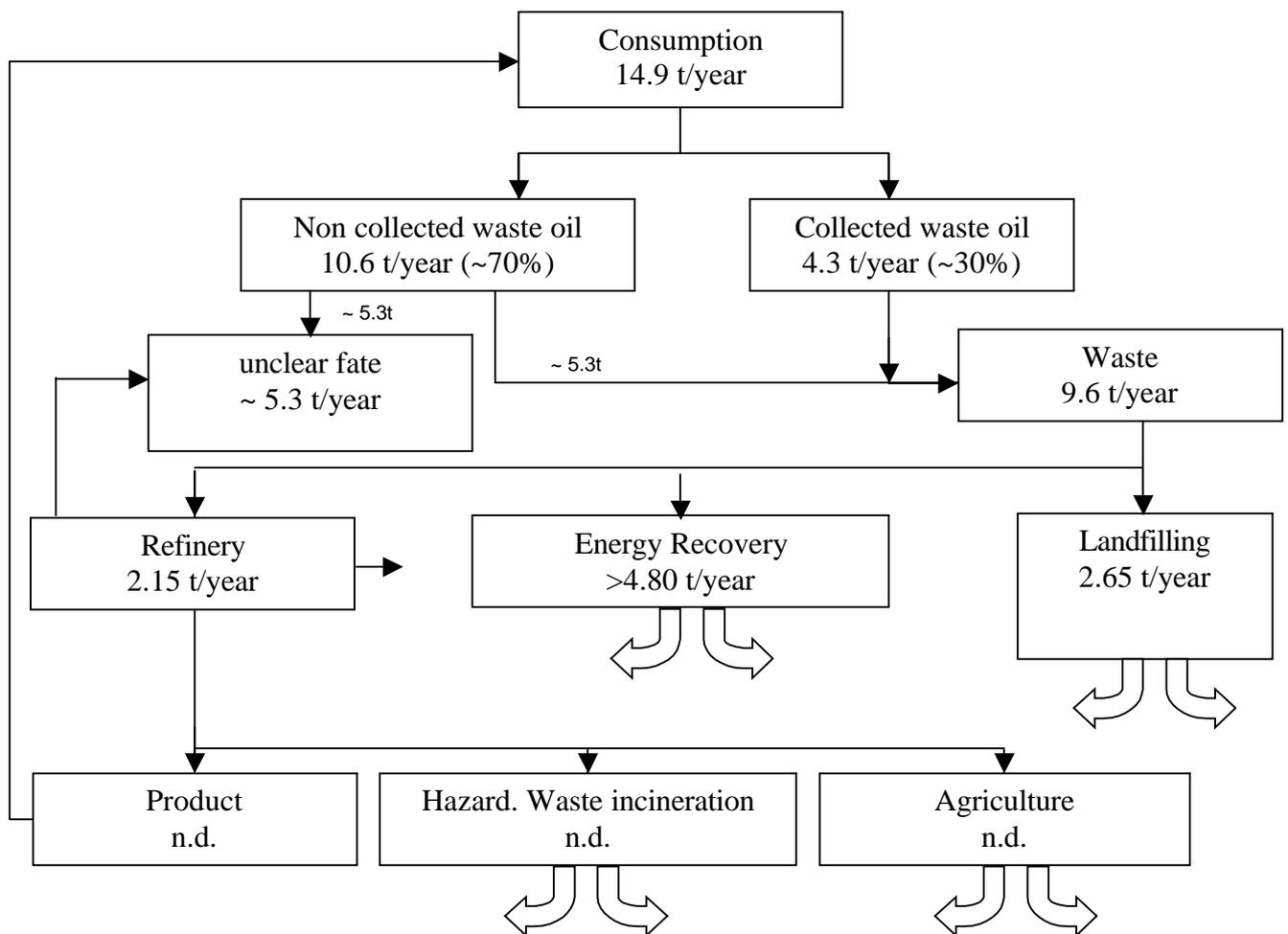


Figure 4-58: Total PCB mass flow for waste oil in EU 25

(H) Waste flow for waste oil

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

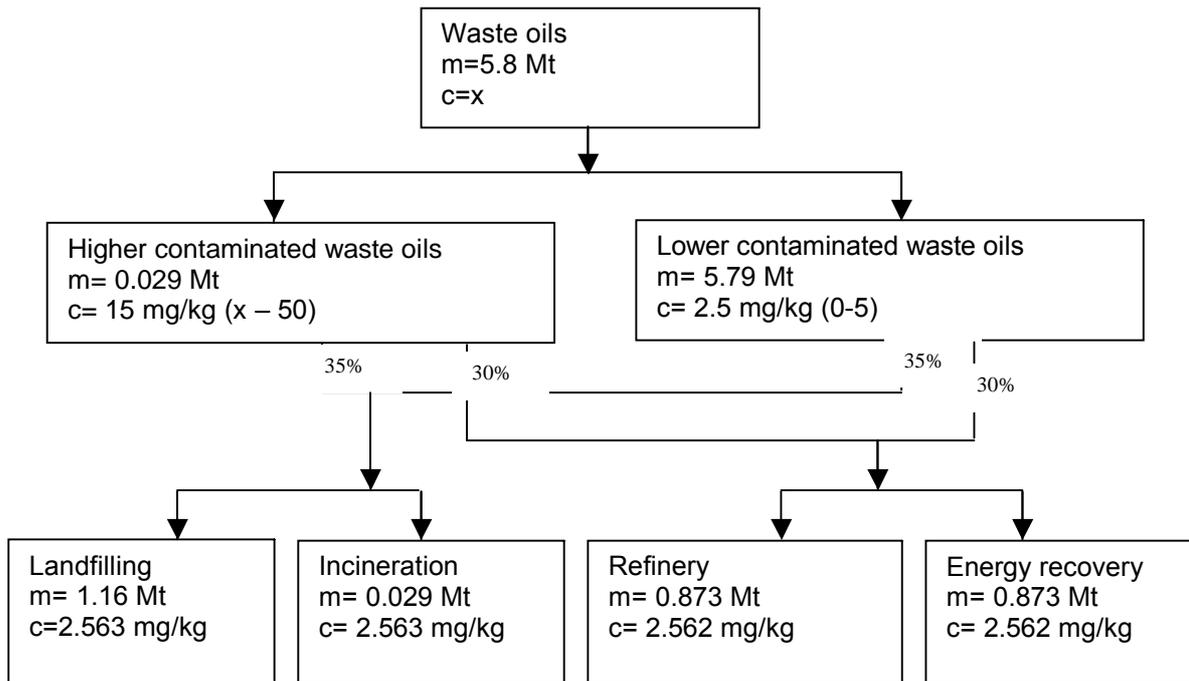


Figure 4-59: Detailed waste flow for waste oils in EU 25

The relevant data and their origin are listed in tables 2.3.1 - 2.3.2 in the Annex.

4.2.4 *Shredder*

(A) *Background*

Different shredder and granulation plants are used to process different end-of-life goods (e.g. ELV, WEEE, insulated cables) by breaking them up and separating the materials they were made of in order to recover secondary raw materials for infeed to subsequent recycling processes. The feed material is crushed and ground or cut into small pellets, which are then separated into two basic shredder fractions. These are metallic fraction, which is used as secondary raw material in the iron and steel and in the non-ferrous metal industry, and the non-metallic, or so-called light fraction containing all other components of the feed material, mainly plastics, rubber and glass. In the cable shredding process the non-metallic fraction consists of the insulation sheeting, which is mainly made of PVC. In general it can be stated that the shredding process basically provides mechanical separation. Shredding is a low temperature mechanical process (40-60°C). Thus neither a new formation nor a thermal destruction of pollutants can be expected. Consequently thorough separation of dangerous components and decontamination of the infeed are crucial factors for the amount of PCB in the shredder fractions. Therefore, the output of a shredder only marginally differs from its input, as regards chemical composition.

The term shredder is normally used in conjunction with the description of the material it processes, whether these are discarded tyres, electrical goods, wood, paper, vehicles etc.

The largest shredder plants in Europe, of which there are some 247 across the EU 25, process end-of-life vehicles (ELVs), white goods and metal scrap. These large plants are subject to both the ELV Directive because of their end-of-life vehicles infeed and the WEEE Directive for their white goods infeed. There are smaller specialist shredder facilities for processing smaller Waste Electrical & Electronic Equipment (WEEE), a growing sector due to recent legislation. Presently less than 50 of these plants are estimated to exist in the EU 25.

On the other hand there are also a number of shredding/granulation plants that process wire and cable scrap by cutting processes that may also be associated with chopping and stripping. The processing of certain cables and wires, with the insulation containing PCB, will produce waste streams with elevated contamination levels.

Whilst the main product of each of these process types principally is metals for material recycling, the processes should be considered separately due to the specificities of their infeed material and the particular waste generated by each of the processes with respect to possible contamination with POPs.

Thus two distinct groups of shredders (shredder plants for ELV, metal scrap and white goods and shredding/granulation plants for wire and cable scrap) are described in this paragraph.

With respect to the distribution of potential contamination over the two shredder fractions, according to expert information a concentration of pollutants and impurities can be observed in the non-metallic fraction.

(B) Process input and output

Shredder plants for End-of-Life Vehicles, white goods and metal scrap

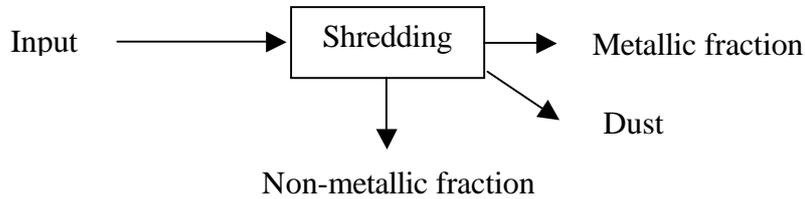


Figure 4-60: Relevant input and output of shredding processes (end-of-life vehicles, white goods and metal scrap)

Input:

- end-of-life vehicles
- white goods
- metal scrap

Output:

- metallic fraction (remelted and/or refined in high temperature metallurgical plants)
- non metallic fraction (so called light fraction) some of which will have to be separated and materially recycled according to the ELV Directive, the rest either recovered or disposed of, dependent on the reuse, recovery and recycling targets in the Directive.

Shredding/granulation plants for wire and cable scrap

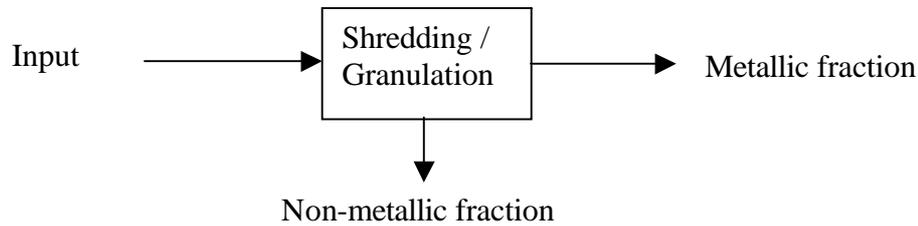


Figure 4-61: Relevant input and output of waste cable shredding

Input:

- coated wire and cable scrap
(note: certain underground cables are more likely to contain PCB)

Output:

- metallic fraction (copper or aluminium, remelted and / or refined in high temperature metallurgical plants)
- non-metallic fraction (insulation exceeding the current limits of 50 ppm has to be disposed of, uncontaminated plastic may be recycled)

(C) Generation factors for waste and other output (air, water)

The generation factor can be assumed as 1 for both processes, because the shredding process neither destroys nor produces POPs.

(D) Contamination data for output (and input)

Shredder plants for End-of-Life Vehicles, white goods and metal scrap

In general contamination data are only available for the shredder non-metallic fraction, which is also known as shredder residue, in contrast to the valuable metallic fraction.

According to information from the European metal recycling association an average contamination for the shredder non-metallic fraction of less than 0.87 mg/kg was measured in recent tests at six different shredder plants in the UK [EFR 2004]. In addition an average contamination of 7.8 ppm (Sum 6 x 5) has been reported for recent data from Schleswig-Holstein in Germany.

On the other hand a median PCB concentration of 25 mg/kg [LUA report 2002] or above has been reported from several German Länder from investigations on shredder residues. In total the available data ranged from <5 mg/kg to 3,263 mg/kg for the total PCB (Sum 6 x 5) content. However these investigations included data from the beginning of the nineties where levels in the feed material have still been higher and separation of dangerous parts less established.

Shredding/granulation plants for wire and cable scrap

For Shredding/granulation plants that process cable and wire the resultant non-metallic fraction may be contaminated with PCB which have been used as plasticiser. According to data reported for Germany, most of the samples show contamination levels of 30 mg/kg (Sum 6 Congener x 5). On the other hand peak contaminations of several hundred ppm can be reached in samples with high shares of specific types of cable (e.g. underground, mining). Cable granulate is thus constantly controlled and charges with POP level of >50 mg/kg have to be destroyed by incineration or stored underground.

(E) Activity data

Shredder plants for End-of-Life Vehicles, white goods and metal scrap

According to the European Ferrous Recovery & Recycling Federation [EFR 2004] around 12,000,000 tons of end-of-life vehicles are processed annually, along with white goods and metal scrap, by the approximately 247 shredders in the EU 25. Shredders sort out about 3,000,000 tons of non-metallics as a fraction (terms such as light fraction, fluff, shredder residue are used to describe different non-metallic fractions). The non-metallic fraction, being fibrous in nature, would contain most of any PCB contamination that may have entered the shredding process [EFR 2004].

Shredding/granulation plants for wire and cable scrap

It can be estimated that some 500,000 tonnes of wire and cable scrap is collected annually in the EU 25, with some 30,000-40,000 tonnes being exported. (In 1997, over 1,800,000 tonnes of insulated wire and cable scrap were generated worldwide [EFR 2005]). Wire and cable scrap contains on average about 60% metal and 40% plastics²², but the ratio can be as low as 40% metal and 60% insulation.

Only a portion of wire and cable, likely that from underground and cables produced from 1955-1985, will have insulation containing PCB. Thus the amount of PCB containing insulation will be reducing year on year.

Based on the data provided by EFR 225,000 tonnes of insulation material (mainly PVC) is processed in the European Union.

(F) Waste Treatment

Shredder plants for End-of-Life Vehicles, white goods and metal scrap

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 provided by the EFR results in a share of 80% for landfilling and about 10% each for incineration with and without energy

²² Recovery and disposal operations, Report March 2004, Ökopol GmbH, Institute for Environmental Strategies, Nernstweg 32-34, D-22765 Hamburg, Germany

recovery. The PCB disposal regulation requires waste contaminated above 50 mg/kg to be landfilled on a landfill for hazardous waste or incinerated. Waste below 50 mg/kg can be landfilled on a landfill for non-hazardous waste. It is not mentioned in the EU regulation whether the total PCB or only the sum of 6 have to be measured.

The mass flows will change as the targets of the ELV Directive and the WEEE Directive require more extensive treatment of the non-metallic fraction from shredding. The ELV Directive sets ambitious targets for the percentage of, end-of life vehicles to be reused, recycled, and recovered, with exigencies increasing over time.

The WEEE Directive sets targets for the rate of recovery of large household appliances and automatic dispensers, as well as component, material and substance reuse and recycling by 31 December 2006. The respective regulation is relevant with regard to the white goods processed with ELVs.

Certain EU Member States have established or intend national restrictions on the operations that the non-metallic shredder output may be subject to. The European Ferrous Recovery and Recycling Federation's European Shredder Group confirms that from the beginning of 2004, Austria allows D10 operations only.

In the future Belgium expects to use incineration, but there is not enough capacity, whereas Wallonia will ban D1 options by 1-1-2006 and Flanders will ban D1 operations from 1-7-2005.

France will have local limitations on D1 operations between 2005-2007, with about half of the Departments facing a landfill shortfall in the future.

Germany is set to ban D1 operations from 5-6-2005, whilst their incineration capacity is questionable and therefore landfill of specific fractions of ASR might still be required.

Ireland exports the non-metallic shredder output to landfill in other Member States. Italy will ban D1 operations by 1-1-2007.

The Netherlands will ban D1 operations by 2005 unless there is no alternative. Spain relies on D1 operations, as there is no incineration capacity. Sweden will ban D1 operations from 1-1-2005.

<u>country</u>	<u>legal provisions</u>
<u>AT</u>	from 2004 D10 only
<u>BE</u>	Wallonia: ban on landfill from 1-1-2006 Flanders: ban on landfill from 1-7-2005
<u>DE</u>	ban on landfill from 5-6-2005
<u>DK</u>	all shredder residues have to be landfilled

<u>country</u>	<u>legal provisions</u>
<u>FR</u>	local limitations on landfilling due to capacity shortage between 2005-2007
<u>IE</u>	export of the non-metallic shredder output to landfill
<u>IT</u>	will ban landfilling by 1-1-2007
<u>NL</u>	will ban landfilling by 2005 unless there is no alternative

Table 4-45: Overview on legal provisions for the management of shredder waste in European Countries

Shredding/granulation plants for wire and cable scrap

A specific sector of the metal reclamation industry has specialised on the processing of cables which contain significant amounts of valuable metals.

The feed material derives from construction and demolition measures and from current production processes. The cable sheathing (mainly PVC) accounts for roughly up to 50% of the weight and is separated as a granulate, which is recycled as far as possible. Simply mechanically separated PVC granulate is down cycled due to impurities and mainly used for signalling material in road maintenance and construction or other public works. At the end of its lifetime this material is largely returned to industry and re-introduced into the recycling process.

An alternative recycling process (VINYLOOP) uses solvents to completely liquefy the PVC and recovers a highly pure PVC raw material from the purified solvent.

Substance recovery of the non-metallic fraction can also be performed by high temperature recovery of HCl used for the production of chlorine as a basic substance for PVC production.

According to German information, 48% of the cable waste is recycled and 52% disposed of by landfilling. Due to missing data from other European Member States this distribution is used for the calculation of the overall European mass flow.

The potential to use the non-metallic fraction as a secondary fuel in combustion processes is limited due to a high chlorine content.

*(G) PCB flow*Shredder plants for End-of-Life Vehicles, white goods and metal scrap

Based on the assumption that most of the PCB can be found in the 3,000,000 tonnes of non-metallic light fraction, and with the contamination data of 3,6 mg/kg (Sum 6 x 5) an amount of 10,9 t PCB/y results as a source for the PCB mass flow. With respect to emissions of PCB from the shredding process an overall additional maximum of 10% is assumed for the purpose of the mass flow.

country	light fraction (t/y)	PCB (t/y)
EU 25	3,000,000	10.9

Table 4-46: PCB mass flow for ELV shredder processes in EU 25

The PCB flow is calculated on a European scale and is not differentiated by Member States.

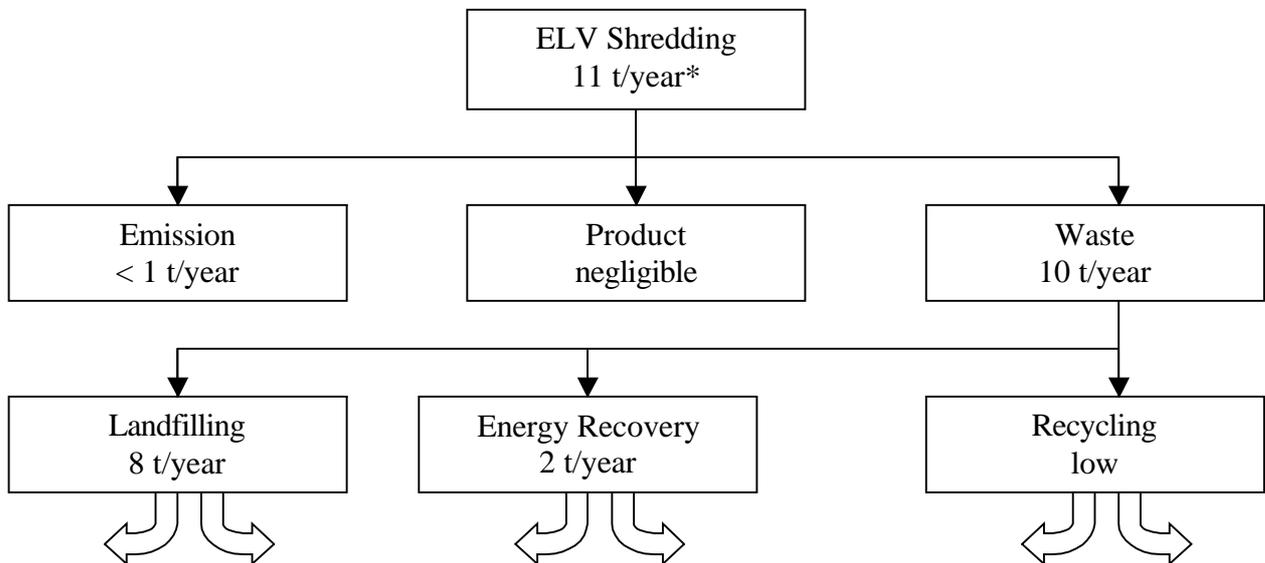


Figure 4-62: PCB mass flow for shredding of vehicles and white goods

* Calculated amount based on newest figures from UK and Germany on the basis of thorough separation and cleaning of feed materials. Older figures from Germany including data from 1990 till 2001 show average contaminations exceeding the presented figures by factors of 5-10. Provided an effective implementation of WEEE and ELV Directives and taking into account the fact that the use of contaminated feed material will further decline, the assumed PCB figures can be used.

(H) Waste flow for ELV residues

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

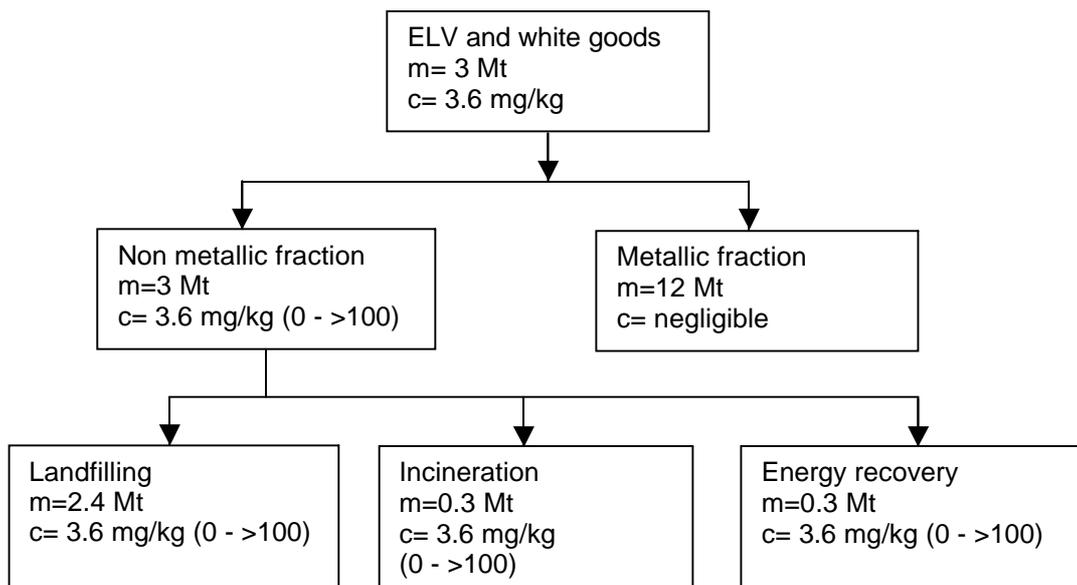


Figure 4-63: Waste flow for ELV shredder processes in EU 25

The relevant data and their origin are listed in table 2.4 in the Annex.

Shredding/granulation plants for wire and cable scrap

According to data provided by German industry associations and authorities (VDM/AGPU/BMU), this material is in most cases contaminated with PCB at levels of 30 mg/kg (Sum 6 x 5) with specific fractions (e.g. post consumer underground and mining cables) reaching contamination levels of several hundred ppm and other fractions (e.g. production residues) with contamination levels < 10 ppm.

Thus an average contamination of 30 ppm is used for the mass flow. Based on these data an amount of 6.75 tonnes of PCB/y results as a source for the PCB mass flow.

country	light fraction [t]	PCB (t/y)
EU 25	225,000	7

Table 4-47: PCB mass flow for waste cable shredding/granulation in EU 25

The PCB flow is calculated on a European scale and is not differentiated by Member States.

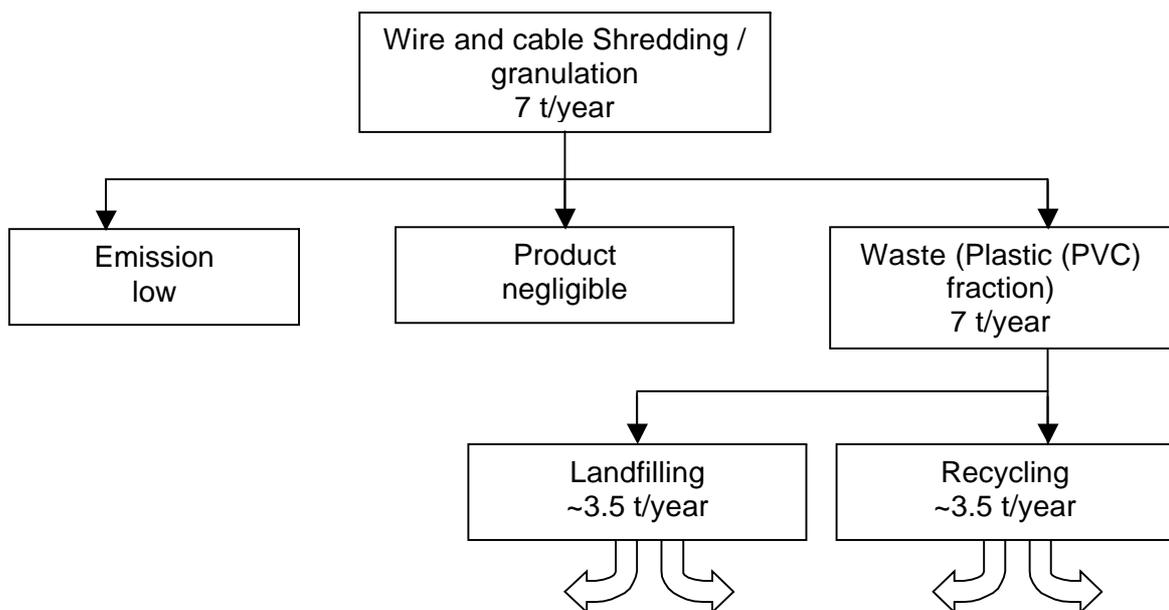


Figure 4-64: PCB mass flow for shredding/granulation of waste cables in EU 25

(H) Waste flow for waste cables

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

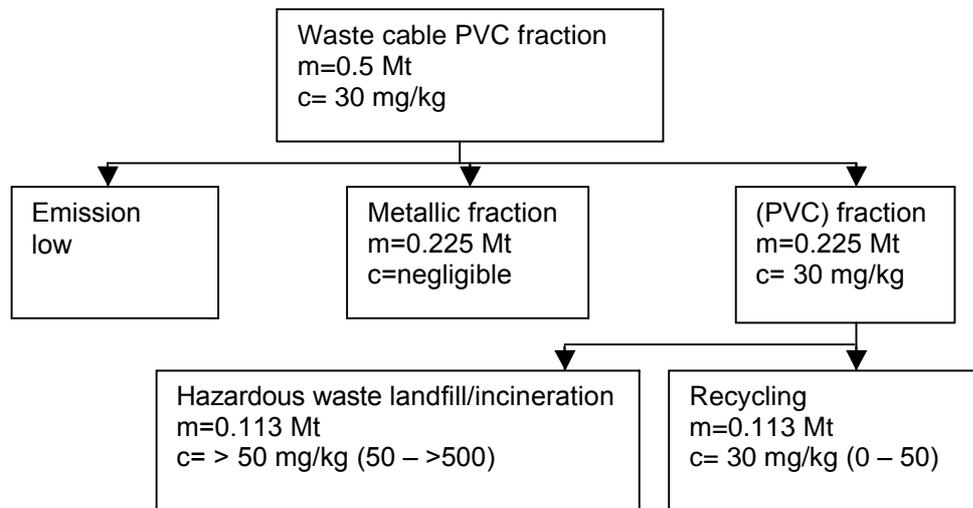


Figure 4-65: Detailed waste flow for cable shredding in EU 25

The relevant data and their origin are listed in table 2.4 in the Annex.

4.2.5 Sewage sludge

(A) Background

Sewage sludge is the residue from municipal solid waste water treatment and as such represents the contamination of all water bound residential and commercial residues. Sewage sludge is rich in organic material and concentrates substances with low water solubility which absorb to the particulate matter.

Consequently sewage sludge does not only contain valuable minerals but also heavy metals, PCDD/PCDF and PCB. Many of the issues discussed in chapter 4.1.15 are also valid for the mass flow analysis of PCB.

(B) Process input (raw material) and output (waste, air, water, product)

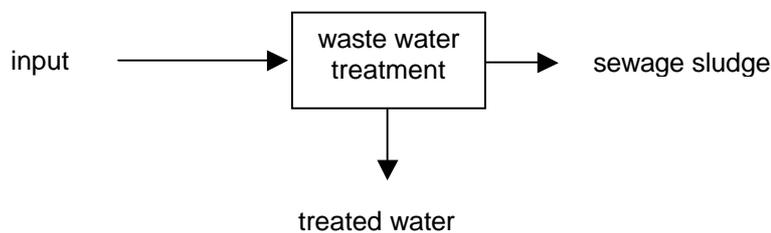


Figure 4-66: Relevant input and output of waste water treatment

Input:

- waste water

Output:

- sewage sludge
- treated water

(C) Generation factors for waste and other output (air, water)

No generation factor is used because the amount of sewage sludge produced from the waste water depends on the composition. The waste water is not taken into further account because of the low solubility of PCB in water.

(D) Contamination data for output (and input)

Average contamination data for PCB in sewage sludge have been reported for some Member States. For other countries an average value of ~0.61 mg/kg d.w. is assumed for the calculation in the mass flow. In the annex data are given which are used for estimation in this report. All given data range from 0.003 mg/kg to 1.5 mg/kg.

country	PCB concentration [mg/kg d.w.]
DE	0.57
DK	0.15
LU	0.50
SE	0.91

Table 4-48: Reported total PCB concentrations in sewage sludge in EU 25

(E) Activity data

Based on the data on annual amounts of sewage sludge produced in each of the 25 Member States [Sludge use acceptance report 2001] a total amount of approximately 8,050,900 t sewage sludge from municipal solid waste water treatment is calculated for EU 25. A compilation of the specific annual amounts in the different Member States is given in the annex.

country	generation of sewage sludge (t/y)	reference
AT	200,000	[Sludge use acceptance report 2001]
BE	100,000	[Sludge use acceptance report 2001]
CY	20,000	[Sludge use acceptance report 2001]
CZ	175,000	[Sludge use acceptance report 2001]
DE	2,250,000	[Sludge use acceptance report 2001]
DK	150,000	[Sludge use acceptance report 2001]
EE	50,000	[Sludge use acceptance report 2001]
ES	700,000	[Sludge use acceptance report 2001]
FI	150,000	[Sludge use acceptance report 2001]
FR	850,000	[Sludge use acceptance report 2001]
GR	50,000	[Sludge use acceptance report 2001]
HU	30,000	[Sludge use acceptance report 2001]
IE	43,000	[Sludge use acceptance report 2001]
IT	800,000	[Sludge use acceptance report 2001]
LT	25,000	[Sludge use acceptance report 2001]
LU	7,500	[Sludge use acceptance report 2001]
LV	25,000	[Sludge use acceptance report 2001]
MT	400	[Sludge use acceptance report 2001]

country	generation of sewage sludge (t/y)	reference
NL	200,000	[Sludge use acceptance report 2001]
PL	330,000	[Sludge use acceptance report 2001]
PT	250,000	[Sludge use acceptance report 2001]
SE	250,000	[Sludge use acceptance report 2001]
SI	100,000	[Sludge use acceptance report 2001]
SK	95,000	[Sludge use acceptance report 2001]
UK	1,200,000	[Sludge use acceptance report 2001]
EU-25	8,050,900	
EU-15	7,200,500	
EU-10	850,400	

Table 4-49: Annual generation of sewage sludge in EU 25

(F) Waste treatment

Treatment options for sewage sludge include application on land, landfilling and incineration. The shares of the different treatment options are specific for each country. As far as available, data on the specific shares of treatment options for sewage sludge in European Member States are given in the annex. Where no specific information is available, an average share of 38% for application on land, 38% for incineration and 25% for landfilling is taken as the basis for calculation.

country	land fill [%]	incineration [%]	application to land [%]	reference
AT	48	32	20	[Sludge use acceptance report 2001]
DK	4	42	54	[Affaldsstatistik 2003]
ES	25	25	50	[Dioxin Congress 2003]
FR	25	15	60	[Sludge use acceptance report 2001]
NL	25	60	15	[ISWA: international waste information 2003]
PL	42	43	15	Country Report Poland 2002 (ECN)
UK	8	42	50	[Duarte-Davidson et al. 1997 (AEA)]

Table 4-50: Reported treatment options for sewage sludge in EU Member States

(G) PCB flow

Based on the available data, the amount of PCB to the different treatment options can be calculated. The values for each treatment option are calculated for each country and are compiled in the annex. The total amount of PCB in sewage sludge in the European Union results as 4,820 kg/y (4.8 t/y).

country	Generation sewage sludge [kt/y]	PCB landfilled (kg/y)	PCB incinerated (kg/y)	PCB applied to land (kg/y)	total PCB in sewage sludge (kg/y)
AT	200	58.6	39.1	24.4	122.1
BE	100	15.0	23.1	22.9	61.1
CY	20	3.0	4.6	4.6	12.2
CZ	175	26.3	40.4	40.1	106.8
DE	2,250	314.8	483.8	480.1	1,278.7
DK	150	0.9	9.5	12.1	22.5
EE	50	7.5	11.5	11.5	30.5
ES	700	106.8	106.9	213.7	427.4
FI	150	22.6	34.7	34.4	91.6
FR	850	129.7	77.8	311.4	519.0
GR	50	7.5	11.6	11.5	30.5
HU	30	4.5	6.9	6.9	18.3
IE	43	6.5	9.9	9.9	26.3
IT	800	120.3	184.8	183.4	488.5
LT	25	3.8	5.8	5.7	15.3
LU	7.5	1.1	1.7	1.7	3.7
LV	25	3.8	5.8	5.7	15.3
MT	0.4	0.1	0.1	0.1	0.2
NL	200	30.1	73.3	18.3	122.1
PL	330	84.6	86.6	30.2	201.5
PT	250	37.6	57.7	57.3	152.6
SE	250	54.5	83.8	83.1	221.4
SI	100	15.0	23.1	22.9	61.1
SK	95	14.3	21.9	21.8	58.0
UK	1,200	58.6	307.7	366.4	732.7
EU-25	8,051	1127.6	1712.2	1980.2	4,819.6
EU-15	7,201	964.70	1505.3	1830.7	4300.3
EU-10	850	162.86	206.9	149.5	519.3

Table 4-51: PCB mass flow for sewage sludge in EU 25

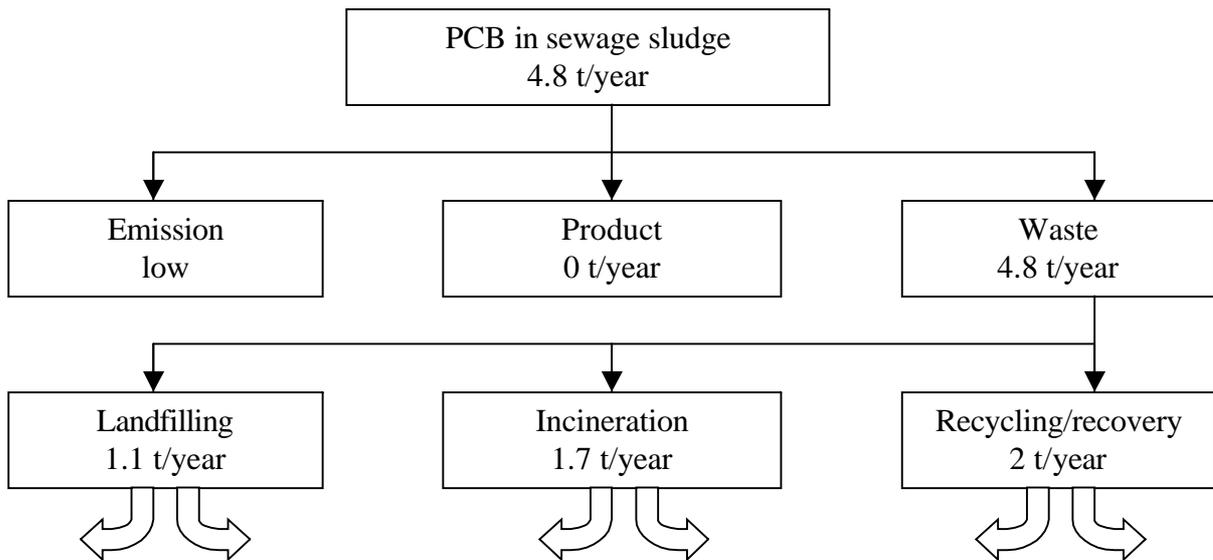


Figure 4-67: PCB mass flow for sewage sludge in EU 25

(H) Waste flow for sewage sludge

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

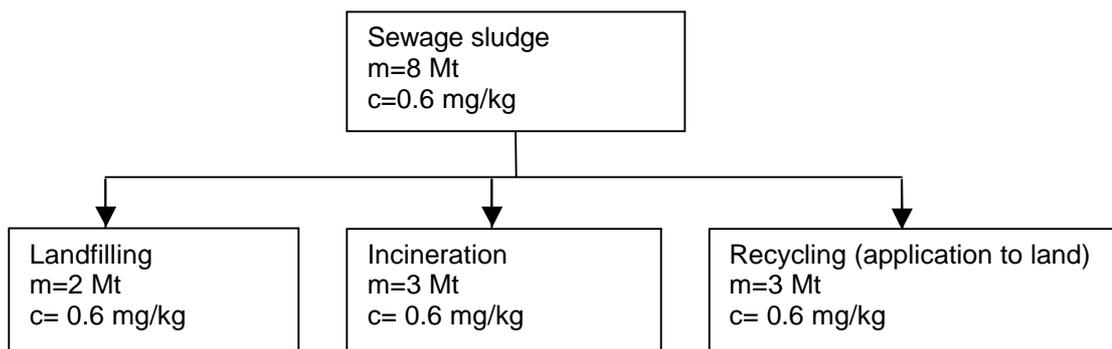


Figure 4-68: Waste flow for sewage sludge in EU 25

The relevant data and their origin are listed in tables 2.5.1 - 2.5.3 in the Annex.

4.2.6 Compost

(A) Background

Compost which is investigated in this report includes bio compost and green compost. Even more than sewage sludge, compost represents and concentrates environmental contamination with pollutants such as heavy metals and POPs. Information on contamination levels in compost is available for PCB and PCDD/PCDF. The potential recoverable amount of bio waste and green waste in EU 15 is about 49 million tons. Currently about 17 million tons bio waste and green waste are separately collected, which results in a compost production of around 9 million tons in Europe

(B) Process input (raw material) and output (waste, air, water, product)

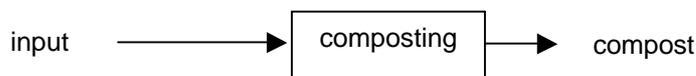


Figure 4-69: Relevant input and output of composting

Input:

- bio waste
- green waste

Output:

- compost

(C) Generation factors for waste and other output (air, water)

According to the ECN report 9 million tons of compost result from 17 million bio and green wastes. Therefore a generation factor of, 0.53 can be estimated.

(D) Contamination data for output (and input)

In the DEFRA health report [defra health report 2004] a concentration value of 300 ng/g d.w. (0.3 mg/kg) is given for PCB in compost derived from green wastes. Relying on the CQS&G report for America, an average value of (0.373 mg/kg d.w. (ppm)) is calculated based on several values for bio compost, green compost and garden compost. By German sources, mean values between 0.09 and 0.3 ppm are reported. Based on these data an average contamination level of (0.307 mg/kg d.w.) is calculated. All given data range from 0.004 to 0.8 ppm.

(E) Activity data

Based on the available activity data from Member States a total amount of approximately 27,335 kt bio and green waste and a resulting amount of 14,487 kt of compost is calculated.

Specific annual amounts for the Member States are given in Table 4-52. The amounts of bio and green waste for AT, BE, DK, FI, FR, LU, NL, PT, SE und UK are derived from the above mentioned ECN report. Data for ES and IT are taken from the ISWA country reports [ISWA country report Spain], [ISWA country report Italy]. The value for DE is taken from the BMU report 2002 [BMU report 2002]. Activity data for the other countries are extrapolated via a per capita approach.

country	Generation of bio and green waste (t/y)	generation of compost (t/y)	reference
AT	650,000	344,500	[ECN 2002]
BE	850,000	450,500	[ECN 2002]
CY	50,552	26,793	extrapolated
CZ	672,932	356,654	extrapolated
DE	7,575,000	4,014,750	[BMU 2002]
DK	687,000	364,110	[ECN 2002]
EE	92,569	49,062	extrapolated
ES	2,759,645	1,462,612	[ISWA 2004]
FI	100,000	53,000	[ECN 2002]
FR	1,550,000	821,500	[ECN 2002]
GR	700,505	371,268	extrapolated
HU	659,801	349,695	extrapolated
IE	257,355	136,398	extrapolated
IT	2,824,000	1,496,720	[ISWA 2004]
LT	236,347	125,264	extrapolated
LU	30,000	15,900	[ECN 2002]
LV	154,282	81,769	extrapolated
MT	26,261	13,918	extrapolated
NL	3,100,000	1,643,000	[ECN 2002]
PL	2,535,475	1,343,802	extrapolated
PT	10,000	5,300	[ECN 2002]
SE	290,000	153,700	[ECN 2002]
SI	127,365	67,503	extrapolated
SK	356,490	188,940	extrapolated
UK	1,039,000	550,670	[ECN 2002]
EU-25	27,334,579	14,487,327	
EU-15	22,422,506	11,883,928	
EU-10	4,912,073	2,603,399	

Table 4-52: Annual generation of bio and green wastes and resulting amounts of compost in EU 25

(F) Waste treatment

After a number of digestion processes compost will in general be almost completely recycled and reused.

(G) PCB flow

Based on the available data the amount of PCB in compost can be calculated. The overall amount of PCB in compost in Europe can be assumed to amount to 4,316 kg/y (4.3 t/y). A list of specific national amounts of PCB in compost is given in the annex.

country	bio and green waste (t/y)	compost (t/y)	PCB in compost (kg/y)
AT	650,000	344,500	105.86
BE	850,000	450,500	138.44
CY	50,552	26,793	8.23
CZ	672,932	356,654	109.60
DE	7,575,000	4,014,750	1233.73
DK	687,000	364,110	111.89
EE	92,569	49,062	15.08
ES	2,759,645	1,462,612	449.46
FI	100,000	53,000	16.29
FR	1,550,000	821,500	252.45
GR	700,505	371,268	114.09
HU	659,801	349,695	107.46
IE	257,355	136,398	41.92
IT	2,824,000	1,496,720	459.94
LT	236,347	125,264	38.49
LU	30,000	15,900	4.89
LV	154,282	81,769	25.13
MT	26,261	13,918	4.28
NL	3,100,000	1,643,000	504.89
PL	2,535,475	1,343,802	412.95
PT	10,000	5,300	1.63
SE	290,000	153,700	47.23
SI	127,365	67,503	20.74
SK	356,490	188,940	58.06
UK	1,039,000	550,670	33.04
EU-25	27,334,579	14,487,327	4,315.77
EU-15	22,422,506	11,883,928	3,515.75
EU-10	4,912,073	2,603,399	800.02

Table 4-53: PCB mass flow for compost in EU 25

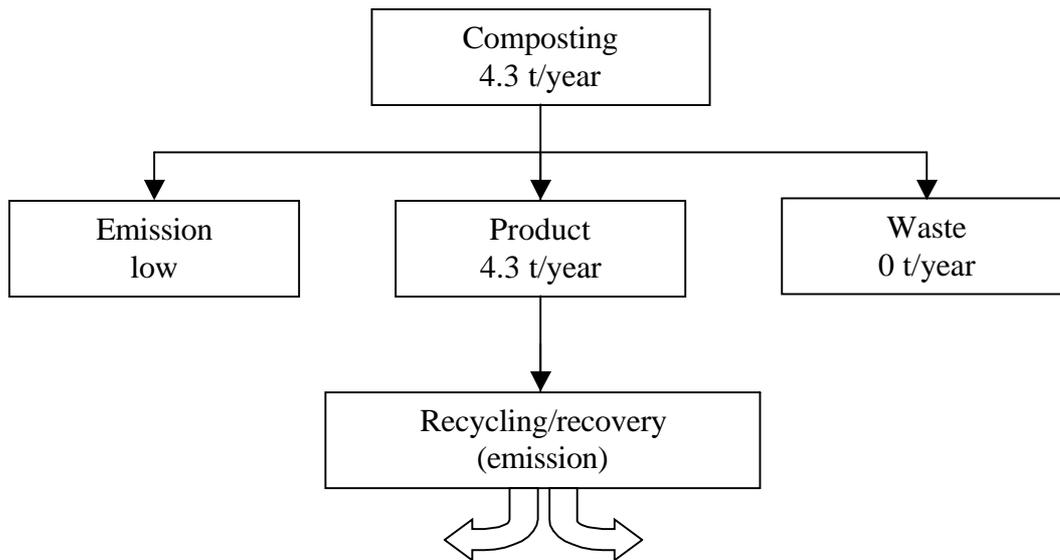


Figure 4-70: PCB mass flow for compost in EU 25

(H) Waste flow for compost

In order to illustrate the amounts of residues generated in EU 25 and the importance of currently used disposal/recovery operations which are of high relevance in the evaluation of impacts of proposed limit values, a waste flow has been drawn up in the following figure. Mean contaminations and concentration ranges for each of the residues have been included for better interpretation.

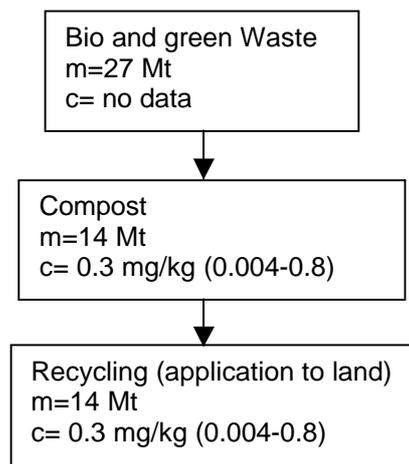


Figure 4-71: Waste flow for compost in EU 25

The relevant data and their origin are listed in table 2.6 in the Annex.

4.3 POP Pesticides Flow

4.3.1 Reduction of stocks

POP mass flows resulting from the reduction of stocks pose a diminishing but still existent problem. Mainly in the New Member States huge amounts of POP pesticides have been stored in former times.

As long as the stock piles are not reduced, no mass flow exits. A reduction of the existing stock piles can take place via emissions (typically unwanted, e.g. leakage), via disposal (typically planned, mainly in Old Member States) or via use (not allowed for most of the stored POP pesticides).

The elaboration of mass flows is a difficult task as it is not possible to predict the annual reduction of stocks on a basis of plannings of the concerned Member States. However, National Implementation Plans (NIPs) can be taken as one basis and it can be assumed that within a ten years period all existing stocks will be reduced to 0.

Taking all available information together, a volume of POP pesticides of about 5,370 t can be calculated with the following shares of Member States.

country	amount
Czech republic	19 t
Cyprus	No stocks
Estonia	6 t
Hungary	59 t
Latvia	375 t
Lithuania	378 t
Malta	No stocks
Poland	4,500t
Slovenia	No stocks
Slovakia	29

Table 4-54: Existing stocks of POP pesticides in Member States

Major POP components within these 5,370 t are:

- DDT (622 t)
- HCH (270 t)
- Toxaphene (213 t)
- Endrin (0.2 t)

- Aldrin/ Dieldrin (40t)
- HCB (62t)

In Poland most of the POP-Pesticides (4,500 tons) in stocks, are not specified. As already mentioned it is difficult to predict which amount a Member State will dispose of in which year, on average a linear decline over 10 years is assumed. This leads to an annual source of about 537 t for the mass flow.

Most of this mass flow is expected to be directed to incineration, but there might be also emissions mainly as eolian drift, leakage to soil and water due to inappropriate storage. These emissions are assumed with 1% meaning a total of 5 t/y (upper bound estimation). The resulting mass flow reads as follows:

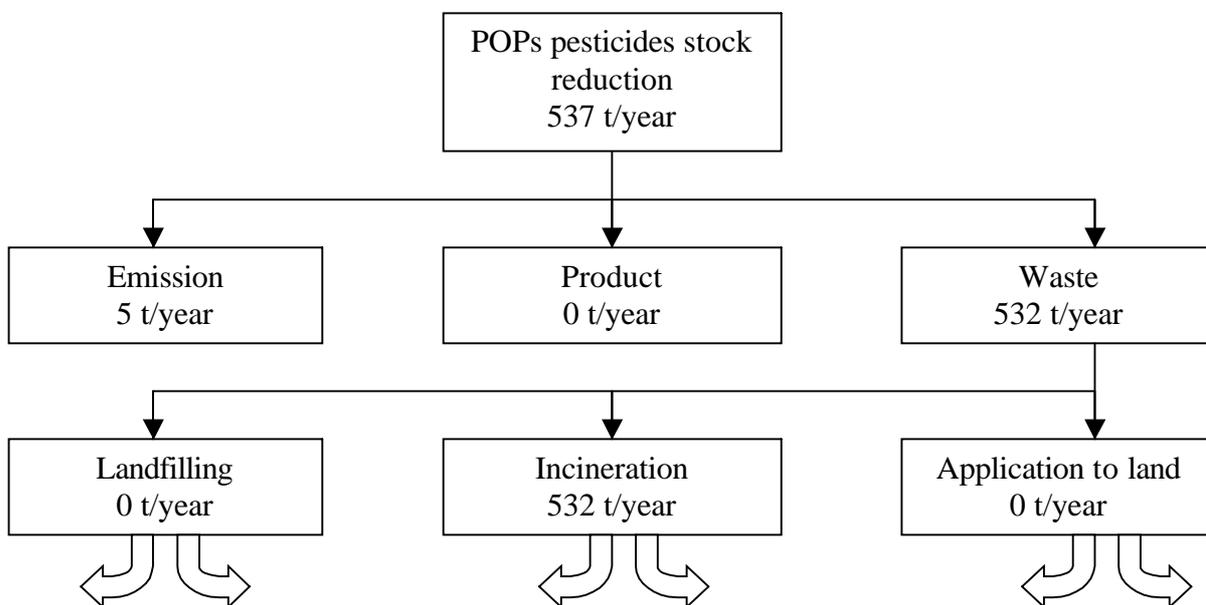


Figure 4-72: Assessment of the POP pesticides flow related to stock reduction

4.3.2 Production of POP pesticides

Different pieces of information [UNEP Regional Report Mediterranean, ECB-ESIS European chemical Substances Information System, CEFIC] state that there is still a production of POP pesticides in Europe. Additionally imports in a dimension of 1,000 – 2,000 t/y are mentioned. Both production and imports concern DDT which is used as a pre-product for Dicofol. The total dimension of the source of the corresponding mass flow is about 3,000 t/y.

It is not expected that there is significant emission in Europe nor that there are significant waste flows existing. Consequently, the resulting mass flow has got the following form:

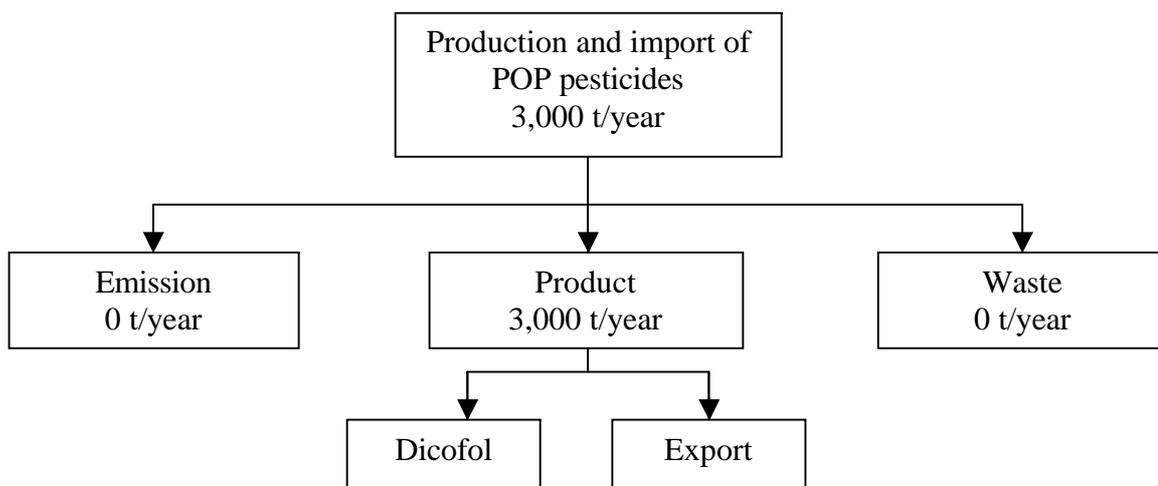


Figure 4-73: Assessment of the POP pesticides flow related to production of POP pesticides

4.4 Other POPs Flow

4.4.1 Reduction of stocks

The assessment of stocks for other POPs and their future reduction is even more difficult than the calculation of the stocks of POP pesticides. Substances to investigate are HCH as production residue, HCB and HxBB. HCH can be found in soils and dumps at former production sites in concentrations of several hundred ppm in an estimated amount of 10,000 tons. Dumps have been reported e.g. from Spain [4th Pesticide Forum]. HCB occurs as unwanted by-product during the production of chlorinated solvents, however residues are nowadays normally burned in on-site hazardous waste incinerators destroying the incoming HCB. While according to the European chemical Substances Information System (ECB-ESIS) production/import of HCB has been reported and HCB is only allowed for use as an intermediate in chemical processes and as a solvent for pesticides, there is no ongoing HCB production in EU 25 according to information from industry experts (EUROCHLOR) and national authorities.

HxBB has been produced in the US only until 1974 under the trade name “ Firemaster”. Products which might contain HxBB are mainly plastics used in TV, computers and other plastic products which have to be protected against flammability. Most of these products have got an average life period of 5 years. Given the time span of 30 years since production has ceased, almost all imported articles probably have been disposed off. In Europe only other polybrominated biphenyls (octa-biphenyl in Germany until 1984 and deca-biphenyl until 1977 in the United Kingdom and until 2000 in France) have been produced. These flame retardants may still be present in shredder residues – mainly in the Mediterranean Member States, however they are not yet included into the list of POPs to eliminate.

γ -HCH (Lindane) is still produced as a topical insecticide, for indoor applications and wood treatment and as an intermediate in chemical manufacturing at three different locations in Europe. At the moment it is not possible to quantify the amount of production. It is estimated to be higher than 1,000 t/y, Data might be available from the competent authorities. But the corresponding mass flow is not expected to have consequences for emission or waste.

As discussed in chapter 3.7.4 HCB discharge to residues from unintentionally formation in combustion processes seems to be in the dimension of 5 t/y as a sum from all major processes.

The following figure shows the overall result of the mass flow analysis for other POPs. The combination of the mass flows from ongoing production and from reduction of stocks results in the following total mass flow.

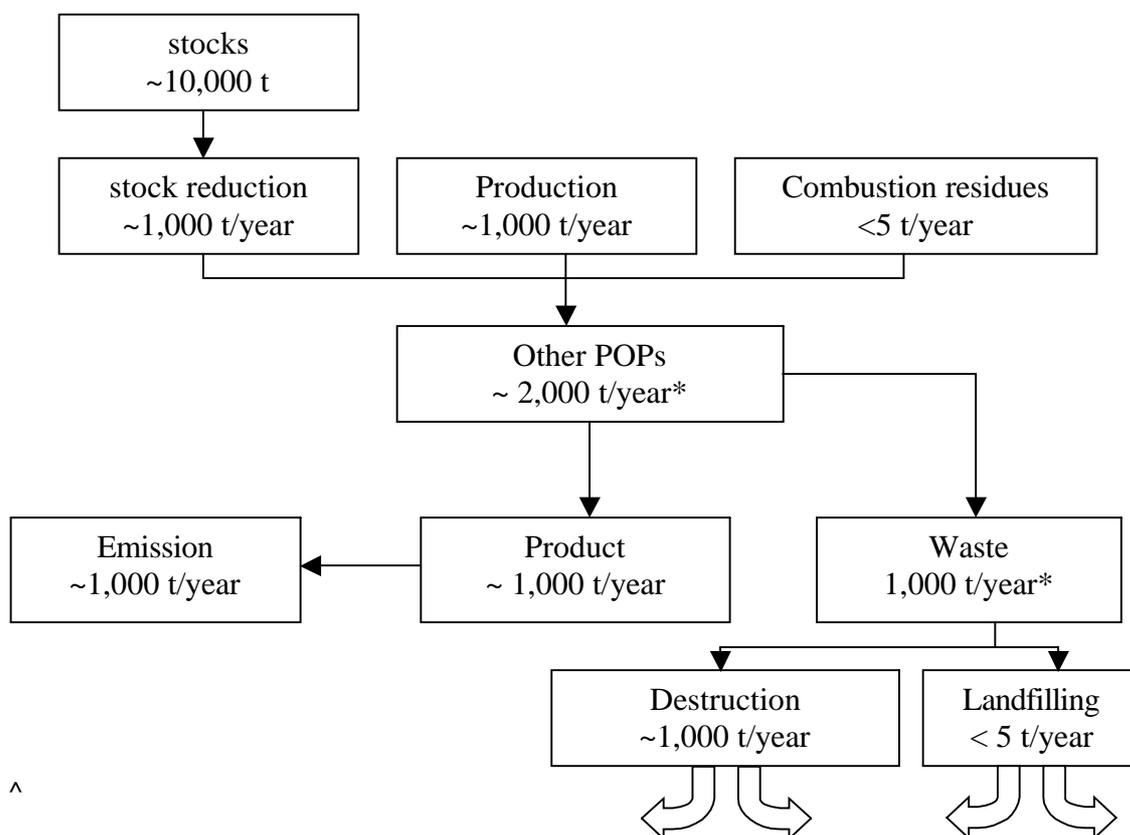


Figure 4-74: Total flow of other POPs

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

5 Environmental levels of POPs

Environmental contamination with POP substances is not the focus of this project. Nevertheless it is reasonable to take into account environmental contamination in the assessment of the impact borne to the environment by POP wastes. Therefore this chapter contains a summarising overview on environmental levels calculated or measured for a number of POPs in the environment. It has to be stated however that this compilation does not contain an exhaustive list of all measurements performed but refers to information compiled in the EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air pollutants in Europe) database²³, in the UNEP Regional reports²⁴ on persistent toxic substances (December 2002) and to the ELICC report "PCDD/PCDF and PCB: Environmental Levels and Human Exposure in Candidate Countries" (2004)²⁵.

Due to a comparable calculation method, modelled information from the EMEP database can be assumed to be widely comparable. However, data are only available for PCDD/PCDF, PCB and HCB in air, soil and vegetation. Furthermore it has to be stated that measured and calculated information do not necessarily correspond to each other, which shows the limitations of the data as representative information on the real contamination levels. However they can be used to show the order of magnitude of contamination with POPs. Consequently, data from studies have been used for other substances and media being aware that they cannot be assumed to be representative in all cases.

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. It should, however, be significantly higher than average or background levels observed in the environment. This would help to focus on the elimination of stockpiles as major potential sources of further contamination, and may enable to set provisions for the remediation of hot spots.

5.1.1 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 Table 5-1. 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 GTGSM final 2005]. However, regional differences in contamination levels can be distinguished.

²³ http://www.emep.int/index_data.html,

EMEP data base is a scientifically based and policy driven program under the Convention on Long-range Transboundary Air Pollution for international co-operation to solve transboundary air pollution problems.

²⁴ Regionally based assessment of persistent toxic substances region III (Europe), region IV (Mediterranean) www.chem.unep.ch

²⁵ <http://europa.eu.int/comm/environment/dioxin/index.htm>

As for PCDD/PCDF highest contamination levels have been calculated for Belgium, the Czech Republic and Luxembourg, while contamination seems to be very low in Cyprus, Malta, Finland and Ireland. With respect to PCB highest contamination levels have been calculated for Germany and Belgium whereas Cyprus, Greece and Ireland show low contamination. As concerns HCB all calculated results are in the same order of magnitude expect of the results reported for Belgium showing higher results.

country	PCDD/F [fg TEQ/m ³]	PCB [ng/m ³]	HCB [ng/m ³]
	10 ⁻⁶ ppb	10 ⁻⁶ ppm	10 ⁻⁶ ppm
AT	5.73	0.36	0.07
BE	19.13	0.56	0.23
CY	0.47	0.02	0.04
CZ	23.65	0.40	0.07
DE	6.23	0.77	0.07
DK	3.18	0.18	0.06
EE	1.50	0.12	0.07
ES	1.29	0.14	0.06
FI	0.51	0.09	0.05
FR	2.98	0.29	0.06
GR	2.83	0.07	0.05
HU	9.03	0.20	0.07
IE	0.49	0.03	0.04
IT	2.97	0.22	0.06
LT	2.17	0.14	0.07
LU	15.93	0.38	0.06
LV	1.66	0.11	0.07
MT	0.62	0.05	0.04
NL	8.60	0.51	0.06
PL	9.86	0.25	0.07
PT	1.07	0.07	0.05
SE	0.84	0.09	0.05
SI	3.49	0.26	0.07
SK	14.70	0.24	0.07
UK	2.500	0.110	0.05

Table 5-1: modelled mean ambient air concentration in European countries according to EMEP data base

5.1.2 POP levels in water

Concerning concentration levels in water, no modelled contamination levels are available in the EMEP data base. Consequently a number of studies have to be used in order to give an impression on the contamination of this environmental medium.

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 Table 5-2 below.

		contamination level in water	reference
PCDD/PCDF	Elbe suspended sediments	max 0.00009 ppb	[UNEP regional report region III Europe]
PCB	ocean water; hot spot sites in Slovakia	~ 1pg/l (10 -9 ppm); max 10 -6 ppm	
DDT	Slovak Danube	0.000047 ng/l 10-6 ppm	
HCB	various samples	<LOD -0.000001 ppm	
HCH (Lindane)	North Sea	0.1-0.7 ng/l(mean 0.28) (ppt)	

Table 5-2: Selected contamination levels for water

5.1.3 POP levels in sediments

Background levels in the UK are <1000 pg/g with PCDD/PCDF-I-TEQ< 6 pg/g. The Gulf of Finland, a sub-basin of the Baltic Sea was found to be severely polluted, with total PCDD/PCDF concentrations as high as 101,000 pg/g d.w and 479 pg TEQ /g d.w.

Toxaphene concentrations in UK surface sediments, which indicate long-range transboundary transport, were at 0.42 ng/g in the nineties.

Aldrin, dieldrin, endrin, heptachlor, chlordane were found in the Ebro River sediments all along the course at concentrations ranging from 0.02 to 1.7 ng/g d.w. (meaning 0.4 ± 0.6 ppb). Aldrin was only found in 46% of the samples (Fernandez et al., 1999).

Dieldrin was found in 4 out of 9 sampling locations of river sediments in Cyprus in a survey carried out from 1997- 1998. The values ranged from 1.7-133 ng/g on dry basis (Michaelidou and Christodoulidou, unpublished data).

HCB is widely distributed in the Western Mediterranean. High concentrations have been reported for the Gulf of Fos, the Rhone and the Ebro Deltas (30-39 and 19 ng/g dw, respectively). In the coastal shelf the values were below 1 ng/g (Prats et al., 1992; Tolosa et al., 1995). HCB was found in shallow sediments of the Venice Lagoon (Italy) at concentrations ranging from 0.85-1.11 ng/g dw (Bernstein et al., 2002) and in 4 out of 9 sampling locations of river sediments in Cyprus, at levels ranging from 0.1-4.8 ng/g dw (Michaelidou and Christodoulidou, 1998, unpublished data).

DDT levels in river sediments and estuaries from European Mediterranean countries range from <1 to 50 ng/g d.w. with a maximum level of 660 ng/g d.w. in Cypriote dams.

HCH concentrations (γ -HCH) in sediments from Mediterranean rivers are reported at around 1 ng/g d.w. with peak levels of 100 ng/g d.w. at the Portuguese coast. (UNEP Med.)

A compilation of reported contamination levels in relation to the proposed limit values for POPs under the Basel Convention (PCDD/PCDF 15 ppb; PCB and HCB 50 ppm) is given in Table 5-3 below.

		contamination levels in sediments	reference
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 μ g/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/cm ²	

		contamination levels in sediments	reference
	sediments		
HCB	Mediterranean river estuaries	0.8-40 ng/g (ppb)	
HCHs	Mediterranean river estuaries	~1 ng/g (ppb); max 0.1 ppm	

Table 5-3: Selected contamination levels in sediments

5.1.4 POP levels in soils

Information on contamination levels in soil is derived from a number of studies performed over the last decade and from modelled data compiled in the EMEP database. All this information has been used to calculate the average European background level in rural/urban soils. A compilation of reported concentrations is given in Table 5-5.

Mean levels of PCDD/PCDF, PCB and HCBs in soils, as modelled in the EMEP data base, are compiled for all European Member States in Table 5-4 below. 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 table, 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 regional differences in contamination levels can be noted.

As regards PCDD/PCDF, highest contamination levels have been calculated for Belgium and Luxembourg, medium levels for the Netherlands, the Czech Republic and Germany, while contamination seems to be very low in Cyprus and Malta and low in Ireland, Greece, Finland, Estonia, Portugal and Sweden.

With respect to PCB highest contamination levels have been calculated for Belgium, Germany, the Netherlands and UK whereas Cyprus and Malta and low in Ireland, Greece, Finland, Estonia, Portugal and Sweden show low contamination.

As for HCB all calculated results are in the same order of magnitude except for the results reported for Malta, Greece and Cyprus, these show lower contamination.

A compilation of reported contamination levels in relation to the proposed limit values for POPs under the Basel Convention (PCDD/PCDF 15 ppb; PCB and HCB 50 ppm) is given in Table 5-4 below.

country	PCCD/F [pg TEQ/g]	PCB (ng/g)	HCB (ng/g)
	10 ⁻³ ppb	10 ⁻³ ppm	10 ⁻³ ppm
AT	0.93	23.31	0.37
BE	2.84	40.15	0.23
CY	0.03	0.25	0.02
CZ	1.44	20.13	0.24
DE	1.56	40.02	0.27
DK	0.63	13.09	0.20
EE	0.29	8.84	0.33
ES	0.26	7.04	0.15
FI	0.23	12.24	0.44
FR	0.94	17.75	0.22
GR	0.24	2.38	0.06
HU	0.56	12.80	0.36
IE	0.21	8.72	0.27
IT	0.67	19.26	0.20
LT	0.36	9.61	0.27
LU	2.88	25.99	0.26
LV	0.29	8.84	0.31
MT	0.03	0.13	0.02
NL	1.81	46.96	0.25
PL	0.75	13.72	0.32
PT	0.21	6.63	0.19
SE	0.31	11.52	0.29
SI	0.75	17.68	0.33
SK	0.81	13.15	0.33
UK	0.70	33.22	0.38

Table 5-4: modelled mean contamination levels for soil in European countries according to EMEP data base

Measured soil contamination levels have been examined in a number of studies as compiled in the ELICC report.

PCDD/PCDF background levels in rural soil range from <1-43 ng I-TEQ/kg. At contaminated sites, levels between 1,000 ng I-TEQ/kg, near MSWTP, and 100,000 ng I-TEQ/kg (1ppm) can be found (see INERIS 2002). A corresponding conclusion can be found in the UNEP regional report for region III (Europe), reporting PCDD/PCDF peak concentrations at contaminated sites of 0.9 ppm, while average concentrations in European urban soils range from <0.001 to 0.08 µg/ PCDD/PCDF-TEQ/kg d.w. (ppb).

PCDD/PCDF levels in Mediterranean Member States show background levels of 0.02–4.31 ng I-TEQ/kg d.w. ($\times 10^{-3}$ ppb), urban levels of 0.2–24 $\times 10^{-3}$ ppb and point source levels of up to 1000 $\times 10^{-3}$ ppb.

With respect to POP pesticides only single studies from the Czech and Slovak Republic have been reported in the UNEP regional reports. DDT levels in Czech soils in 1995 ranged from 1.3–5,000 ng/g d.w. (ppb), which corresponds to up to 5 ppm in heavily contaminated soils. Levels for HCB in the Slovak Republic were 0.6–5 ng/g d.w., corresponding to maximum 0.0005 ppm. According to the UK review on environmental contamination, reported levels in normal soils can be up to 5 mg/kg DDT.

A compilation of reported contamination levels in relation to the proposed limit values for POPs under the Basel Convention (PCDD/PCDF 15 ppb; PCB and HCB 50 ppm) is given in Table 5-5. In contrast to the calculated mean values, contamination levels of specific hot spot soils would significantly exceed the proposed limit for PCDD/PCDF of 15 ppb and would come close to the limit for PCB of 50 mg/kg. As for the measured POP pesticides none appear in the range of the low POP limit for pesticides proposed under the Basel and Stockholm Conventions.

	contamination levels in soils	reference
PCDD/PCDF	<0.001 ppb (background levels) to 100-900 ppb at contaminated sites Mediterranean point source levels 10 ppb	[UNEP Regional reports Europe and Mediterranean]
	0.001-0.1 ppb EU 15 (1900-1995)	[AEA 1999]
	median 0.001	[UBA 2003]
PCB	<0.001-0.4 mg/kg (ppm) for all types of soils; hot spot level in Slovakia 30 mg/kg (ppm)	[UNEP Regional reports Europe and Mediterranean]
total POPs pesticides	< 0.001 ppm (90perc.) in German soils	[UMEG 1999]
Dieldrin	1.7-133 ng/g (ppb); max. 0.12 ppm in Cyprus	
DDT	<0.001-5 mg/kg (ppm) in CZ 1995; 0.003-0.05 ppm in average German soils	[UMEG 1999]
HCB	0.0006-0.005 mg/kg (ppm) 90.Perc. in middle European soils	[UMEG 1999]
HCHs	~1 ng/g (ppb); max 0.1 ppm	[UMEG 1999]

Table 5-5: Selected measured data for soil contamination

5.1.5 POP levels in vegetation

Mean levels of PCDD/PCDF, PCB and HCBs in vegetation, as modelled in the EMEP data base, are compiled for all European member states in the table below. Levels in vegetation are generally highly dependent on the season and reflect the regional air pollution of the preceding vegetation period.

Information on POP concentrations in vegetation is taken from the annual EMEP summary reports. In this report concentration data for HCB and PCB were taken from the POPCYCLING Baltic project (Pacyna et al., 1999). For PCDD/PCDF official emission data submitted to the UN ECE secretariat were used.

The reported data show highest concentration levels for PCDD/PCDF for the Czech Republic, Luxembourg and Belgium and low levels for Denmark, Estonia and Latvia. The highest levels for PCB have been calculated for Germany, Luxembourg, Belgium and the Netherlands, while levels in Greece, the Baltic states, Denmark, Spain and Portugal appear to be low. HCB, on the other hand, does not show a uniform distribution like in other environmental compartments. Unlike for other compartments and for other contaminants, highest levels for HCB have been reported for the Scandinavian countries and Ireland.

The overall levels however are still two to four orders lower than the "low POP" limits proposed under the Basel and Stockholm Convention.

A compilation of reported contamination levels in relation to the proposed limit values for POPs under the Basel Convention (PCDD/PCDF 15 ppb; PCB and HCB 50 ppm) is given in Table 5-6.

country	PCDD/F [pg TEQ/g]	PCB (ng/g)	HCB (ng/g)
	10 ⁻³ ppb	10 ⁻³ ppm	10 ⁻³ ppm
AT	2.06	121.94	0.78
BE	3.97	147.27	0.46
CY	--	--	--
CZ	4.67	83.33	0.51
DE	1.72	176.80	0.65
DK	0.24	16.97	0.15
EE	0.25	25.28	0.91
ES	0.46	34.02	0.28
FI	0.43	105.69	1.87
FR	1.42	101.98	0.53
GR	1.42	15.63	0.21
HU	0.96	35.82	0.42
IE	0.90	77.11	1.32
IT	0.85	38.68	0.27
LT	0.40	33.90	0.78
LU	4.39	148.99	0.52
LV	0.27	23.39	0.87
MT	--	--	--

country	PCCD/F [pg TEQ/g]	PCB (ng/g)	HCB (ng/g)
NL	1.82	123.27	0.42
PL	1.36	46.15	0.48
PT	0.57	28.13	0.31
SE	0.53	90.56	1.23
SI	1.43	87.39	0.59
SK	1.64	38.35	0.46
UK	1.20	95.82	0.89

Table 5-6: modelled contamination levels in vegetation in European countries according to EMEP data base

5.1.6 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.

PCDD/PCDF concentrations in herring muscle along the Finnish coast, which is among the highest contaminated in Europe, varied between 165 and 329 pg TEQ/g fat (0.2 – 0.4 ppb) in the mid-nineties (Vartiainen et al., 1997).

PCB concentrations in otter muscle tissues in European countries in the seventies until the beginnings of the nineties (Sjöasen et al., 1997) ranged from 1.6 –1,000 ppm for PCB. PCB loads in herring muscle are highest in southern Baltic Proper and decrease towards the north and west. They are similar in the Kattegat and the Bothnian Bay. Concentrations vary between 120 and 2,800 ng/g fat.

With respect to pesticides, studies have been performed for a number of substances showing in general somewhat higher levels of these substances in wildlife from the Mediterranean countries, compared to levels in middle and northern Europe.

DDTs in herring muscle are highest in southern Baltic Proper and decrease to the north and west and are similar in the Kattegat and the Bothnian Bay. Concentrations vary between 61-710 ng/g fat . DDT levels in perch muscle are < 2 ng/g fat since 1995. DDTs concentrations in otter muscle tissues in European countries till the beginnings of the nineties ranged from <LOD - 85 µg/g (Sjöasen et al., 1997). DDT levels in Po River fish species range from 17–4000 ng/g fat weight. Mean DDT values in mussels from the French coasts ranged from 6–25 ng/g d.w. Levels in Tuna and Swordfish were about 50 ng/g w.w.

Aldrin levels of 0.01–0.3 ng/g dw and Heptachlor levels of 0.3–0.9 ng/g dw have been found in Cormorants from Greek wetlands. Levels of 0.8–1.5 ng/g dw for Aldrin, 0.6–2.5 ng/g dw for Dieldrin, 0.2–0.3 ng/g dw for Endrin and 0.9–1.2 ng/g d.w. for Heptachlor have been measured in mussels from Cyprus.

Lindane concentrations were at 11–29 ng/g fresh weight in fishes collected in the Seine, Marne and Yonne in the beginning of the nineties and at 0.5–63 ng/g d.w. in mussels.

HCB levels in mussels have been reported in the range of 0.2–2.8 ng/g ww from Mediterranean coasts. HCB levels in Po River fish species range from 26–130 ng/g fat weight (4–21 ng/g fresh weight).

According to the UK comments on the drafted POP guidelines, levels of 3.2 mg/kg chlordane have been reported in young arctic bears; 18 mg/kg DDT in European river otters; 1.3 mg/kg toxaphene in Russian river fish; and 10 mg/kg DDT in the blubber of marine mammals. Occasionally figures for DDT up to 1,000 mg/kg on a dry weight basis have been reported for dolphins.

A compilation of reported contamination levels in relation to the proposed limit values for POPs under the Basel Convention (PCDD/PCDF 15 ppb; PCB and HCB 50 ppm) is given in the table below. It clearly shows that contamination levels of PCB and POP pesticides may exceed the proposed “low POP” limits in end-of-chain marine predators.

		contamination levels in wildlife	reference
PCDD/PCDF (I-TEQ)	Herring (baltic average)	0.2 – 0.3 ppb/fat	[UNEP Regional report Europe Greenpeace report 2001]
	baltic herring	max 0.006 ppb/wet weight	
	ringed seals	max. 0.1 –0.4 ppb/fat	
PCB	fish	average 0.5 –5 mg/kg /fat (ppm); max 3 – 300 ppm at Czech and Slovak hot spots	[UNEP Regional reports Europe and Mediterranean]
	grey seals	mean 77 ppm/fat in the Baltic Sea	[Greenpeace report]
POPs pesticides total	fish samples from Cyprus	< 0.001 ppm d.w. in	
Aldrin	cormorant	0.01 –0.3 ppb/dry weight	
Dieldrin	baltic fish	~ 0.02 ppm/fat	[Falandysz 1999]
	baltic cormorant/sea eagle	0.07 – 20 ppm/fat in the Baltic Sea area	[Koistinen/ Falandysz]
Chlordane	baltic fish	max 0.014 ppm/fat	[Strandberg 1998]
	Baltic cormorant/sea eagle	0.07 – 20 ppm/fat in the Baltic Sea area	[Koistinen/ Falandysz]
	seals	1 –10 ppm/fat	
Heptachlor	fish	~0.004 ppm/fat	[Strandberg 1998]
	cormorant	0.3 – 0.9 ppb/d.w.	
DDT		max. 4 ppm in fish samples of the Po River; Baltic max 2 ppm	
	cormorant	~ 10 ppm/fat	[Falandysz 1999]

		contamination levels in wildlife	reference
	sea eagle	800 – 4000 ppm/fat	[Strandberg, Koistinen, Falandysz (1995-2000)]
	harbour seals	mean 27 ppm/fat	
Toxaphene	fish	congener 26 ~ 0.02 ppm/fat	[Fromberg 2000]
	harbour seals	1 –10 ppm/fat	
HCB	fish	max 0.1 ppm wet weight; Baltic max 0.04 ppm w.w.	[Strandberg, Koistinen]
	cormorant, sea eagle	0.04 –0.6 ppm/wet weight	
		0.07 – 9 ppm/fat weight	
	ringed seals	<0.04 ppm/fat	
HCHs	fish	< 0.06 ppm/fat (Lindane) < 0.13 ppm/fat α -HCH	[Olsson 1999, UNEP regional reports]
	cormorant , sea eagle	0.02 – 0.4 ppm/fat	[Falandysz, Koistinen]
	harbour seals	0.02 –0.04 ppm/fat (Lindane)	

Table 5-7: Selected measured data for contamination levels in wildlife

5.1.7 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.

According to the report on PCDD/PCDF and PCB, environmental levels and related human exposure in candidate countries (ELICC), the average contamination level for PCB is <0.1 ppm/fat; however levels of >3 ppm/fat have been reported for eggs from the Slovak hot spot region.

5.1.8 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.

In the last cycle of the WHO study on POP contamination of human milk, levels in European breast milk were at about 15 pg TEQ/g lipid (0.015 ppb) for PCDD/PCDF and ranged from 300–500 ng/g lipid (0.3–0.5 ppm) for the PCB.

With respect to POP pesticides, mean levels of Aldrin, Dieldrin and Endrin in France ranged from 50 to 200 ng/g lipid (0.05–0.2 ppm) in the beginning of the nineties. Chlordane levels were at ~80 ng/g lipid (0.08 ppm). Levels of HCB and HCH ranged from 150 to 300 ng/g lipid (0.1–0.3 ppm) in France and Italy. These levels are two orders of magnitude lower than the limit values proposed for POP pesticides under the Basel and the Stockholm Convention. The situation is somewhat different for DDT/DDE where levels of up to 2 ppm lipid in France and Italy and up to 5 ppm lipid in Spain have been measured. These are only one order of magnitude below the proposed “low POP” level for pesticides of 50 ppm.

5.1.9 POP levels in consumer products

According to information launched by the WCC (World Chlorine Council), certain commodity products (leather wallets, socks, shoes) in Germany were found to contain PCDD/PCDF levels of up to 10 ppb. German studies have shown leather goods (wallets and shoes) to be contaminated with 430 –6,400 ng I-TEQ/kg²⁶ However, these data are relatively old and singular; therefore they have not been deemed relevant in the last UNEP draft on BAT and BEP anymore. PCP-treated wood can have very high PCDD/PCDF concentrations near the surface, with concentrations up to 1,500 – 19,000 ng I-TEQ/kg being measured.

²⁶ Compilation of EU Dioxin Exposure and Health Data. Report for the EC DG XI and UK DETR, AEA Technology, October 1999.

6 Analysis of 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.

6.1 Legal frameworks

6.1.1 *International Conventions*

On the international level POPs are covered by the following Conventions focused either on environmental emissions and environmental and health protection or on transboundary transport and public information:

- 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (entry into force May 1992)
- 2001 Stockholm Convention on Persistent Organic Pollutants (entry into force May 2004)
- 1998 Aarhus Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants (entry into force 2003);
- 1998 Rotterdam Convention laying down a common notification and information system and the "Prior Information Consent" (PIC) for the export of chemicals (entry into force February 2004).
- 2003 Protocol on Pollutant Release and Transfer Register (adopted 2003) to the UNECE Aarhus Convention (2001) on Access to Information, Public Participation in Decision-making and Access to Justice in Environment Matter;
- OECD Council Decision C(2001)107 Decision of the Council Concerning the Transfrontier Movements of Wastes Destined for Recovery Operations

The Basel Convention stipulates that any transboundary movement of waste is only permitted if the movement itself as well as the disposal of the concerned waste are environmentally sound.

The objective of the Stockholm Convention is to protect human health and the environment from persistent organic pollutants. To this purpose each party shall take legal and administrative measures to eliminate or heavily restrict production and use of Aldrin, Chlordane, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene, Mirex, Toxaphene and PCB, and DDT and to minimise the unintentional production and release of PCDD/PCDF, PCB and HCB via improved technology standards and the promotion of recovery and recycling of wastes and intermediates generated.

The objective of the Aarhus Protocol signed for the implementation of the UNECE Convention on Long-range transboundary Air Pollution is to control, reduce and eliminate discharges, emissions and losses of persistent organic pollutants. In Annex I elimination of production and use as well as specific exceptions are listed for POP pesticides and PCB. DDT, HCH and PCB in use are listed in Annex II for substances with restrictions on use.

The Rotterdam Convention regulates the process of prior informed consent (PIC), a mutual information exchange in the international trading with dangerous chemicals. The convention defines in detail specific rules and requirements in international trading of chemicals. All POP substances are listed in annexes to the Convention.

A compilation of the most relevant international agreements relating to persistent organic pollutants is given in Table 6-1.

name	subject
Stockholm Convention (in force May 2004)	Requires measures to eliminate or heavily restrict production and use of POP pesticides and PCB and to minimise the unintentional production and release of POPs.
Basel Convention (in force May 1992)	Stipulates that any transboundary movement of waste is only permitted if the movement itself as well as the disposal of the concerned waste are environmentally sound
OSPARCOM	Co-operative approach for Protection of the North Sea from pollutants; Decision 92/3 on the phasing out of PCB by the End of 1999.
HELCOM	Protection of the marine environment and its ecological balance in the Baltic Sea
BARCOM	Prevention and Abatement of pollution in the Mediterranean Sea
UNECE Convention on long-range transboundary air pollution (in force 1981)	Control and reduction of air pollution via strategies based on intensified monitoring and exchange between parties
Aarhus Protocol to the 1979 UNECE Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants	Covers also HCH, Chlordecone and HBB Control, reduction and elimination of discharges, emissions and losses of POPs. Ban on production and use for POP pesticides. DDT, HCH and PCB in use are listed as substances with restrictions on use
Rotterdam Convention (in force February 2004)	The Rotterdam Convention or so called "PIC" (prior informed consent)-Convention defines specific rules and requirements in the international trading of chemicals. All POP substances are listed in annexes to the Convention.

Table 6-1: International Conventions related to persistent organic pollutants

6.1.2 *European Legislation*

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

6.1.2.1 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" (see below).

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 dm³ 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.

6.1.2.2 Chemicals – classification, production, and use

The basic regulation for all chemicals including all intentionally produced POPs is the dangerous substances regulation (67/548/EEC). This regulation and the corresponding daughter directives list all parameter relevant for the classification of substances and their hazardous characteristics.

POP pesticides are specifically regulated in directive 79/117/EEC. Placing on the market and use is prohibited from 1990 for all pesticide uses. HCB is allowed by derogation as intermediate in Poland, DDT is allowed as intermediate in the Dicofol production and HCH/Lindane is in use in a number of Member States as a biocide.

Council Directive 85/467/EC amending for the sixth time (PCB/PCTs) Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations prohibited the open use of PCB containing material and provided certain provisions for packaging and labelling of PCB containing material.

Directive 1999/45/EC relates to classification, packaging and labelling of hazardous preparations.

The ROHS Directive (2002/95/EC) on the restriction of the use of certain hazardous substances in electrical and electronic equipment prohibits the use of PBBs and PBDEs in new products from 2006.

6.1.2.3 Atmospheric pollution – air emissions

Legislation with respect to atmospheric emissions is almost completely restricted to PCDD/PCDF. Relevant regulations are the IPPC directive (96/61/EC) laying down permit conditions and monitoring obligations for emissions to air for major activities exceeding a given threshold capacity and the waste incineration directive (2000/76/EC) setting up permit conditions and limit values for air emissions and waste water discharge.

Directive 2000/76/EC progressively repeals directives 89/369/EEC and 89/429/EEC for existing municipal solid waste incineration plants as well as directive 94/67/EC for the incineration of hazardous waste. The scope of 2000/76/EC is broad (certain exclusions are specifically listed in Article 2) and is not restrained by a capacity limit.

Emission standards have to be adopted for new waste incineration plants, from 28 December 2002 and for existing waste incineration plants, by 28 December 2005 at the latest.

6.1.2.4 Water protection

The water directive (76/464/EC) required to apply a system of zero-emission to discharges into ground water of organohalogen compounds and to set limit values for the discharge of biocides. Directive 88/347/EEC relates to limit values for discharge of POP pesticides to waste water. In Directive 98/83/EC on the quality of water intended for human consumption limit values for pesticides including POP pesticides are set for drinking water.

Under the water framework directive (2000/60/EC) a list of priority substances including HCBs and Lindane has been established in Decision 2001/2455/EC. Limit values for POP pesticides as environmental quality standards in surface waters are currently under discussion.

6.1.2.5 Food and feed safety

Directive 2001/201/EC, Directives 2001/2375/EC, Directive 2002/69/EC, Directive 2003/806/EC and Directive 1986/363/EC set limit values for POP pesticides and PCDD/PCDF in food and feeding stuffs and contain provisions for monitoring and control. Directive 2001/2375/EC will be revised in December 2004 and will then probably set limit values also for dioxin-like PCB.

As demonstrated above a lot of legal measures have been taken to manage POP substances in different media and sectors in order to reduce environmental impacts and risks to humans.

However the European legislation has not been complete with respect to prohibition of production and use of the currently listed POPs, neither have emission reduction targets been set at Community level, nor do the current release inventories cover all sources of persistent organic pollutants.

Furthermore, in the current legislation there is no framework to subject additional POP substances to restriction or elimination and to prevent the production of new substances which exhibit POP characteristics. Besides this, the current Community Legislation on waste does not lay down specific rules or limit values as regards persistent organic pollutants.

6.1.2.6 POP regulation

In order to close these gaps and to ensure a coherent and effective implementation of the above mentioned Protocol and Conventions 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.

A chronological compilation of major European legislation relating to POPs is given in Table 6-2 (Older Legislation is referred to with all relevant amendments.)

	legislation	main objectives
EU	Dangerous substances Directive 67/548/EEC	classification and limits for POP pesticides and PCB
EU	Waste Directive 74/442/EEC	definition of waste; waste categories; R & D codes
EU	Waste oil Directive 75/439/EEC	regulate the treatment, discharge, deposit and collection of waste oils (sets limit value for PCB,PCT)
EU	Water Directive 76/464/EC	discharge to groundwater; zero-emissions for Organohalogens
EU	Directive 76/769/EEC restrictions on the marketing and use of certain dangerous substances and preparations.	ban of open uses in 1976; ban of closed use 1986 (85/467/EEC) existing equipment is allowed to be kept in use according to provisions set in 1996/59/EC
EU	Directive 79/117/EEC on plant protection products	stepwise ban of use from 1979; Complete ban as pesticide for all substances from 1990
EU	Directive 88/347/EEC amending Annex II to Directive 86/280/EEC on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC	Annex II contains emission limit values for discharge of aldrin, dieldrin, endrin, DDT and HCB to waste waters from production.

	legislation	main objectives
EU	Directive 89/369/EEC on air pollution from new municipal solid waste incineration plants	regulates treatment of new incineration plants to prevent air pollution
EU	Directive 89/429/EEC on air pollution from existing municipal solid waste-incineration plants	recommends limits for PCDD/PCDF with waste incineration processes
EU	Council Directive on hazardous waste 91/689/EEC	defines and lists properties and characteristics that render waste hazardous
EU	Shipment of waste 93/259/EEC	transposes Basel Convention
EU	Directive 94/67/EC on the incineration of hazardous waste	limits PCDD/PCDF emissions from hazardous waste incineration plants
EU	PCB Directive 96/59/EC	requires the registration and phasing out of all PCB (>50 ppm; >5 dm ³) by 2010 or by 1999 under OSPARCOM. Existing transformers and other electrical equipment which contain 50-500 mg/kg PCB may be retained in service until the end of their useful life
EU	IPPC-Directive 96/61/EC	lays down permit conditions and monitoring obligations for emissions to air for installations exceeding a threshold capacity
EU	Directive 1999/45/EC concerning the approximation of the laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations	general Provisions for classification, packaging, and labelling
EU	Water Directive 98/83/EC	quality of water intended for human consumption (limits for pesticides)
	ELV-Directive 2000/53/EC	basic requirements for separation of dangerous materials in shredder plants; recycling targets for waste vehicles
	Waste incineration Directive 2000/76/EC (progressively repealing all previous Directives)	sets up permit requirements and emission limits (air, waste water) for all waste incineration activities
EU	Commission Decision 2000/532/EC	contains a harmonised list of wastes (European waste code)
EU	Water Framework Directive* 2000/60/EC 88/347/EEC	quality standards for priority substances in water; only lists HCB as a priority substance, but values are under discussion
	Directive 2001/2375/EC	lays down limit values for PCDD/PCDF in food

	legislation	main objectives
EU	Directive 2001/102/EC amending Directive 1999/29/EC	addresses undesirable substances and products in animal nutrition POP pesticides, PCDD/PCDF and dioxin-like PCB
	Directive 2002/69/EC	defines sampling for PCDD/PCDF control in food
	Directive 2003/806/EC	defines measurement and sampling obligations for undesired substances including PCB in food of animal origin and feeding stuffs
	Directive 1986/363/EC	defines limit values for POP pesticides in foodstuff
	Decision 2001/2455/EC	list of priority substances under the water framework directive (2000/60/EC); includes HCB and Lindane
EU	ROHS Directive 2002/95/EC	prohibits the use of PBBS and PBDEs in electrical and electronic equipment from 2006
EU	WEEE-Directive 2002/96/EC	requires separate collection of waste electrical and electronic equipment and removal of all liquids (e.g. PCB containing capacitors)
EU	Council Decision 2003/33/EC pursuant to Directive 1999/31/EC	establishes criteria and procedures for the acceptance of waste at landfills Limit values are set for PCB with respect to landfills for inert waste
	Regulation 2003/304 on export and import of dangerous chemicals	implementation of the Rotterdam Convention; contains information on notification requirements for all POP pesticides and PCB.
EU	POPs Regulation 2004/850/EC	contains provisions for monitoring and disposal/recovery of "POP waste"; time schedule for phase-out of HCH/Lindane production; limit values for POP substances; permitted disposal/recovery operations for waste categories listed in Annex V

Table 6-2: Chronological overview on European Legislation relating to persistent organic pollutants (POPs)

6.1.3 National legal framework

European legislative standards in general have been adopted in all member states so that these regulations are not specifically mentioned in this paragraph.

However some countries reported derogations granted for the implementation of certain provisions or have established national regulations going beyond the requirements set on Community level.

Therefore this paragraph compiles specific national regulatory measures concerning the management of POP substances.

As on the Community level, regulations on national level basically pertain to the following sectors of environmental policy and consumer health:

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

In addition to the sectors regulated at Community level a number of countries have established a number of provisions relating to POP in the sectors of:

- soil protection
- ambient air

In the waste sector a number of countries have taken additional measures to restrict the use of sewage sludge and waste oil by the introduction of stricter limit values. Disposal/recovery of construction and demolition waste on landfill sites has been widely restricted as well. The provisions mainly refer to mandatory separation and recycling of all reusable material as well as mandatory incineration of all combustible fractions.

Furthermore, Germany reported a waste wood ordinance restricting substance recovery and thermal recovery of treated waste wood.

	legislation	main objectives
AT	Soil Protection Acts (corresponding to German limits)	<ul style="list-style-type: none"> • Contains limits for usage of PCB, PCDD/PCDF contaminated sewage sludge as fertiliser.
		<ul style="list-style-type: none"> • There is an obligation to sort and recycle C&DW above specified thresholds
BE		<ul style="list-style-type: none"> • In Flanders a ban on mixed waste landfilling was implemented in 07/98. In Wallonia restrictions are less strict.
DE	Federal Soil Protection and Contaminated Sites Ordinance	<ul style="list-style-type: none"> • Contains action levels regarding sites contaminated with Aldrin, DDT, HCD, PCB, PCDD/PCDF.
DE	Ordinance on Landfills and Long-Term Storage Facilities	<ul style="list-style-type: none"> • Contains limits for use of PCB contaminated soils as recultivation layers of landfills.
		<ul style="list-style-type: none"> • Mixed or recoverable C&DW may not be landfilled.
DE	Ordinance on Underground Waste Stowage	<ul style="list-style-type: none"> • Contains limits for use of PCB contaminated waste as stowing material.
DE	Sewage Sludge Ordinance	<ul style="list-style-type: none"> • Contains limits for usage of PCB, PCDD/PCDF contaminated sewage sludge as fertilizer.

	legislation	main objectives
DE	Waste Wood Ordinance	<ul style="list-style-type: none"> Contains limits for recycling of PCB contaminated waste wood.
DE	The Chemicals Prohibition Ordinance	<ul style="list-style-type: none"> All PCB containing capacitors have to be scrapped by 2000.
DK	Statutory Act on Waste	<ul style="list-style-type: none"> No explicit ban, but municipalities are obliged by law to assign C&DW which cannot be recycled, to incineration if possible.
FR		<ul style="list-style-type: none"> From 07/2002, installations for the elimination of wastes by storage will not be authorised to receive other than ultimate wastes.
NL		<ul style="list-style-type: none"> National ban on landfilling of reusable C&DW since 1997

Table 6-3: Legal situation in Member States

The legal situation in a number of other developed countries has not been further investigated at this stage of the project. In the consequence only a first compilation of exemplary regulation is briefly viewed in the following table.

	legislation	main objectives
Switzerland	<i>Soil Burden Ordinance</i>	<ul style="list-style-type: none"> Contains action levels regarding sites contaminated with PCB, PCDD/PCDF.
Canada	<i>Federal Mobile PCB Treatment and Destruction Regulations</i>	<ul style="list-style-type: none"> Contains emission standards for release of gases, liquids and solids contaminated with PCB, PCDD/PCDF.
United States	<i>US EPA 40 CFR 63 Subpart EEE National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors</i>	<ul style="list-style-type: none"> Contains standards for releases of PCDD/PCDF within air emissions.
United States	<i>40 CFR 268.48 Universal Treatment Standards for Hazardous Wastes</i>	<ul style="list-style-type: none"> Contains standards for the treatment of solid waste prior to land disposal and aqueous waste prior to release. Covers all POPs except Mirex.
United States	<i>40 DFR 761.70 Incineration</i>	<ul style="list-style-type: none"> Contains standards for releases of PCB within air emissions

Table 6-4: Legal situation in other developed countries

6.2 Existing concentration limits for POPs in European countries (EU 25)

In order to facilitate the reading and the understanding of the relation between limit values in different environmental compartments and the proposals for limit values set under the Basel Convention the transcription of units used in the different regulations and Conventions or given for analytical results is shortly presented below:

- ppm = mg/kg = µg/g
- ppb = ng/g = µg/kg
- ppt = pg/g = ng/kg

Concentrations of PCDD/PCDF are normally given in TEQ (the sum of toxicity equivalents) taking into account the varying toxicity of different congeners.

6.2.1 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 6-5: Limit values proposed under the Basel Convention

6.2.2 Existing limit values at EU and national level

In the European Union a number of limit values relating to persistent organic pollutants have already been established in a number of policy sectors. These limit values will have to be discussed in the evaluation process when developing proposals for common limit values under the European POP Regulation (2004/850/EC). Consequently a compilation of existing concentration limits shall be given in the following paragraph.

In order to structure the results and facilitate the reading the limit values are listed separately for the different policy sectors as follows:

1. waste management
2. chemicals – classification, production, and use
3. atmospheric pollution – air emissions and ambient air
4. water protection
5. soil protection
6. soil protection – sewage sludge
7. food and feed safety

6.2.2.1 Waste Management

The regulation of POP substances and substance groups in the waste sector is scarce. Up to now PCB are the only substance group which is explicitly mentioned and subject to regulation and limit values.

The POP pesticides are covered by the dangerous substance Directive and the Waste List as far as the definition of hazardous waste is concerned.

In the consequence legislation with respect to POP substances in waste is also scarce in most of the European member states. Additional limit values and regulations have been reported from Austria, Germany, Finland, Sweden, The Netherlands and the Slovak Republic. Also in the Czech Republic stricter limit values and additional regulations had been in force. However these shall all be transposed to the limit of 50 ppm set up in the European PCB Directive.

	legislation	purpose	limit values
EU	Waste Oil Directive 75/439/EEC	disposal/recovery of waste oils (for regenerated oils or oils used as fuel)	PCB: 50 mg/kg
EU	Regulation 93/259/EEC shipment of waste	Notification to authorities if pollutant containing waste is to be shipped	PCB, PBB 50 mg/kg
EU	PCB Directive 96/59/EC	disposal according to the operations mentioned in the Directive	Any mixture with PCB >50mg/kg (0.005%)
EU	2000/532/EC Waste Register	Hazardous wastes are supposed to contain dangerous substances in concentrations above the limits; (most POP pesticides are classified highly toxic)	highly toxic substances >0.1% = 1000 mg/kg toxic substances >3%

	legislation	purpose	limit values
EU	Decision 2003/33/EC (acceptance of waste at landfills)	Waste acceptable at landfills for inert waste	PCB: 1 mg/kg
AT	Hazardous Waste Ordinance BGBl. II Nr. 227/1997 idF BGBl. II Nr. 178/2000	Wastes	PCB 100 mg/kg d.w. PCDD/PCDF 10 ng TEQ/g d.w.
AT	Ordinance: Ban on halogenated biphenyls, terphenyls, naphthalenes, and diphenylmethanes	definition as PCB waste	PCB ≤ 30 mg/kg
		substance recovery of waste oils	≤ 5 mg/kg
CZ	Act on Waste 185/2001	classification as hazardous	PCB 20 mg/kg (all existing limits shall be converted to 50 mg/kg)
CZ	Regulation 383/2001		> 10 mg/kg - internal dump disposal is prohibited; > 0.2 mg/kg - the using in under ground places and on the surface is prohibited
	Decree No. 41/2005		PCB: > 50 mg/kg - dump disposal is strictly prohibited;
DE	Waste Oil Ordinance	limit for substance recovery	PCB: <20 mg/kg
DE	Ordinance on Underground Waste Stowage	limit for the use of wastes as stowing material	PCB 1 mg/kg (no limit for use in salt/potassium mines) Leachate: total PCB < 0.05 μ g/l
DE	Waste Wood Ordinance	limit for the material recycling	PCB: 5 mg/kg
DE	Ordinance on Landfills and Long-Term Storage Facilities (Deponieverordnung,)	Use of soils as recultivation layers of landfills	PCB: 0.1 mg/kg (sum 6 cong.)
DE	Ordinance on deposition (Version adapted 2004)	Recovery actions for improving the geological barrier layer at disposal sites(DK0, DK1, DKII, DKIII)	PCB: $\leq 0,02$ mg/kg
		Recovery in mineral isolation layer (DKII, DKIII), in mineral isolation layer (DKI – DKIII), in protection layer (DKII, DKIII), in drainage layer (DKI – DKIII)	PCB: $\leq 0,1$ mg/kg

	legislation	purpose	limit values
FI	Waste Oil Ordinance 101/1997	waste oil	PCB: <10 mg/kg
LU	Waste acceptance to landfill Ordinance		category 1: 1 mg/kg PCB category 2 (without barrier) 0.2 mg/kg PCB
SE	PCB and PCB disposal Ordinances	definition of POP waste	PCB: insulating oil >2ppm other wastes >50 ppm
SK	Act on Waste 2001 as amended 2002 and 2003		hazardous waste: PCB > 0.001%

Table 6-6: Limit values in EU and Member States for wastes

6.2.2.2 Chemicals – classification, production and use

Specific POP-related legislation within chemicals regulation has been reported for several countries. Their legislation affirms the PCB threshold fixed in European legislation, but is discernibly geared to the total phase-out and destruction of PCB releasing material and installations.

The dealing with different congeners differs among the countries, although the basic problem is attacked in a similar manner. This holds similarly for PCDD/PCDF as for PCB.

	legislation	purpose	limit values
EU	PCB Directive	No material containing PCB in concentrations >50 ppm may be placed on the market or be used. Equipment above the limits has to be decontaminated or disposed of until 2010	PCB: < 50 mg/kg (ppm)
AT	Waste management plan	Disposal of all equipment >1l and all transformers < 500 ppm until 2002	
BE	Waste management plan	All equipment >5 dm ³ shall be destroyed until 2005	
DE		Equipment containing >1l PCB may be operated with a special permit only	
DE	Chemicals Prohibition Ordinance (Chemikalienverbotsverordnung,)	prohibition of putting into circulation	PCB: 50 mg PCB/kg PCDD/PCDF: 1 – 100 µg TEQ/kg (dependent on the congeners)

	legislation	purpose	limit values
DK		All equipment containing >1l PCB had to be disposed of until 2000	
LUX	PCB disposal Ordinance	All equipment >500 ppm has to be disposed of until 2005	
NL	Ministerial Regulation on the disposal of PCB 1998	all equipment exceeding the limit has to be decontaminated ore disposed of by 2001	PCB: <5 mg/kg (per congener)

Table 6-7: Limit values in EU and Member States for production and use

6.2.2.3 Atmospheric pollution – emission and ambient air

National regulations in most countries exist for emissions to air and for specific production processes. Limit values for PCDD/PCDF emissions, e.g. regarding metal production and processing, differ considerably between the Member States and may exceed general EU limit values by a factor 10. On the other hand, national limit values can be significantly stricter than foreseen by Europe-wide regulation.

A comparison is problematic, as regulations are based on different reference parameters. This can however, only partly explain the broad spectrum of concentrations judged acceptable, for example regarding indoor exposure.

	legislation	purpose	limit values
EU	Directive 89/429/EEC	recommend to minimize the human exposure	PCDD/PCDF 0,1 ng TEQ/Nm³
EU	Waste Incineration Directive (94/67/EC)	limit for emission of hazardous waste incineration plants	PCDD/PCDF 0,1 ng TEQ/Nm³
EU	Waste Incineration Directive 2000/76	air emission	PCDD/PCDF: 0,1 ng TEQ/Nm³
		waste water from the cleaning of exhaust gases	PCDD/PCDF: 0,3 ng TEQ/l
AT		metal production and processing	PCDD/PCDF 0,1 ng TEQ/Nm³
		iron sintering plants	PCDD/PCDF: 0,4 ng TEQ/Nm³
BE		metal production and processing	PCDD/PCDF: 1 ng TEQ/Nm³
		iron sintering plants	PCDD/PCDF: 0,5 ng TEQ /Nm³

	legislation	purpose	limit values
CZ	AHEM, No. 6/1986	Ambient air	PCDD/PCDF: 20 fg TEQ/ Nm³
		metal and paper production	PCDD/PCDF: 1 ng/ Nm ³
DE	Ordinance on indoor air contamination DE	up to 3,000 considered long-term acceptable (100% ADI if 24h exposed);	PCB: limit values 3000 ng/Nm³ prevention level 300 (10% of ADI) target level 30 ng/Nm³
DE	Ordinance on immission control (BlmSchV Nr. 17)	emission limit values	PCDD/PCDF: 0,1 ng TEQ/Nm³
	Technical Guidance Air	emission limits class I substances	POP pesticides: <20 mg/m³
DE		work place air	PCDD/PCDF: 50 pg/m³ PCB: 0.7-1.1 mg/m³ POP pesticides: 0.1-1 mg/m³
FR		limit for metal production and processing, paper mills	1 ng TEQ/Nm³
		manufacture of cement and lime	0,1 ng TEQ/Nm³
HU	GO 193/2001 (X.19) GO 21/2001 (II.14)		1.4 ng TEQ/m³
HU	MO 14/2001 (V.9) MO 3/2002 (II.22)	Immission	PCDD/PCDF: ≤ 1 pg TEQ/Nm³
	MO 11/1991	Ambient Air	: PCDD/PCDF: 1pg TEQ/24h
LT		ambient air daily average	PCB/PCDD/PCDF: 500 fg/Nm³
LV	Regulation on Air Quality (No. 286/2002)		limit values and alert thresholds
MT	LN 166 of 2002	emissions are controlled but not limited	
NL		Air at workplace	PCB: 1mg/Nm³
NL		Iron sintering plants	0.4 ng TEQ/Nm³
PL		Air at workplace	PCDD/PCDF: 1mg/Nm³
SK	Air Protection Act No. 170/2002 Coll.	recommended values for workplaces	PCDD/PCDF: 0.7 ng/Nm³

	legislation	purpose	limit values
	No. 478/2002 Coll.	workplaces	PCB: 2 ng/Nm³ over 24h 6 ng/Nm³ for 30min
UK		limit for metal production and processing, paper mills	PCDD/PCDF: 1 ng TEQ/Nm³
		emission from industrial combustion processes	0,1 ng TEQ/Nm³
USA	USA	new municipal solid waste incinerators (emission)	PCDD/PCDF: 0,2 ng TEQ/Nm³
		new hazardous waste incinerators (emission)	PCDD/PCDF: 0,15 ng TEQ/Nm³
Japan	Japan		PCDD/PCDF: 0,1 – 5 ng TEQ/Nm³ (depending on the dimension of the plant)
		Japan Air Pollution Control Law	electric arc furnaces (EAF) for steel production
Canada	Canada (CCME 1989 and 1992)	guideline concentration for municipal solid waste, hazardous waste and clinical waste incinerators (emission)	
Japan		ambient air	PCDD/PCDF: 0.18 pg TEQ/Nm³
Japan		working room atmosphere	PCDD/PCDF: 2.5 pg TEQ/Nm³
			PCB: 0.1 mg/Nm³

Table 6-8: Limit values in EU and Member States for air

6.2.2.4 Water protection

In the field of water protection, extensive preoccupation with POP management can be perceived. Extensive data sets are available for analysis. Regulations discern substances very precisely, and set out thresholds distinguished by their source, and by the location of their accrual.

Besides emission limit values, environmental standards and target values are notified. It is difficult though to identify a comprising approach linking these individual measures.

Differences in concentration levels are striking. As regards PCB levels in drinking water, e.g., thresholds differ by a factor 20. The range of reported PCB pollution limits for surface water is

equally broad. Regulations on other POPs such as DDT and Aldrin do not present a consistent image either.

	legislation	purpose	limit values
EU	Directive 98/83/EC on quality of drinking water	quality of water intended for human consumption	Pesticides (except of Aldrin, Dieldrin, Heptachlor) 0,1 µg/l
			Aldrin, Dieldrin, Heptachlor: 0,03 µg/l
			total: 0,5 µg/l
EU	Directive 86/280/EC on discharge to waste water from production	Discharge to waste water from production of the substances, or of other chemicals	HCB: 1-3 mg/l (monthly), depending on specific production
			Aldrin, Dieldrin, Endrin 3 g/t total production capacity (monthly), 15 g/t total production capacity (daily)
			DDT: 0.7 mg/l total production capacity (monthly), 1.3 mg/l total production capacity (daily)
EU	water framework directive 2000/60/EC	values in discussion environmental quality standards for priority substances in water; inland waters, transitional waters, coastal waters, territorial waters (AA-EQS)	HCH: 0,002 µg/l (except of inland waters: 0,02µg/l)
			DDT: 0,025 µg/l
			para-para-DDT 0,010 µg/l
			Aldrin 0,010 µg/l
			Dieldrin 0,010 µg/l
		Endrin 0,005 µg/l	
	inland water, transitional water (MAC-EQS)	HCH 0,04 µg/l	
BE		limit values in ground water	Aldrin, Dieldrin: 0,03 µg/l
			Chlordane: 0,2 µg/l
			DDT: 2 µg/l
			HCB: 1 µg/l
			χ-HCH: 2 µg/l

	legislation	purpose	limit values
			α -HCH: 0,06 $\mu\text{g/l}$
			β -HCH: 0,2 $\mu\text{g/l}$
		limit values in surface water	DDT (total): 25 $\mu\text{g/l}$
			Aldrin: 10 ng/l
			Dieldrin, Endrin: 5 ng/l
			Organochlorine pesticides (individual): 10 ng/l
			PCB: 7 ng/l
			HCB: 0,03 $\mu\text{g/l}$ (yearly mean value)
			HCH (incl. Lindane): 100 ng/l
BE		discharge to waste water from production of the substances	HCB, HCH: 2 mg/l (monthly)
			DDT: 0,15 mg/l and 1g/t (monthly)
			Aldrin, Dieldrin, Endrin 2 $\mu\text{g/l}$ (monthly) or 3 g/t total production capacity, 10 μl (daily) or 15 g/t total production capacity
CZ	: Nat. Standard ČNS 75 7221 and Dec. No. 82/1999 (surface water)	Surface water and water courses	PCB: 0,01 $\mu\text{g/l}$
	Decree No.290/1997	Bottled drinking water	PCB: 0.01 $\mu\text{g/l}$
DE	Ordinance on Drinking water (TWVO)		PCB: 0.0001 each (Σ6PCB 0.0005) mg/l
EE	Govern. Reg. 58, June 16, 1999	ground water	<u>target value</u> PCB: 0.5 $\mu\text{g/l}$, <u>recommend value</u> PCB: 1 $\mu\text{g/l}$
HU	GO 203/2001; MO 9/2002	waste water	PCDD/PCDF: 0.3 pg TEQ/l

	legislation	purpose	limit values
HU	MO No. 10/2000 ()	surface water	PCB Action limits: increased sensitive area 0.05 µg/l sensitive area 0.1 µg/l , less sensitive area 1.5 µg/l <u>target value:</u> Pollution limit: 0.001 µg/l <u>recommended value:</u> Background: 0.0005 µg/l
			PCDD/PCDF: Pollution limit: 0.3 pg TEQ/l Action limit: - on the basis of risk assessment
NL		target values and intervention values for soil remediation, limit values for groundwater	PCB: target value: 0,01 µg/l intervention value: 0,01 µg/l
			DDT: target value: 0,004 ng/l intervention value: 0,01µg/l
			α-HCH: target value: 33ng/l
			β-HCH: target value: 8 ng/l
			γ-HCH: target value: 9 ng/l
			Aldrin: target value: 0,009 ng/l
			Dieldrin: target value: 0,1 ng/l
			Endrin: target value: 0,04 ng/l
			Heptachlor: target value: 0,005 ng/l intervention value: 0,3 µg/l
PL	Dz. U. 02.212.1799 PCDD/PCDF and PCB, e.g. in sewage	wastewater	PCB: 0,1 mg/l

	legislation	purpose	limit values
SI	OJRS No. 46/97, 52/97, 54/98, 7/00, 52/00	drinking water	PCB: 0.1 µg/l
	OJRS No. 11/02 chemical status of surface water	surface water	PCB (sum 28, 52, 101, 138, 153, 180): 0.01 µg/l
SK	Act on Water No. 184/2002 Coll..	surface water	PCB: <LOD (water courses) 0.025 µg/l (other surface water)
		irrigation water	PCB: 0.05 µg/l (acceptable)
Japan			PCDD/PCDF: 0.24 pg TEQ/l public waters
			Aldrin: 0.0003 mg/l
			Chlordane: 0.0013 mg/l
			Dieldrin: 0.0003 mg/l
			Endrin: 0.0005 mg/l
			Heptachlor: 0.0003 mg/l
USA		waste water from treatment of POP chemicals	Aldrin: 0.021 mg/l Chlordane: 0.0033 mg/l DDT: 0.0039 mg/l Dieldrin: 0.017 mg/l Endrin: 0.0028 mg/l Heptachlor: 0.0012 mg/l HCB: 0.055 mg/l Toxaphene: 0.0095 mg/l PCB: 0.1 mg/l PCDD/PCDF: 63 ng/l
	Toxic Substances Act	material send to waste water treatment plants	PCB: <3 ppb (µg/kg)
		waste water	PCB: 0.5 ppb (µg/l)

Table 6-9: Limit values for water in EU, Member States and other countries

6.2.2.5 Soil protection

As far as soil protection is concerned, there is a greater accordance of pollution limit values and target concentrations. Still, PCB limit values regarding soil used for agriculture range from 1 ng/kg to 0,2 mg/kg TEQ. POP concentrations judged critical in one Member State may correspond to another country's assumed background concentration of the same pollutant.

The broad scope of accessible information reveals that the methodology applied to systematise regulated cases is mostly unique to a Member State. It is therefore not possible to speak of a coherent legal situation on a European scale.

	legislation	purpose	limit values
EU	Towards a Thematic Strategy for Soil Protection	currently no directive,	none
BE	VLAREA, 2003	limit for use as secondary raw material (building material)	7-PCB: 0,5 mg/kg d.w.
BE	VLAREBO, 1996	limits for usage on agricultural soils (type I)	PCB 0,002 mg/kg d.w. HCB: 0.02 mg/kg d.w. Organochloro pesticides total: 0.1 mg/kg d.w.
		limit values for usage of soils other grounds (type II-IV)	PCB: 0.004 mg/kg d.w. Organochloro pesticides: 0.2 mg/kg d.w.
		background values for soil quality	HCB: 0.02 mg/kg d.w. aldrin/dieldrin: 0.02 mg/kg d.m chlordan: 0.01 mg/kg d.m DDT: 0.005 mg/kg d.m γ-HCH: 0.005 mg/kg d.m α-HC: 0.005 mg/kg d.m β-HCH: 0.005 mg/kg d.m
CZ	Directives of Ministry of Environment	soils	PCB: 0.02 mg/kg - (background); 2.5 mg/kg - (pollution limit); Action limit 5 mg/kg (living areas) 10 mg/kg (recreational) 30 mg/kg (industrial)

	legislation	purpose	limit values
CZ			TCDD-I-TEQ: 1 ng/kg - (background); 100 ng/kg- (pollution limit); Action limit: 500 ng/kg-(living area) 1000 ng/kg (recreational) 10,000 ng/kg (industrial)
CZ	Act on Waste 185/2001 (all existing limits shall be converted to 50 mg/kg)	usage of soils	PCB: 0.2 mg/kg (ppm)
		landfilling	PCB: 100 mg/kg (will be 50)
DE		soil used for agricultural purposes	target concentration PCDD/PCDF: < 5 ng TEQ/kg
		control of products for PCDD/PCDF transfer	PCDD/PCDF: 5-40 ng TEQ/kg
		restriction to crops with minimum PCDD/PCDF transfer	PCDD/PCDF: > 40 ng TEQ/kg
		soil exchange on children playground	PCDD/PCDF > 100 ng TEQ/kg
		soil exchange in residential areas	PCDD/PCDF: > 1000 ng/TEQ/kg
		Soil exchange independent of the location	PCDD/PCDF : > 10000 ng TEQ/kg
DE	Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV1999,)*	Perform more detailed investigations or to take measures for the reduction/elimination of the POP content	PCB: 0.4 - 40 mg/kg (checking level; dependent on the type of use) 0.2 mg/kg (action level for meadows) 0.05 - 0.1 mg/kg (action level for organic matter; dependent on the organic matter content)
			PCDD/PCDF: 0.1 - 10 µg TEQ/kg (action level; dependent on the type of use)

	legislation	purpose	limit values
DE	Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV1999,) *		0.1 µg TEQ/kg soils for sensitive use
			Aldrin: 2-10 mg/kg (checking level; dependent on the type of use)
			DDT: 40-200 mg/kg (checking level; dependent on the type of use)
			HCB: 4 - 200 mg/kg (checking level; dependent on the type of use)
DE		Requirements for substance recovery of mineral residues	PCB: <0,02 mg/kg no restrictions
			< 0,1 mg/kg restricted open recovery (Z1.1)
			<0,5 mg/kg (restricted open recovery) Z1.2
			>1 mg/kg (restricted recovery with defined technical safety measures) Z2
EE	Gov. Reg. 58/1999		<u>target value</u> PCB: 0,1 mg/kg <u>recommended value</u> PCB: 5 mg/kg (living area) 10 mg/kg (industrial)
HU	Joint Decree 10/2000 (VI.2.)		PCB: Background: 0.02 mg/kg Pollution limit: 0.1 mg/kg Action limit: increased sensitive area 0.2 mg/kg, sensitive area 1.0 mg/kg, less sensitive area 5 mg/kg

	legislation	purpose	limit values
HU	Joint Decree 10/2000 (VI.2.)		PCDD/PCDF: Background: 0.5 ng TEQ/kg Pollution limit : 5 ng TEQ/kg Action limit: increased sensitive area 10 ng TEQ/kg sensitive area 100 ng TEQ/kg less sensitive area 1000 ng TEQ/kg
NL	1994	limit for agricultural use	PCDD/PCDF: guideline level: 1 ng I-TEQ/kg d. m.
		limit for diary farming	guideline level: 10 ng I-TEQ/kg d. m.
NL	(Ministry of housing, spatial planning and environment)	target values and intervention values for soil remediation	PCB: target value: 0,02 mg/kg d. m. intervention value: 1 mg/kg d. m.
			DDT: target value: 0,01 mg/kg d. m. intervention value: 4 mg/kg d. m.
			α -HCH target value: 0,003 mg/kg d. m.
			β -HCH target value: 0,009 mg/kg d. m.
			γ -HCH target value: 0,00005 mg/kg d. m.
			aldrin target value: 0,00006 mg/kg d. m.
			dieldrin target value: 0,0005 mg/kg d. m.

	legislation	purpose	limit values
NL	(Ministry of housing, spatial planning and environment)	target values and intervention values for soil remediation	endrin target value: 0,00004 mg/kg d. m.
			heptachlor target value: 0,0007 mg/kg d. m. intervention value: 4 mg/kg d. m.
PL			PCB 0.02 mg/kg (protected areas) 0.02 mg/kg (farm land, forests, residential and recreation areas) 2 mg/kg (industrial and communication areas)
SE		guidance values for soil contamination	HCB: sensitive use: 0.005 mg/kg d.w. less sensitive: 20 mg/kg d.w. without groundwater use: 30 mg/kg d.w.
			PCB: sensitive use: 0.002 mg/kg d.w. less sensitive: 4 mg/kg d.w. without groundwater use: 7 mg/kg d.w.
			PCDD/PCDF: sensitive use: 10 ng N-TEQ/kg d.w. sensitive: 250 ng N-TEQ/kg d.m without ground water use: 250 ng N-TEQ/kg d.m
SI	OJRS No. 68/96		PCB: 0.2 mg/kg (limit threshold) 0.6 mg/kg (warning quantity) 1.0 mg/kg (critical quantity)
SK	Bulletin of MoA of SR No. 26, part 1/1994 Coll.		<0.1 ng/kg – (soil is not contaminated)

	legislation	purpose	limit values
CH	Soil Burden Ordinance	to perform more detailed investigations or to take measures for the reduction/elimination of the POP-content	PCB: 0.2 mg/kg (checking level; dependent on the type of use) 3 mg/kg (action level; dependent on the type of use)
Japan			PCDD/PCDF: 6.5 µg TEQ/g d.w.
		mg/l in leaching tests	Aldrin: 0.0003 mg/l Chlordane: 0.0013 mg/l Dieldrin: 0.0003 mg/l Endrin: 0.0005 mg/l Heptachlor: 0.0003 mg/l

Table 6-10: Limit values in EU and Member States for soil protection

6.2.2.6 Soil protection – sewage sludges

Sewage sludges constitute one comparably well-defined case of POP occurrence that accounts for formally comparable data from different countries. In the case of PCDD/PCDF existing limit values seem to be in accordance among the Member States and with the European proposal.

On the other contrary it can be stated that the existing limit values for one same case of PBC occurrence, such as the agricultural use as a fertiliser, hardly lie within the same order of magnitude. Proposed European levels are exceeded in some Member States and fallen below in other countries' legislation. Derogations are in the dimension of a factor 2 to 5.

	legislation	purpose	limit values
EU	EU proposal 2003 for sewage sludge		PCB (Σ6): 0.8 ppm (draft)
			PCDD/PCDF: 0.1 µg TEQ/kg (draft)
AT	Soil Protection Acts	sewage sludge as fertilizer	PCB: 0.2 mg/kg (for each of 6 congeners)
			PCDD/PCDF: 0.1 µg TEQ/kg d.w. (ppb)
BE		limits for sewage sludge as fertilizer	7-PCB: 0,8 mg/kg d.w.

	legislation	purpose	limit values
			HCb: 0.23 mg/kg d.w.
BE		maximum yearly dosage	PCB: 1,6 g/ha/a
			HCb: 0.46 g/ha/a
CZ	Decree 185/2001 Regulation 382/2001	sewage sludge applied on agricultural soils	PCB: 0,6 mg/kg d.m
DE	Sewage Sludge Ordinance (Klärschlammverordnung,)	sewage sludge as fertilizer	PCB: 0.2 mg/kg (for each of 6 congeners); total 1ppm PCDD/PCDF: 0.1 µg TEQ/kg d.w. (ppb)
HU	Gov. Decree 50/2001 (IV.3) Annex 5	sewage sludge as fertilizer	PCB 1 mg/kg (ppm)
SE	SNV 1995 and 1996 UMEG (2001)	limit for permissible maximum organic pollutant in sewage sludge	PCB: 0.4 mg/kg d.w.
SE		limit for sensitive uses	PCDD/PCDF: guideline concentration: 10 ng I-TEQ/kg d. m.
		limit for less sensitive uses	guideline concentration: 250 ng I-TEQ/Kg d. m.
US		solid residues from treatment of POP chemicals	aldrin: 0.066 mg/kg chlordan: 0.26 mg/kg DDT: 0.087 mg/kg dieldrin: 0.13 mg/kg endrin: 0.13 mg/kg heptachlor: 0.066 mg/kg HCb: 10 mg/kg Toxaphene: 2.6 mg/kg PCB: 10 mg/kg PCDD/PCDF: 0.001 mg/kg

Table 6-11: Limit values in EU and Member States for sewage sludge

6.2.2.7 Food and Feed Safety – Legislation on comestibles

In the field of food and feedstuff addressed by Community legislation sound data is available for diverse categories of edibles as well as drinking water. Legislative attention lies predominantly on possible PCDD/PCDF loads.

The regulatory situation in European countries is inhomogeneous: Among Member States; PBC limit values, which have been in force far longer than the “new” PCDD/PCDF limits, differ by a factor 2-5 in the cases of eggs and milk containing the pollutants, and by factors up

to 9 in the case of meat. The tolerated PCB load in fish diverge by a factor 20 within the European Union. At this stage, there is no information on whether the PCB limits in the new Member States shall be replaced by the European PCDD/PCDF limits, or whether they will be kept in force.

The most impressive difference is between limit values for drinking water pollution with PCB, amounting to a factor 50 between different countries. The foreseen limit values, however, are currently exceeded by far in all of the before mentioned areas.

	legislation	purpose	limit values
EU	2001/102/EC	levels in feed material	PCDD/PCDF: (action level and maximum)
		feed material of plant origin and compound feedingstuffs	0.4 – 0.75 ng TEQ/kg
		minerals	0.5 – 1.0 ng TEQ/kg
		animal fat	1.2 – 2.0 ng TEQ/kg
		meat and bone meal	0.75 ng TEQ/kg
		fish oil	4.5 – 6.0 ng TEQ/kg
		fish meal	1.0 – 1.25 ng TEQ/kg
		feedingstuffs for fish and pets	1.5 – 2.25 ng TEQ/kg
EU	2001/2375/EC	maximum levels in foodstuffs (will be reviewed by December 2004)	PCDD/PCDF
		meat of ruminants, poultry and pigs	1 –3 pg WHO-TEQ/g fat
		liver and derived products	6 pg WHO-TEQ/g fat
		milk, eggs and derived products	3 pg WHO-TEQ/g fat
		animal fat	2 –3 pg WHO-TEQ/g fat
		fish and fishery products	4 pg WHO-TEQ/g fresh weight
		vegetable oil	0.75 pg WHO-TEQ/g fat
EU	86/363/EC, amended by 2004/61/EC	maximum residue levels for pesticides prohibited for use	

	legislation	purpose	limit values
		meat and derived products, offals, animal fat	toxaphene (Camphechlor): 0.05 mg/kg fat aldrin/dieldrin: 0.2 chlordane: 0.05 DDT: 1 Endrin: 0.05 Heptachlor: 0.2 HCB: 0.2 α -HCH: 0.2 β -HCH: 0.1 Lindane: 0.02 (poultry 0.7)
EU	86/363/EC, amended by 2004/61/EC	milk	toxaphene (Camphechlor): 0.01 mg/kg fat aldrin/dieldrin: 0.006 chlordane: 0.002 DDT: 0.04 Endrin: 0.0008 Heptachlor: 0.004 HCB: 0.01 α -HCH: 0.004 β -HCH: 0.003 Lindane: 0.001
		eggs	aldrin/dieldrin: 0.02 chlordane: 0.005 DDT: 0.05 Endrin: 0.005 Heptachlor: 0.02 HCB: 0.02 α -HCH: 0.02 β -HCH: 0.01 Lindane: 0.1
			Aldrin, Dieldrin, Chlordane, HCH, HCB: fruits, pulses, potatoes: 0.01 mg/kg vegetables: 0.01 mg/kg (with some exceptions for Aldrin/Dieldrin) tea, oil seeds: 0.02 mg/kg
CZ	Decree No.290/1997	Bottled drinking water	PCB: 0.01 μ /l
CZ	Decree No. 3/1999 Coll.	food	PCB: milk - 0.1 mg/kg meat - 0.2 mg/kg egg - 0.2 mg/kg fish - 0.1 - 0.3 mg/kg (different species) fat - 0.5 mg/kg

	legislation	purpose	limit values
DE	Ordinance on the maximum permissible quantities of contaminants in foodstuffs	to interdict the circulation of contaminated foodstuffs on a commercial basis	PCB: 0.008-0.6 mg /kg (dependent on the congener and the respective foodstuff)
		PCB 28, 52, 101, 180	0.04 mg/kg fat in milk
		PCB 138, 153	0.05 mg/kg fat in milk
EE	Govern. Reg. 58, June 16, 1999	fish and products	PCB: 2.0 mg/kg fat weight
HU	Hungarian Regulation 40/2000 (XII.20.)		PCB: mg/kg fat weight
		Muscle, liver, fat meat products from cattle, sheep, pig, poultry	0.5 mg/kg
		milk, dairy product from milking animals	0.5 mg/kg
		egg (without shell) and egg products	0.5 mg/kg
		muscle, fat from game birds and mammalian games	1.0 mg/kg
		fish products	1.0 mg/kg;
		fish liver and fish liver products	3.0 mg/kg
LV	Regulation No. 292/1999 "on food contamination"		PCB:
		meat & meat products	3.0 mg/kg fat weight
		milk & milk products	1.5 mg/kg fat weight
		eggs	0.3 mg/kg fat weight
		fish	2.0 mg/kg fat weight
PL			PCB: mg/kg
		meat/meat products	0.2 mg/kg fat weight
		milk/dairy product <4% fat:	0.1 mg/kg fat weight
		eggs (without shell):	0.2 mg/kg fat weight

	legislation	purpose	limit values
		Drinking water	: 0.5 µg /l
SI	OJRS, No. 52/97, 54/98, 7/00, 52/00	Drinking water	Total PCB: 0,1 mg/m³

Table 6-12: Limit values in EU and Member States for food and feed

6.2.2.8 Legislation-human tissues

Health regulation with respect to POPs has not been finally investigated. So far, the regulation from the Slovak Republic has been the only accessible information related to permissible levels of POP contaminants in human tissues.

	legislation	purpose	limit values
SK	Regulation 45/2002 Health Protection at Work	human blood	PCB 0.05 mg/l

Table 6-13: Limit values in EU and Member States for human tissues

6.2.2.9 Conclusion

European legislation on acceptable concentrations of persistent organic pollutants is still far from presenting a coherent, integrative system. Introducing a Europe-wide regulation will thus bring eminent changes for several Member States and demand from them significant effort in renewing their regulatory system.

A reconfiguration of the POP regime is, however, inevitable if the Community is supposed to provide homogeneous conditions regarding quality of life and economic opportunities. It will also provide a lucidity of legal provisions that is inexistent at present.

6.3 Existing policy instruments

The EU Member States have varying levels of experience concerning policy instruments with regard to managing wastes (see "Waste minimisation profiles of OECD member countries", Environment Directorate, OECD, 1998). This includes variation in the use of bans and fees or taxes on wastes and disposal. EU Member States generally seem to use additionally financial support and economic incentives as part of their waste minimisation policy as well as persuasive instruments as e.g. information services and statistics. However, Member States reported only little on experiences with different policy instruments in the field of POPs. Examples with a broader applicability and a possible correlation to POPs are reported in the following.

6.3.1 *Regulatory instruments*

Chapter 6.2 describes the whole range of existing regulations and limit values. With mandatory approaches most of the issues related to POPs are covered.

6.3.2 *Economic instruments*

Taxes and fees

Austria regards economic instruments such as a disposal fee as an effective instrument, and tax instruments in Denmark (on waste destined for incineration or depositing) have proven effective as well. In Italy, taxes and duties are levied on e.g. waste treatment, landfilling and incineration, the tax depending on the type of waste. Spain does not apply taxes or duties as waste minimisation instruments.

The wastewater tax in *Germany* is a "downstream" charge on discharges, comprising a tax on sewage discharges; the amount payable is established on the basis of the amount and harmfulness of the waste. The objective of this measure was to promote an overall reduction in wastewater pollution, but its impact was found to be limited. A study carried out by Jass (1990) concludes that while the charge had led to considerable improvements in the purification of sewage and in environmental technology, it had not constituted an incentive to go beyond minimal compliance. (Lubbe-Wolf, 1996 in Cremer and Fisahan, 1998)

Public disposal facilities

To deal with this scattered appearance of hazardous wastes, many governments have established depots where small quantities of wastes consisting of, containing or contaminated with POPs can be "dropped-off" by the owner at no charge or for a nominal fee. These small quantities can arise from household or commercial-size pesticide containers, PCB fluorescent light ballasts, small containers of pentachlorophenol-based preservatives with PCDD/PCDF contamination, small amounts of "pure" POPs in laboratories and research facilities, and pesticide-coated seeds used in agricultural and research settings.

Depots may be permanent or temporary in nature, or may be located at an existing commercial hazardous waste transfer station. The waste collection depots and transfer stations may be set up on a regional basis by a group of countries, or may be provided by a developed country to a developing country [see UNEP GTGESM final 2005].

6.3.3 *Voluntary instruments*

Management plans

Austria has good experiences with establishing voluntary waste management plans on national and regional levels.

Denmark has set up a wide variety of mandatory (e.g. at municipality level) and voluntary plans and programmes as well. In *Spain* financial support programmes and economic incentives are used extensively for hazardous waste minimisation, including for R&D, pilot plant design and construction, development and consulting services.

Voluntary plans and programmes in *Spain* cover hazardous wastes, whereas mandatory plans and programmes have been set up to improve implementation and control of compliance with legal restrictions.

In the *United Kingdom* economic and persuasive instruments, voluntary plans and programmes, are clear policy priorities in the field of waste minimisation. Experiences are too early to judge, but the UK has stated that it would be likely to consider further economic instruments in the future.

The Waste Minimisation Strategy for the Leather Industry in *Italy* is an example of targeted intervention by public authorities engaging a particular sector in the long-term management of industry specific problems..

Recycling agreements

The opportunity for recycling construction and demolition waste (C&DW) is seen as the best incitement and instrument to obtain maximum sorting of the wastes. Voluntary agreements (VAs) can be used to raise the awareness of developers, demolition contractors and civil engineering contractors to the extent of existing knowledge *about* best practice. Although unlikely to be very effective on their own VAs can usefully supplement other policy measures and interventions by clearly signalling a preferred approach to complex issues such as selective demolition.

By requiring a demolition plan and a C&DW management plan to be submitted before a demolition permit is issued, selective *demolition*, as well as C&DW recycling, is encouraged.

Targeted Waste Collection

This measure constitutes a specific drive and effort made by *French* authorities to collect dangerous and harmful waste from homes. While effective in its own terms it is not a long-

term solution to the problem of discharges to UWW. It may be effective to deal with continuing risks of contamination from smaller and diffuse sources, and be used in connection with the adoption of a longer-term waste minimisation and collection strategy and public education campaign. One of the first targeted waste collection initiatives was carried out in France.

Special Conventions

The Anjou Recherche and 'Eaux Industrielles Initiatives': Special Conventions in France constitutes the first example of a truly voluntary initiative through the adoption of negotiated approaches to the reduction of problematic discharges. Anjou Recherché has studied five regions of France which have full statistical data and 34 UWW collecting systems. This research programme allows many SME polluters to be identified. Following the identification of industries that are potential polluters, a contract is drawn up between local industry and the mayor of the area.

Local Initiatives

Promotion of Environmental Management and Cleaner Production is realised on a local level in Denmark.

6.3.4 Educational instruments

Consumer Information

Provision of Consumer Information is being specially focused in France, and Eco-labelling is strongly established in Scandinavian countries. Eco-labelling initiatives such as the 'Nordic Swan' and 'Good Environmental Choice'- were developed by the Swedish Society for Nature Conservation (SSNC) and the Danish Society for the Conservation of Nature (DSCN) respectively.

Awards for Company Innovation

One example for incentives provided through decoration of pioneer companies is the award for Waste Management and Minimisation granted in *France*.

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 \leftrightarrow solids
 “soil like” \leftrightarrow “plastics”
 homogeneous \leftrightarrow complex mixture
 << interferences \leftrightarrow >> 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 inhomogeneity 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 tailor-made waste standards based on CEN- Work and already provide important information with respect to sampling and analysis of PCBs [Harmsen 2004].

7.1.1.1 Basic principles of standard development

Scientific literature provides a variety of further methods or method modifications for certain questions, however, a suggestion for reference methods in context with the control of regulatory limits has to be based on broadly accepted and validated methods which are primarily represented by methods from standardisation bodies.

Besides the recommendation of well defined individual methods it is an accepted strategy used by authorities and standardisation bodies to define critical performance or quality criteria to be met by analytical methods in order to obtain accepted results. The advantage of this strategy is that it admits highest flexibility in method development (e.g. inclusion of cost efficient techniques; adaptation of methods to complex waste matrices) without neglecting quality related issues.

Following this approach of critical performance criteria, in a first step available standardised methods for POPs in waste materials have to be reviewed on a world-wide basis including the identification and evaluation of their performance/quality criteria. By identifying consensus or minimum criteria a suggestion for criteria for reference methods could then be performed.

However this is a complicated process considering the complexity of the matrix waste and the variety of individual analytical processes to be regarded (sampling, pre-treatment, extraction, clean-up, measurement, QA/QC).

As currently comprehensive activities (e.g. project HORIZONTAL) are on the way concerning the harmonisation of analysis in this field, so the project team supposes not to anticipate upcoming results and recommendations of ongoing harmonisation activities to which - among others - also standardisation bodies are involved (e.g. considering the methodical validation effort necessary to support a suggestion for reference methods).

Therefore, the project team has to confine itself on collecting currently available information on standard methods and try to illustrate relevant performance/quality criteria in view of a proposal of such criteria for POPs analysis in wastes. Final definition of reference methods and performance/quality requirements has to be based on outputs from standardisation bodies in order to achieve accepted methods. The proposals as presented by this project have therefore to be updated in accordance with up-coming results of the official standardisation and harmonisation process.

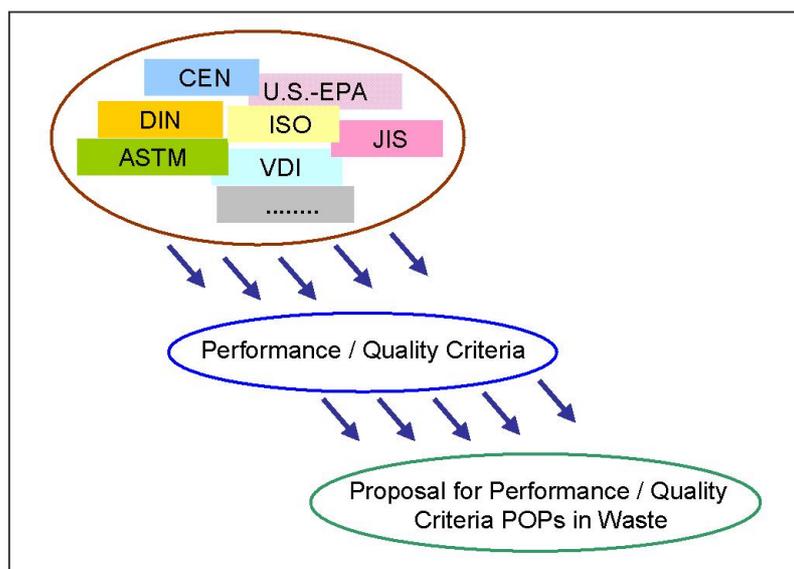


Figure 7-2: Methodical approach for suggestion of performance/quality requirements for reference methods for POP analysis in waste

7.2 International overview on measurement methods for POPs in waste

In the following chapter the results of a world-wide investigation on measurement methods for detection of POP concentrations in different matrices are compiled and discussed separately for PCDD/PCDF, PCB, POP pesticides and other POPs. The overview is based on available results from the HORIZONTAL project [HORIZONTAL DRAFT 2004, Harmsen 2004] and is extended by further findings.

7.2.1 PCDD/PCDF

Table 7-1 summarises the results of a survey on standardised analytical methods to be considered for PCDD/PCDF analysis.

Method (Reference)	Matrix (acc. to method scope)	Extraction	Clean-up	Detection
EN 1948-2 EN 1948-3	Stationary source emissions	Soxhlet / Toluene (solids, filter) Liquid/liquid, toluene or dichloromethane (liquids)	- gel permeation - multi layer silica - carbon - alumina	HRGC/HRMS
EPA Method 23	Stationary source emissions	Soxhlet / Toluene	- multi layer silica - alumina - carbon	HRGC/HRMS
CARB 428	Stationary source emissions,	Soxhlet / Benzene Soxhlet / Toluene	- silica gel - alumina - carbon	HRGC/HRMS HRGC/LRMS
VDI 3499-1 VDI 3499-2 VDI 3499-3	Stationary source emissions, filter dust, ash, slag	Soxhlet / Toluene Pre-treatment, Soxhlet / Toluene	- multi-layer silica - alumina - multi-layer silica - alumina	HRGC/HRMS HRGC/HRMS
JIS K 0311	Stationary source emissions,	Soxhlet / Toluene	- multi-layer silica - alumina - carbon	HRGC/HRMS
EPA Compendium Method TO 9A	Ambient air	Soxhlet / Toluene Soxhlet / Benzene	- multi-layer silica - carbon - alumina	HRGC/HRMS
VDI 3498	Ambient air	Soxhlet / Toluene	- multi-layer silica - alumina - HPLC	HRGC/HRMS
ISO 18073	Water	Soxhlet / Toluene	- gel permeation - multi layer silica - active carbon - silica - florisil - AgNO ₃ /silica	HRGC/HRMS

Method (Reference)	Matrix (acc. to method scope)	Extraction	Clean-up	Detection
EPA 1613, B	Water, soil, sediment, sludge, tissue	Not described	- gel permeation - multi layer silica - carbon - alumina - C18	HRGC/HRMS
EPA 8280	Water, soil, fly ash, chemical waste, fuel oil,	Dichloromethane Soxhlet / Toluene	- multi layer silica - carbon - silica - alumina	HRGC/LRMS
EPA 8290	Soil, sediment, water	Soxhlet / Toluene Dichloromethane Dean-Stark Toluene Soxhlet/Hexane-Dichloromethane	- multi layer silica - carbon - silica - alumina	HRGC/HRMS
AbfklärV, Germany	Sewage sludge	Soxhlet / Toluene	- alumina - multi layer silica - gel permeation	GC/MS
Klärschlammverordnung, Austria	Sewage sludge	Soxhlet / Toluene	- alumina - multi layer silica - gel permeation	GC/MS
Commission Directive 2002/70/EC	Feedingstuff	Not described (ref. to EPA 1613 B or comparable method)	Not described (ref. to EPA 1613 B or comparable method)	HRGC/HRMS (confirmatory) Screening possible
SAEFL Guidelines	Soil	Soxhlet / Toluene	- metallic mercury - multi layer silica - carbon	HRGC/HRMS HRGC/LRMS
DIN 38412-24	Sediment Sludge	Soxhlet / Toluene	- multi layer silica - AgNO ₃ -silica - alumina - gel permeation	HRGC/HRMS 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 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) 40 – 130 (Cl ₇ -Cl ₈)	± 20%
EPA Method 23		70 – 130	± 15%
CARB 428	Ng – pg/m ³	60 - 140	
VDI 3499-1 VDI 3499-2 VDI 3499-3	< 0,1 ng I-TEQ/m ³ , > 0,1 ng I-TEQ/m ³ (emission) LOD 0,012 µg/kg (fly ash)	50 – 130 (Cl ₄ -Cl ₆) 40 – 130 (Cl ₇ -Cl ₈)	± 20%
JIS K 0311	< 0,1 I-TEQ/m ³	50 – 120	± 20%
EPA Compendium Method TO 9A	0,02 – 0,15 pg/m ³ (Cl ₄ – Cl ₆) 0,05-0,25 pg/m ³ (Cl ₇ -Cl ₈)	50 – 120	
VDI 3498	MDL 0,5 – 3 fg/m ³	50 – 130	
ISO 18073	"few pg/l)	50 – 130 (Cl ₄ -Cl ₆) 40 – 130 (Cl ₇ -Cl ₈)	
EPA 1613, B	Minimum: Cl ₄ 1 ng/kg Cl ₅ -Cl ₇ 5 ng/kg Cl ₈ 10 ng/kg		
EPA 8280	>/= 10*method calibration limit	40 - 135	
EPA 8290	2 ng/kg (TCDD), 20 pg/l (TCDD)	40 – 120	
AbfklärV, Germany	ng/kg	> 70 (OCDD/F > 40)	

Method (Reference)	Scope	Recovery ratio of extraction standard (% , min – max)	Deviation of Isotope ratios from theoretical value
Klärschlamm-verordnung, Austria	ng/kg	> 70	
Commission Directive 2002/70/EC		60 – 120	
SAEFL Guidelines	50 fg/µl – 5 ng/µl	50 – 115	
DIN 38412-24	Minimum: 1 – 10 ng/kg per congener	≥ 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).

7.2.2 PCB

The following table (Table 7-3) summarises the results of a survey on standardised analytical methods to be considered for PCB analysis. It lists standardised methods for the specific analysis of PCB but considers also multiple component methods which include PCB analysis.

Method (Reference)	Matrix (acc. to method scope)	Extraction	Clean-up (options)	Detection
EPA 1668	water, soil, sediment, sludge, biosolids, tissue, other	SPE Dean-Stark/Toluene Soxhlet / Hexane-Dichloromethane	- Gel permeation - multi-layer silica - carbon - silica gel - florisil - carbon	HRGC/HRMS
DIN 38414-20	sewage sludge, sediments	Soxhlet/hexane or pentane	- AgNO ₃ -silica	GC/ECD
ISO 10382	soil	Shaking, petrolether,	- alumina - silica gel	GC/ECD
DIN 38407-3	water	Liquid/liquid, hexane	- H ₂ SO ₄ - silica gel - alumina	GC/ECD GC/MS

Method (Reference)	Matrix (acc. to method scope)	Extraction	Clean-up (options)	Detection
			- AgNO ₃ -silica - copper	
ISO 6468	water	Liquid/liquid, hexane, petrolether or heptane	- alumina - silica gel	GC/ECD
DIN 38407-2	water	Liquid/liquid, hexane, petrolether or heptane	- H ₂ SO ₄ - silica gel - AgNO ₃ -silica - copper	GC/ECD
DIN EN 12766-1 prEN 12 766-3	petroleum products and used oils	Solving in heptane, hexane, cyclohexane or 2,2,4-trimethylpentane	- silica gel - alumina - H ₂ SO ₄ - copper - TBA - 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 - AgNO ₃ /silica gel - TBA	GC/ECD
ASTM 5175	Water	Liquid/liquid, hexane		GC/ECD (confirmation by GC/ECD with 2 nd and 3 rd column or GC/MS)
EPA 8082	solid and aqueous samples	Soxhlet, hexane-acetone ore dichloromethane-acetone Liquid/liquid dichloromethane	- H ₂ SO 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: Minimum LOQ for PCB 126 = 5 µg/l Solids: 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, 2nd column confirmation 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) 10-100 ng/l (MS)	Internal std. method or isotope dilution (GC/MS)	> 60% 40 – 150%	Retention time, 2nd column confirmation (ECD)
ISO 6468	1 – 10 ng/l per congener	External calibration method	> 60%	Retention time, 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 (total PCB)	External standard method		Retention time,
EPA 8082	0.05 – 0.9 µg/l (MDL, as Aroclor), 5-25 ng/l per congener 57-70µg/kg (MDL as Aroclor), 160 – 800 ng per congener	External standard method (Aroclor) Internal standard method (congeners)	80 – 120%	Retention time, confirmation : 2 nd 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 tetrachlorobiphenylmethane mixtures, chlordane, chlorinated paraffins, PCN, PCT, PBB, toxaphene, PCDE, PBDE, low volatile organochlorine compounds or sulphur.

7.2.3 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).

7.3 Evaluation of existing measurement methods and proposals in view of European reference methods

7.3.1 PCDD/PCDF

Based on the results of the world-wide investigation of standardised measurement methods (see Table 7-1 and Table 7-2) it can be stated that GC/MS techniques are state-of-the-art in the field of standardised confirmatory analysis for PCDD/PCDF. Requirements to performance criteria are quite comparable and only very selected extraction and clean-up procedures are available and sufficient for analysing a broad spectrum of matrices. Although waste matrices are not extensively listed in the scope of the currently available methods, the listed methods are applied successfully to different waste matrices in routine practice.

From this point of view, the available techniques are sufficient. Furthermore, activities are on the way to harmonise these methods in view of analysing certain type of wastes [HORIZONTAL Draft 2004].

Major problems that hamper the development of reference standards are the current lack of pure calibrants or traceability to them as a basic prerequisite for requested comparable and reliable measurement data and the method validation.

Suitable quality test by means of interlaboratory tests with use of certified reference materials may be of higher importance as the method alone. This QC is especially essential when different analysis methods will be allowed.

With respect to method validation there are problems with the harmonisation of quality criteria and control (QA/QC). Although issues like LOD and LOQ are addressed in accredited laboratories in all of the Member States there is no consensus on how to calculate these and other methods performance criteria.

Assessment of feasible LOQ for PCDD/PCDF in waste

Available standard methods are able to detect PCDD/PCDF at levels down to ppt (pg/g) depending on the analytical effort applied. However these levels are not per se achievable for complex waste matrices with the original standard.

Considering very difficult measurable matrices a factor of 10 was included to represent the decreased sensitivity due to the matrix with the standard method. Trying to improve sensitivity needs extra effort (e.g. repeat standard clean-up, include further clean-up steps, turn to more specific measurement (e.g. HRMS) with increased costs.

Based on a cost –benefit analysis a LOQ of 0.1 ppb seems to be achievable for PCDD/PCDF at reasonable conditions even in the most unfavourable matrix. (see Figure 9-15)

Current extraction techniques (such as ASE) and increasing automation of clean-up steps have led to reduced analyses periods and increased capacities. From this point of view, a

high analytical capacity in routine laboratories is already available in Europe even if laboratory capacity is not homogeneously distributed all over Europe.

Based on the experience of the rapid development of appropriate analytical capacity after the implementation of maximum levels for PCDD/PCDF in food and feed, it can be expected that routine laboratory capacity will be rapidly adapted to the requirements of the analytical market.

7.3.2 PCB

In view of the variety of waste matrices it is suggested to provide a list of possible methods (e.g. clean-up methods) instead of strictly focusing on a single reference standard for certain types of waste. Although recommendation should be given to the analyst, which methods are adequate for which kind of matrix and which quality criteria and standards have to be achieved, the analyst should be free to take the final decision depending on his individual target.

For the detection of PCB GC/ECD is the method of choice in available standards. Besides this, GC/MS techniques are also available.

In contrast to the situation for other POPs harmonised standards are already under development at the European scale. The following standards have been developed by CEN / TC 292 and are currently under approval:

Reference	Domain	Status
prEN 14899	Sampling of waste materials-Framework for the preparation and application of a sampling plan	Under approval
prCEN/TR 15310-1	Sampling of waste- Part 1: Guidance on selection of basic statistical approach to sampling	
prCEN/TR 15310-2	Sampling of waste- Part 2: Guidance on sampling techniques	
prEN 14899	Determination of selected PCB in solid waste, soil and sludge by using GC/MS or GC/ECD	

Table 7-6: Harmonised EU standards for sampling of waste under development in CEN / TC 292

The experiences will be usable for the development of standards for the other POP substances.

The individual methods are able to detect the target compounds at quite low levels. However, these levels are not per se achievable for complex waste matrices with the original standard method. So levels which should be measurable following a standardised method (e.g. 0,1

ppm for individual PCB congener following the criteria for performance testing of petroleum products according to Din EN 12766) were used as the basis for the calculation of the LOQ achievable under reasonable conditions. Taking into consideration applicability for highly difficult matrices a factor of 10 was included to represent the decreased sensitivity. Trying to improve sensitivity needs extra effort (e.g. repeat standard clean-up, include further clean-up steps, turn to more specific measurement (e.g. HRMS) with increased costs.

Thus based on a cost –benefit analysis a LOQ of 1 ppm (per congener) seems to be achievable for PCB at reasonable conditions even in the most unfavourable matrix. (see Figure 9-16).

Details on relevant sample types and corresponding extraction, clean-up and analysis methods are available in the report on horizontal standardisation of PCBs [Harmsen (2004):] A compilation of the recommendation is given in the figures below.

		Shaking/ ultrasonic	ASE	Soxhlet
Sludge				
Sewage sludge	dry	++	x	+
	wet	++	+	+
Industrial sludge	dry	++	+	+
	wet	++	+	+
Sediment/dredged sludge	dry	++		
	wet	++		
Waste				
Soil like waste	dry	++		
	wet	++		
Building materials, Shredder, plastic, bitumen	dry		++	++
	dry		++	++
Mixed waste	dry	+	+	+
	wet	+	+	+
Soil improvers				
Compost	dry	++	x	x
	wet	++		
Biowaste	dry	+	++	++
	wet	+		
Soil				
Sandy	dry	++	+	+
	wet	++		
Clay	dry	++		
	wet	++		
Organic rich	dry	++	++	++
	wet	++		

++ = well applicable
+ = may be applicable

Figure 7-3: Feasible methods for per-treatment for PCB analysis in soil-like waste matrices as developed in the project HORIZONTAL [Harmsen 2004]

Clean-up	Removal of	Special for	Also applicable for	Described in	Remarks
Washing with water	Most polar compounds		PAH	O28, ISO 10382	
Aluminium oxide	polar		PAH	O28, ISO 10382, N0633	Difficult to adjust water content and keep it constant
Silica	polar		PAH	O28, ISO 10382, N0633	Attention; some charges of silica can contain low concentrations of PCBs
Florisil	polar			O28, N0633	
H ₂ SO ₄ /Silica NaOH	Polar. PAH, lipides			O28	
Benzenesulfonic acid/ sulfuric acid	Polar, (poly)aromatics, bases, hetero compounds			EN 12766	
gelpermeation	High molecular	MS	PAH	N0633	
H ₂ SO ₄ (conc)	lipids			O28, EN 12766	
TBA	sulphur	ECD		O28, EN 12766, ISO 10382	
Cu	sulphur	ECD		O28, EN 12766, ISO 10382	
AgNO ₃ /Silica	Sulphur + polar	ECD		DIN 38414, N0633	
DMSO/hexane	Aliphatic hydrocarbons	MS		O28	
Thermal shock	Chlorinated waxes			O28, EN 12766	

Figure 7-4: Feasible methods for clean-up for PCB analysis in soil-like waste matrices as developed in the project HORIZONTAL [Harmsen 2004]

On this basis, a scheme has been suggested indicating the different possibilities of using individual methods for wastes [Harmsen et al. 2004].

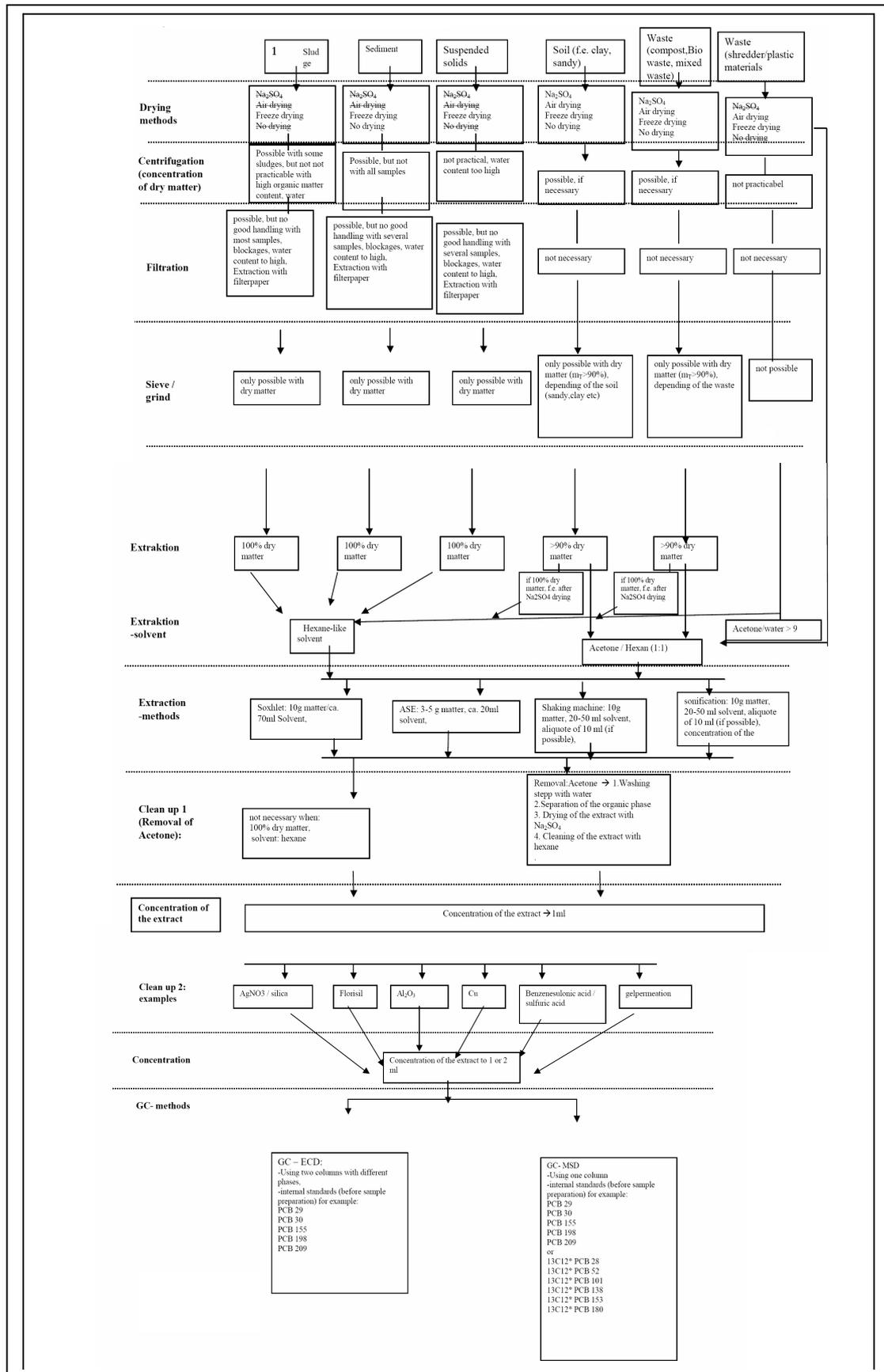


Figure 7-5: Methodical approach for suggesting performance / quality requirements for reference methods of POPs in waste in the Project HORIZONTAL [Harmsen et al. 2004]

7.3.3 POPs Pesticides and other POPs

The statements given for PCB generally apply for POP pesticides and other POPs as well. Again, GC/ECD and GC/MS techniques are accepted methods for detection.

As for PCDD/PCDF specific standards for analysis in waste are not yet available.

Major problems that hamper the development of reference standards are the current lack of pure calibrants or traceability to them as a basic prerequisite for requested comparable and reliable measurement data and the method validation.

Suitable quality test by means of interlaboratory tests with use of certified reference materials may be of higher importance as the method alone. This QC is especially essential when different analysis methods will be allowed.

With respect to method validation there are problems with the harmonisation of quality criteria and control (QA/QC). Although issues like LOD and LOQ are addressed in accredited laboratories in all of the Member States there is no consensus on how to calculate these and other methods performance criteria.

The individual methods are able to detect the target compounds at quite low levels. However, these levels are not per se achievable for complex waste matrices with the original standard method. Trying to improve sensitivity needs extra effort (e.g. repeat standard clean-up, include further clean-up steps, turn to more specific measurement (e.g. HRMS) with increased costs.

Thus based on a cost –benefit analysis a LOQ of 1 ppm (per congener) seems to be achievable for POP pesticides and other POPs at reasonable conditions even in the most unfavourable matrix. (see Figure 9-16).

7.4 International overview related to representative "isomers" for PCDD/PCDF, PCB and Toxaphenes and proposal for "Indicator" isomers for analysis of specific substance groups

7.4.1 Evaluation of information on PCDD/PCDF

The individual congeners to be detected by the standardised methods listed in Table 7-1 are summarised in Table 7-7 below.

Method (Reference)	Congeners to be analysed
EN 1948	17 2,3,7,8-substituted PCDD/PCDF
EPA Method 23	17 2,3,7,8-substituted PCDD/PCDF
CARB 428	17 2,3,7,8-substituted PCDD/PCDF
VDI 3499	17 2,3,7,8-substituted PCDD/PCDF
JIS K 0311	17 2,3,7,8-substituted PCDD/PCDF
EPA Compendium Method TO 9A	17 2,3,7,8-substituted PCDD/PCDF
VDI 3498	17 2,3,7,8-substituted PCDD/PCDF
ISO 18073	17 2,3,7,8-substituted PCDD/PCDF
EPA 1613, B	17 2,3,7,8-substituted PCDD/PCDF
EPA 8280	17 2,3,7,8-substituted PCDD/PCDF
EPA 8290	2,3,7,8-TCDD and total TCDD
AbfklärV, Germany	17 2,3,7,8-substituted PCDD/PCDF
Klärschlammverordnung, Austria	17 2,3,7,8-substituted PCDD/PCDF
Commission Directive 2002/70/EC	17 2,3,7,8-substituted PCDD/PCDF
SAEFL Guidelines	17 2,3,7,8-substituted PCDD/PCDF
DIN 38412-24	17 2,3,7,8-substituted PCDD/PCDF

Table 7-7: PCDD/PCDF congeners to be analysed according to standardised methods

As shown in Table 7-7 it is common consensus in all available methods to analyse the 17 2,3,7,8-substituted PCDD/PCDF congeners to be considered within the I-TEF or WHO-TEF scheme (see Table 7-8).

Although detection of selected individual congeners has been used for screening purposes with some special contamination cases in the past (specific indicator congeners available for these contaminations), this can not be suggested as a general alternative for wastes. There is not a homogeneous isomer pattern valid for all samples to be analysed as "waste" and, if regulative limits will be TEQ-based, the complete set of the 17 congeners has to be analysed.

As measurement and calculation is highly automated in routine analysis the calculation of single isomers instead of all 17 congeners will not lead to a significant cost reduction.

Thus it is recommended to use the 17 TEQ congeners for an European reference standard as well.

		NATO/CCMS-TEF	WHO-TEF
Dioxins	2,3,7,8-TCDD	1	1
	1,2,3,7,8-PeCDD	0.5	1
	1,2,3,4,7,8-HxCDD	0.1	0.1
	1,2,3,6,7,8-HxCDD	0.1	0.1
	1,2,3,7,8,9-HxCDD	0.1	0.1
	1,2,3,4,6,7,8-HpCDD	0.01	0.01
	OCDD	0.001	0.0001
Furans	2,3,7,8-TCDF	0.1	0.1
	1,2,3,7,8-PeCDF	0.05	0.05
	2,3,4,7,8-PeCDF	0.5	0.5
	1,2,3,4,7,8-HxCDF	0.1	0.1
	1,2,3,6,7,8-HxCDF	0.1	0.1
	1,2,3,7,8,9-HxCDF	0.1	0.1
	2,3,4,6,7,8-HxCDF	0.1	0.1
	1,2,3,4,6,7,8-HpCDF	0.01	0.01
	1,2,3,4,7,8,9-HpCDF	0.01	0.01
	OCDF	0.001	0.0001

Table 7-8: PCDD/PCDF congeners considered for TEQ calculation according to NATO/CCMS (I-TEQ) and WHO (WHO-PCDD/PCDF-TEQ)

7.4.2 Evaluation of information on PCB

Table 7-9 summarises the PCB congeners to be considered by the individual standards.

Method (Reference)	Congeners to be analysed	Calculation of total PCB content
EPA Method 1668, A	DL-PCB, remainder: total PCB on basis of individual congener analysis (125 individual congeners and remaining 70 congeners as mixture of isomers)	Not mentioned. Possible by measuring all 209 congeners
DIN 38414-20	6 PCB (28, 52, 101, 138, 153, 180)	Not mentioned
ISO 10382	7 PCB (28, 52, 101, 118, 138, 153, 180)	Not mentioned

Method (Reference)	Congeners to be analysed	Calculation of total PCB content
DIN 38407-3	6 PCB (28, 52, 101, 138, 153, 180) (further possible), technical mixture (total PCB), total content via homologues sum	Factor for calculating total content not allowed total amount
ISO 6468	6 PCB (28, 52, 101, 138, 153, 180), + 194, further possible	Not mentioned
DIN 38407-2	6 PCB (28, 52, 101, 138, 153, 180), + 194,	Not mentioned
DIN EN 12766-1	6 PCB (28, 52, 101, 138, 153, 180) technical mixture	6 PCB * 5 total amount
ASTM 4059	technical mixtures	total amount
ASTM 6160	technical mixtures	total amount
AbfKlärV	6 PCB (28, 52, 101, 138, 153, 180)	Not mentioned
ASTM 5175	technical mixtures	total amount
EPA 8082	1, 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187, 206 technical mixture	
EPA 8270	technical mixtures	total amount

Table 7-9: PCB congeners covered by individual standards

As illustrated in the table there is no consensus about the most suitable number of congener to use for the calculation of a PCB content. Basically there are two strategies used, detecting selected congeners or analysing on the basis of the technical mixture. Concerning individual congeners two approaches are used, focusing on six selected PCB (28, 52, 101, 138, 153, 180) or seven PCB including CB 118.

As both approaches do not result in identical figures it will be necessary to clearly define which congeners and/or which factors shall form the basis for the established limit values.

For waste oils a European standard (EN 12766-2) has been established. Part 2 specifies the calculation of the PCB content. A corresponding approach could be used for other matrices.

It has to be taken into account that dioxin-like PCB are currently not considered in the limit discussion and data on dioxin-like PCB are not available for wastes.

The dioxin-like PCB as considered for the calculation of WHO-PCB-TEQ are listed in Table 7-11. Available methods for the analysis of dioxin-like PCB are listed in Table 7-10.

If there will be toxicity based (TEQ) limits for PCDD/PCDF, the contribution of the dioxin-like PCB to this kind of toxicity should however be taken into consideration. Therefore, it should be evaluated to which extent the acceptable limits for PCB in waste will increase the dioxin-

like property of a waste material (incl. the probability that total WHO-TEQ (PCDD/PCDF + PCB) will exceed the limit for PCDD/PCDF alone for individual waste matrices.

This has to be evaluated by analytical data of dioxin-like PCB from samples with total or indicator PCB levels at corresponding limit values.

No information is currently available on PCB-TEQ concentrations in wastes.

As a rough first estimation of the dimension of dioxin-like toxicity in technical PCB mixtures and products can be taken from literature. 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 sheets²⁷].

Methods for or including DL-PCB
Draft DIN EN 1948, 2004-02
JIS K 0311
Commission Directive 2002/70/EC
EPA 1668, A

Table 7-10: Detection methods for or including analysis of dl-PCB

		WHO-TEF
dioxin-like PCB	3,4,4',5-TeCB (PCB 81)	0.0001
	3,3',4,4'-TeCB (PCB 77)	0.0001
	3,3',4,4',5-PeCB (PCB 126)	0.1
	3,3',4,4',5,5'-HxCB (PCB 169)	0.01
	2,3,3',4,4'-PeCB (PCB 105)	0.0001
	2,3,4,4',5-PeCB (PCB 114)	0.0005
	2,3',4,4',5-PeCB (PCB 118)	0.0001
	2',3,4,4',5-PeCB (PCB 123)	0.0001
	2,3,3',4,4',5-HxCB (PCB 156)	0.0005
	2,3,3',4,4',5'-HxCB (PCB 157)	0.0005
	2,3',4,4',5,5'-HxCB (PCB 167)	0.00001
	2,3,3',4,4',5,5'-HpCB (PCB 189)	0.0001

Table 7-11: List of dioxin-like PCB to be considered for calculation of WHO-PCB-TEQ

²⁷ www.epa.gov/toxteam/pcb/aro/aro_cpcb_comp_frame.htm

7.4.3 *Toxaphene*

Toxaphene represents a complex mixture of up to 670 signals identified with GC/ECD. Still not all components can be chromatographically separated. Furthermore, some components are not very stable during analysis.

With respect to the standardised methods for environmental samples as listed in Table 7-5 two types of quantification do occur:

- total area determination of the complex mixture response in the chromatogram using internal or external standard method comparing to technical mixtures
- major peak quantification using internal or external standard method (e.g. using 4-6 major peak of the toxaphene pattern, EPA 8081 A).

Both types can be regarded as a kind of screening method as no confirmation of well defined individual congeners is used. Identification and quantification is executed by using technical mixture. Using this approach, no proposal for well defined individual congeners is necessary.

For confirmatory purposes of individual compounds selected isolated toxaphene components are available for analysis. Furthermore, very selected isotope labelled internal standards are available for isotope dilution confirmatory analysis. However, there is no standardised method available for individual toxaphene component analysis.

Consequently the measurement of toxaphene will have to be based on technical mixture using existing American standards. In addition the development of a European standards and of methods for individual congener will have to be of highest priority.

8 Scenarios and Prognosis on future development

Chapter 3 and 4 of this report describe the mass flows of POPs and POP wastes whereas chapter 9 presents a methodology to establish low POP content limit and maximum POP content limit values and results in proposals for feasible limits for the different POP substance groups. Results from current mass flows are a major input for the development of limit values in chapter 9. Limit values on the other hand may have an important impact on future mass flows. Therefore in the following chapter different scenarios are presented and discussed to show the consequences of different possible limit values.

8.1 Function of limit values under the European POP regulation

To date POP substances, except for PCB, are not regulated in the waste sector on Community level. As a consequence the European POP regulation (2004/850/EC) adopted in May 2004 has the purpose to clearly define the management regime for wastes consisting of, containing or contaminated with POPs (further referred to as POP wastes) in accordance with the provisions of the Stockholm Convention.

To this purpose besides other the two following sets of limit values for POP content in wastes shall be established until December 2005:

1. A "concentration limit referred to in article 7 (4)(a)" in Annex IV hereafter referred to as "**low POP content limit**" (LPCL) for the classification as POP waste
2. A "maximum concentration limit of substances listed in Annex IV" (Annex V) hereafter referred to as "**maximum POP content limit**" (MPCL) concerning derogation from destruction

The first set of limit values will have the function of a limit, above which wastes will become subject to the management regime of the POP regulation. These limits will therefore define whether a waste due to its POP content will have to be treated by the destruction or irreversible transformation methods defined in Annex V, part 1²⁸ to the regulation. The low POP content limit corresponds to the low POP content defined under the Stockholm Convention.

By way of derogation from article 7, paragraph 2, alternative treatment options –as defined in annex V²⁹ - may be permitted by Member States for a number of wastes listed in annex V if destruction and/or irreversible transformation do not represent the environmentally preferable option and if the maximum POP content limit is not exceeded. In practice this means that combustion residues as well as non-combustible POP wastes may be disposed of underground or on hazardous waste landfills up to a maximum concentration limit.

²⁸ D9: Physico-chemical treatment, D10 Incineration on land, R1 use as a fuel, excluding waste containing PCB

²⁹ permanent storage in safe, deep, underground hard rock formations, permanent storage in salt mines, permanent storage on a landfill for hazardous waste

The second set of limit values for POP substances in wastes listed in annex V of the POP regulation does not have a correspondence in any of the international Conventions on POPs.

8.2 General implications of limit values

8.2.1 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.

8.2.2 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 MPCCL 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 Waste and Mass flow scenarios in relation to limit values

The volumes of waste flows concerned as well as the specific contamination levels of POPs in the wastes are the major criteria relevant for the impact of potential limit values on the overall mass flow.

In addition it is of special interest to identify the volumes of waste streams currently disposed of at inert waste landfills, non-hazardous waste landfills or by non-hazardous waste incineration as well as the waste streams currently directed to recovery operations, as the exceeding of the low POP content limit would eliminate these waste management options for waste types then classified as POP waste, leaving only hazardous waste incineration or, other destruction / irreversible transformation methods, use as fuel, hazardous waste landfills and underground storage in salt mines or safe hard rock formations as permitted operations.

Based on the data collected and evaluated in the detailed mass flows it is possible to draw conclusions on the concrete effects of different limit values on specific and overall mass flow of the POP substances in question. Thus it is possible to derive conclusions on economic impacts and possible restraints in disposal/destruction capacity that work as limiting criteria in the assessment of feasible limit values. A detailed explanation of the applied assessment methodology is given in chapter 9 while detailed information on the specific mass flows can be found in chapter 4.

In assessing the impacts of limit values it has to be taken into account, that average values do not represent more than 50% of all samples and that the average values used for calculation are partly based on limited data, thus hampering the identification of medians which would give a clearer picture about the distribution of measurement values.

Furthermore it has to be taken into account that the implementation of a limit requires appropriate control. That means that wastes with an average contamination level close to a limit will have to be controlled frequently to detect exceeding. These aspects have to be taken into account when assessing the monetary impacts, technical and administrative efforts of limit values. It may also be reasonable to set up different standards for measurement requirements (frequency, number of samples, pooling) in accordance with the distance to the low POP content limit of average contamination levels in different waste types.

8.3.1 Scenario for PCDD/PCDF

As explained above the impacts of the low POP content limit on the overall mass flow of PCDD/PCDF are a function of the limit value, the contamination level (average and range) of relevant waste types and the volume of waste streams concerned. Thus it is necessary to compile and evaluate the waste streams investigated in the mass flow chapters. An overview on amounts concerned at different low POP content limits (LPCL) is given in the figures below. Detailed information is presented in the related tables in Annex III.

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

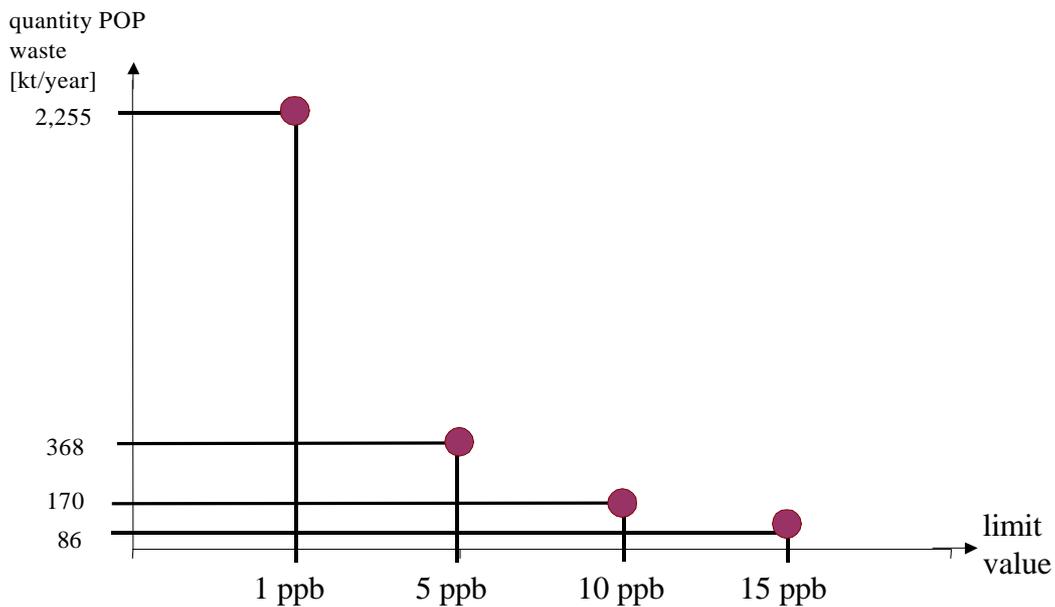


Figure 8-1: Estimated annual quantities of waste classified POP waste due to its PCDD/PCDF concentration (ng TEQ/g) in relation to different low POP content limits

A more detailed compilation illustrating the contribution of individual waste types is given below :

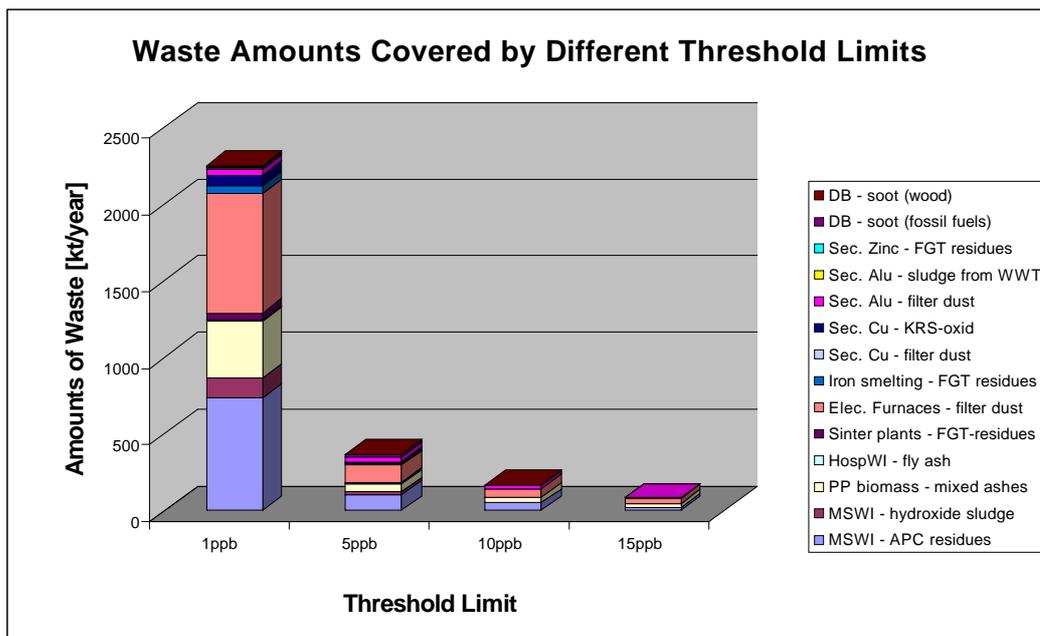


Figure 8-2: Contribution of specific wastes types to amounts exceeding different potential low POP content limits for PCDD/PCDF in EU 25

As illustrated in Figure 8-2 EWC classes 19 (waste incineration) and 10 (thermal processes in metal industry) both listed in Annex V provide the largest share of wastes exceeding all potential limits.

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.

As illustrated in Figure 8-2 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.

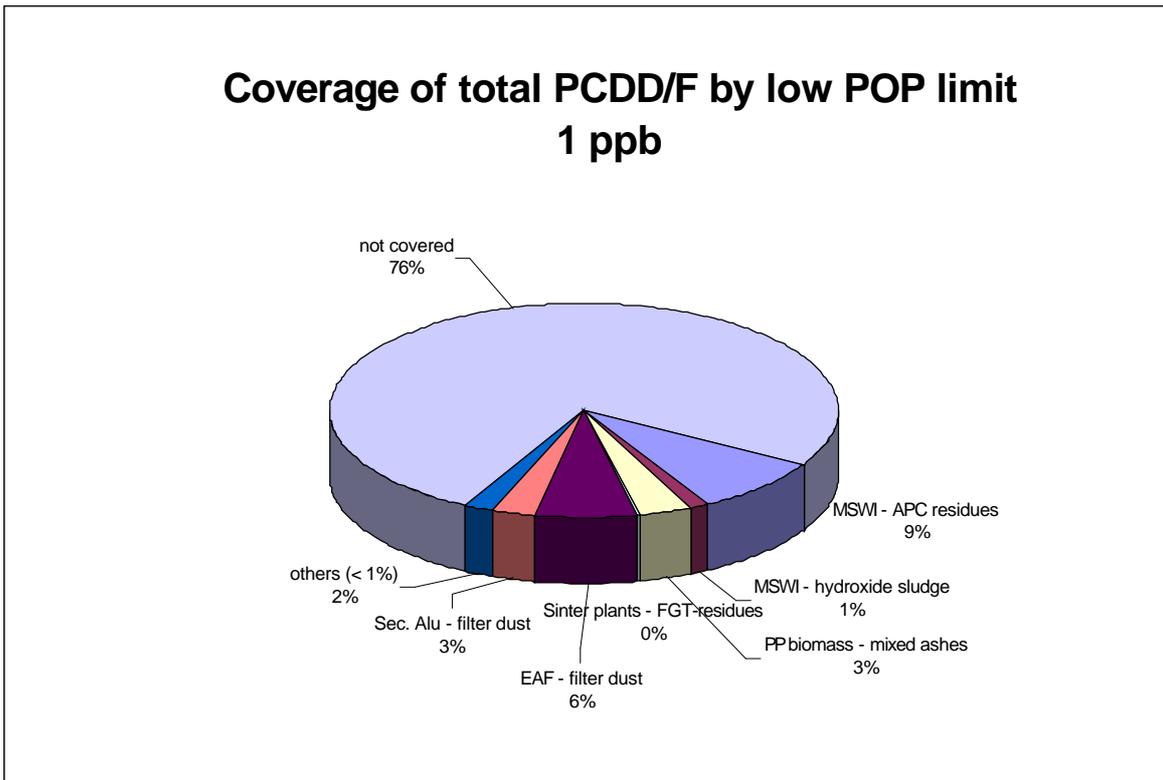


Figure 8-3: Share of total annual PCDD/PCDF discharge to waste in EU 25 covered by potential low POP content limits

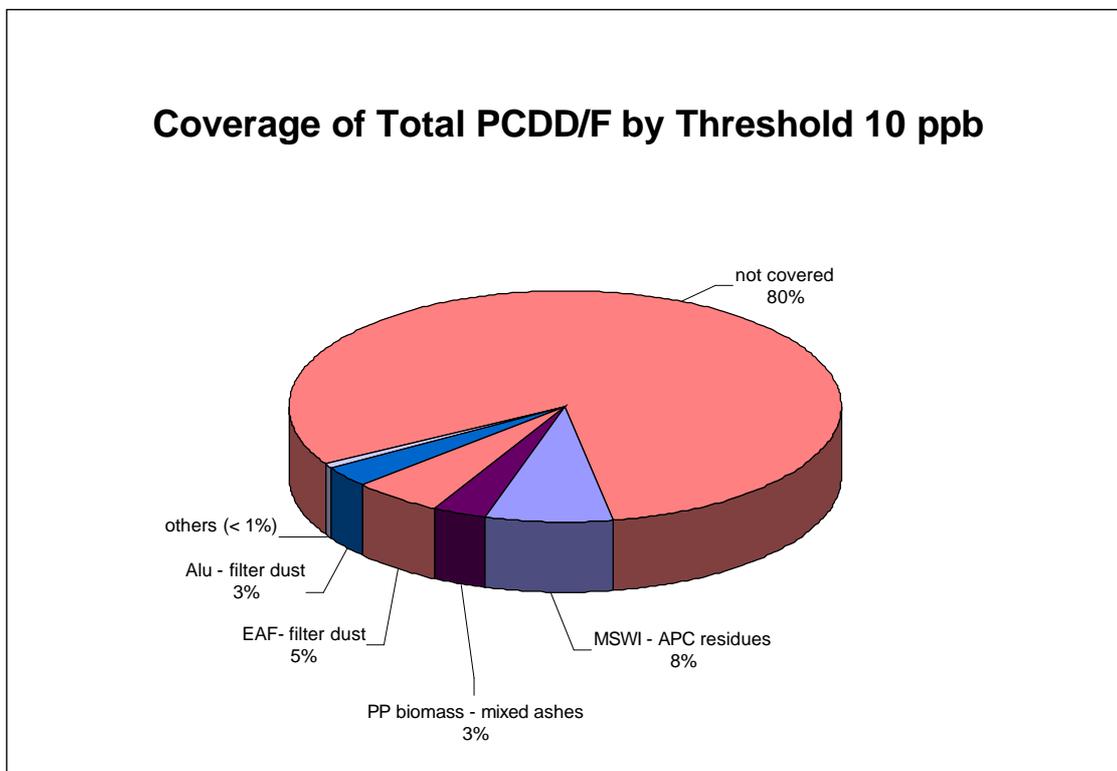


Figure 8-4: Share of total annual PCDD/PCDF discharge to waste in EU 25 covered by potential low POP content limits

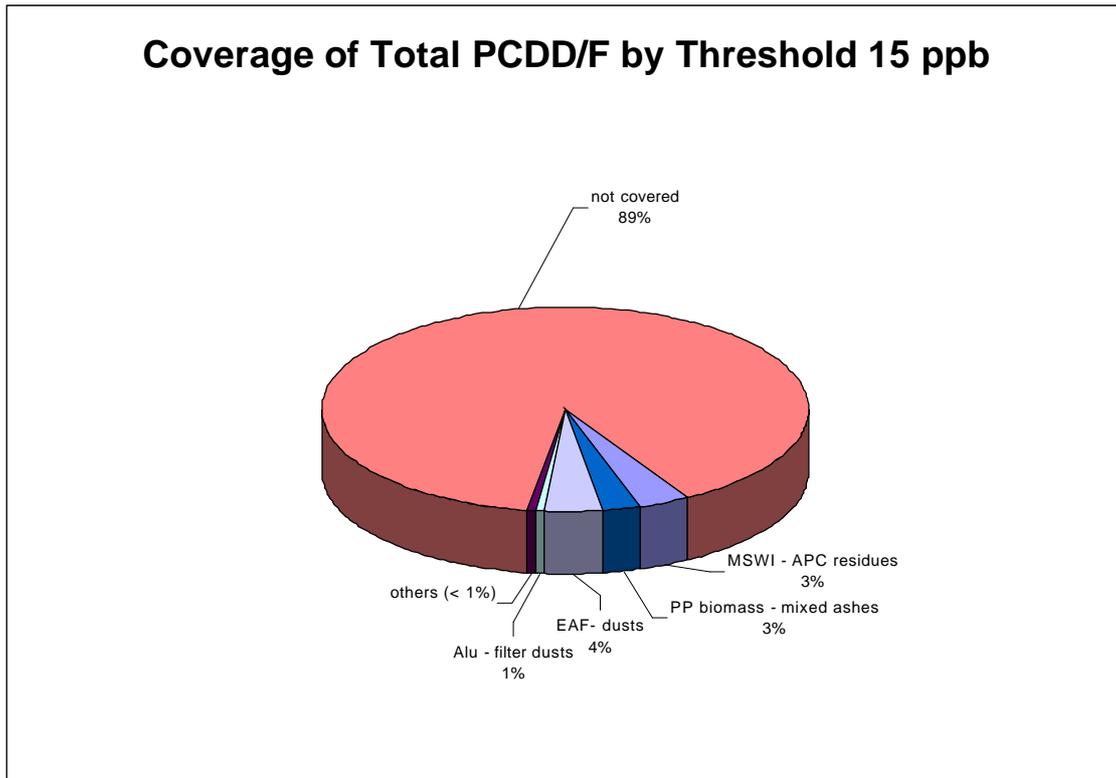


Figure 8-5: Share of total annual PCDD/PCDF discharge to waste in EU 25 covered by potential low POP content limits

8.3.2 Scenarios for PCB

As explained above the impacts of the low POP content limit on the overall mass flow of PCB are a function of the limit value, the contamination level (average and range) of relevant waste types and the volume of waste streams concerned. Thus it is necessary to compile and evaluate the waste streams investigated in the mass flow chapters. An overview on amounts concerned at different low POP content limits (LPCL) is given in the figures below. Detailed information is presented in the related tables in Annex III.

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

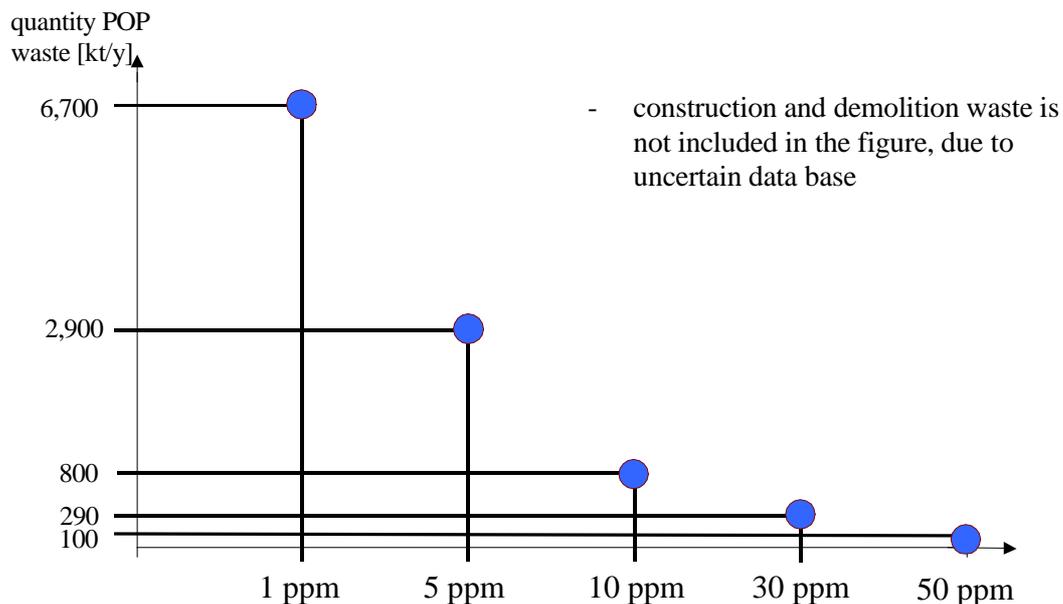


Figure 8-6: Estimated annual quantities in (kt/y) of waste classified POP waste due to its PCB concentration (mg/kg) in relation to different low POP content limits

A more detailed compilation of the relation between limit value and amounts of wastes exceeding them, which illustrates the contribution of individual waste types in given in Figure 8-7 below :

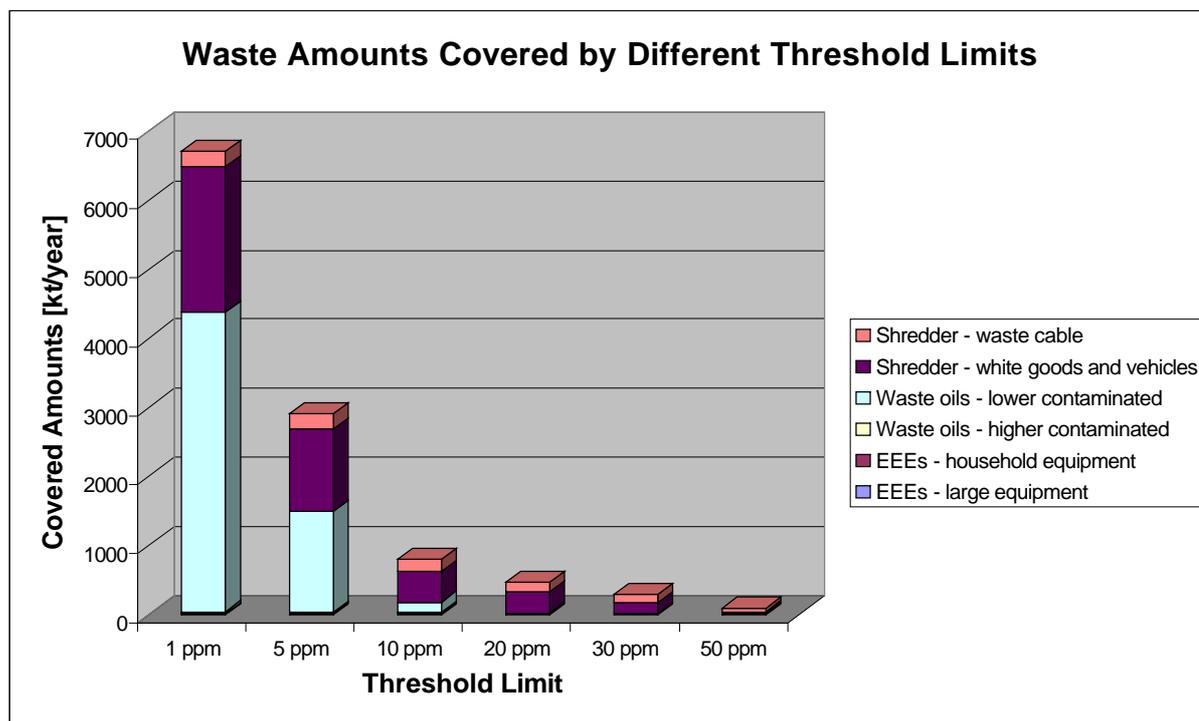


Figure 8-7: Contribution of specific wastes types to amounts exceeding different potential low POP content limits for PCB in EU 25 (C&D wastes not included)

Problems with substance recovery operations and landfilling can be expected for waste oil, construction and demolition waste and shredder non-metallic fraction if the low POP content limit for PCB is low.

As illustrated in Figure 8-7 this effect starts at 50 ppm with the non-metallic fraction of waste cable processing. At 30 ppm and below shredder residues from ELV and white good shredding might get larger importance. Due to large quantities waste oils contribute with the largest share of concerned amounts at lower limits. While there is a limited increase of concerned amounts down to 10 ppm a almost 10-fold raise in amounts occurs at a limit value of 1 ppm as large amounts of waste oil and ELV shredder as well as parts of the sewage sludge would then also be included.

Any of the waste types included in the figure are Annex V wastes as C&D wastes are the only PCB related wastes of importance listed in Annex V to the POP regulation.

In detail the following impacts will be observed in different affected sectors:

Based on the scarce data on PCB contamination and the current legal situation permitting substance recovery of waste oil up to a PCB content of 50 ppm, substance recovery from waste oil would probably already be affected in part by a limit value of 30 ppm even though the overall average contamination in waste oil calculated on the basis of German figures is only 2.5 ppm.

With respect to the shredder non-metallic fraction (light fluff) a low POP content limit will first affect the sector of waste cable residues where average values of 30 ppm have been reported, while ELV shredder residues shows an average contamination of 3 ppm if contaminated parts are carefully separated.

C&D waste which constitutes an important sector with respect to the PCB mass and waste flow has not been included in Figure 8-7 as it is difficult to assess the concerned amounts due to an insufficient data basis. A first rough estimation is presented in Table 8-1.

A contamination of 4.6 ppm (total PCB) has been extrapolated on the basis of available data as average concentration level in potentially contaminated fractions (see chapter 4.2.2). However the actual concentration in waste samples can range from zero to several thousand ppm, which complicates the assessment of this sector.

C&D waste fraction	% total	expected amounts EU 25 [Mt]	% contaminated	expected amounts contaminated [Mt]	EWC	expected average contamination
excavated soil and stones	65	442	5	24	170503	5 ppm
concrete, bricks and tiles	22	150	0.6 -3	1-5	170106 170801	14 ppm 29 ppm
mixed construction and demolition waste	5	34	0.3	0.12	170204 170603 170902 170903	10,000 ppm 9,500 ppm 3,400 ppm 500 ppm

Table 8-1: First estimate on a waste flow of C&D waste and related PCB contamination

Based on this data the C&D sector would play a dominating role with respect to the effects of limit values on disposal capacity.

The use of compost with an average contamination of 0.3 ppm (0.005-0.8), the major part of sewage sludge with average contamination of 0.06 ppm (0.003-1.5) and FGT residues from combustion processes (0.001 – 0.04 ppm) - would only be affected by limit values <1 ppm.

Due to the dominating role of large PCB containing equipment in the overall mass flow of PCB over 80% of the overall discharge of PCB to waste is covered already by a low POP content limit of 50 ppm. The share does almost not change if the limit is lowered to 30 ppm (82.6% to 82.7%).

That means that on the EU 25 scale the major part of PCB discharge will be covered both – by the existing limit of 50 ppm set up in the PCB directive (96/95/EC) and a lower limit of 30 ppm.

The situation however is different for Member States where large PCB containing equipment has already been decontaminated or disposed off. In this case the lower contaminated waste streams gain higher relative importance.

Thus a review of the PCB limit is recommended after 2010 when the highly contaminated waste streams are disposed of.

An illustration about the coverage of the total PCB discharge to waste by potential limit values is given below.

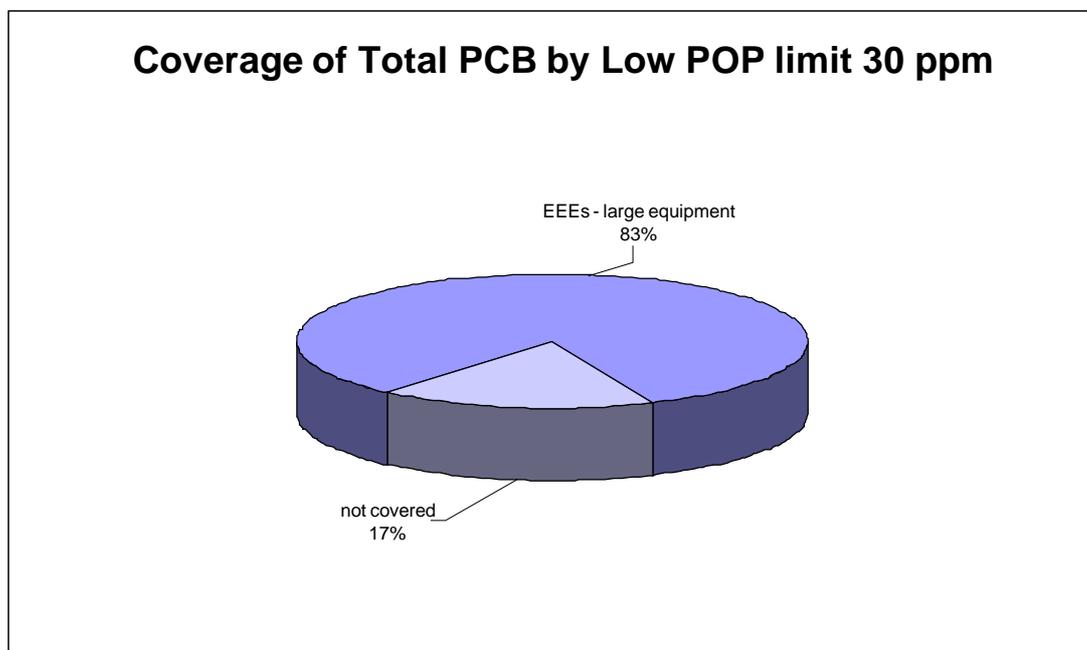


Figure 8-8: Share of total annual PCB discharge to waste in EU 25 covered by potential low POP content limits

8.3.3 Scenarios for POP pesticides and other POPs

Information about concentration levels of POP pesticides and other POPs in waste types other than obsolete products is so scarce that it is difficult to draw conclusions about the impacts of different low POP content limits on these waste streams. The limited information however suggests that contamination levels are either high (up to several hundreds of ppm in obsolete products, contaminated soil and other C&D waste fraction from contaminated sites) or low (<10 ppm e.g. in MSW).

Consequently the decision for a limit of 30 ppm or 50 ppm will most probably not have any effect on the amounts of waste that will be subjected to Annex V of the POP regulation.

8.3.4 *Scenarios in relation to different maximum POP content limits*

Based on information derived from leaching tests performed for POPs in waste and on the technical standards for different landfill classes required in the Landfill Directive 1999/31/EC a maximum POP content limit of 5,000 ppb for the PCDD/PCDF TEQ, 2,000 ppm for PCB and 5,000 ppm for POP pesticides and other POPs has been calculated as level assuring sufficient protection of the adjacent environment.

Based on the information collected and evaluated in the mass flow chapters these limits will normally not be exceeded by any of the investigated waste types listed in Annex V to the European POP regulation.

As suggested by available data exemptions will only occur in C&D waste from contaminated sites.

8.3.5 *Scenarios in view of disposal and recovery*

The following scenarios form the basis for the assessment of impacts of foreseen limit values on disposal capacity and economic feasibility.

8.3.5.1 Impacts on disposal/recovery for PCDD/PCDF waste

In this calculation wastes that are currently directed to hazardous waste landfills, incinerated or sent to underground recovery or disposal are not included. Only the share of fly ash currently recovered in asphalt in the Netherlands (30% from the annual generation of 100,000 tons) is included in the figure. The overall potential for fly ash recovery in EU 25 is calculated separately for the different potential limits.

1 ppb

As illustrated in table Table 8-2 about 1.1 million tonnes of solid residues from metal industry, domestic burning, power production from biomass and fly ashes from MSWI which are currently recycled in the Netherlands will have to be sent to destruction/transformation operations or directed to hazardous waste landfills or underground storage due to elevated PCDD/PCDF levels at a low POP content limit of 1 ppb.

As illustrated in the tables the dominating sector that will be concerned is the secondary metallurgical industry which alone contributes with almost 1 million tonnes to the residues exceeding a PCDD/PCDF-TEQ concentration of 1 ppb. These are largely filter dusts from EAFs and furnace-oxide from the secondary copper industry. Both residues are currently sold and used as infeed material for other high temperature processes in the secondary metal industry for metal recovery. Some industries as the secondary zinc production rely 100% on the EAF dusts and furnace-oxide as raw material and thus would experience severe problems. For other industries as the secondary copper industry both the infeed side and the

product side would be concerned. At a European scale, a limit of 1 ppb would annually exclude from recovery operations e.g. almost 400,000 tons of ashes from biomass power production, almost 800,000 tons of EAF dusts and 66 kt of furnace-oxide from secondary copper production. In addition 20 kt of soot from domestic burning which are currently added to municipal solid waste will be subjected to Annex V.

With respect to recycling of fly ash the amount actually concerned is about 30 kt/y. In case the overall potential for fly ash recycling in EU 25 would be taken into consideration the amount concerned at 1 ppb would be about 700 kt/y.

10/15 ppb

As illustrated in table Table 8-3 about 104 kt of solid residues from metal industry, domestic burning, power production from biomass and fly ashes from MSWI which are currently recycled in the Netherlands will have to be directed to hazardous waste landfills or underground storage due to elevated PCDD/PCDF levels at a low POP content limit of 10 ppb. At 15 ppb this amount will be reduced to 62kt/y (see Table 8-4).

Limit values of 10 (15) ppb would currently impede the recovery of 4,000 (2,500) tonnes of filter dust in the Netherlands provided the European average contamination as calculated in chapter 4.1.1 is transposed to the Dutch situation and the share of 30% that has been reported for recovery is also applied to the fraction of ashes exceeding 10 ppb. The actual figure may be higher . If the overall potential of fly ash recovery in EU 25 is used for the calculation this figure would raise to over 90,000 (70,000) tons.

In addition about 56,000 tonnes of secondary raw material would be lost with a low POP content limit of 10 ppm (mainly EAF dust) from which more than 42,000 kt/y are already currently recycled. This amount could be further reduced to 33 kt/y by adopting a 15 ppm low POP content limit (see table Table 8-3 and Table 8-4).

The coverage of biomass ashes and soot from domestic burning would be reduced to 38 (26) kt and 3 kt respectively.

The following tables show related waste amounts and currently used recovery/disposal operations in relation to potential limit values.

	waste and product	annual waste generation	concerned amounts at 1ppb	substance recovery/non-hazardous disposal	potential substance recovery	disposal hazardous
		[kt/y]	[kt/y]	[kt/y]	[kt/y]	[kt/y]
MSWI	Fly ash, filter dust and other FGT residues	1,048	733.9		733.9	708.5
MSWI (NL)		110	77.0	25.4		
	Hydroxide sludge	187	130.9		130.9	130.9
Power production biomass	fly ash and other solid residues	533	372.9	335.6		37.3
Sinter plants	Residues from FGT	64	44.8	22.4		22.4
EAF	Filter dust	1,113	779.4	545.5		233.8
Iron smelting	Residues from FGT	69	48.5	24.3		24.3
secondary copper	KRS-oxid	95	66.2	66.2		
secondary aluminium	Filter dust	43	39.0	11.7		27.3
secondary zinc	Absorption and filter material	2	1.6	1.6		
domestic burning	soot (fossil fuels)	14	10.1	10.1		
	soot (wood)	15	10.7	10.7		
total		390,879	2,254	1108.2	1947.6	1138.8

Table 8-2: Amounts of waste exceeding a low POP content limit of 1 ppb (PCDD/PCDF-TEQ) in relation to disposal/recovery operations (current practice/potential)

As illustrated in the table recovery/non-hazardous disposal and disposal as hazardous waste are currently almost equally distributed. However there would be a significant recovery potential that could be used provided there are no limitations due to other pollutants (e.g., heavy metals). At a low POP content limit of 10 ppb the related amounts will drop significantly as illustrated in Table 8-3.

	waste and product	annual waste generation	concerned amounts at 10 ppb	substance recovery/non-hazardous disposal	potential substance recovery	disposal hazardous
		[kt/y]	[kt/y]	[kt/y]	[kt/y]	[kt/y]
MSWI	Fly ash, filter dust and other FGT residues	1,048	52.4		104.8	101.2
MSWI (NL)		110	5.5	3.63		
Power production biomass	fly ash and other solid residues	533	37.3	33.57		3.7
EAF	Filter dust	1,113	55.7	42.9		12.8
secondary aluminium	Filter dust	43	21.7	6.51		
domestic burning	soot (fossil fuels)	14	1.4	1.4		
	soot (wood)	15	1.5	1.5		
total		390,879	224	89.6	104.8	117.8

Table 8-3: Amounts of waste exceeding a low POP content limit of 10 ppb (PCDD/PCDF-TEQ) in relation to disposal/recovery operations (current practice/potential)

As illustrated in the table recovery/non-hazardous disposal and disposal as hazardous waste are currently almost equally distributed. However there would be a significant recovery potential that could be used provided there are no limitations due to other pollutants (e.g., heavy metals).

	waste and product	annual waste generation	concerned amounts at 15 ppb	substance recovery/non-hazardous disposal	potential substance recovery	disposal hazardous
		[kt/y]	[kt/y]	[kt/y]	[kt/y]	[kt/y]
MSWI	Fly ash, filter dust and other FGT residues	1,048	21.0		73.4	70.9
MSWI (NL)		110	2.2	2.54		
PP Biomass	Mixed ashes	533	26.6	22.9		2.7
Secondary Alu production	Filter dust	43	4.3			
EAF	Filter dust	1,113	33.4	25.7		7.7
total		390,879	138.0	52.0	73.49	81

Table 8-4: Amounts of waste exceeding a low POP content limit of 15 ppb (PCDD/PCDF-TEQ) in relation to disposal/recovery operations (current practice/potential)

8.3.5.2 Impacts on disposal/recovery for PCB waste

As illustrated in Table 8-5 and Table 8-6 below the following effects on waste management can be observed at different potential limit values. The PCB low POP content limit mainly determines the part of the shredder residues that will be classified POP waste and cannot be processed for material recovery.

1 ppm

1.7 Mt of shredder residues from end-of-life vehicles and waste cables plus 4 Mt of waste oils would require disposal by incineration at a low PCB limit of 1 ppm.

5 ppm/10 ppm

At a limit of 5 ppm 1.6 Mt of shredder residues and waste oils which are currently recovered or disposed of as non-hazardous waste will be subjected to Annex V operations. This amount drops to about 510 kt at a limit of 10 ppm.

In relation to the overall generation of the residues it can be stated that 75% of the cable shredder volume (169,000 tons) and parts (15%) of end-of-life vehicle shredder residues (450,000 tons) will be affected by a limit value of 10 ppm³⁰.

30 ppm/50 ppm

In relation to the overall generation of the residues it can be stated that still 50% for waste cable shredding will be affected by a limit value of 30 ppm. The figure will drop to <25% at a limit of 50 ppm. For ELV and white good shredding residues the share will be <10% or even lower at 30 ppm already. Thus the waste cable shredding is the sector of concern with respect to economic effects of a PCB limit.

The potentially PCB contaminated plastic fraction of waste cables is currently recycled and are mainly used in road maintenance and signalling equipment, in plastic banks for public parks, floorings etc.. The equipment is largely collected and recycled at its end-of-life time, so that the risk for emissions to the environment is limited. Cable shredding is a specialised industry . Besides metal recovery the recovery of the plastic fraction is an important output form the production process as cables consist to about 50% of plastic.

C&D waste

For C&D waste only a rough calculation on concerned amounts is possible for the moment as data have not been provided from industry and the majority of countries. However based on data from German Länder a first extrapolation can be made.

Based on these data about 25 Mt of soils and stones might be expected annually in EU 25

³⁰ (Σ PCB 28+52+101+153+138+180) x 5.

with an average contamination of 5 ppm (range 0 to 2,000 ppm) thus exceeding a potential limit of 1 ppm. At a limit of 10 ppm <5 million tons of contaminated concrete, bricks and tiles might be expected with an average contamination of 14 ppm (range 0.002->1,000 ppm). At a limit > 20 ppm this amount will certainly be < 1 Mt. The highly contaminated fractions such as sealants, floorings etc. might account for about 100,000 tons with an average contamination of several hundred to some thousand ppm. These wastes however have to be sent to destruction operations already today according to the provisions in the PCB directive (96/95/EC).

PCBs											
	PCB containing wastes and products	amount (kt/y)	Amounts of waste exceeding 1 ppm	recovery/non-hazardous disposal	disposal hazardous	Amounts of waste exceeding 5 ppm	recovery/non-hazardous disposal	disposal hazardous	Amounts of waste exceeding 10 ppm	recovery/non-hazardous disposal	disposal hazardous
EEEs	large equipment	14.5	14.5	0	14.5	14.5	0	14.5	14.5	0	14.5
	household equipment	0.61	0.58		0.5795	0.549		0.549	0.,488		0.488
Waste oils	higher contaminated	29	29	15	15	25	12	12	22	11	11
	lower contaminated	5,793	4,345	2,200	1,086	1,448	724	362	145	73	36
Shredder	white goods and vehicles	3,000	2,100	1,680	420	1,200	960	240	450	360	90
	waste cable	225	225	113	113	214	107	107	169	84	84
Total			6,714	3,438	1,648	2,902	1,622	736	800	510	236

Table 8-5: Amounts of waste exceeding low POP content limits for total PCB (1, 5, 10 ppm) in relation to disposal/recovery operations (current practice/potential)

PCBs								
	PCB containing wastes and products	amount (kt/y)	Amounts of waste exceeding 30 ppm	recovery/non-hazardous disposal (kt/y)	disposal hazardous	Amounts of waste exceeding 50 ppm	recovery/non-hazardous disposal	disposal hazardous
EEEs	large equipment	14.5	14.5	0	14.5	14.5	0	14.5
	household equipment	0.61	0.244		0.244			0
Waste oils	higher contaminated	29	7	4	4			0
	lower contaminated	5,793						0
Shredder	white goods and vehicles	3,000	150	120	30	30.0		30
	waste cable	225	113	56	56	56.0		56
Total			284	180	105	100.5	0	101

Table 8-6: Amounts of waste exceeding low POP content limits for total PCB (30, 50 ppm) in relation to disposal/recovery operations (current practice/potential)

8.3.6 Mass flow scenarios in view of mixed contamination patterns and current disposal/recovery routes

It is important to highlight that namely the above mentioned combustion residues are not only contaminated with POPs (mainly PCDD/PCDF) but in general are to a much higher degree contaminated with other substances, such as metals, heavy metals and salts which per se are responsible for the classification as hazardous and as such require the disposal at hazardous waste landfills or underground regardless of any limit on POPs. In the consequence it can be expected that the currently used disposal/recovery path for combustion residues would not change, even if with respect to the POP content a specific treatment was not requested.

8.3.7 Mass flow scenarios as regards environmental contamination

Contamination levels with POPs in various environmental compartments are normally so low that they are several orders of magnitude below the limit values in question.

Elevated levels can only be observed in certain wildlife – namely carnivores feeding on aquatic organisms – if calculated on a fat weight basis. However animal carcasses are explicitly excluded from the scope of the Waste Directive (75/442/EC, article 2 (b,iii)) where they are already covered by other legislation.

8.4 Prognosis on future developments

8.4.1 Prognosis under status quo conditions

8.4.1.1 Prognosis 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 8-9 is expected for 2015.

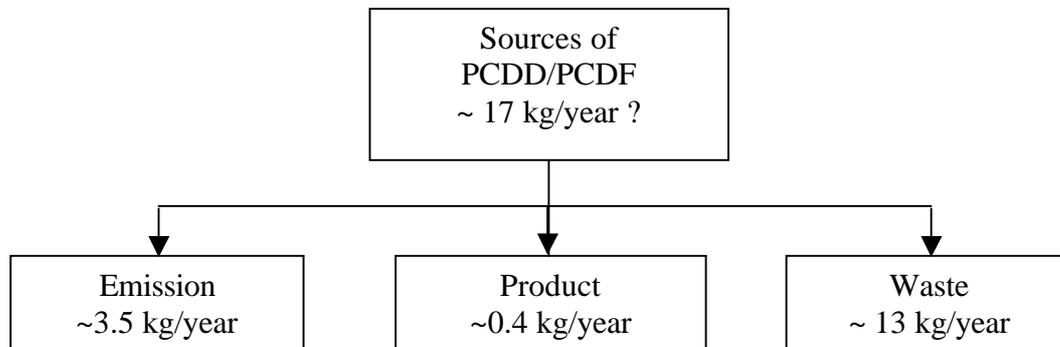


Figure 8-9: Prognostic mass flow of PCDD/PCDF in the year 2015

A prognosis in relation to proposed low POP contents is given in chapter 9.4.1.

8.4.1.2 Prognosis 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 $\frac{1}{4}$ 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 (see chapter 3.7.2) 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

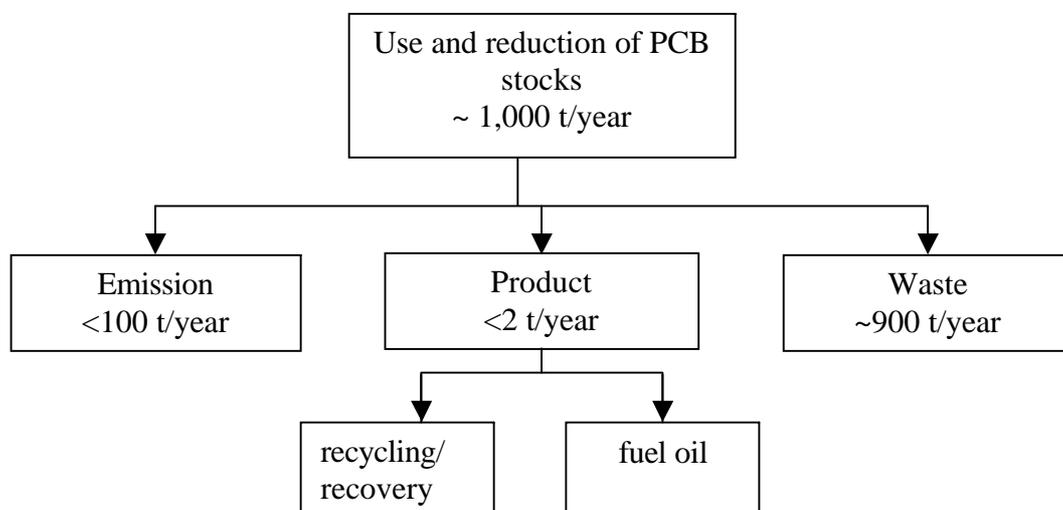


Figure 8-10: Prognostic mass flow of PCB in the year 2015

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 chapter 9.4.2.

8.4.1.3 Prognosis POP Pesticides 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.

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

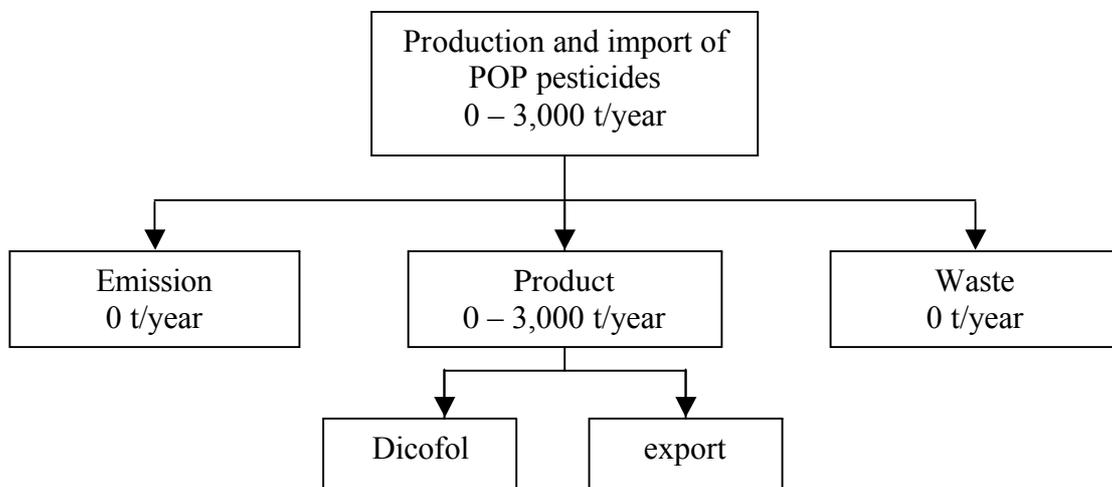


Figure 8-11: Prognostic mass flow of POP pesticides in the year 2015

A prognosis in relation to proposed low POP contents is given in chapter 9.4.3.

8.4.1.4 Prognosis 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 to assess and suggest low POP content limit and maximum POP content limits

9.1.1 Overview and objective of the methodology

For the requirements laid down in the annexes to the European POP regulation (2004/850/EC), two limit values are of major importance:

The **low POP content limit, that has to be established until December 2005 under Annex IV** serves to classify whether a waste is a POP waste or not. It therefore defines the "entry into the POP waste regime" of the Regulation. The low POP content limit might show different limit values for different POPs.

As stipulated in Annex V part 1 for all wastes exceeding this concentration limit, only the following disposal and recovery operations are permitted when applied in such a way as to ensure that the POP content is destroyed or irreversibly transformed:

- D9: (physico-chemical treatment),
- D10 (incineration on land)
- R1 (use as a fuel) .

However, permanent storage (D12) in safe, deep hard rock formations, salt mines or landfill sites for hazardous waste may be permitted according to Article 7 (4)(b) by national authorities in exceptional cases for wastes listed in part 2 of Annex V.

This exemption is possible under two conditions. First, it has to be demonstrated that the selected operation is environmentally preferable. Second, the relevant waste must not exceed a certain maximum POP concentration limit. A corresponding maximum concentration limit for POP substances listed in Annex IV has to be established for these operations.

For wastes listed in Annex V part 2 with a POP content exceeding the **maximum POP content limit as to be established under Annex V**, destruction or irreversible transformation of the POP content by means of D9 (physico-chemical treatment), D10 (incineration on land) or R1 (use as a fuel) operations will be obligatory, as for all other wastes exceeding the low POP content limit in Annex IV to the POP regulation.

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.

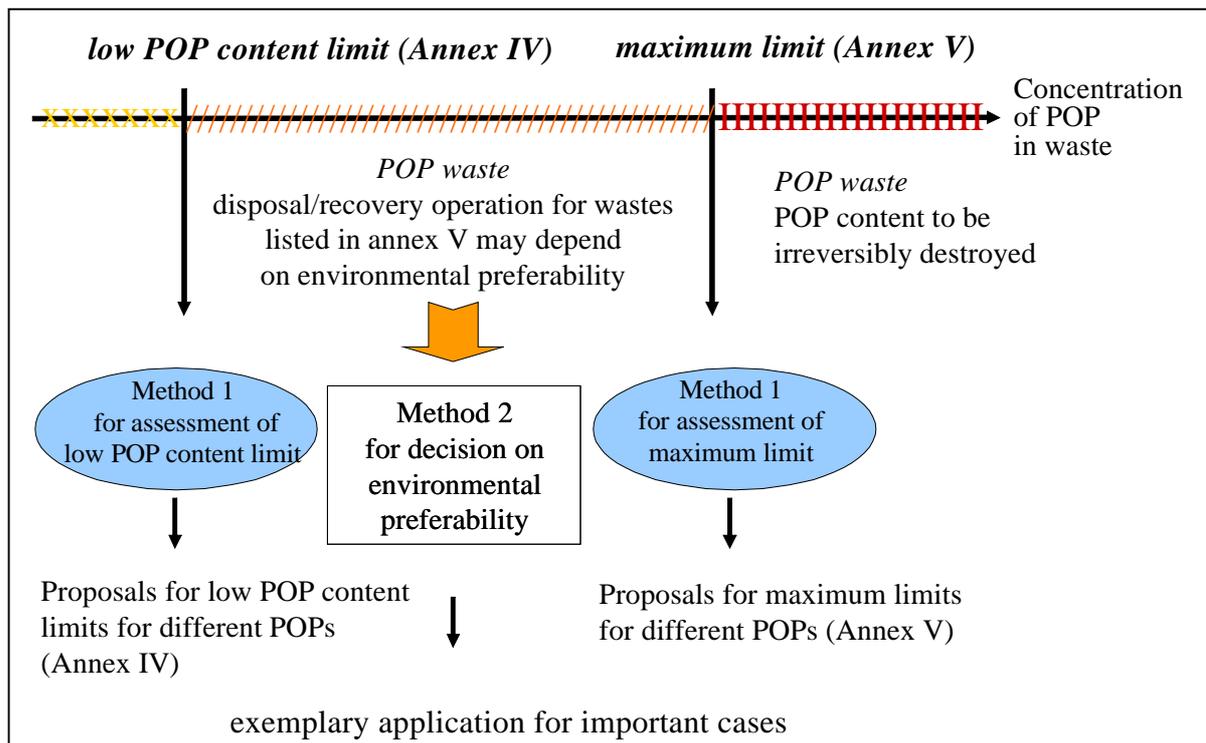


Figure 9-1: Limit values and corresponding methods

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. Method 2 is discussed in chapter 9.5.

9.1.2 Basic principles of Method 1 and corresponding assessment criteria

According to the Communication (2000) 1 final with respect to the Stockholm Convention "measures taken should inter alia be proportional to the chosen level of protection ... (and therefore shall be)...based on an examination of the potential benefits and costs of action or lack of action (including where feasible an economic cost-benefit analysis) ... (Besides this) the scope includes non-economic considerations, such as efficacy of possible options and their acceptability to the public."

Thus the derivation of low POP content limits for the classification of wastes as POP wastes should take into account a number of criteria relevant for the evaluation of impacts and implications of measures to take. These shall include environmental and health aspects as well as technical feasibility, economic impacts and existing commitments. Furthermore the

relative importance of waste streams in terms of amounts of waste and amounts of POPs, as well as the relation between annual contribution and environmental load from other sources have to be taken into account for the suggestion of appropriate low POP content limit values.

The basic principles of the developed methodology are:

- I A set of lower limitation criteria for the low POP content limit indicate POP concentrations below which limit values should not be established.
- II A set of upper limitation criteria for the low POP content limit indicate POP concentrations above which potential limit values should not be established.
- III According to target functions a resulting range allow to reduce the range to a precise low POP content limit.
- IV In case of contradictions between lower and upper limitation criteria additional requirements have to be established to dissolve the contradiction.

Based on the requirements for the methodology mentioned above the following limitation criteria for low POP content limits have been used after evaluation of scientific literature and discussion with stakeholders:

Lower limitation criteria:

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

Upper limitation criteria:

- ◆ X: Precautionary principle 
- ◆ Y: Potential risks to human health and the environment 
- ◆ Z: Existing limit values already agreed by the European Union 

It has to be stated that the limitation criteria are not of equal significance and weight with respect to health and environmental protection, however they are important for implementation and acceptability of the intended measure and are important to assess the efficacy and proportionability of a potential limit value. However the methodology has been designed to be flexible to up-coming knowledge and technical development and thus will be able to take up new information.

Consequently the proposals for limit values in chapter 9.2 reflect implementable limits based on current knowledge and the present technical status. The results however will change with up-coming knowledge and technical changes, so that a review process and a flexible adaptation of the limits in the Annexes to the POP regulation should be foreseen.

All limitation criteria are described and justified in detail in chapter 9.1.3.

A possible distribution resulting from evaluation of the lower and upper limitation criteria is illustrated in Figure 9-2.

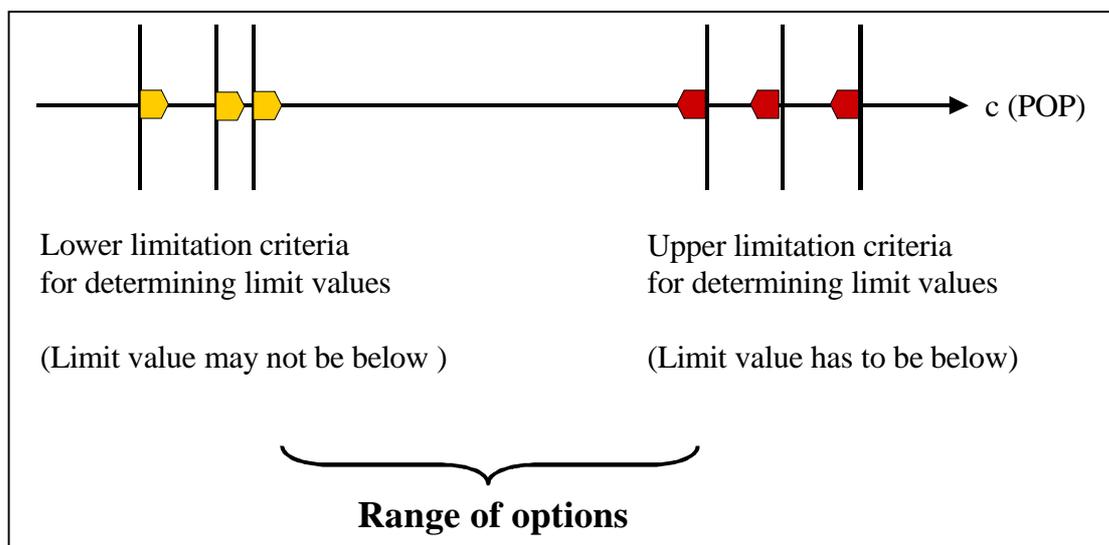


Figure 9-2: Resulting range after application of lower and upper limitation criteria

One can expect that the resulting range of feasible limit values differs for different POPs and different results will turn up for different waste codes. Thus it will not be possible to derive feasible proposals for limit values. Consequently the number of possible limits has to be reduced to a come up with a implementable proposal. For this purpose the methodology makes use of target functions as standard decision tool in decision theory in order to reduce or eliminate the range of potential limit options.

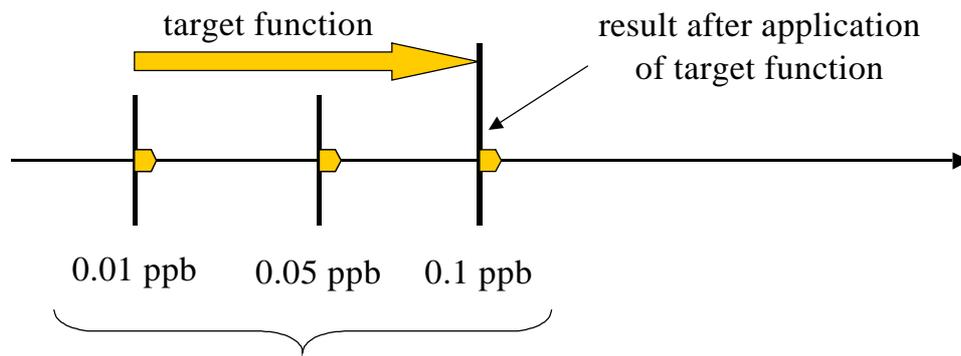
Target function I "Reduce results for different waste matrices to the most unfavourable waste matrix" has been applied to Criterion A (analytical potential) in order to reduce the large variety of achievable limits of quantification to an implementable value.

As a second tool criterion X (precautionary principle) as defined under the Stockholm Convention (Articles 5-7)

"Each party shall ...take ...measures to reduce the total releases...with the goal of their continuing minimization and, where feasible, ultimate elimination "

has been used as target function II in the final decision on a limit proposal in the range marked by upper and lower limitation criteria.

An exemplary illustration for the effect of target function I is given in Figure 9-3 below.



Analytical sensitivity in different waste matrices

Figure 9-3: Target function I for reduction of varying analytical sensitivity in different waste matrices

The effect of target function II is exemplarily illustrated in Figure 9-4.

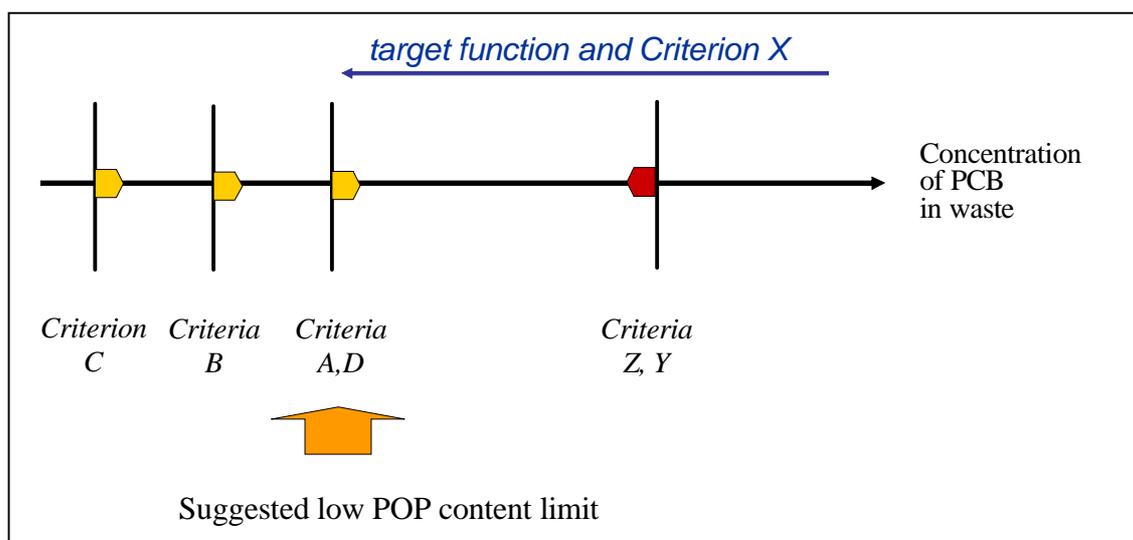


Figure 9-4: Target function II for decision on low POP content limit in the range between upper and lower limitations

If target function II is not applied the two edges of the range can be taken as two options for suggestions of limit values.

However it is not necessarily assured that requirements resulting from upper and lower limitation criteria follow the clear arrangement presented in the figure above. Instead they may result in controversial and contradictory requirements for limit values:

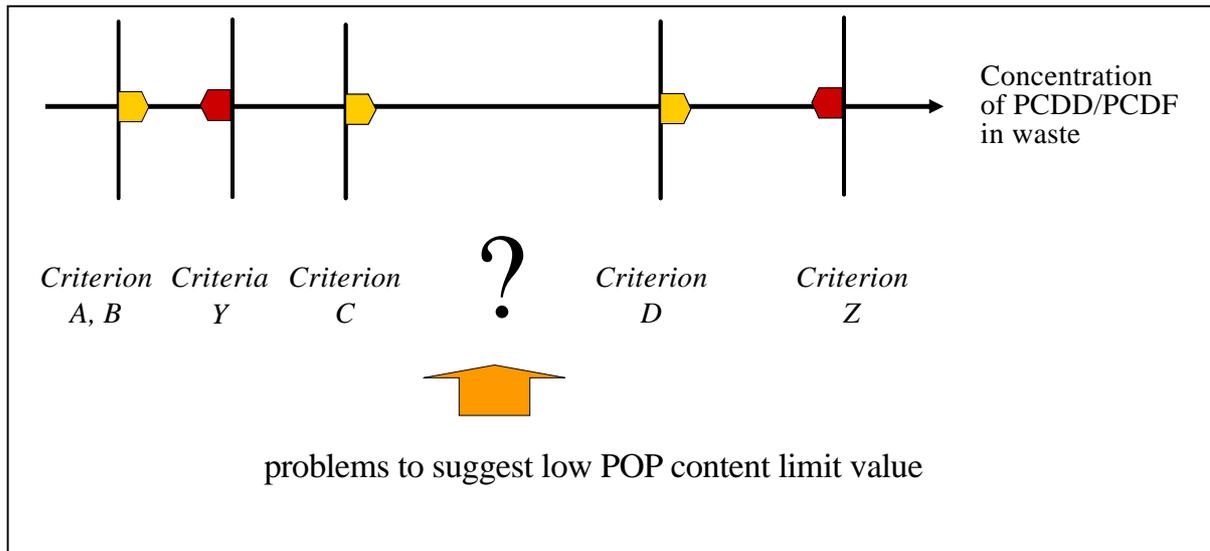


Figure 9-5: Conflict of interest between lower and upper limitation criteria

In this case there is a contradiction between the results of the criteria. Additional requirements have to be established to dissolve the contradiction (following basic principle IV).

For the derivation of maximum POP content limit values the same lower limitation criteria can be used in principle. However, according to the POP Regulation, the maximum POP content limit values can not be established below the low POP content limit value (see Figure 9-1). therefore, once the low POP content limit values are derived, the lower limitation criteria for maximum POP content limit values can be concentrated into one single lower limitation criterion: "low POP content limit values".

For the application of upper limitation criteria the following considerations can be made: Following the intention of the POP Regulation and the application of Method 2 for environmental preferability, it is not necessary to apply criterion Y, because the precautionary principle is already taken into account when the decision on environmental preferability is taken (application of Method 2). Also criterion Z is not applicable as limit values are not yet agreed.

As a consequence the derivation of maximum POP content limit values is reduced to the following question/criterion:

Above which POP concentration can risks occur in a worst case scenario to humans or the environment that do not allow application of an environmental preferable solution other than destruction or irreversible transformation?

9.1.3 Lower and upper limitation criteria of Method 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.

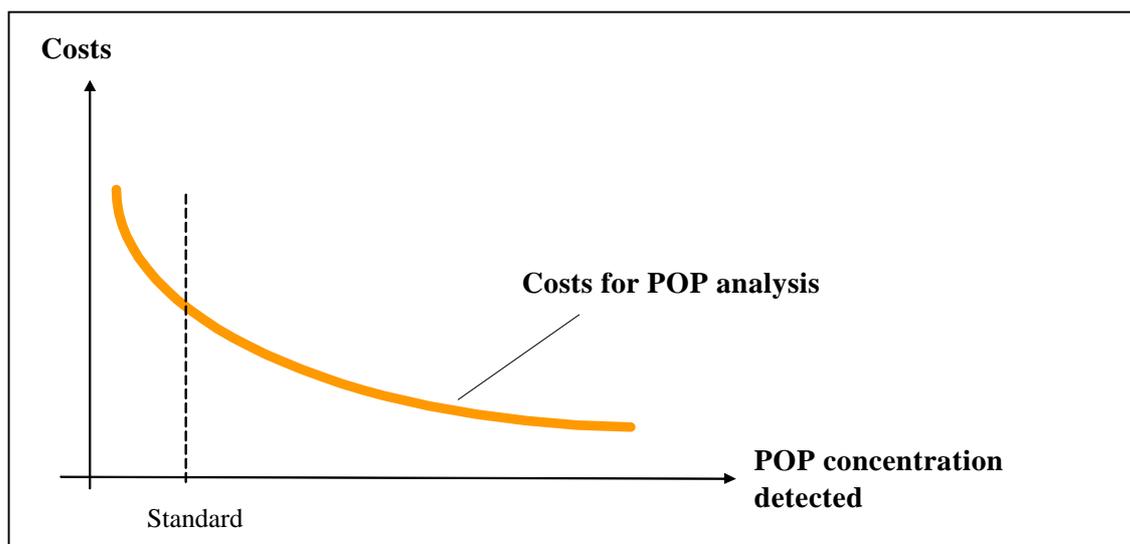


Figure 9-6: Feasible level of quantification as a function of costs and analytical sensitivity (schematic curve)

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 2³¹ and Level 3 On-site verification³²). Measurement techniques will have to be validated and issued as CEN 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.

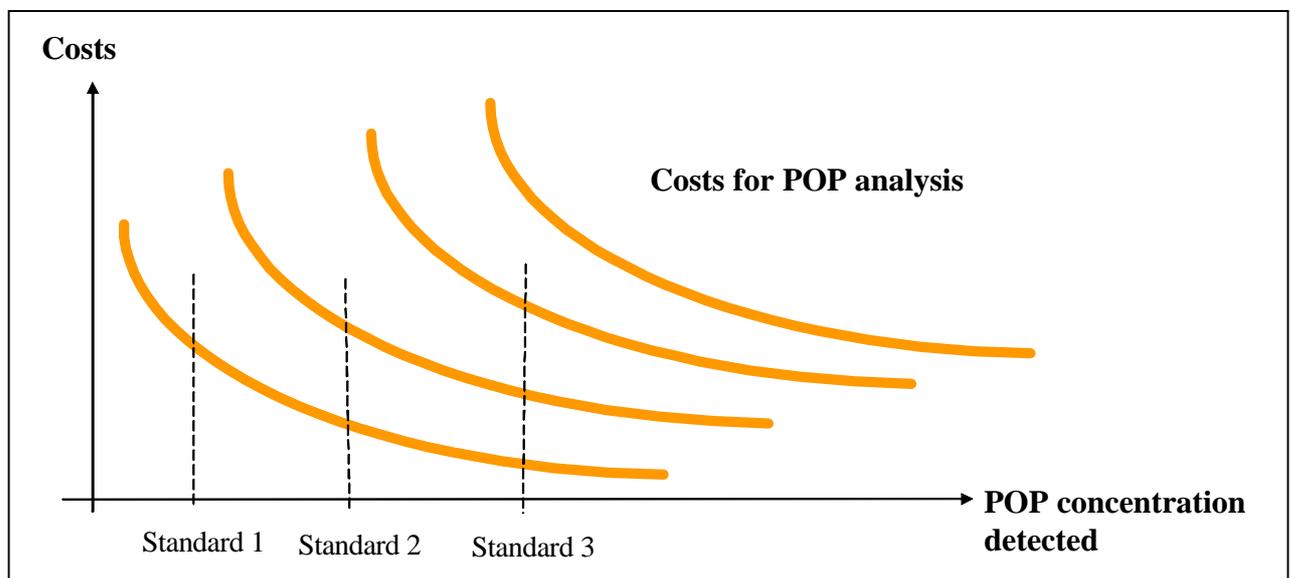


Figure 9-7: Series of cost-measurable concentration curves (schematic curves)

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 (see Figure 9-3).

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

³¹ Compliance testing. This constitutes periodical testing by simpler standardised analysis and behaviour testing methods.

³² 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

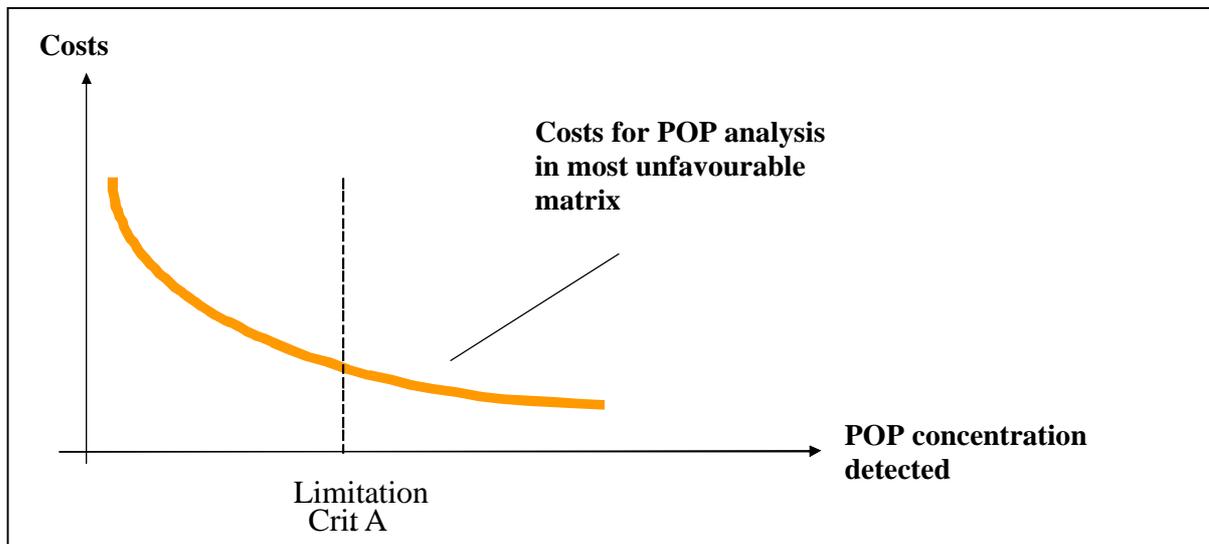


Figure 9-8: Limitation for most unfavourable matrix (schematic curve)

Besides quality requirements that have to be fulfillable 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. The results are presented in chapter 9.2.

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 chapter 5. “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.

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 (see chapter 4) and follows the scheme below.

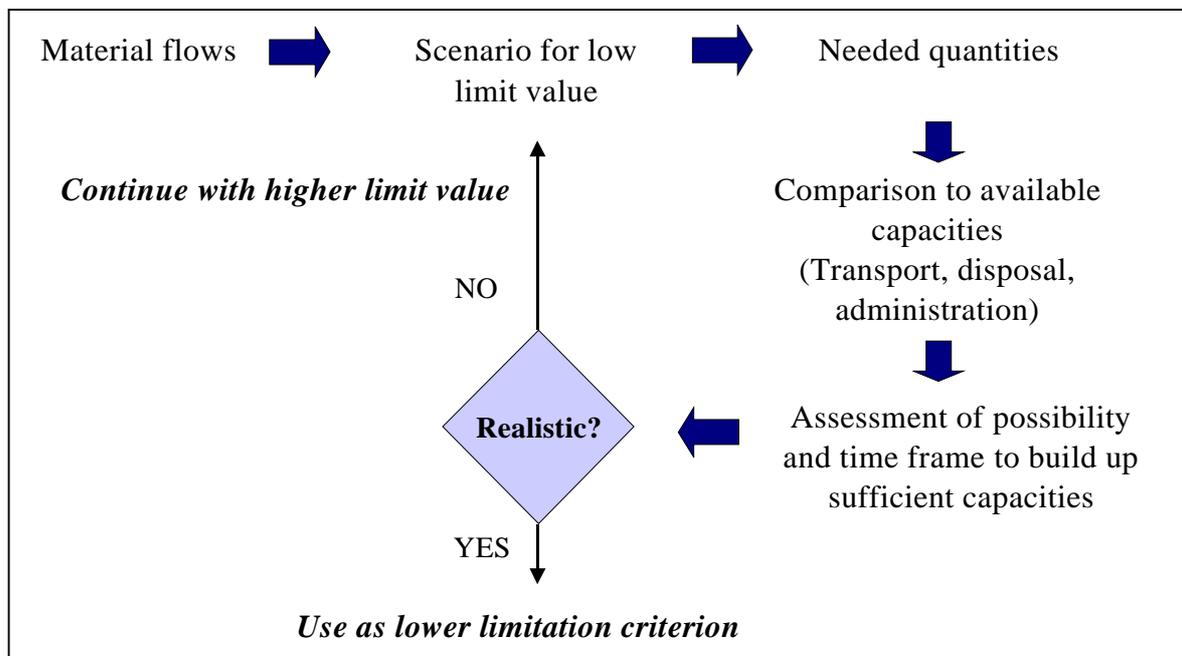


Figure 9-9: Impact on mass flow and disposal/recovery capacity as a limitation criterion for the definition of the low POP content limit

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 in chapter 8.3 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 9-10 exemplarily:

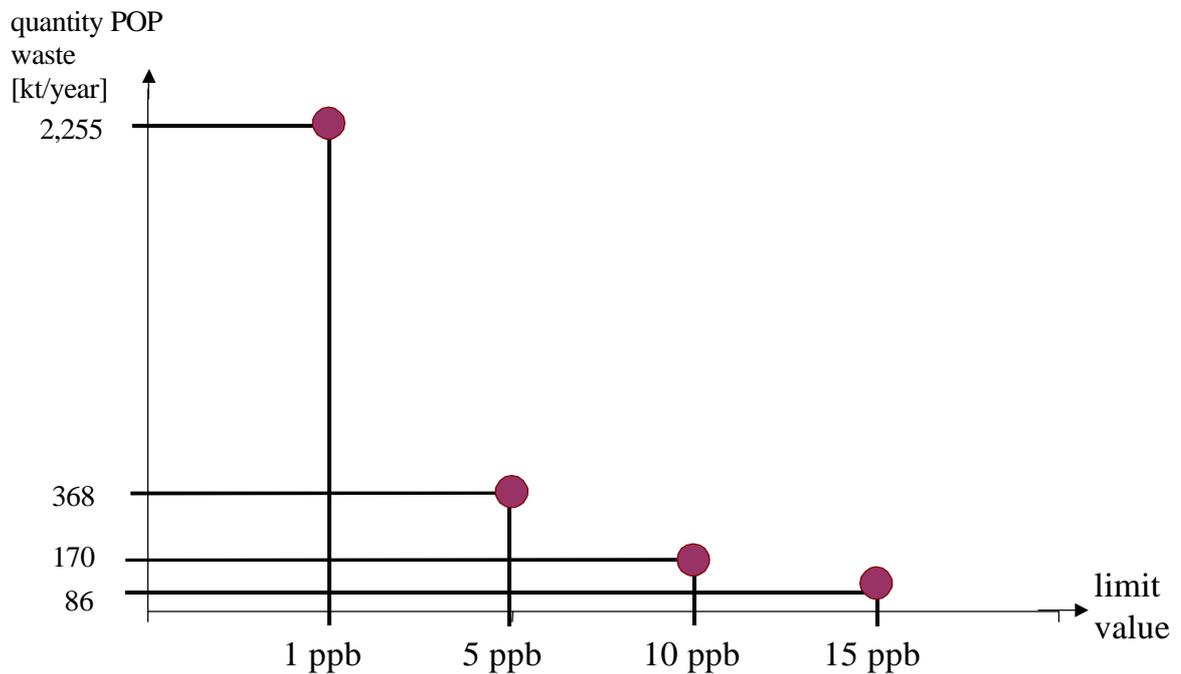


Figure 9-10: Exemplary correlation of low POP content limit and quantities waste exceeding the concentration

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

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.

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 9-11.

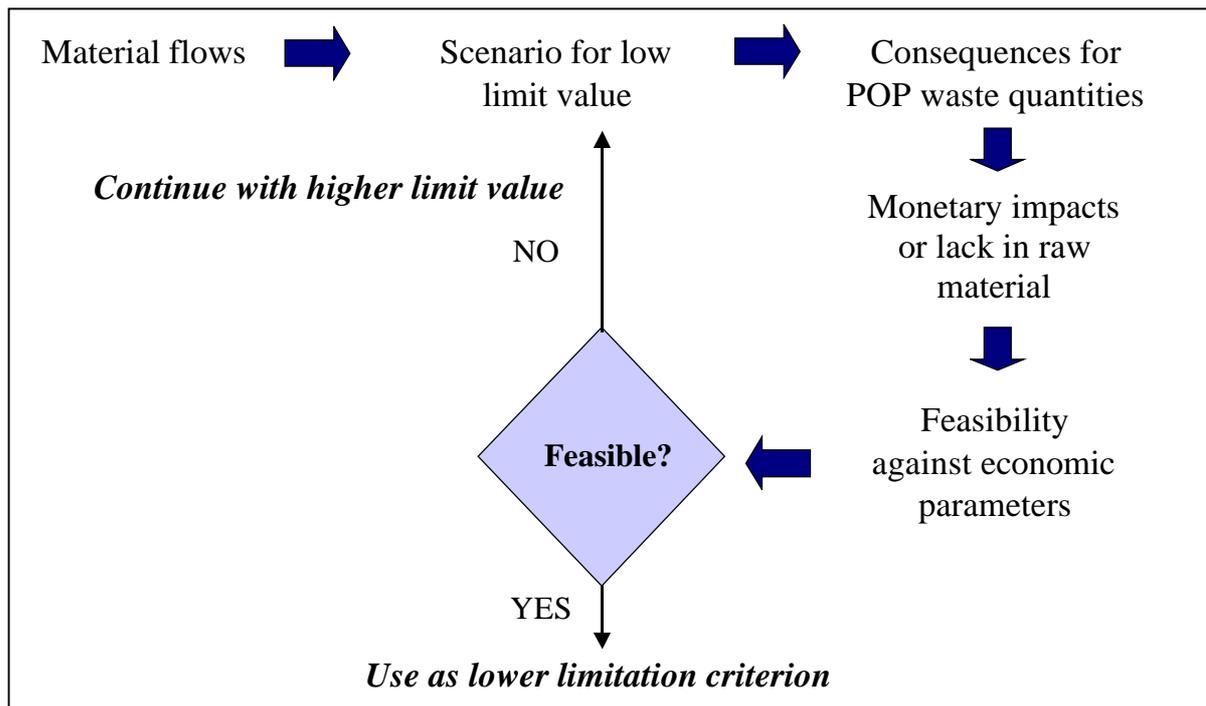


Figure 9-11: Economic impacts as a limitation criterion for the definition of low POP content limits

On the other hand 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 does not allow a complete economic and environmental risk assessment as part of an economic impact assessment (corresponding information will be therefore shortly discussed in paragraph 9.2.1).

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

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.

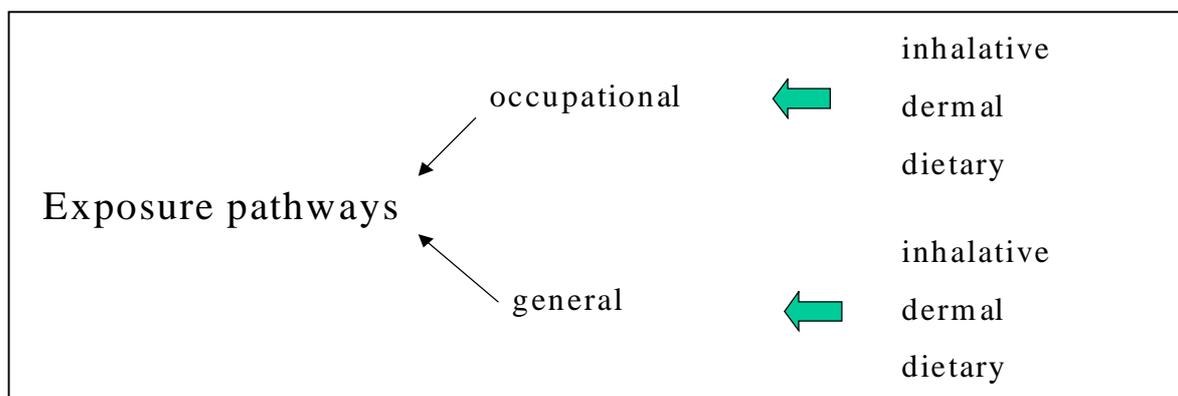
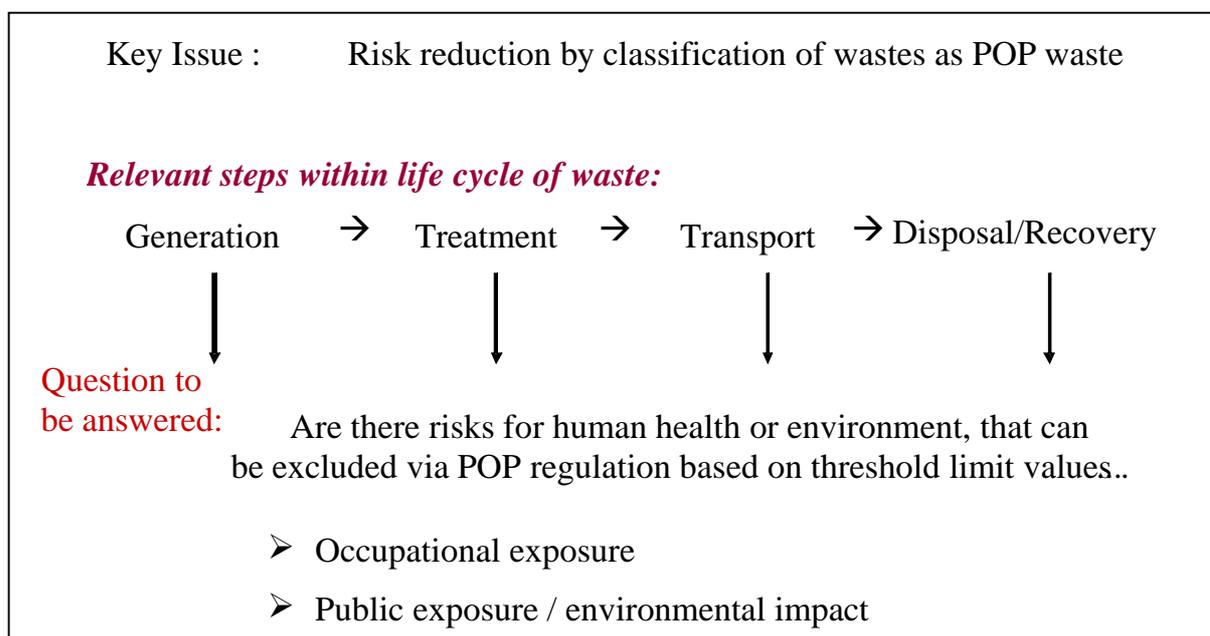


Figure 9-12: Exposure model according to the Risk Assessment methodology

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.



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 will be explained in detail in paragraph 9.2.1 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.

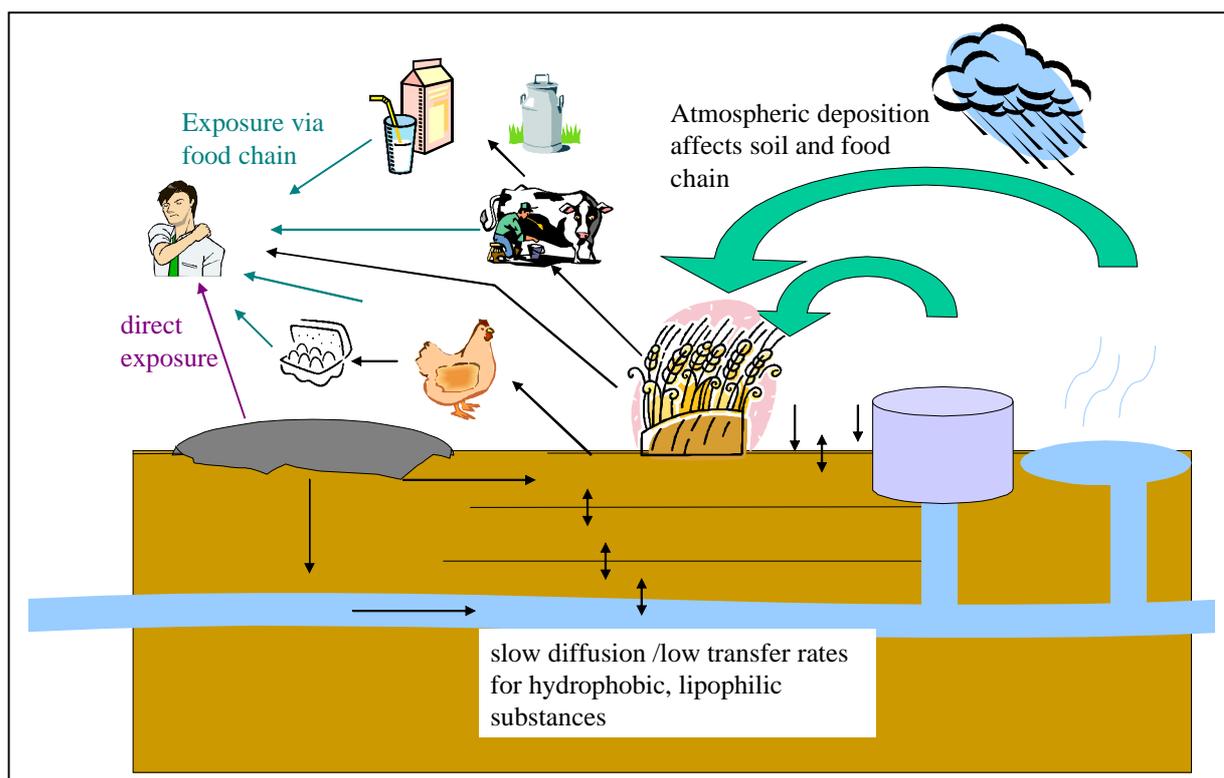


Figure 9-14: Releases from application of PCDD/PCDF contaminated material to soil

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. For further details and precise results see chapter 9.2.

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.

Following guidance documents of the European Commission to the precautionary principle

the mentioned target function II will be applied in a differentiated way. This means, that the resulting benefits for the environment, which can be demonstrated by changes of the material flows will be considered with respect to other impacts of low POP content limit values.

9.2 Proposals for low POP content limits

The proposals for low POP content limit values presented in this chapter reflect implementable limits based on current knowledge and the present technical status. The results however will change with up-coming knowledge and technical changes, so that a review process and a flexible adaptation of the limits in the Annexes to the POP regulation should be foreseen. As explained in chapter 9.1.2 the final proposals are the intersection of the requirements from each of the investigated criteria A-D (lower limitations) and X-Z (upper limitations).

The investigation is restricted to effects due to the POP content of wastes. Classification as hazardous or restriction in use due to other pollutants is not in the scope of this study. However current disposal/recovery practice reflecting this is taken into consideration for the assessment of disposal capacity and economic impacts.

9.2.1 Results of lower limitation criteria

The requirements with respect to acceptable concentration limits for POPs in waste discussed in this chapter result from an investigation of the current status and state of the knowledge in all investigated issues in order to provide a technical basis for the political discussion. It has however to be pointed out, that requirements and limitations for most of the criteria are flexible and will change with up-coming knowledge and technical development. Thus a review process and further investigations in a number of topics should be foreseen.

Results for criterion A: Analytical potential

This chapter compiles the results of investigations on measurement methods and achievable analytical sensitivity. A more in depth discussion of basic measurement requirements, available standards and the ongoing standardisation process in CEN TC 292 is presented in chapter 7.

The assessment is not based on lowest achievable limit of detection (LOD) but based on well justified limits of quantification (LOQ) in currently used standard methods including state of the art and expert knowledge on limitations and restrictions due to matrix properties.

Based on these internationally agreed standard methods, using the most unfavourable matrix as a reference³³, the following limits of quantification (LOQ) are achievable for the different POP substance groups.

³³ being well aware that the different POPs can usually be measured at concentrations far below the concentrations that are measurable in unfavourable matrices

	limitation A	example for most unfavourable waste
Dioxins	0.1 ppb	Solvent mixtures containing chlorinated solvents
PCBs	1 ppm ind. congen. 30 ppm tot. PCB*	Solvent mixtures containing chlorinated solvents
POP pesticides HCB, HxBB	1 ppm ind. congen.	Solvent mixtures containing chlorinated solvents

* concentration calculated as PCB on the basis of $\Sigma 6$ cong. x 5

Table 9-1: Legally justified limits of quantification for different POP substances and substance-groups in the most unfavourable matrices,

The concentrations indicated as limitation level are derived from the assessment of the analytical potential of a established standard suited best for the substance in question and most appropriate for waste matrices, taking into consideration also applicability for the intended purposes – mass screening. The curves depict sensitivity-cost relations of available measurement techniques that have been plotted for the different POP categories.

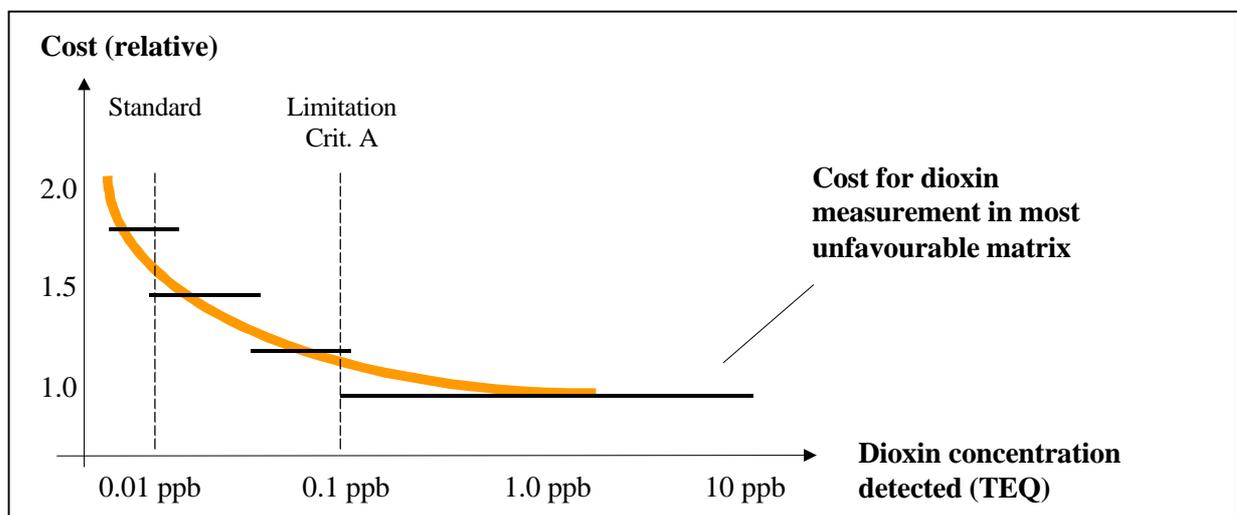


Figure 9-15: Analytical potential for the measurement of PCDD/PCDF concentrations (Detection method: HRGC/HRMS)

In contrast to the analysis of PCDD/PCDF where measurement of the TEQ concentration is generally based on 17 congener, the applied limit concentration for PCB is highly depending on the calculation system used. Thus a limit proposal for PCB will necessarily have to be accompanied by the mode for calculating the PCB content.

As the project team had to decide on a uniform calculation system for all levels in waste and for analytical sensitivity in order to work with comparable figures it has - for the purpose of this study - decided on the calculation a PCB based on the measurement of 6 Indicator congener multiplied by a factor of five.

This leads to the following calculation:

Limit of detection (LOD) for individual congener = 0.2 ppm

LOD for the Sum of 6 Indicator congener (28, 52, 101, 153, 138, 180) = 1.2 ppm

multiplication factor for limit of quantification (LOQ) = 5

multiplication factor for total PCB (German standard) = 5

LOQ per individual congener: $0.2 \text{ ppm} \times 5 = 1 \text{ ppm}$

or

LOQ for total PCB (German standard): $0.2 \text{ ppm} \times 6 \times 5 \times 5 = 30 \text{ ppm}$.

All concentrations in waste and all suggestions for limit values in this study are based on the sum 6 Indicator congener approach.

If it is decided by the European Commission to base the limit values in the POP regulation on a total PCB calculation by the Sum 7 approach (Σ PCB 28, 52, 101, 153, 138, 180, 118) the resulting limitation A would be:

LOQ for total PCB (based on Sum 7): $0.2 \text{ ppm} \times 7 \times 5 = 7 \text{ ppm}$

Both approaches provide the same preciseness. Currently there are some practical problems if limit values are established on a sum 6 Indicator congener approach and measurements are done on a sum 7 approach. Therefore it is essential to clearly define the same approach as a basis for limit values and necessary measurements.

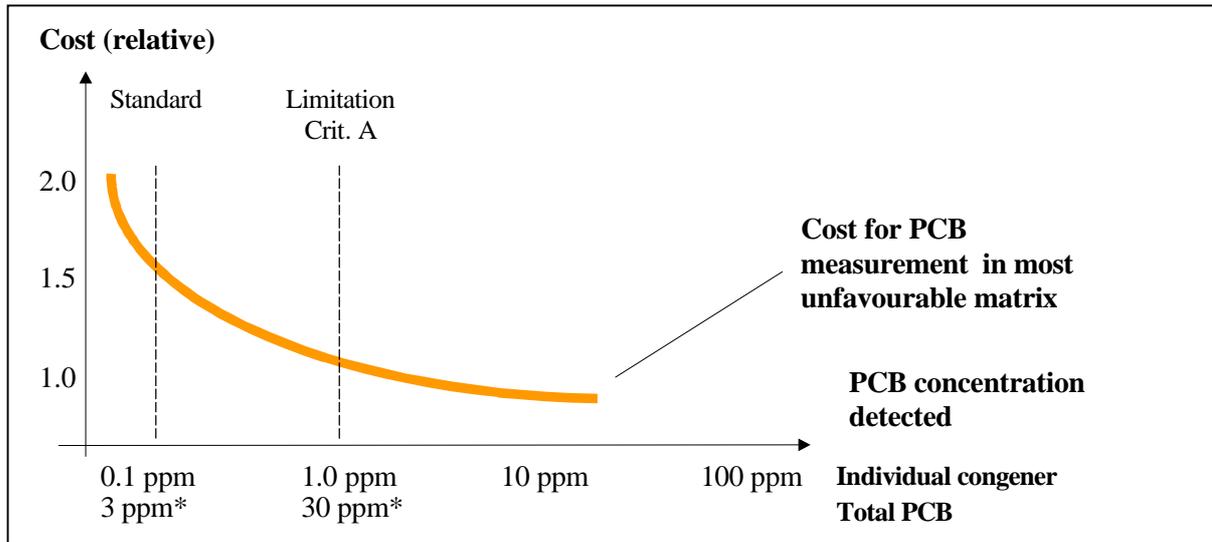


Figure 9-16: Analytical potential for the measurement of PCB concentrations (Detection method: GC/ECD, GC/MS)

* (Σ PCB 28, 52, 101, 153, 138, 180) x 5

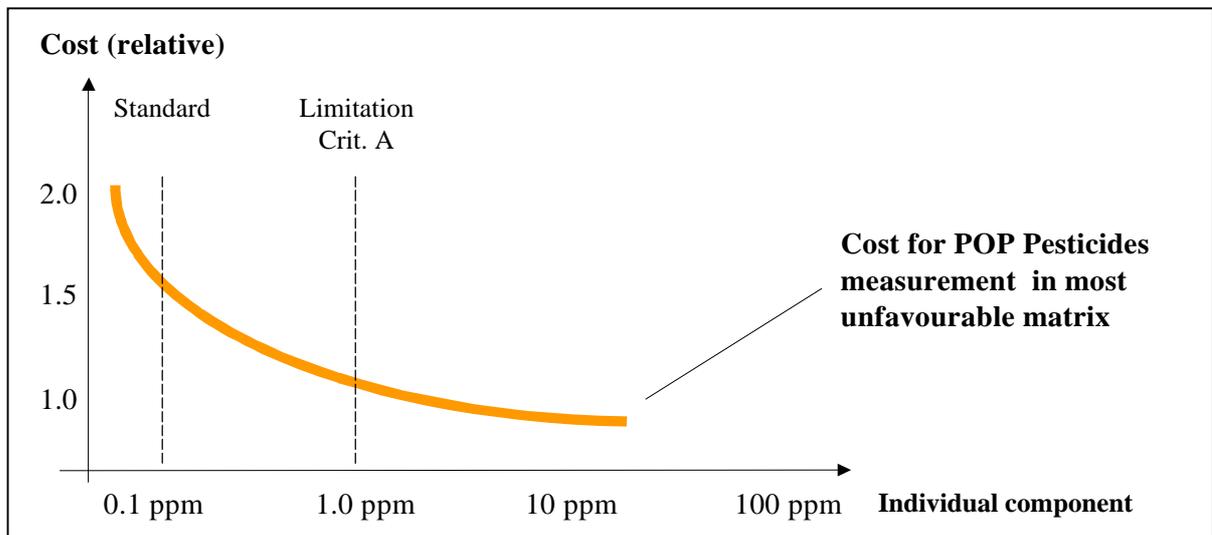


Figure 9-17: Analytical potential for the measurement of POP pesticide, HCH, HCB, and HxBB concentrations (Detection method: GC/ECD, GC/MS)

The analytical sensitivity for POP pesticides and other POPs is based on single congener measurements.

Measurement standards for these POPs are not yet available for waste matrices but have been extrapolated from standards for other compartments which can be used for waste as well. For detailed information see chapter 7.

Results for criterion B: Environmental background contamination

Information on common contamination levels in different environmental compartments has been derived from various studies and is discussed in more detail in chapter 5. As levels have declined significantly over the last decades recent data have been used where possible. To facilitate the comparison to average levels in environment with a number of investigated types of waste, a comparative overview is given in Table 9-2 below. For more detailed information on the environmental background status see chapter 5.

compartment/waste	PCDD/PCDF	PCB	Pesticides	HCH, HCB, HxBB
ambient air	0.5-24 10^{-6} ppb	0.1-0.7 10^{-6} ppm		0.05-0.2 10^{-6} ppm
Water	max. 90 10^{-6} ppb	10^{-9} ppm	0.05 10^{-6} ppm	< 10^{-6} ppm
Soil	<0.001-0.1 ppb	<0.001-0.4 ppm	< 10^{-3} -0.1 ppm	0.2-5 10^{-3} ppm
hot spots	>1,000 ppb			
Vegetation	0.2-5 10^{-3} ppb	20-200 10^{-3} ppm		0.2-2 10^{-3} ppm
Wildlife	0.1-0.4 ppb fat weight (<0.006 ppb w.w.)	0.5-5 ppm fat weight	0.01-20 ppm /fat	0.04-0.1 ppm
wildlife hot spot		3-300 ppm fat weight	800-4000 ppm	9 ppm
Food	< 10^{-3} -0.05 ppb/fat	<0.01-1 ppm/fat		
human milk	0.015 ppb	0.3-0.5 ppm	0.05-5 ppm	0.1-0.3 ppm
ashes coal combustion	0.01 ppb	n.d.	/	/
fly ash MSWI	1.68 ppb		/	/
fly ash HWI	0.3 ppb	0.1 ppm	/	0.04 ppm (0.02-0.06 ppm)
ashes EAF steel production	1.1 ppb	n.d.	/	/
fly ash secondary Aluminium prod.	10 ppb	n.d.	/	/
ashes secondary zinc production	0.1 ppb	n.d.	/	/
construction and demolition waste	low	4.7 ppm	cont. material up to > 1,000 ppm	cont. material up to > 1,000 ppm
waste oil		3 ppm	/	/
shredder residues		3 ppm		n.d.
municipal solid waste	0.04 ppb	0.0004 ppm		
Compost	0.01 ppb	0.67 ppm		
sewage sludge	0.03 ppb	0.09 ppm		
bottom ash	0.021 (MSWI) –	0.04 ppm	/	/

compartment/waste	PCDD/PCDF	PCB	Pesticides	HCH, HCB, HxBB
	0.013 (HWI) ppb			
slag	0.001 – 0.005 ppb (iron+steel production) 0.01 – 0.02 ppb (non ferrous industry)	/	/	/
ash domestic burning - wood	0.11 ppb	0.0085-0.025 ppm	/	/
ash domestic burning - coal	0.056 ppb	0.01-0.02 ppm		

Table 9-2: Dimension of contamination in environmental media and exemplary waste categories in EU 25

For the derivation of limitation criterion B, soil has been chosen as the corresponding environmental compartment as it resembles best by property to solid residues. Hot spot levels are not included in the specification of the background level but rural and urban background is contained where possible. Furthermore the data background is rather different for the different POP groups. In particular for the group of other POPs the available representative data background is very limited. This is compensated for by an “uncertainty factor” that shall express the uncertainty related to the availability of representative data and that shall take into account the likelihood for common background levels to be exceeded.

The calculation leading to limitation criterion B values is presented in Table 9-3, with Table 9-4 explaining the different uncertainty factors chosen.

	background concentration	uncertainty factor	criterion B
PCDD/PCDF	0.001 ppb	10	0.01 ppb
PCB	1 ppm	10	10 ppm
POP pesticides	0.1 ppm	100	10 ppm
other POPs	0.1 ppm	100	10 ppm

Table 9-3: Results for limitation criterion B

	Uncertainty factor	justification
PCDD/PCDF	10	higher levels occur in urban/industrial soils and wildlife
PCB	10	
POP pesticides	100	higher uncertainty factor due to insufficient data basis
other POPs	100	

Table 9-4: Uncertainty factors for environmental background levels

Results for criterion C: Disposal/recovery capacities

The amount of waste to be dealt with as POP waste strongly depends on the applied low POP content limit value. Based on the information derived from the mass flow (see tables in chapter 8.3 and annex III) the potential quantities of waste subject to the POP regime can be plotted as a function of the low POP content limit. Figure 9-18 and Figure 9-19 show the impacts on waste flows in relation to potential low POP content limits for PCDD/PCDF and PCB.

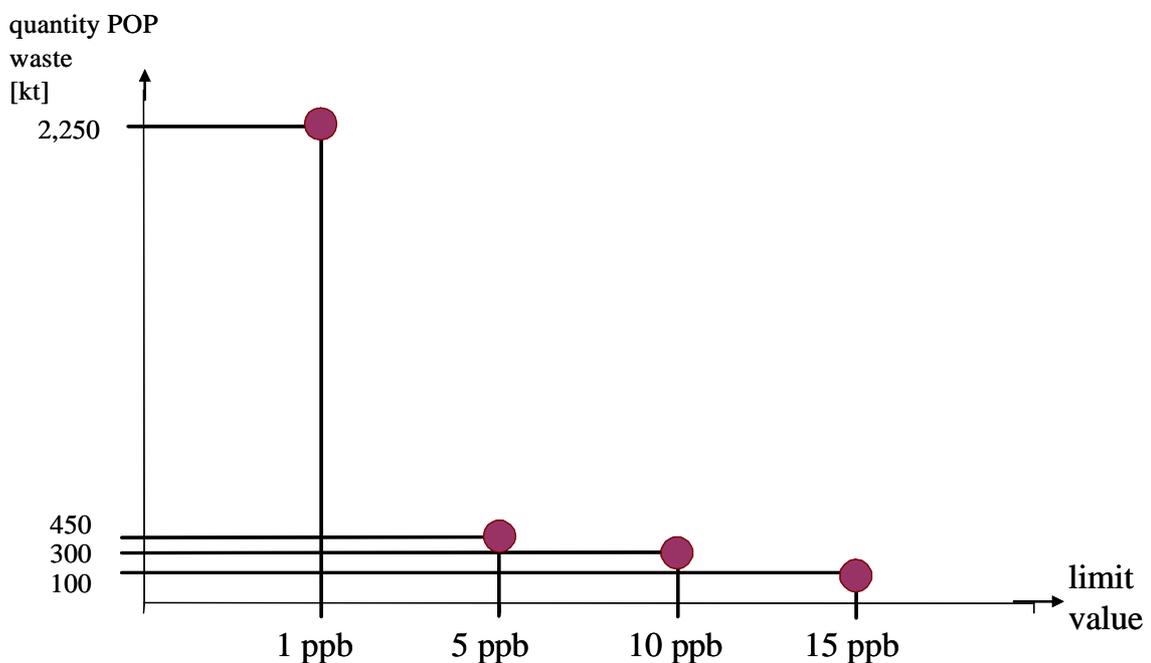


Figure 9-18: Correlation of PCDD/PCDF low POP content limit and quantities of POP waste

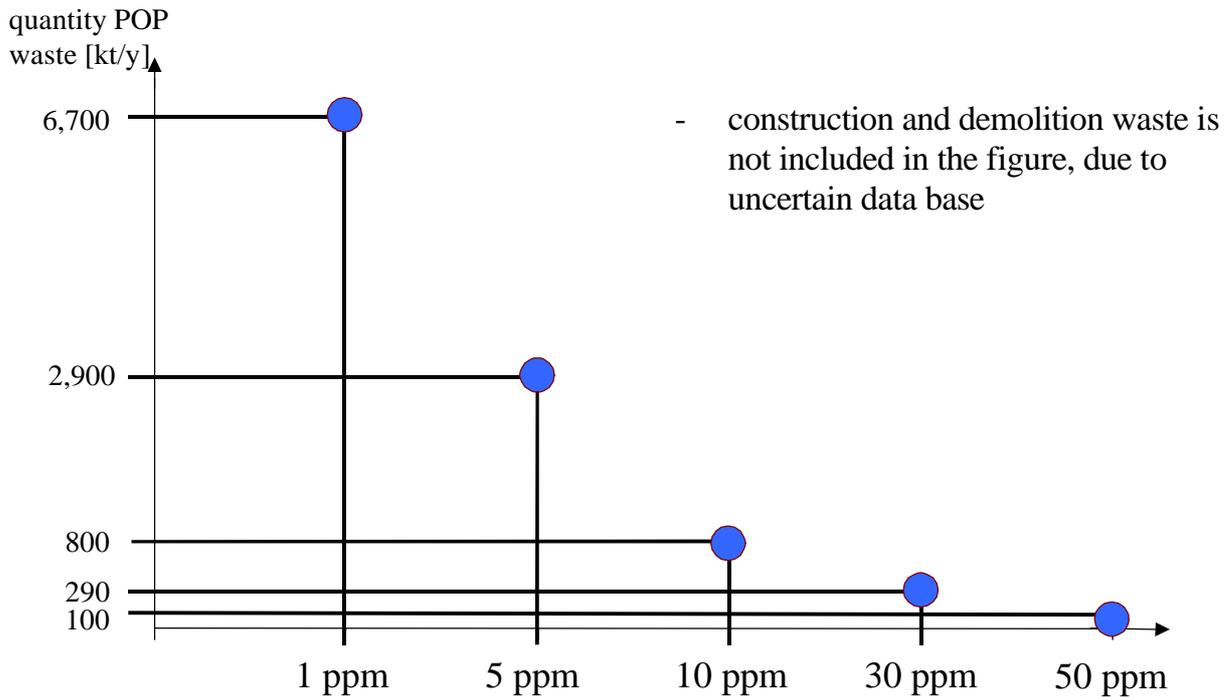


Figure 9-19: Correlation of PCB low POP content limit and quantities of POP waste

The remaining disposal volume has to be checked for the limitation criterion C. However, additional factors like infrastructure and administrative capacity might cause further restrictions. Based on current expert statements, knowledge and expertise, additional waste amounts in a dimension of less than 10% of the annual total disposed volume will not cause capacity shortage.

To date, 23 million tonnes of hazardous waste are annually landfilled (including underground storage) across and appropriate combustion capacities for hazardous waste amount to about 5 million tonnes Europe-wide. Additionally capacities of co-incineration in cement kilns 2-3 Mt and capacities of non combustion destructive technologies of less than 1 Mt have to be considered.

The 10% approach thus leads to possible additional disposal in a dimension of 2.3 million tonnes landfilling per year and less than 0.8 million tonnes destruction/ irreversible transformation. Against this background the remaining disposal volume does not cause further restrictions.

If additional amounts of POP waste exceed 10% of the current totals, it can be assumed that local or regional shortages will occur. Furthermore, a significant increase in transport expenses and administration (transboundary transport, decision on environmental

preferability) have to be expected.

According to the provisions in annex V, part 2 of the POP regulation landfilling is only possible if environmental preferability is accepted by the authorities. Therefore only the 0.8 million tonnes of additional destruction and irreversible transformation capacity can be taken into consideration for the assessment.

For the calculation of capacity problems due to limit values of the POP regulation only those waste amount are considered that are not yet disposed off as hazardous waste.

In chapter 4 there is a detailed compilation on the relation between waste amounts exceeding different POP concentrations and currently used waste management operations. This allows conclusions on additional waste volumes at different potential limit values.

As illustrated in Table 8-3 in chapter 8 about 90 kt of solid residues from metal industry, domestic burning, power production from biomass and fly ashes from MSWI which are currently recycled in the Netherlands will have to be directed to hazardous waste landfills or underground storage due to elevated PCDD/PCDF levels at a low POP content limit of 10 ppb. This figure however will raise to 210 kt at 5 ppb and will reach 1.1 million tonnes if the limit value is 1 ppb.

Due to PCB concentrations 1.8 Mt of shredder residues from end-of-life vehicles and waste cables which are currently landfilled or recycled plus 2.2 Mt of waste oils would require disposal by incineration at a low PCB limit of 1 ppm. This amount would drop to 1.6 Mt (1.0 shredder + 0.6 waste oil) at a limit of 5 ppm and to about 500 kt (440 shredder + 60 waste oil) at a limit of 10 ppm (see Table 8-5).

For C&D waste only a rough calculation on concerned amounts is possible for the moment as data have not been provided from industry and the majority of countries. However based on data from German Länder a first extrapolation can be made. According to this information about 25 Mt of soils and stones might be expected annually in EU 25 with an average contamination of 5 ppm (range 0 to 2,000 ppm); in addition 1-5 million tons of contaminated concrete, bricks and tiles might be expected with an average contamination of 14 ppm (range 0.002->1,000 ppm). The highly contaminated fractions such as sealants, floorings etc. might account for about 100,000 tons with an average contamination of several hundred to some thousand ppm. The 1-5 Mt of higher contaminated concrete, bricks and tiles as well as the 100 kt of highly contaminated PCB containing materials are already currently disposed of as hazardous waste, so that they would not require additional disposal capacity. The low contaminated are assumed to be not relevant for incineration or irreversible transformation due to low caloric values.

Obsolete POP pesticides and impregnated waste woods are already currently destroyed. Only contaminated soils and C&D wastes might be relevant for POP pesticides and other POPs. Due to caloric values no major amounts are expected in a concentration range between 1 and 50 ppm.

In Table 9-5 amounts of waste are summarised that are currently not disposed off as hazardous waste and will in any case need additional capacities as POP waste.

	additional amounts at 10 ppb/ppm	additional amounts at 5 ppb/ppm	additional amounts at 1 ppb/ppm
PCDD/PCDF (TEQ)	90 kt	210 kt	1.1 Mt
PCB	500 kt	1.6 Mt	4.0 Mt
POP pesticides and other POPs	not relevant within range 1-50 ppm	not relevant within range 1-50 ppm	not relevant within range 1-50 ppm

Table 9-5: Additional installation capacities designated for the destruction** of the POP content in waste depending on different low POP content limits

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 9-6: Combined effects of PCDD/F and PCB related waste streams on required disposal/recovery capacity

As a result of the table and of the "available capacity approach" problems are expected at the following low POP content limit values:

PCDD/PCDF:	1 ppb
PCB:	5 ppm
POP pesticides:	no problem
Other POPs:	no problems

No problems are expected at low POP content limit values of 5 ppb for PCDD/PCDF and 10 ppm for PCB.

The project team is well aware that this is a rough calculation (considering the 10% factor as stated above and the uncertainty of existing data), on the other hand the differences of waste amounts between 10 ppb, 5 ppb and 1 ppb limit values for PCDD/PCDF and a 10 ppm, 5ppm and 1 ppm limit values for PCB are quite obvious.

Taking future developments into consideration it might be possible that even for a 1 ppb limit value for PCDD/PCDF capacity problems can be solved, a 5 ppb level for PCDD/PCDF should be ok in any case.

Results for Criterion D: Economic feasibility

Based on the results of the mass flow analysis (see chapters 3 and 4) it is possible to assess economic impacts of potential low POP content limits, in terms of arising restrictions for reuse and recovery operations. Such restrictions will create both additional costs of disposal and analysis or loss of return for the waste owner, and additional costs of primary raw materials for the receiving industry (e.g. asphalt manufacturers, waste management/recovery facilities, secondary metal industry, etc.) .

This chapter compiles the results of waste flow scenarios in relation to potential low POP limits. It was not possible in the scope of the project to perform a economic impact analysis in all details and for every single case where consequences arise from low POP content limit values. It has to be taken into consideration that costs strongly depend on market conditions and can differ significantly between countries.

It is nearly impossible to assess economic feasibility with a consensus of all concerned stakeholders as interests are obviously different. For economic feasibility also costs of a no action option (including possible environmental damage) have to be considered what defines problems due to a lack of data for many cases.

Consequently the project team restricted the investigations on the most critical sectors and concentrated on examples/case studies with quite obvious results. Examples, that potential

low POP content limit values offend economic feasibilities can be seen in the following case studies:

As illustrated in chapter 8 the dominating sector that will be concerned is the secondary metallurgical industry. This industry contributes with almost 1 million tonnes to the residues exceeding a PCDD/PCDF-TEQ concentration of 1 ppb and with about 150,000 t exceeding 5 ppb which are currently recovered to a large extent or disposed off as non hazardous wastes. These are mainly filter dusts from EAFs and furnace-oxide from the secondary copper industry. Both residues are sold and used as infeed material for other high temperature processes in the secondary metal industry for metal recovery. Some industries as the secondary zinc production rely 100% on the EAF dusts and furnace-oxide as raw material and thus would experience severe problems most probably this industry would disappear in Europe. For other industries as the secondary copper industry both the infeed side and the product side would be concerned. Competitiveness of this industry in Europe would suffer significantly within the worldwide competition if recovery would not be permitted anymore.

Additional costs of PCDD/PCDF can be roughly calculated in the following way:

EAF filter dusts:	recovery: + average assumed with 100 €/t (depending on market situation)
	disposal: - 200 €/t (price for hazardous waste disposal)
Furnace oxide:	recovery: + average assumed with 100 €/t (depending on market situation)
	Disposal: - 200 €/t
MSWI fly ashes:	recovery: + average assumed with 10 €/t (depending on market situation)
	Disposal: - 200 €/t
Mixed ashes biomass:	Disposal: - 100 €/t (additional costs for hazardous waste compared with non hazardous waste disposal)
FGT residues aluminium:	Disposal: - 200 €/t
FGT residues sinter:	Disposal: - 100 €/t (additional costs for hazardous waste compared with non hazardous waste disposal)
Soot domestic burning:	Disposal: - 100 €/t (additional costs for hazardous waste compared with non hazardous waste disposal)

	Limit value 10 ppb	Limit value 5 ppb	Limit value 1 ppb
Concerned amount	90 kt	210 kt	1.1 Mt
Concerned additional costs	18 million €		230 million €

On the other hand recovery of metal dusts in secondary processes in these industries is a high temperature operation which destroys almost all of the incoming POP content. In addition it has the benefit to save primary resources. Negative effects to the environment due to air emissions are low provided BAT standards are used for the process. In total the effect on air emissions is significantly below 1%. The processes do not cause environmental problems compared to a potential disposal of POP wastes following the POPs Regulation. Consequently there are nearly no costs on the "no action side" to be considered.

Regarding the PCB low POP content limit, cable recycling is the industry sector that is most affected by potential limit values. The PCB low POP content limit determines the part of the shredder residues that will be classified POP waste and cannot be processed for material recovery. 75% of the volume of PVC residues from cable shredding (169,000 tons) and parts (15%) of end-of-life vehicle shredder residues (450,000 tons) will be affected by a limit value of 10 ppm³⁴. This share will be still 50% for waste cable shredding in case of a 30 ppm limit and drop to 25% at a limit of 50 ppm. For ELV and white good shredding residues the share will be <10% or even lower at 30 ppm already. Thus the waste cable shredding is the sector of concern with respect to economic effects of a PCB limit.

Cable shredding is a specialised industry . Besides metal recovery the recovery of the plastic fraction is an important output form the production process as cables consist to about 50% of plastic.

The following calculation can be made:

Loss of earnings: 50 – 100 €/t granulate

Costs for disposal: 200 €/t (hazardous waste disposal)

Thus the resulting impact for the waste cable recovery sector has to be calculated with a minimum of 250.- €/ton. Provided 10% of the currently processed amount of plastic fraction contains PCB concentrations above the limit value this would result in additional costs of about 5.5 mio Euro. The total turnover of waste cable recovery is currently in a dimension of 11 million € (220 kt with earnings of 50 €/t). Therefore severe economic problems have to be expected for this industry sector.

The potentially PCB contaminated plastic fraction of waste cables is currently recycled and are mainly used in road maintenance and signalling equipment, in plastic banks for public parks, floorings etc.. The equipment is largely collected and recycled at its end-of-life time, so that the risk for emissions to the environment is limited. Consequently “costs” on the "no action side" seem to be small and they will further decrease as contaminated cables will slowly be eliminated. However they can not be completely neglected as PCB will be kept cycling.

Due to its caloric value contaminated PVC could theoretically be used as secondary fuel in high temperature processes (cement, power production) as R1 operation however this is excluded for PCB containing material according to Annex V to the POP regulation.

³⁴ (Σ PCB 28+52+101+153+138+180) x 5.

Selected additional costs of PCB can be roughly calculated in the following way:

Waste cables: recovery: + average assumed with 50 - 100 €/t (depending on market situation)

disposal: - 200 €/t (price for hazardous waste disposal)

ELV shredder residues: Disposal: - 100 €/t

	Limit value 30 ppm	Limit value 5 ppm	Limit value 1 ppm
Concerned amount	180 kt	1,600 kt	4,000 kt
Concerned additional costs	26 million €	150 million €	220 million €

For pesticides and other POPs the relevant mass flows indicate no essential importance of the low POP content limit, as levels are either low or highly above any of the discussed limit values. No important differences in economic impacts can be detected - on the basis of the data available - in relation to a decision for one of the three discussed low POP content limits 1, 10, and 15 ppm. C&D and soils from contaminated sites (production sites, dumps, storage sites), contaminated with POP pesticides and other POPs as well as stocks of POP pesticides are normally contaminated at concentrations of several hundred to thousand ppm and thus will require destruction or an alternative Annex V operation anyhow. A sector that may be important in certain Member States with high amounts of wooden construction may be waste woods contaminated either with pesticides (Lindane), PCBs or PCP (see chapter 3.7). Due to its caloric value contaminated wood can be used as secondary fuel in high temperature processes (cement, power production) as R1 operation.

As a compilation of the assessment results for criterion D, the following limit values seem to be feasible:

PCDD/PCDF: 10 ppb

PCB: 30 ppm

POP pesticides: 1 ppm

other POPs: 1 ppm

Overview on results for lower limitation criteria

By applying the results of the assessment against criterion D of the four criteria A-D, the following recommendations, as illustrated in Table 9-7, have been derived for the lower boundary of the range of possible low POP content limits.

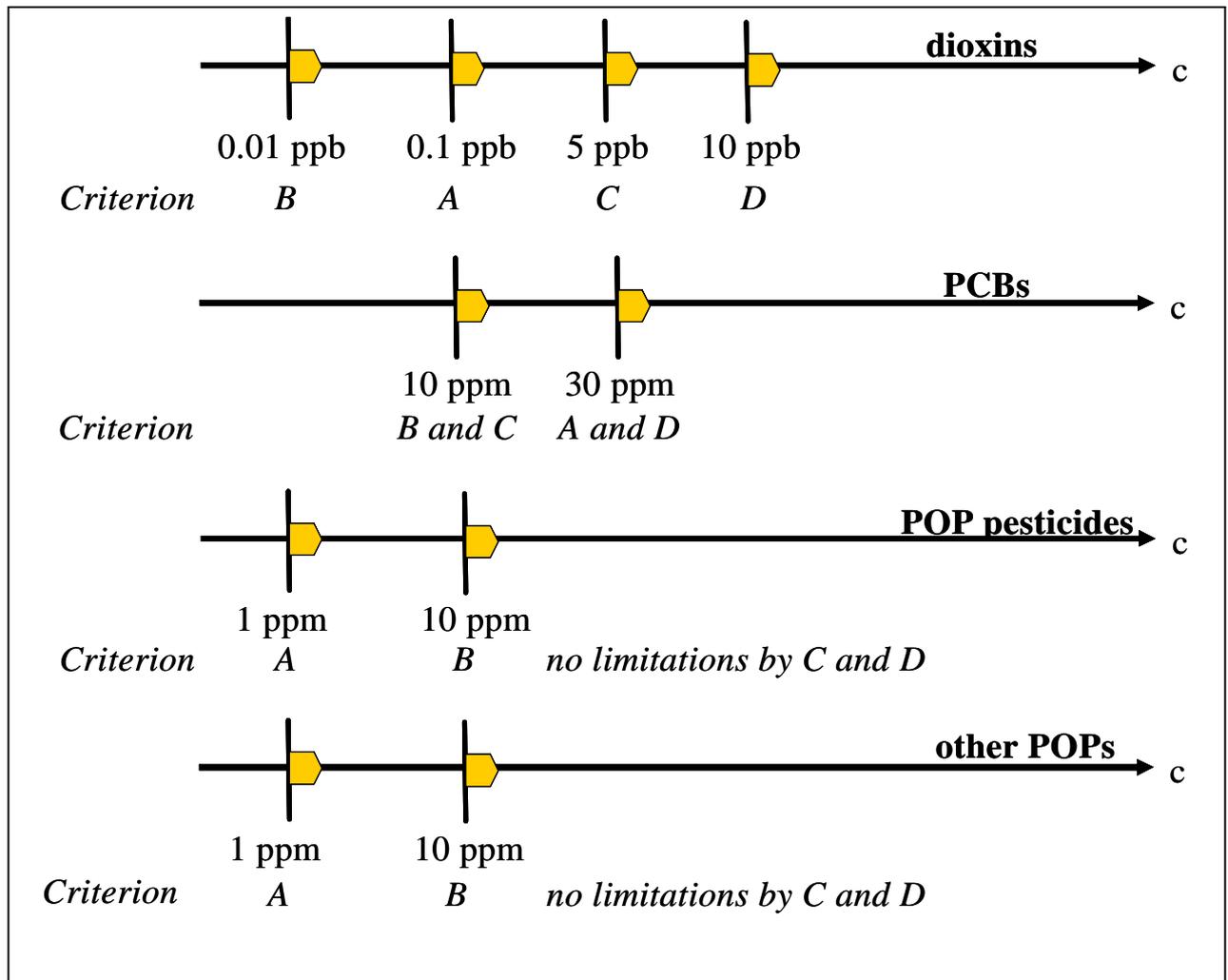


Table 9-7: Lower limitations for the different low POP content limits

9.2.2 Results for upper limitation criteria

Results for criterion Z: Existing limit values agreed by the European Union

The Basel Convention is the only international convention limiting the PCDD/PCDF content in waste. So far there is no stricter European limit set with respect to waste contamination. The General Technical Guideline on environmentally sound management of POP waste³⁵ and the Technical Guidelines on environmentally sound management of PCB/PCTs³⁶ have set the following limit values:

PCDD/PCDF: 15 ppb

PCB: 50 ppm

POP pesticides: 50 ppm

National legislation in a number of Member States goes beyond these limits and has regulated contamination levels in sectors such as sewage sludge, compost, waste oil, or waste wood. However, these limits may not be taken into account on the Community level. For details on national legislation and limit values, see chapter 6.

Results for Criterion Y: Worst case scenario for human health risks

As for the sectors to investigate in the course of a risk assessment regarding POPs exposure in the scope of the POP regulation it can be stated that for the three stages: waste generation, storage and transport, legislation in place does not require differing management relating to whether or not the waste is classified POP waste. Thus only the sector waste disposal/recovery is investigated in the scope of this project.

As regards the waste disposal/recovery, management requirements for POP waste – subject to Annex V of the POP regulation - differ from those applying to other waste. While the latter can – in view of its POP content - undergo any disposal/recovery operation in accordance with the waste directive (1999/31/EC) and the thematic strategy on recycling and recovery, POP waste requires specific treatment. The POP content has to be destroyed or irreversibly transformed by means of D9³⁷, D10³⁸ or R1³⁹ operations only. In exceptional cases,

³⁵ [UNEP GTGESM final 2005]

³⁶ adopted by COP 7 under the Basel Convention, Geneva 2004

³⁷ D9: physico-chemical treatment

³⁸ D10: incineration on land

³⁹ R1: use as a fuel

authorities may permit disposal in salt mines, hard rock formations or at hazardous waste landfill sites, if the environmental preferability has been demonstrated (see chapter 9). Thus, the risk assessment can be restricted to all disposal/recovery pathways that may be used for "non-POP" waste (below the low POP content limit), but which will not be permitted for POP wastes.

In order to decide about the exposure settings to investigate both possibilities: occupational and general population have to be evaluated with respect to their relevance for this topic.

For occupational exposure settings, the importance of dermal and inhalative exposure increases. However, appropriate measures and regulations for workplace safety are in place and the POP Regulation is not necessary to prevent risks against the background of this existing legislation. According to literature and personal communication, MAK levels are currently not exceeded in most relevant cases, and no elevated blood levels are detected, if precautionary measures according to individual permits are adhered to. Thus the occupational settings does not need to be further investigated.

The risk of exposure of the general population however needs some investigation. As the average risk for the general population is predominantly due to oral intake via contaminated food (>90%) [e.g. AEA 1999, UNEP regional report Europe] analysis has to be based on the potential contamination of foodstuff via wastes.

For this purpose literature has been searched for information concerning transfer rates from waste to environment and environmental compartments to food. It has to be admitted that knowledge and understanding of the related processes currently is not sufficient developed. However there is a basic consensus about certain aspects which helps to further reduce the number of pathways to investigate for a first worst case assessment.

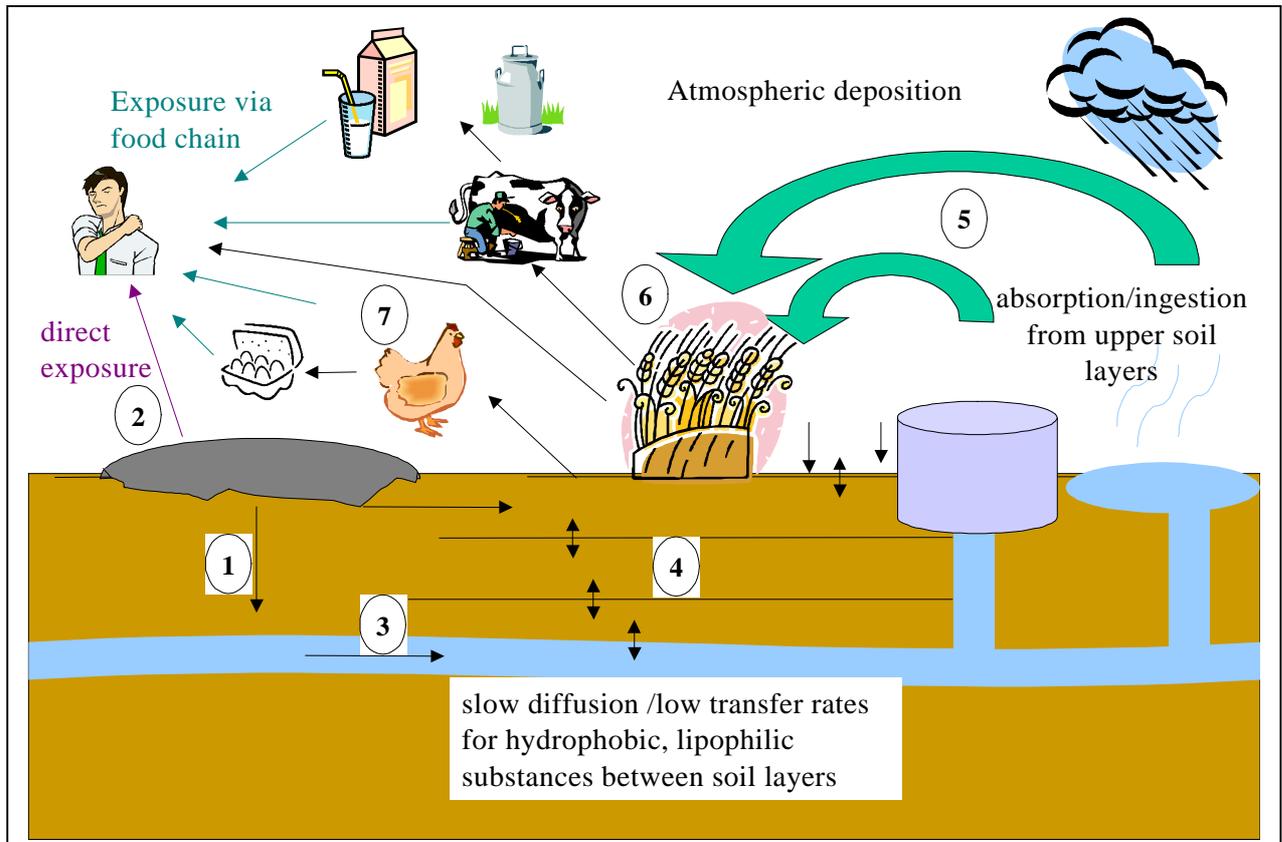


Figure 9-20: Releases from application of PCDD/PCDF contaminated material to soil

As illustrated in Figure 9-20 the following aspects are relevant for POPs flows in the environment:

1. Diffusion, elution from a contaminated material to the adjacent soil and ground water
2. Evaporation, erosion and atmospheric transport
3. Transport from ground water to surface water and soil
4. Intra soil transport
5. Irrigation and precipitation
6. Effects on plants and derived comestibles
7. Effects on animals and derived foods

Based on a number of studies and intrinsic properties of POPs the following preliminary statements can be made:

1. due to the lipophilic properties POPs strongly adsorb to particles; diffusion and elution is existing but a significant dilution effect can be expected. Disposal at a dedicated landfill strongly reduces this pathway due to the protective function of required sealing layers.
2. Evaporation and eolian erosion is not negligible as all POPs are classified semi-volatile. It leads to long-range transboundary transport and atmospheric deposition. A dilution can be expected and calculated.
3. Transport from ground to surface water is existing. However due to the lipophilic properties of the POPs they strongly adsorb to particles and sediments which largely decreases the mobility so that levels in water are far below levels in soil or sediment and a strong dilution effect can be expected.
4. Transport between different soil layers is not very well investigated, however transport can only be by diffusion or elution by infiltrating rain water. As an up-ward transport from deeper to superficial soil layers would have to work against the effect of infiltrating precipitation the resulting effect can be assumed to be at least extremely small.
5. Irrigation and atmospheric precipitation have a significant effect on top soil concentrations and plant surfaces. However this effect is dominated by long-range transboundary transport. The impact from a contaminated solid material can be assumed as small if not negligible.
6. Plants react to soil contamination, however studies have shown that there is a relatively large tolerance to soil concentrations.
7. Numerous studies have shown a bioaccumulation of POPs in foodstuff from animal origin. A specially strong relation has shown to exist between elevated contamination in soil and levels in free-range eggs. Although concentrations vary over a significant range an elevation in the average concentration seems to be obvious at hot spot sites.

Thus R10 operations (Land treatment resulting in benefits to agriculture or ecological improvements) and its potential effect e.g. on eggs has been selected for a first worst case assessment of potential impacts on humans. A more detailed analysis has not been possible in the scope of this study but further research in this topic would be needed.

The cross-check with existing European waste and dangerous substance legislation (e.g. 75/442/EC, Decision 2001/118/EC) shows that there is no ban for R10 operations at the discussed POP levels.

Worst case scenario for PCDD/PCDF

Publicly available information on relations between concentrations in soil and eggs is scarce, however more information might be available in future. According to expert information there is a large fluctuation in contamination in free-range eggs which hampers linkage to soil levels. However there is a correlation in case of hot spot contamination of soils.

For a first assessment two studies providing information on hot spot levels and average levels in both soil/contaminated material and eggs could be used. [Pless-Mulloli et al 2001a, Nouwen et al 2004]

In both studies soil/contaminated material with an average contamination of 0.04 - 0.9 ppb lead to an increase in egg contamination of 7-10 pg/g fat in relation to average contamination levels.

According to European legislation on food maximum levels for PCDD/PCDF in eggs have been set at 3 pg TEQ/g fat [2375/2001/EC] based on tolerable daily intake (TDI) estimations proposed by the WHO. In this case only intra-species variations (variety in response of individuals) have to be taken into account. Thus only a safety factor of 10 for the protection of vulnerable groups is included in the calculation.

Consequently 30 pg/g fat must be assumed as critical contamination level. Beyond risks to human health cannot be excluded.

As the above mentioned studies correlate a 7-10 pg/g fat concentration in eggs to a soil/material concentration of 0.4 - 0.9 ppb the critical value of 30 pg/g fat could be expected to be exceeded at soil/material levels of >1 ppb.

The project team is aware that the calculation is loaded with considerable uncertainty. However the assessment shows that risks might exist that require specific provisions on management for all wastes exceeding levels of 1 ppb .

max. PCCD/F level in eggs:	3 pg TEQ/g fat*
safety factor:	10 (intra-species variations) assessment
critical level where safety factor is exceeded:	30 pg/g fat
assumption:	
contamination soil/material	→ contamination eggs
0.4 - 0.9 ppb	→ elevation by 7 -10 pg/g fat
1 – 4 ppb	→ elevation > 30 pg/g fat in eggs
<p>➔ health risk might not be excluded by >1 ppb low POP content limit</p>	

Figure 9-21: Assessment of critical pathways from wastes into the food chain

In the framework of a plausibility check this result fits quite well to the dimension of the proposed limit in sewage sludge and action/target values for soil set up in a number of Member States based on TDI recommendations (see chapter 6.2). It has to be taken into account that these limits include safety factors following the precautionary principle which have been excluded for the above worst case estimation.

Worst case scenario for PCB

Corresponding information for total PCB is not available because recent studies and risk assessment have focused on dioxin-like PCB, for which not sufficient information is available with respect to waste. Consequently a relatively old risk assessment has to be used for a first estimation of potential risks from PCB.

According to an EPA risk assessment [US EPA 1988]

"Use, processing and distribution in commerce of products with less than 50 ppm PCB concentration will not generally present an unreasonable risk of harm or injury to health or the environment"

In addition national limits for PCB in food (see chapter 6.2) can be used as another indicator for potential risks. Maximum limits for eggs range from 0.2 – 0.5 ppm ($\mu\text{g/g}$) which is a factor of 5 higher than the current EU limits for PCDD/PCDF-TEQ (3 ppb (ng/g)). This supports the EPA assessment as it would suggest that critical value might be in the range of 100 ppm.

Another possibility for comparison is the TDI for PCB proposed by WHO/UNEP/ILO. The PCB-TDI is fixed to 0.01-0.03 $\mu\text{g/kg}$ b.w. day while the PCDD/PCDF-TEQ TDI is at 1-4 pg/kg b.w. day. This corresponds to a factor of 4 between the two recommendations and would suggest that the critical value might be in the range of 10 ppm.

Given the limited information the project team decided to use for the time being 50 ppm as results for PCB.

Following the physico-chemical and toxicological attributes of POP pesticides and other POPs (see Annex IV), the POP carrying media (soil, C&D waste) and the potential to enter the food chain, there are similarities between PCB, POP pesticides and other POPs. Therefore the risk assessment results may be transferred.

Consequently health risks might not be excluded above the following concentrations:

PCB:	50 ppm
POP pesticides:	50 ppm
other POPs:	50 ppm

Results for criterion X: Precautionary principle

The precautionary principle demands that the low POP content limits are as low as possible (taking into consideration the benefits for health and the environment and possible impacts). In any case low POP content limit values have to be equal or lower than those concentrations defined by criterion Y.

In this way criterion X results as target function that reduces resulting ranges for potential low POP content limits to options and recommendations.

In chapter 9.3 a quantification of the impacts of different limit values on the overall mass flows and in this way on environment and health is given.

It is a clear result, that applying the target function of the precautionary principle on PCCD/PCDF will enhance the covered dioxin mass flows by about 1 kg TEQ/year. This means an improvement of 6% based on a total waste mass flow of about 15 kg TEQ/year. The additional 1 kg TEQ/year has also to be seen against total air emissions of about 4 to 5 kg TEQ/year.

For PCB the difference in mass flows following limit values of 30 ppm or 50 ppm is currently relatively small. However, applying the precautionary principle with the target function covers wastes that are mainly responsible for keeping PCB in the circulation.

For POP pesticides and other POPs the target function via the precautionary principle can not generate a significant ecological added value concerning mass flows.

9.2.3 Options for low POP content limits

The combination of lower and upper limitation criteria leads to clear recommendations for low POP content limits for PCB, POP pesticides and other POPs.

Dependent on a strict application or less strict application of the precautionary principle two options are proposed and discussed with respect to their impacts and implication for each POP substance/substance group.

It has to be taken into consideration that the proposals represent implementable limits according to current knowledge and the present technical status as result of the discussion in the previous chapters in order to provide a technical basis for the political discussion. The proposals may not be regarded as definite. Due to the flexibility of the developed methodology results will change with up-coming knowledge and technical changes, so that a review process and a flexible adaptation of the limits in Annex IV and V to the POP regulation should be foreseen.

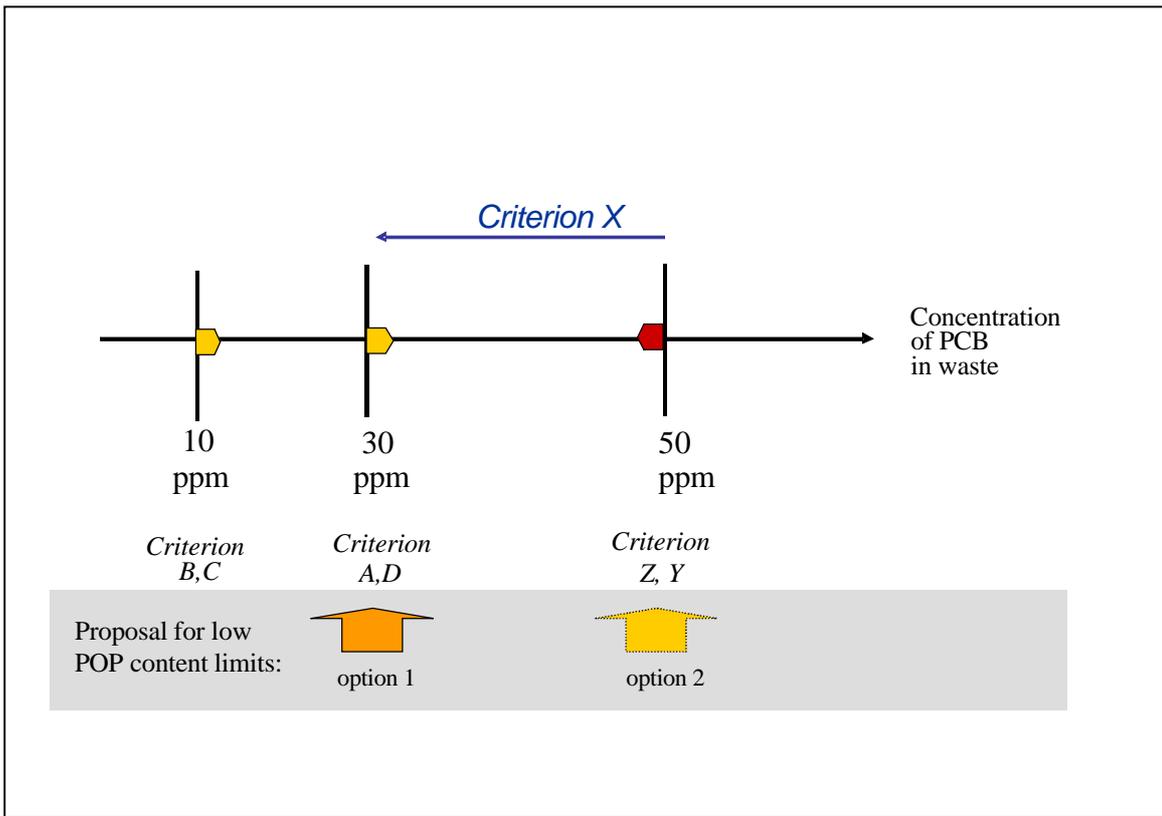


Figure 9-22: Overall Result for Method 1: Low POP content limit for total PCB

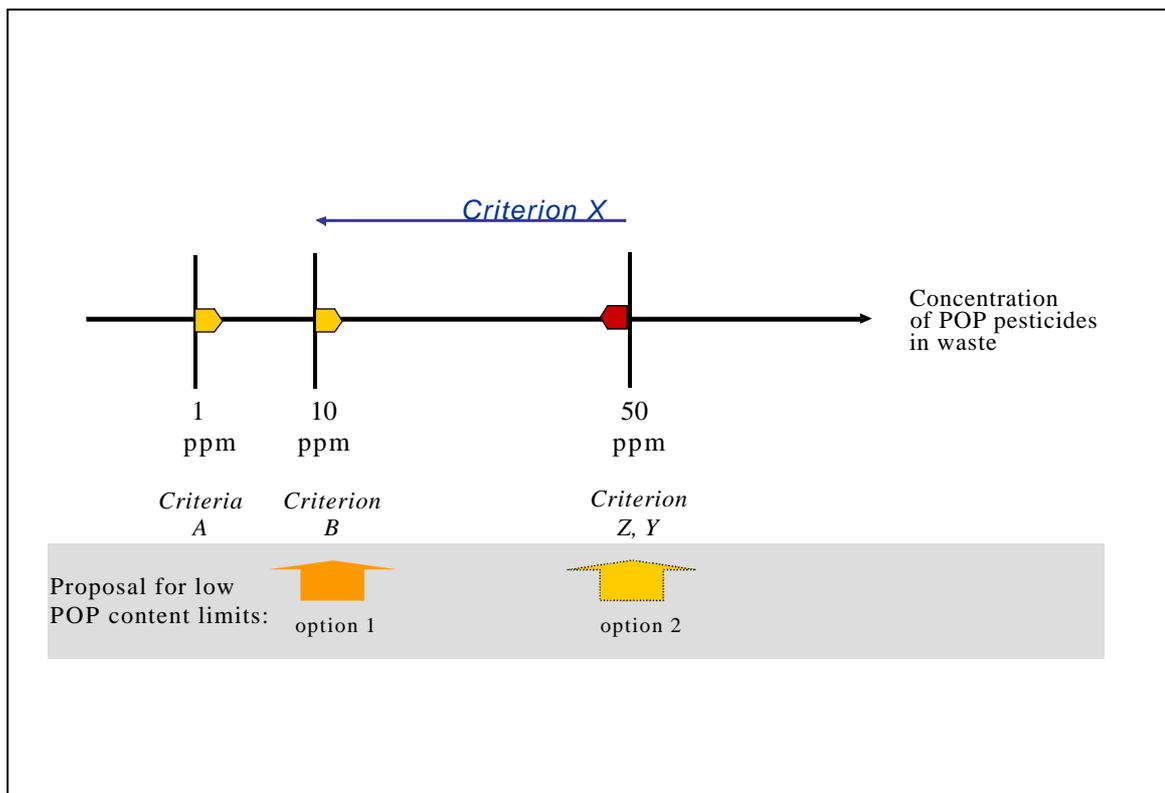


Figure 9-23: Overall Result for Method 1: Low POP content limit for POP pesticides

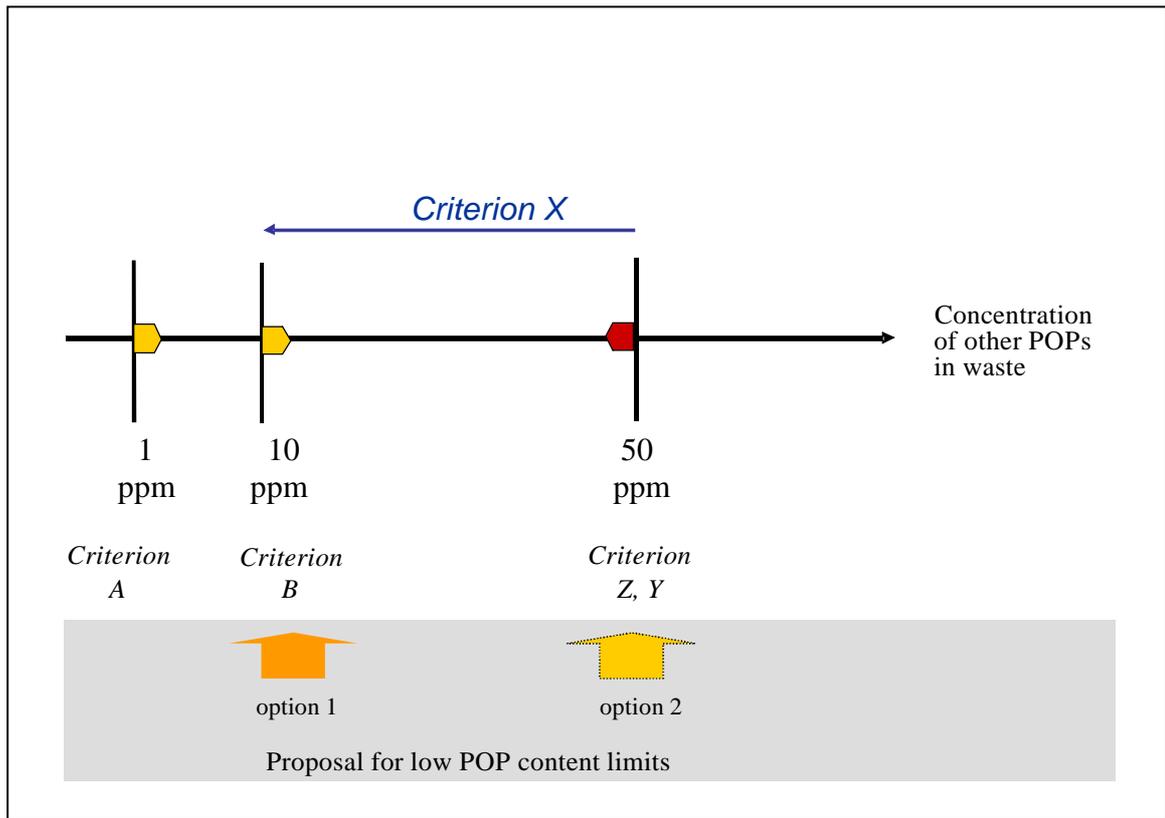


Figure 9-24: Overall Result for Method 1: Low POP content limit other POPs

In the case of PCDD/PCDF there is a contradiction between lower and upper limitation criteria:

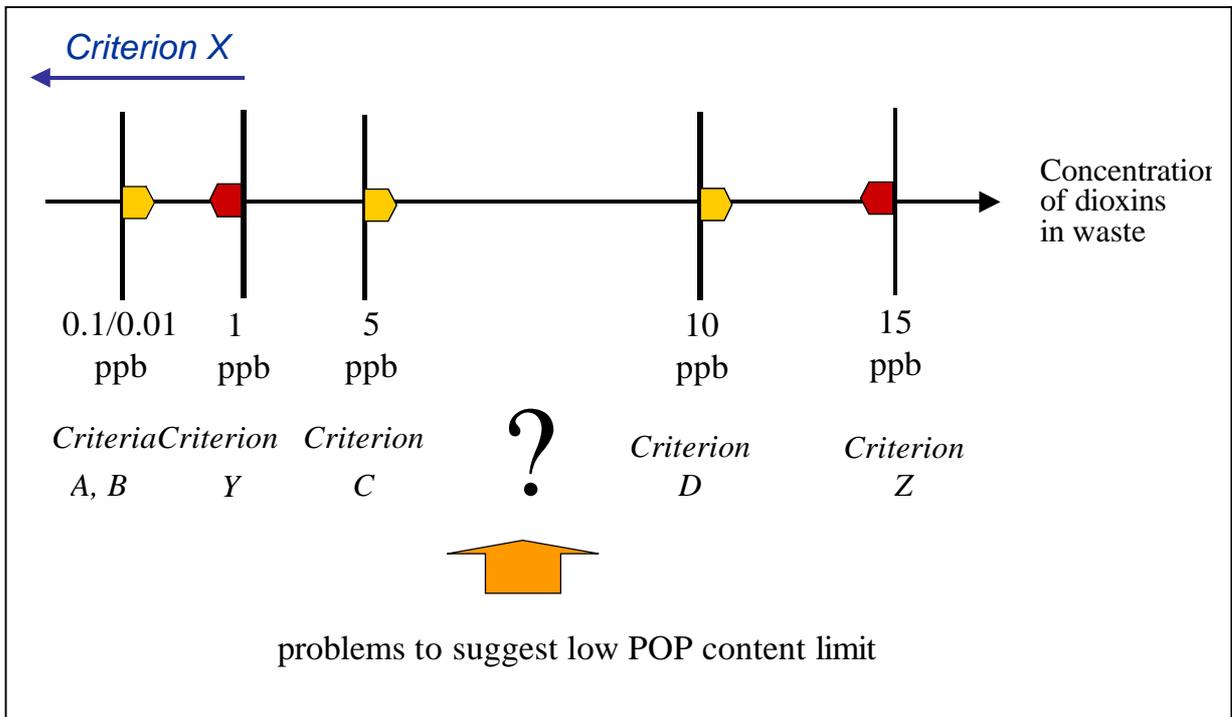


Figure 9-25: Overall Result for Method 1: Low POP content limit for PCDD/PCDF (Standard procedure)

This means that additional requirements have to be set in order to allow either low limitation criteria to shift to the left to the lowest upper limitation criterion or that the upper limitation criterion Y will shift to the right to the level requested by criterion D (economic feasibility).

For this purpose the risk to enter the food chain and be discharged to soil and other environmental compartments is investigated for the next critical currently used disposal/recovery operation identified in the mass flows.

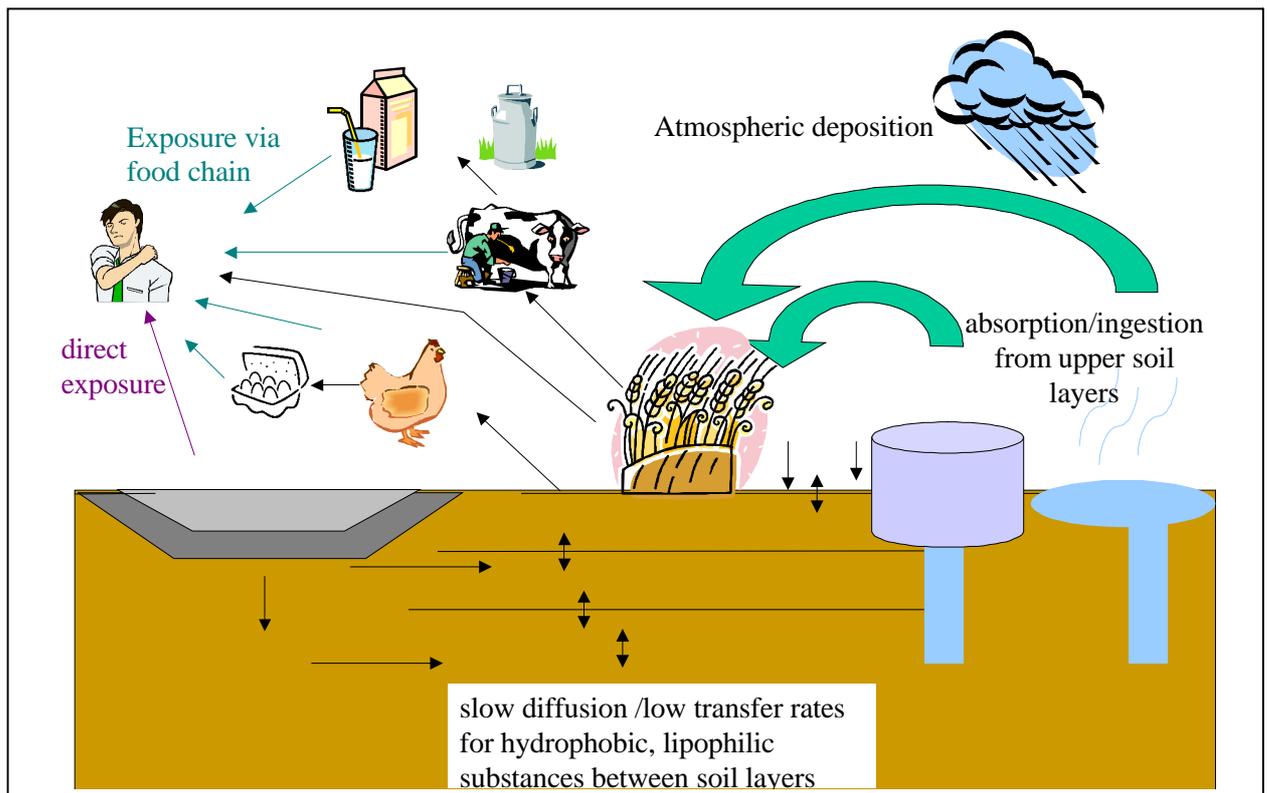


Figure 9-26: PCDD/PCDF contaminated material in asphalt for road construction

This is the use of ash with PCDD/PCDF contamination in asphalt for road construction.

According to the evaluation of leaching tests on fly ash a recent LCA on use of fly ash as filler in asphalt for road construction, which has been performed in the framework of the Dutch national waste management plan [LCA-AVI- 2002] concludes that leaching will be in a dimension of 10^{-3} % over 100 years which corresponds to a annual dilution factor of 10^{-7} . Using a worst case approach the leaching has been fixed at 1% over 100 years corresponding to leaching estimates for media with high organic and detergent concentration. Thus a maximum $0.0015 \mu\text{g}/\text{kg}$ processed fly ash can be assumed to be discharged annually to the environment by leaching effects. (for details on the leaching tests see chapter 10.1.6). This leads to the conclusion that for this management option a low POP content limit of 15 ppb PCDD/PCDF-TEQ will not be likely to cause risks to health and environment. Actual values may be significantly lower however it has to be noted that uncertainty remains with respect to superficial mechanical abrasion. Additional information will be needed in the future.

First approach to solve the contradiction between upper and lower limitation demands

Low POP content limit is set at 15 ppb for PCDD/PCDF contamination

 Ban of unconsolidified application of waste material to soil if PCDD/PCDF concentration of 1 ppb is exceeded.

By means of modification of annex IV

As discussed above use of R 10 or other forms of unconsolidified application of waste material to soil with a PCDD/PCDF-TEQ >1 ppb might cause negative effects on environment and health. If such operations are excluded, as is possible by a modification of annex IV of the POPs Regulation, there is no indication for a conflict between upper and lower limitation criteria as the next critical recovery operation (solidified/stabilised application see Figure 9-26) does not seem to present a health risk with respect to its PCDD/PCDF content.

The following figure shows the resulting options for the low POP content limit for PCDD/PCDF:

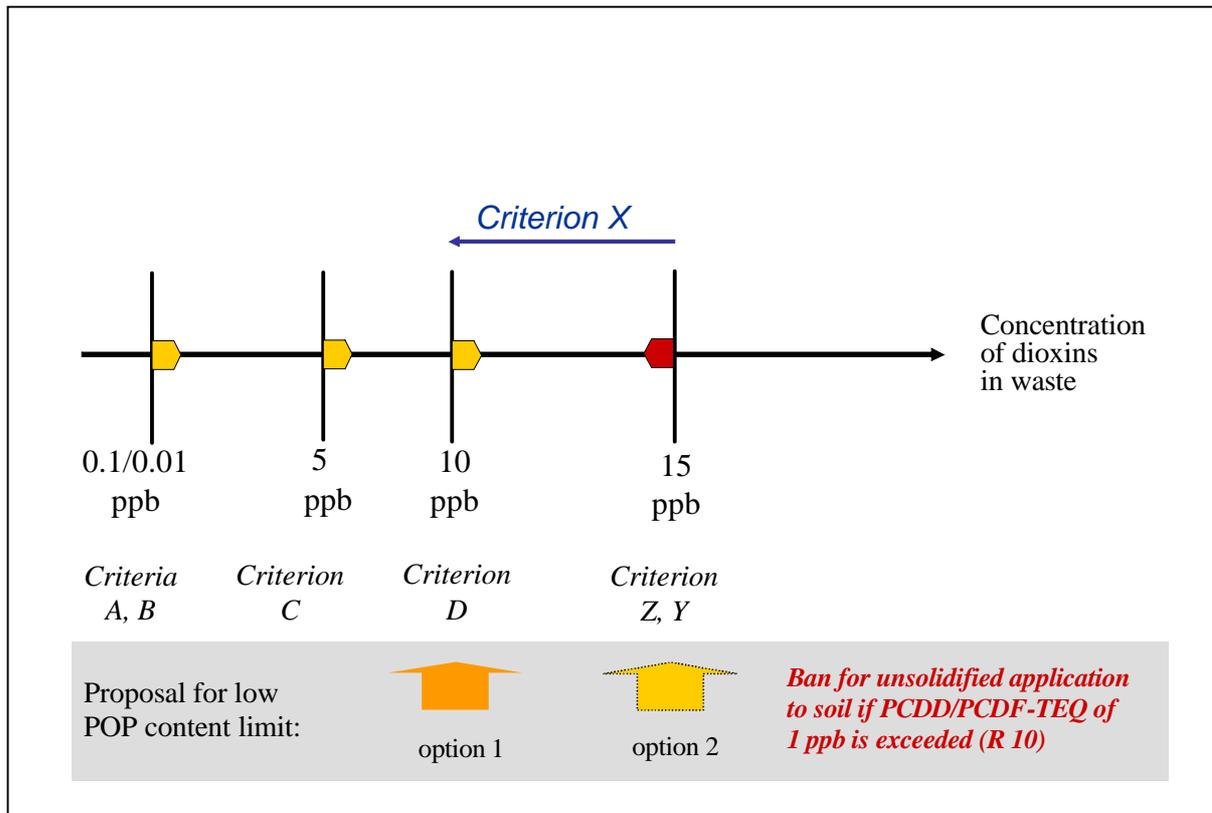


Figure 9-27: Proposals for low POP content limit for PCDD/PCDF (first approach)

There is no contradiction and a clear recommendation exists for a low POP content limit.

Second approach to solve the contradiction between upper and lower limitation demands

In case a application of Article 7 (6) is not feasible or not intended another approach has to be chosen to derive proposals for a low POP content that respect the demands of all limitation criteria. In this case demands from the point of view of economic feasibility and disposal/recovery capacity have to be taken into account in such a way that they can shift to the left and a limit of 1 ppb becomes implementable.

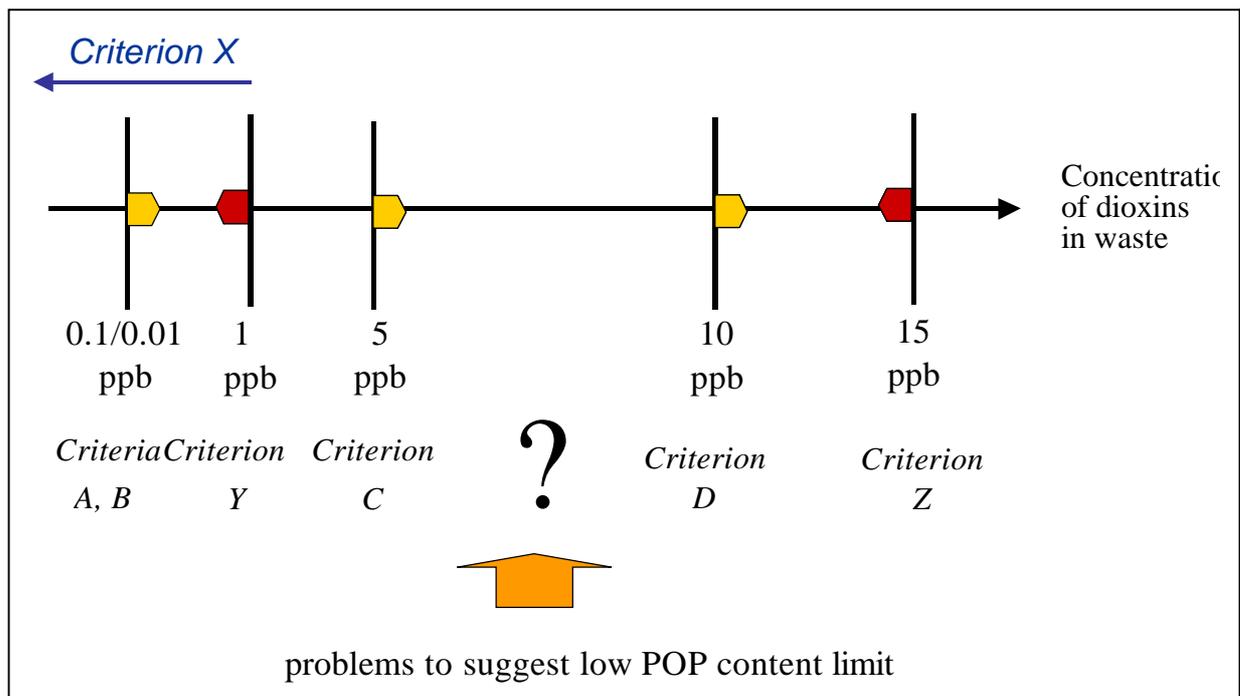


Figure 9-28: Overall Result for Method 1: Low POP content limit for PCDD/PCDF (Standard procedure)

As discussed in the paragraph on economic feasibility and disposal/recovery capacity the metal industry (namely EAF steel production and secondary non-ferrous metal industry) is most strongly affected and thus the major base for economic arguments against a lower limit. The second sector is the reuse of fly ash which is currently practiced in a limited number of Member States.

Recovery of metal dusts in secondary processes is a high temperature operation which destroys almost all of the incoming POP content. In addition it has the benefit to save primary resources and thus corresponds very well to the recycling premise of the waste directive. Negative effects to the environment due to air emissions are low provided BAT standards are used for the process. In total the effect on air emissions is significantly below 1%. (see 3.4.1

Figure 3-5).

Thus the project team proposes a second option to solve the conflict between upper and lower limitation criteria. If R4 operations for a selected number of waste codes will be added to the operations permitted under Annex V part 1 criterion D and C will shift to 1 ppb and a clear proposal can be made.

The following figure shows the resulting options for the low POP content limit for PCDD/PCDF:

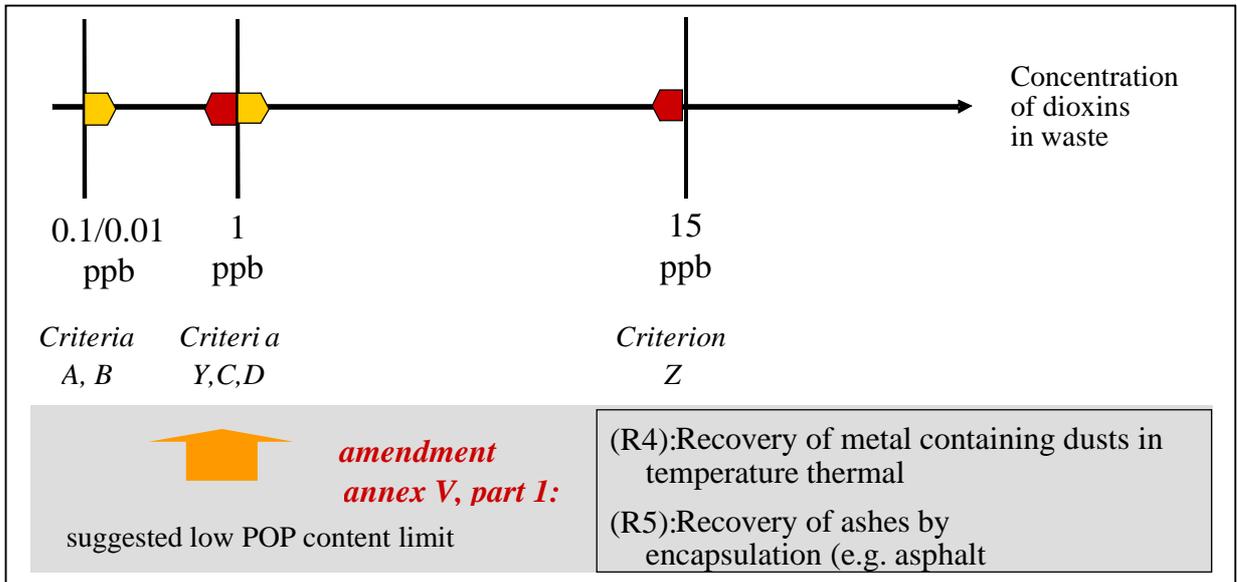


Figure 9-29: Overall Result for Method 1: Low POP content level for PCDD/PCDF (second approach)

Summary on proposals for low POP content limits

As a consequence of the analysis and the application of the methodology developed, the following recommendations for low POP content limits result:

		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.

If a sum 7 approach for PCB is applied the suggested low POP content limit values have to be adapted correspondingly (7ppm and 11,7ppm).

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.

9.3 Impacts and implications of proposed low POP content limits

9.3.1 PCDD/PCDF: Comparison of option 1A and option 2 A (first approach)

The differences for the two options are comparatively small. It is expected that for

- APC residues from MSWI
- Ashes from biomass fired power plants
- EAF dusts

- FGT residues from secondary aluminium

a total of about 80 kt will be additionally covered by a low POP content limit value of 10 ppb compared to 15 ppb.

It is not obvious that the above mentioned wastes will go to destruction processes, it is assumed that waste owners will try to prove environmental preferability of disposal.

Economic impacts can be calculated only roughly, but it seems realistic to expect additional costs for waste holders due to additional measurements, check of environmental preferability and higher disposal costs in a total dimension of 10 to 20 million €.

With respect to ecological impacts a dimension of the mass flows of 1 kg PCDD/PCDF is concerned:

80 kt	x	12,5 ppb	=	~1 kg
Concerned waste amount		Assumed average contamination between 10 and 15 ppb		Resulting dioxin amount

In relation to the overall discharge to waste of ~ 15 kg/y this corresponds to an additional coverage of 6%. Part of the wastes (APC residues from, MSWI) are however already generally disposed of in hazardous waste landfills due to their classification as hazardous.

9.3.2 PCDD/PCDF: Comparison of first and second approach

In case of a low POP content limit of 1 ppb (second approach) significant parts of APC residues from MSWI, ashes from biomass fired power plants, FGT residues from sinter plants, iron smelting and secondary aluminium and zinc production that can not be internally recycled, EAF dusts Cu-furnace oxide and soot from domestic burning will exceed the limit thus becoming subject to the provisions in Annex V of the POP regulation.

The total amount of volumes, that are additionally covered by a low POP content limit value of 1 ppb can be calculated as 2,035 kt (compared to 10 ppb) and 2,115 kt (compared to 15 ppb).

It is expected that various waste owners have to perform additional measurements and give evidence that other treatment than destruction or irreversible transformation is environmentally preferable.

The economic dimension of additional costs depends on various specific parameters, the amendment of annex V that is foreseen in the second approach is definitely a major one.

Based on a rough estimation of additional costs it seems realistic to expect for waste holders due to additional measurements, check of environmental preferability and higher disposal costs in a total dimension of 150 to 200 million €.

With respect to ecological impacts a dimension of the mass flows of 4 kg PCDD/PCDF is concerned (comparison of limit values 1 to 10 ppm). If the low POP content limit values of 1 and 15 ppb are compared, mass flows of about 5 kg PCCD/PCDF are concerned.

In relation to the overall discharge to waste of ~ 15 kg/y this corresponds to an additional coverage of 25%. Part of the wastes (APC residues from, MSWI) are however already generally disposed of in hazardous waste landfills due to their classification as hazardous.

9.3.3 PCBs: Comparison of option 1 and option 2

The differences for the two options are mainly based on the following wastes:

- Small PCB containing equipment (< 50 ppm)
- Shredder residues (ELV/white good and waste cables)
- Waste oils

Corresponding amounts result in a total of about 180 kt which will be additionally covered by a low POP content limit value of 30 ppm compared to 50 ppm.

As all the wastes have a high caloric value they will get to destruction processes.

Economic impacts can be calculated only roughly, but it seems realistic to expect additional costs for waste holders due to additional measurements, loss of revenue and higher disposal costs in a total dimension of 30 to 50 million €.

With respect to ecological impacts a dimension of the mass flows of about 7 t PCB is concerned:

180 kt	x	40 ppm	=	~7,2 t
Concerned waste amount		Assumed average contamination between 30 and 50 ppm		Resulting PCB amount

In relation to an overall discharge to waste of > 6,000 t/y this amount seems to be neglectable. However, besides sewage sludge and compost these are the only sectors of the mass flow which keep the PCB in circulation. On the other hand the input of new PCB will slowly fade out, so that a dilution effect will be observed. A re-evaluation of the situation should be performed after 2010 at the latest when large equipment has been eliminated.

9.3.4 *POP Pesticides and other POPs: Comparison of option 1 and option 2*

In the discussed range between 10 and 50 ppm only few wastes are expected, e.g. waste woods treated with Lindane. However, there are not enough data available to calculate the amounts concerned in different countries. Due to the high caloric value they will be directed to thermal destruction operations. Data on C&D waste and contaminated soil are very incomplete, but typically concentrations are above 100 ppm. Thus no significant amounts are expected to be concerned in the range of 10 to 50 ppm. Therefore no major economic and ecological differences are expected between a low POP content limit value of 10 and 50 ppm.

9.4 Prognosis for mass flow based on recommended low POP content limits under the EU POP regulation

Based on the data collected and evaluated in the detailed mass flows in chapter 4 it is possible to assess the effects of limit values on the overall waste flow.

9.4.1 PCDD/PCDF

The PCDD/PCDF flow in 2015 will be dominated by the decision whether a low POP content limit value of 1 ppb (plus an amended annex V) or a low POP content limit value of 10/15 ppb (plus a ban of non-solidified application to t land) is implemented in the POPs regulation.

Basis for the various disposal/recovery routes is an input of 13 kg/y PCDD/PCDF to waste (see Figure 8-9) due to an assumed reduced output from MSWI of 1 kg/y, a lower load in MSW 7 kg/y and a changed ratio between MSW incineration and landfilling of 60% to 40%.

It has to be taken into consideration that the prognosis can only be a rough estimation due to the enormous range of influencing factors that can not be assessed. Thus only the potential effects of the POP regulation could be taken into account. Potential impacts of other legislation could not be included.

For a low POP content limit of 1 ppb based on current knowledge and data the following flow might be expected:

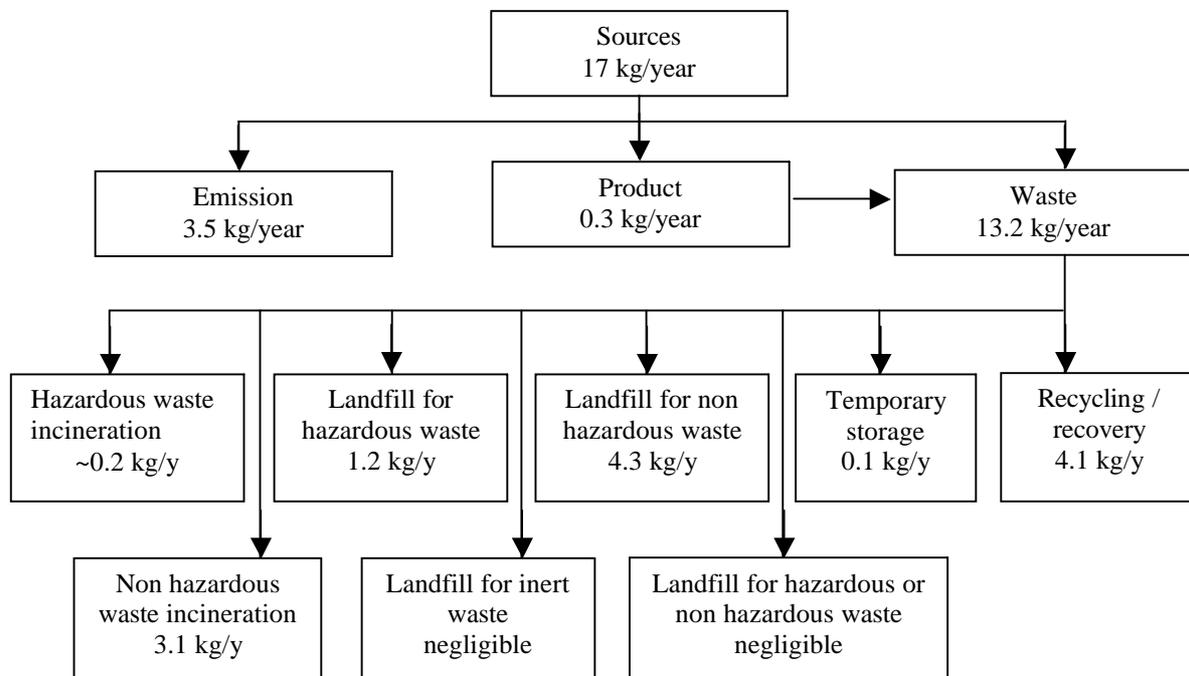


Figure 9-30: Expected mass flow of PCDD/PCDF for 2015 resulting from low POP content limit of 1 ppb

This result is expected due to a higher incineration rate for MSW, higher recovery rates for fly ashes from MSWI and dusts from metal industry and due to a small increase in wastes that have to be disposed of as hazardous due to exceedance of the low POP content limit value.

Compared to the status quo this would mean the following differences:

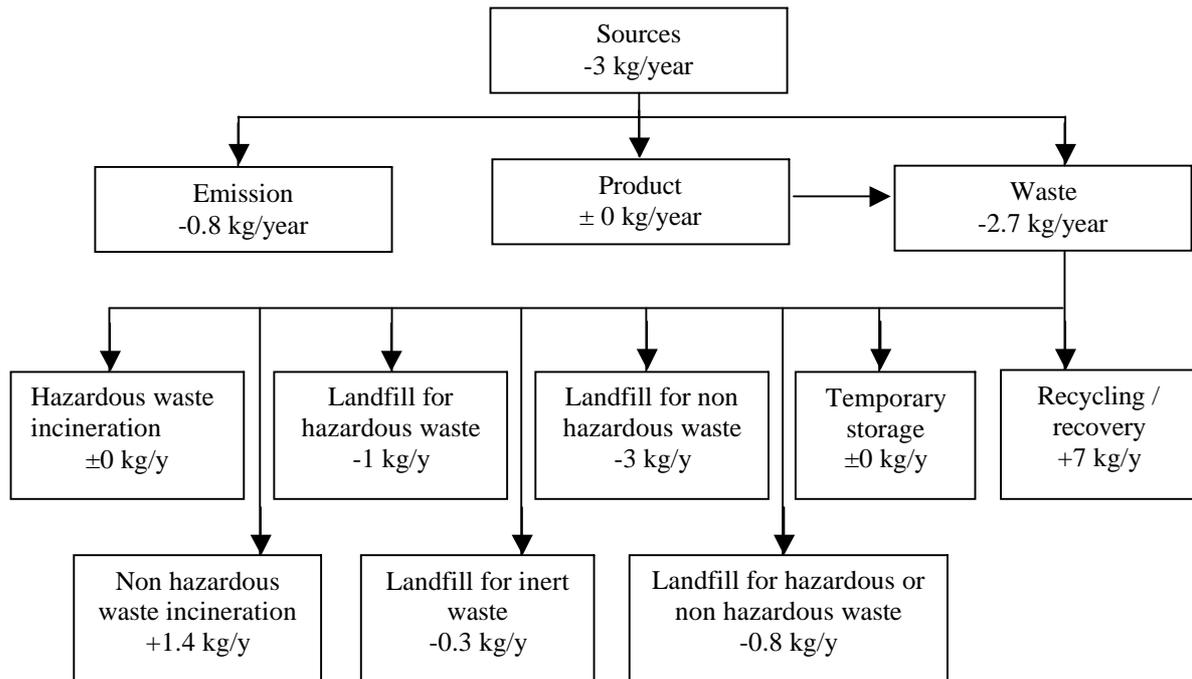


Figure 9-31: Expected changes in mass flow of PCDD/PCDF for 2015 due to low POP content limit of 1 ppb

For a low POP content limit of 10 ppb the following flow might be expected:

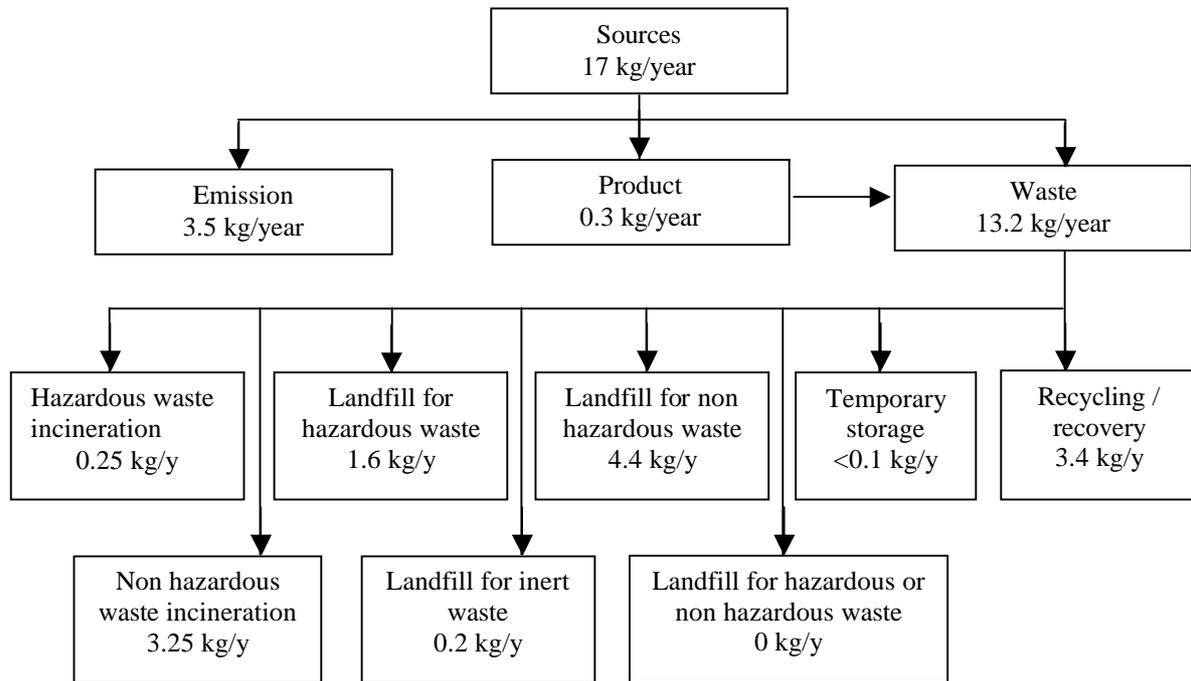


Figure 9-32: Expected mass flow of PCDD/PCDF for 2015 resulting from low POP content limit of 10 ppb

This change might be due to HWI of soot from domestic burning, increase rate of hazardous waste landfilling for residues from secondary aluminium production and biomass power production, increased rate of MSWI for municipal solid waste and higher recycling rates for residues from metallurgical industry.

Compared to the status quo this would mean the following differences:

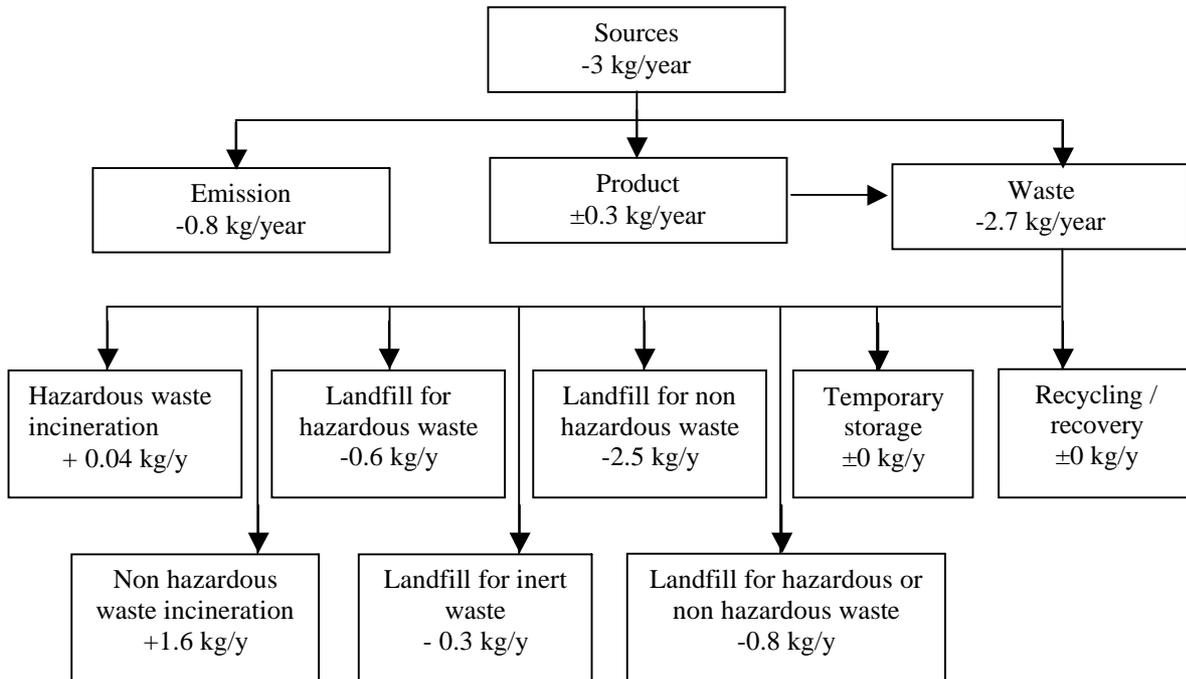


Figure 9-33: Expected changes in mass flow of PCDD/PCDF for 2015 due to low POP content limit of 10 ppb

For a low POP content limit of 15 ppb the following flow might be expected:

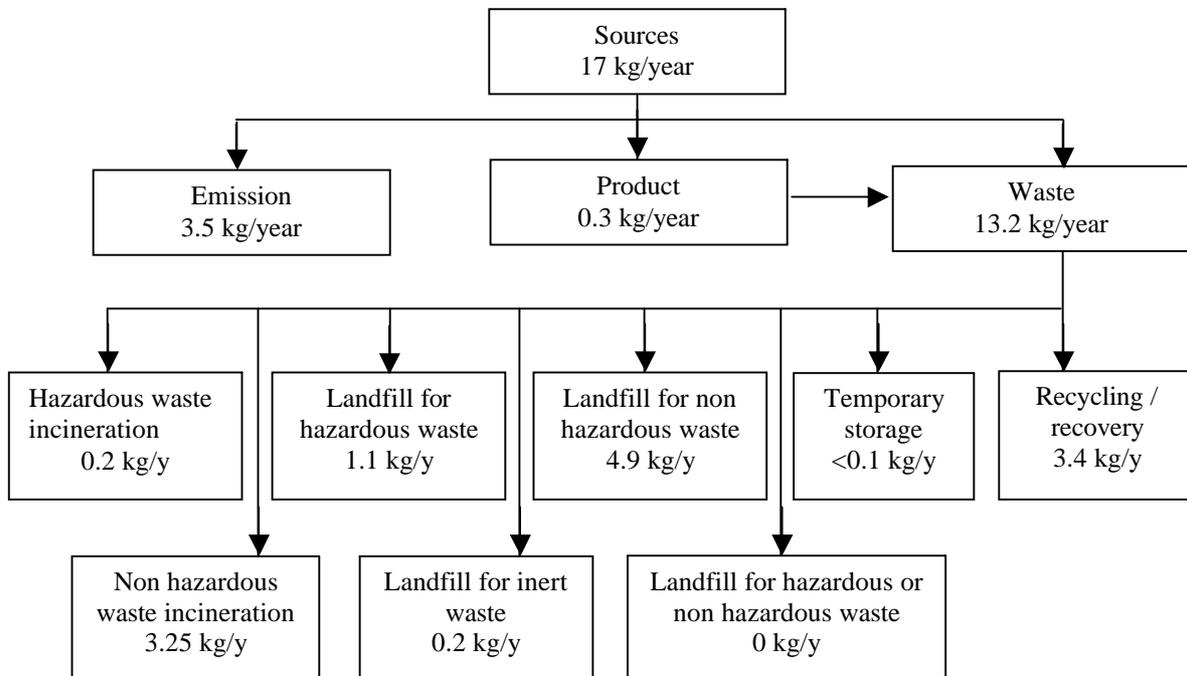


Figure 9-34: Expected mass flow of PCDD/PCDF for 2015 resulting from low POP content limit of 15 ppb

This change in comparison with the prognosis for a limit of 10 ppb is due to fact that soot from domestic burning will not be subjected to destruction/irreversible transformation of the POP content, hazardous waste landfilling for residues from secondary aluminium production and biomass power production will be reduced compared to 10 ppb as smaller amounts exceed the limit.

Compared to the status quo this would mean the following differences:

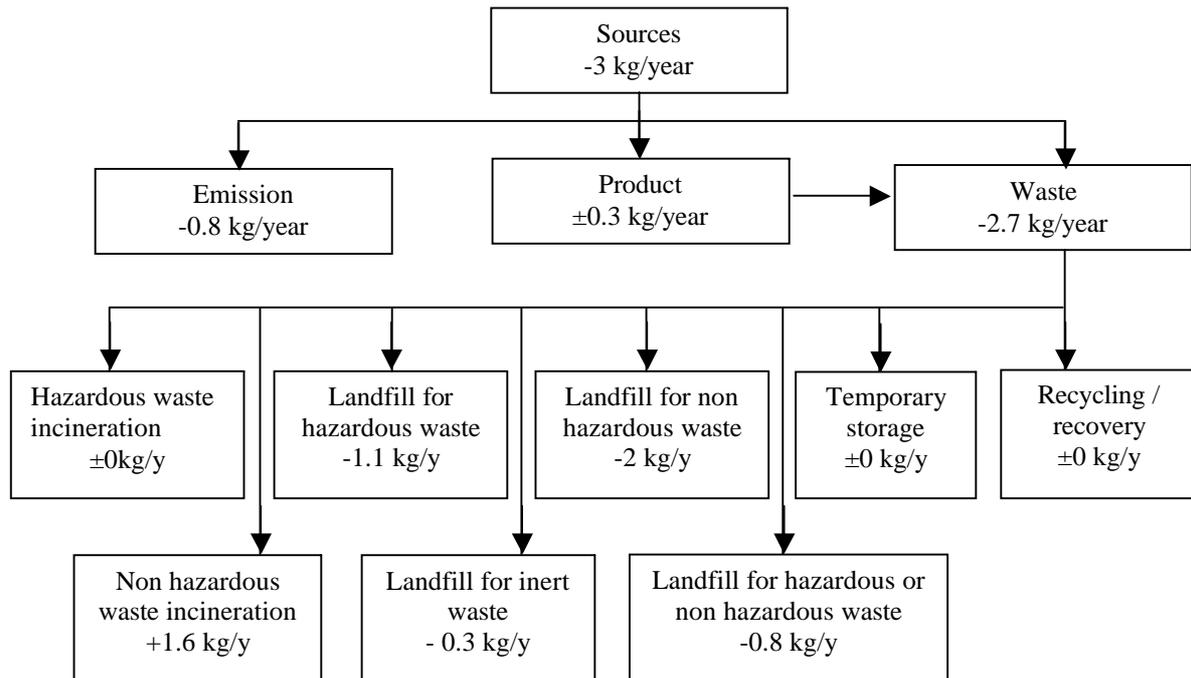


Figure 9-35: Expected changes in mass flow of PCDD/PCDF for 2015 due to low POP content limit of 15 ppb

9.4.2 PCB

Basis for the various disposal/recovery routes is an estimated input of PCB of 800 t/y to waste (see Figure 8-10).

Based on current knowledge and data and being aware of the limitation of the prognosis due to additional impact factors that can not be assessed to date it might be expected that the following flow results:

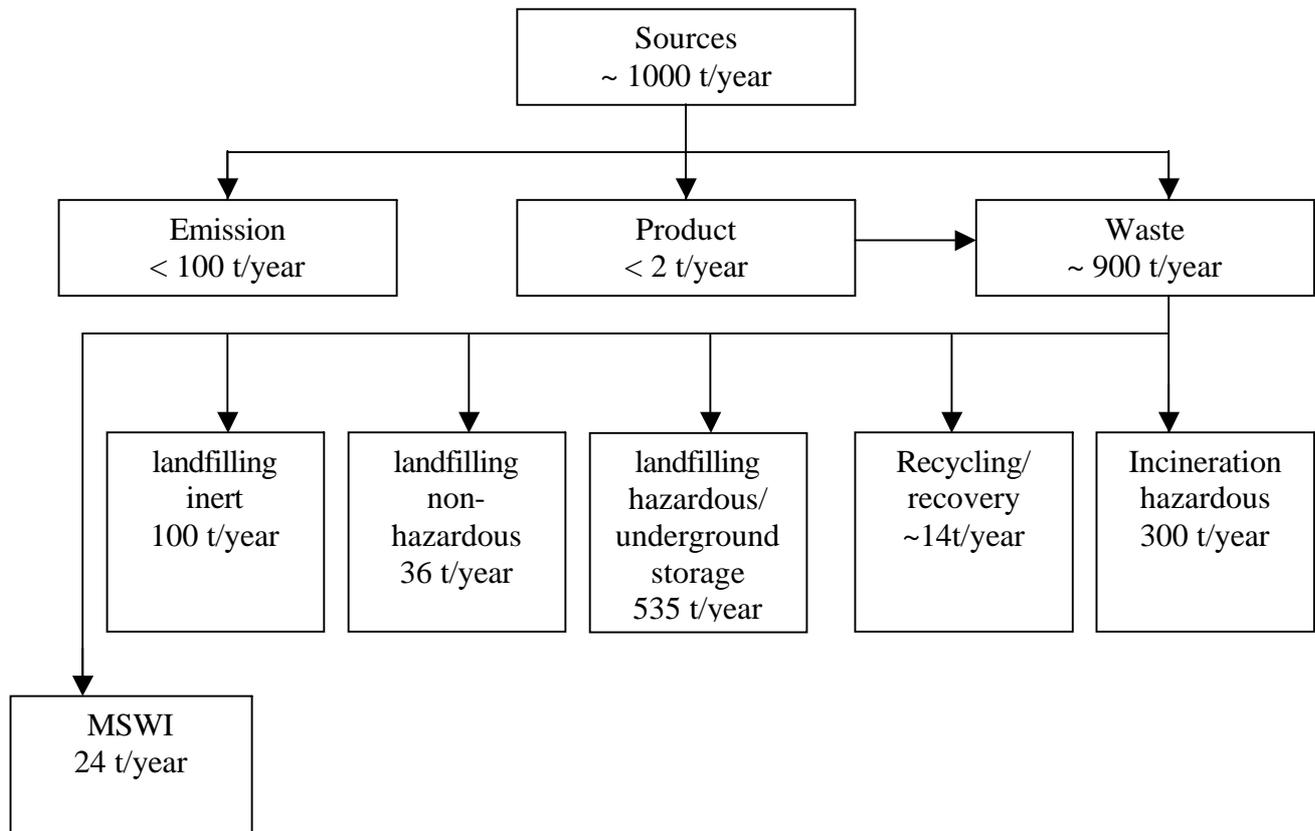


Figure 9-36: Expected mass flow for 2015 resulting from low POP content limit of 30 and 50 ppm

This will probably be due to significantly increased share of hazardous waste incineration and hazardous waste landfiling for C&D waste and the strong overall reduction of the remaining stocks. Recycling/recovery is due to waste oil, shredder residues and sewage, sludge compost. 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 (see chapter 3.7.2) will gain higher importance and add to the amounts directed to MSWI, non-hazardous waste landfill and hazardous waste landfill.

The situation will be quite similar for both discussed low POP content limit as a difference will occur only for shredder residues and waste oil. With a limit of 50 ppm >10 t/y of it will be substance recovery. With a limit of 30 ppm this will probably be slightly lower ~9 t/y.

Compared to status quo conditions this would mean the following differences:

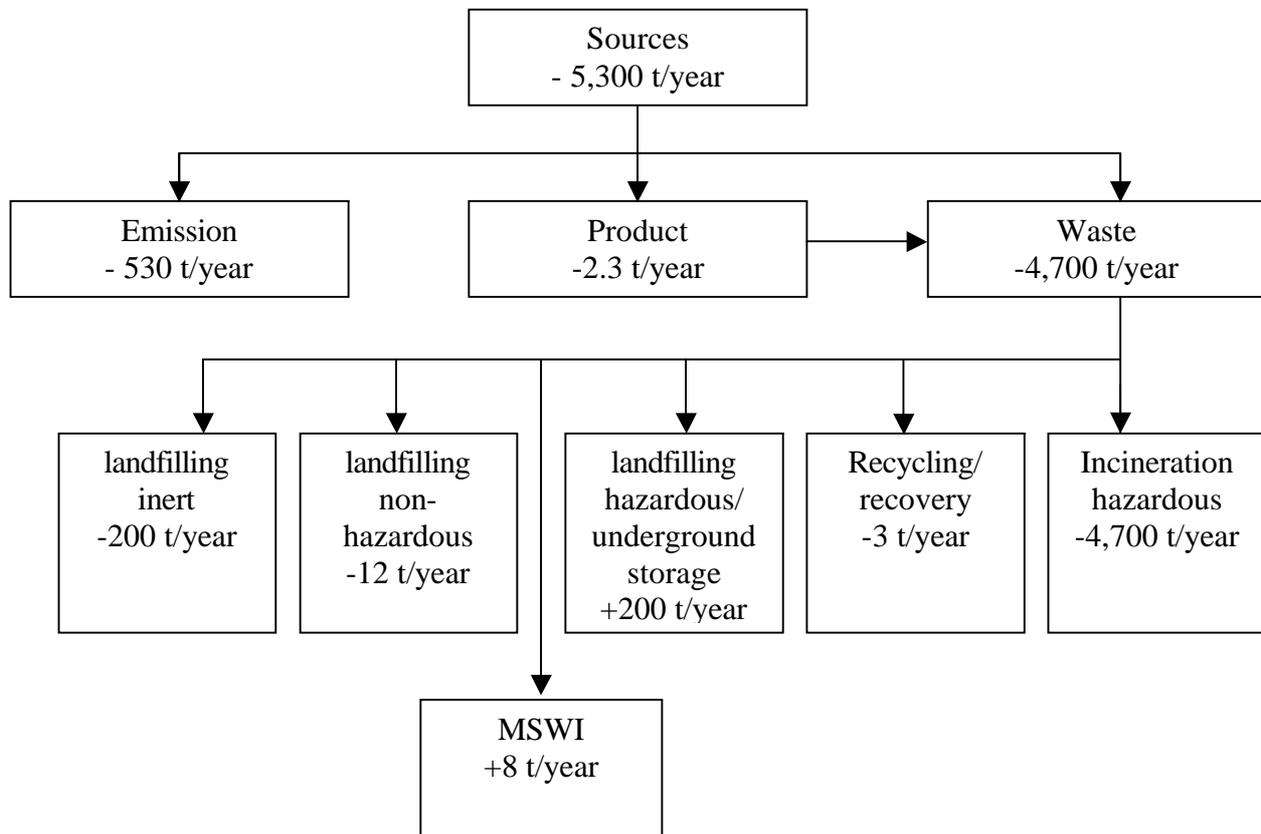


Figure 9-37: Expected changes in PCB mass flow for 2015 resulting from low POP content limit of 30 or 50 ppm

9.4.3 POP pesticides

In the year 2015 it is expected that there is no or nearly no waste from POP pesticides. Consequently the mass flow as indicated in Figure 8-11 under status quo conditions will not change under the conditions of the recommended low POP content limits of the EU POP regulations.

9.4.4 Other POPs

In the year 2015 no waste is expected from other POPs.

9.5 Proposals for maximum POP content limits

The proposals for maximum POP content limits presented in this chapter reflect current knowledge on leaching properties of POPs from waste and long-term safety of landfills engineered according to the requirements in the landfill directive (1999/31/EC). Risks of potential catastrophes have been taken into account in Directive 1999/31 EC and Decision 2003/33/EC. This concerns the general requirements for the location of landfills as well as specific safety assessments required for underground disposal.

The methodology is restricted on effects related to POPs. Restrictions or limitations in management due to other pollutants already subject to existing legislation are not in the scope of this project but will also influence the management of a number of EWC.

The results however might change with up-coming knowledge and technical changes, so that a review process and a flexible adaptation of the limits in the Annexes to the POP regulation should be foreseen

Results for criterion Y (worst case scenario for human health risks)

Following the methodology for the upper limitation criteria, criterion Y and the precautionary principle can support the derivation of a maximum POP content limit.

The disposal routes foreseen as alternatives to an destruction or irreversible transformation include landfill for hazardous wastes and underground storage in salt mines or hard rock formations.

Thus it has to be investigated above which POP concentration risks to human health and the environment might occur that are of dimension that environmental preferable alternatives can not be allowed. This investigation in principle includes the same procedure as for the low POP content limits (see chapter 9.2.2).

As a first step some basic issues have to be clarified in order to be able to identify the most relevant potential pathway to the environment.

1. Only those wastes listed in Annex V may be permitted for alternative management due to low caloric values
EWC 17: bulky residues from construction and demolition
EWC 10, 16, 19: solid residues from thermal processes in power production, waste incineration and metallurgical industry.
All other wastes have to be treated with D10, D9 or R1 operations if exceeding the low POP content limit.
2. Only solidified waste directed to hazardous waste landfills and underground storage is foreseen as potential alternative management operation.
3. The landfill directive (1999/31/EC) applies; (existing sites have to comply with the

standards by 2011)

4. Specific technical requirements as set in Annex I to the directive have to be adhered to and thus can be assumed as prerequisite for the intended disposal.

With respect to all classes of landfills Annex I to directive 1999/31/EC contains the following general requirements related to potential risks and protection of the surrounding nature :

1. The location of a landfill must take into consideration requirements relating to:
 - (a) the distances from the boundary of the site to residential and recreation areas, waterways, water bodies and other agricultural or urban sites;
 - (b) the existence of groundwater, coastal water or nature protection zones in the area;
 - (c) the geological and hydrogeological conditions in the area;
 - (d) the risk of flooding, subsidence, landslides or avalanches on the site;
 - (e) the protection of the nature or cultural patrimony in the area.(acc. to 1.2 The landfill can be authorised only if the characteristics of the site with respect to the abovementioned requirements, or the corrective measures to be taken, indicate that the landfill does not pose a serious environmental risk.)
2. **Water control and leachate management:** Appropriate measures shall be taken, with respect to the characteristics of the landfill and the meteorological conditions, in order to:
 - control water from precipitations entering into the landfill body,
 - prevent surface water and/or groundwater from entering into the landfilled waste,
 - collect contaminated water and leachate.(If an assessment based on consideration of the location of the landfill and the waste to be accepted shows that the landfill poses no potential hazard to the environment, the competent authority may decide that this provision does not apply)
 - treat contaminated water and leachate collected from the landfill to the appropriate standard required for their discharge.
3. **Protection of soil and water:** A landfill must be situated and designed so as to meet the necessary conditions for preventing pollution of the soil, groundwater or surface water and ensuring efficient collection of leachate as and when required according to Section 2. Protection of soil, groundwater and surface water is to be achieved by the combination of a geological barrier and a bottom liner during the operational/active phase and by the combination of a geological barrier and a bottom liner during the operational/active phase and by the combination of a geological barrier and a top liner during the passive phase/post closure.

The geological barrier has to fulfil the following requirements:

- landfill for hazardous waste: $K \leq 1,0 \times 10^{-9} \text{ m/s}$; thickness $\geq 5 \text{ m}$,
- landfill for non-hazardous waste: $K \leq 1,0 \times 10^{-9} \text{ m/s}$; thickness $\geq 1 \text{ m}$,

Leachate collection and sealing system: In addition to the geological barrier a leachate collection and sealing system consisting of artificial sealing liner and drainage layer ≥ 0.5 m is required so as to ensure that leachate accumulation at the base of the landfill is kept to a minimum. In addition a surface sealing may be prescribed if the competent authority after a consideration of the potential hazards to the environment finds that the prevention of leachate formation is necessary.

Landfill category	Non hazardous	Hazardous
Gas drainage layer	required	not required
Artificial sealing lines	not required	required
Impermeable mineral layer	required	required
Drainage layer > 0.5 m	required	required
Top soil cover > 1 m	required	required

Table 9-8: Recommendations for the surface sealing of landfills according to 1999/31/EC

However geological barrier and leachate collection and sealing system can be reduced if, ..., the competent authority has decided, in accordance with Section 2 ("Water control and leachate management"), that collection and treatment of leachate is not necessary or it has been established that the landfill poses no potential hazard to soil, groundwater or surface water.

According to Annex III of directive 1999/31/EC meteorological conditions and emissions to leachate, surface and groundwater have to be sampled and monitored. Ground water has to be monitored for level (every six month) and for composition (according to expected composition of the leachate and groundwater quality in the area).

After-care of a closed landfill has to be done as long as required by the competent authority, taking into account the time during which the landfill could present hazards. (mostly 30 years)

According to expert information hazardous waste landfills are generally covered with an surface sealing, so that leaching from the stored to the leachate and the penetration of the basement sealing layers (artificial sealing liner, drainage layer and geological barrier) have to be considered as the critical pathways for discharge to the environment.

Concerning underground disposal Decision 2003/33/EC contains the following additional specifications:

For the acceptance of waste a site-specific safety assessment as defined in Annex A must be carried out. This has to comprise operational and post-operational phase and must include geochemical, geomechanical and geohydrological aspects and has to demonstrate the long-term safety as concerns the isolation to the biosphere. Containers and cavity linings should

not be taken into account when assessing the long-term risks because of their limited lifetime.

Assessment of discharge via leachate and penetration into surrounding soils.

Based on the above mentioned provisions and requirements in landfill legislation potential leaching and leachate have been identified as the major parameter for the assessment of long-term safety of landfills and the derivation of maximum POP concentration limits (MPCL).

In expert discussions also some other risks besides leachate were mentioned (e.g. fire inside underground disposal sites; flooding, earthquakes). With respect to underground fires it can be stated that waste acceptance criteria for underground disposal exclude all explosive and flammable wastes. Floods, earthquakes and other catastrophes should be taken into account as far as possible already during the planning of a disposal site (see above general requirements of 1999/31/EC) however can not be completely excluded.

Thus due to the precautionary principle the assessment of maximum limits for hazardous waste landfills does not take into account the safety barriers of the landfill itself. This does not apply for underground storage in salt mines, where this aspect is already included in the safety assessment (see above).

According to expert information from France and Germany leachate in hazardous waste landfill is highly reduced in relation to other types of landfill due to the surface linings minimising infiltration of precipitation. In addition leachate water is completely collected, treated by inverse osmosis, filtered and recycled in order to prevent any pollutants to reach the environment.

In addition there was information from Danish and Swedish experts that currently observed levels of PCDD/PCDF in leachate from existing landfills is below levels in rain water.

Thus the project team concentrated on the potential risk to the environment due to diffusion of dissolved pollutants through the geological barrier. This depends on long-term leaching properties of the waste as on technical standards of the landfill as well as meteorological conditions. In this context a lot of research has been performed in the framework of an international network of scientists⁴⁰. However most of the work has been restricted to heavy metals. As general conclusion it can be stated that there are some major release controlling factors which have already been taken into account in the waste acceptance requirements for hazardous waste landfills. The major factors are the following:

Dissolved organic matter (DOC content), physical factors (solubility, porosity, permeability, temperature, etc.) and solid-liquid phase chemistry (pH, redox-potential). With respect to leaching of organic pollutants the DOC seems to be of highest importance as due to the high lipophile of the substances they can leach only by adsorption to dissolved particles. This fact has been taken into account in the waste acceptance criteria directive limiting the DOC content in waste directed to hazardous waste landfills to < 5%. Thus reducing the risk of

⁴⁰ www.leaching.net

leaching of POPs. However no final modelling for leaching of POPs from disposed waste is available which could be used for the definition of maximum limits.

Percolation through the divers layers of the basement sealing system is a slow process which takes a minimum of 200 years (k_s factor 10^{-9} m/s = 170 y for 5 m geological barrier + 33 y for artificial sealing layer) however there is no unlimited isolation from the surrounding environment.

Thus the project team decided to use a worst case approach as a first step to identify the dimension of a potential maximum limit.

For this purpose available data on leaching rate for POPs have been used to calculate the dilution factor that can be expected for POP concentrations in waste matrices.

As illustrated in Table 9-9 leaching tests with unconsolidified fly ash resulted in leaching rates of <0.01%.⁴¹ . A test with high concentration of aggressive LAS however shows that leaching rates can increase significantly under unfavourable conditions.

Leaching medium and test	leaching (%)	Reference
Acid percolate (1), column test	0.001 (2) (factor 10^{-5})	RIVM (95)
demineralised water, column test (both o-NVN 7344)	0.001-0.0001 (3) (factor 10^{-7})	RIVM
200 mg/l humic acid in - demineralised water, shaking test. 24h	0.002	Sakai (97)
1500 mg/l LAS (4), shaking test	2.5	Schramm (95)

Table 9-9: Leaching percentages for PCDD/PCDF from free WIP fly ash, on the basis of leaching tests [leaching test] at L/S 10; (all values applicable for a 100-year period)

(1) A total fatty acid content of 20.000 mg/l (acetic acid, propanoic acid, butyric acid, valeric acid)

(2) based on the assumption that the fly ash contains approximately 3 µg TEQ/kg ds.

(3) The first value is an average derived from a retest, the final value was set after having eliminated a probable maverick

(4) linear alkyl benzene sulphonate (detergent)

Although LAS concentrations of 1500 mg/l are very unlikely to occur in a hazardous waste landfill with low organic content, the leaching rate for unconsolidified fly ash might be set at 1%/100 years under dumping conditions as worst case estimate.

In a Dutch investigation on fly ash [LCA-AVI 2002] leaching factors from free fly ash have

⁴¹ Source: Environmental impact Report – National Waste Management Plans (LCA-AVI-vliegas, final report 2002, TA UW)

been assumed to be reduced by cement solidification by two dimensions. Thus a dilution factor of 1,000,000 might be assumed as a worst case scenario for solidified waste without taking into account any additional dilution effect of the landfill layers.

This dilution factor is then used for comparison with existing target levels set for soil as this will be the receiving environmental compartment.

- existing target levels for agricultural soil (based on ADI and precautionary principle) (see chapter 6):

PCDD/PCDF:	0.005 ppb
PCB:	0.002 ppm
POP pesticides:	0.005 ppm
other POPs:	0.005 ppm

Thus the following calculation can be made:

Dilution factor x target levels → acceptable concentrations in waste:

PCDD/PCDF:	$0.005 \text{ ppb} \times 1,000,000 = 5,000 \text{ ppb}$
PCB:	$0.002 \text{ ppm} \times 1,000,000 = 2,000 \text{ ppm}$
POP pesticides:	$0.005 \text{ ppm} \times 1,000,000 = 5,000 \text{ ppm}$
other POPs:	$0.005 \text{ ppm} \times 1,000,000 = 5,000 \text{ ppm}$

As mentioned above these values can only be applied for solidified waste.

The calculation is rough and may only give a first indication on the dimension of maximum POP content limit values based on leaching risks, however it might support the further process. It has to be stated that based on the current knowledge from the perspective of the risk from leaching through the geological barrier to adjacent soil the limit could theoretically be applied to non-hazardous waste landfills too. However further investigations and in depth modelling would be highly recommended.

It should be noted in addition that the project team considers the collection and appropriate treatment of the leachate water in the operating time of the landfill as a mandatory prerequisite for the proposed limit. This suggestion is made against the background of existing water limit values (see chapter 6) and tests and modelling for heavy metals which show a maximum leaching in the first years which significantly reduces after 20-30 years when a neutral pH has been reached. However further research is needed in order to decide on the period of after-care which would have to be connected with the proposed limits.

Table 9-10 compiles the Annex V wastes suspected to potentially exceed the maximum limit (MPCL) proposed under Annex V.

PCDD/PCDF	Soil and C&D waste from production sites
PCB	contaminated soil and C&D waste
POP pesticides	Soil and other C&D waste from pesticide production, dump and storage sites
Other POPs	Soil and construction material from dump sites for production residues

Table 9-10: Examples for wastes that may exhibit concentrations above the maximum POP content limit criterion Y

A similar calculation for maximum POP content limit values has been performed for salt mines and safe deep hard rock formations. No restrictions can be identified, though, as site specific safety assessments have not shown a need to consider a leakage of contaminants. This holds true for assessments including geological, geo-mechanical, hydro-geological, geo-chemical, and long-term aspects in a historical dimension.⁴²

If any material flows did occur, the resulting leaching rates should be expected to be by a factor 1,000 smaller than the critical material flows. Under these conditions, criterion Y does not give rise to any restrictions.

An overview of proposed maximum POP content limits (based on leaching risks) is given below.

⁴² cf. e.g. O. Natane (2001)

*appropriate non-hazardous landfill and hazardous landfill for solidified wastes**

Dioxins:	5000 ppb
PCB:	2000 ppm
POP pesticides:	5000 ppm
other POPs:	5000 ppm

appropriate storage in salt mines, safe deep hard rock formation

Dioxins:	}	no restrictions
PCB:		
POP pesticides:		
other POPs:		

* Solidification is fulfilled if a leachate rate of 0,01%/100 years is not exceeded

Another approach that could be taken to identify a maximum limit based on leaching properties is a leachate based approach resulting in limit recommendations for the leachate itself. Appropriate leaching tests for waste characterisation and assessment of long-term leaching behaviour for monolithic waste are currently under development in CEN TC 292.

Consequently this experiences should be used and extended for inclusion of POPs.

10 Environmental preferability of waste management options

10.1 Methodology for assessment of environmental preferability

10.1.1 *Functional requirements*

The assessment method to provide information on the environmental preferability of waste management operations, referred to as "Method 2" (see chapter 9.1) 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.

10.1.2 *Assessment criteria for "environmental preferability"*

The most obvious decision criterion for the definition of environmental preferability of the treatment of POP waste is POP emissions. The emissions can be differentiated according to their emission path into air and water and contamination of waste residues. Having in mind possible entry of POPs into the environment or the human food chain emissions to air or natural water (groundwater or surface water) have a higher potential for environment and/or health impact compared to emissions to waste or waste water which are controlled in their further fate.

Environment and health burdens also arise from emissions of other pollutants. These aspects have to be considered as second decision criterion. Important and easily obtainable information in this context are greenhouse gas emissions and emissions of any other relevant environmental pollutants such as heavy metals.

A third decisive criterion for the environmental impact of a waste treatment option are uncertainties and knowledge gaps e.g. related to short or long-term safety associated with a treatment process and the evaluation of the related potential risks.

10.1.3 Evaluation of existing assessment methodologies

As a starting point for the development of a suitable method, existing methodologies have been screened for their appropriateness to cover environmental and health burdens and risks, their complexity and clearness, analytical requirements, associated assessment cost and their treatment of knowledge gaps.

Among the methods considered are Life Cycle Analysis (LCA), Environmental Impact Assessment (EIA), Risk Assessment (RA) and Technology Assessment (TA). Though none of these methods can cover all important aspects of the required assessment their elements can be combined to a suitable methodology.

Additionally, all of them are highly sophisticated approaches that call for simplification if they are supposed to generate quick decisions in individual cases. One very intuitive approach to a complex decision problem is a Multi-Criteria Analysis. It shall be considered as a framework methodology to integrate all essential elements.

Elements to cover	Risk assessment (RA)	Life cycle assessment (LCA)	Environmental impact assessment (EIA)	Technology assessment (TA)
	Focus...	cradle to grave investigation of effects	Focus facility: includes substance volume	Focus process technology (innovation), Comparison with status quo ante
toxicological attributes	+ calculation toxicokinetic, repeated dose toxicity; criteria carcinogenicity assessment	+ human toxicity, aquatic and terrestrial ecotoxicity as impact categories	?	-?
carrying media	+ calculation exposure via filter cakes,	+ ecotoxicities distinguished	+ impacts can be waste, waste water, noise	?
contamination patterns in waste	+? (leaks with landfill)	-?	-	+?
potential to enter the food chain	+	-	+	-?
environmental impacts (bioavailability)	+ evaporation rate; risk characterisation	+ ;consumption and releases (energy, raw material, emissions, waste); processes investigated: processing, manufacture, transport, distribution, use, reuse, recycling, final disposal; 10 categories of env. Impact in SETAC CoP	+, also sensitivity of local ecosystem	+
human risk (NOAEL, LOAEL, ADI)	+ NOAEL and benchmark concept; model calculation for indirect exposure via environment; default factors for absorption	+ consumer safety; + human toxicity as 1 of 10 categories to classify impacts ? NOAEL unclear	-?	-
human exposure settings	+ workplace exposure rating criteria, consumer exposure rating,	“should” criterion, methods being developed	+, also sensitivity of local ecosystem	+?
ability and willingness of stakeholders to cooperate	+? (enhanced probability of compliance)	~ convenience	-+ consultations foreseen but difficulties to find consensus	+?
economic impacts	+ - decision on acceptable risk contained in assessment, but concrete guidelines missing	+; - b/c all are transformed into environmental in-/outputs before entering the inventory	-+ mentioned as criterion for risk assessment, but no common quantification of econ. /ecol./safety arguments	++ e.g. income and employment

Elements to cover	Risk assessment (RA)	Life cycle assessment (LCA)	Environmental impact assessment (EIA)	Technology assessment (TA)
Pros and cons of technologies	+, implicitly	+ give information of the interactions between measures in life cycle of product; e.g. reduction in waste via enhanced reuse may require technical changes increasing energy consumption etc.	+ assessment incl. Risk reduction measures	+ main point
analytical requirements				
analytical capacity				
risks due to knowledge gaps				
flexibility to changes in knowledge, technology		?assumed to hinder technological improvements		
other restrictions, specifications				
other	<ol style="list-style-type: none"> 1. hazard assessment (hazard identification accident frequency; consequence estimation leads to risk potential) 2. exposure assessment under constant emissions and in case of accidents 	goal definition and scope includes process flow environmental impact assessment improvement assessment (includes facts and subjective weighting of different aspects)	<ol style="list-style-type: none"> 3. impact of new emissions in comparison to existing load 	<ol style="list-style-type: none"> 4. effects of new technology in comparison to status quo

+ = issue well covered; ? = uncertain suitability of method

Table 10-1: Methodological elements applied in common assessment methods (RA, LCA, EIA, TA)

In the following, the basic concepts are briefly characterised and evaluated against the above mentioned criteria. The relevant arguments for their respective appreciation are compiled in the corresponding figures, Figure 10-1 to Figure 10-4.

Life cycle assessment (LCA)⁴³

LCA can serve to compare alternative activities serving the same function, in the present case the disposal of a defined amount of hazardous waste. LCA proposes a systematic compilation of resource inputs and emission outputs related to any alternative service system, including all comprised processes. In this so-called inventory assessment, environmental effects of 10 different types are compiled. They are afterwards valued by their contributions to overall annual environmental load, in what is called the impact assessment.

Strengths and drawbacks of Life Cycle Assessment (LCA):	
	coverage of environmental burdens and risks: inventory of emissions and resource demand; human and ecotoxicity as classical evaluation criteria
	complexity and clearness:
	clearly arranged results, but difficult definition of system boundaries
	analytical requirements: demanding, time consuming data generation
	assessment cost: high due to expert knowledge required for system definition and information gathering
	treatment of knowledge gaps: risk considerations neglected, such as uncertain health effects

Figure 10-1: The suitability of the LCA procedure for the environmental preferability assessment

⁴³ *Review literature:* see e.g. EEA (1997) "Life Cycle Assessment – A guide to approaches, experiences and information sources, downloadable at <http://reports.eea.eu.int/GH-07-97-595-EN-C/en/Issue%20report%20No%206.pdf> . For a short introduction see <http://www.uneptie.org/pc/pc/tools/lca.htm>.

Environmental impact assessment (EIA)⁴⁴

Alternatively, environmental impacts of each process step can be valued by their relative importance to a baseline environmental load, determined by existing pollutant concentrations at the affected site, as is done in the course of an EIA.

The EIA method, however, focuses on a specific installation and its site-specific environmental conditions. One related element of EIA that may be of use is the Control of Effects assessment, which means reviewing assumed exposure data with regard to risk mitigation measures.

The inclusion of risk issues into the assessment is an important issue. The risk of accidents could be considered one decision criterion, and balanced against the preferability in case of regular operations, as revealed by an LCA.

Strengths and drawbacks of Environmental Impact Assessment (EIA)



coverage of environmental burdens and risks:

substance transfer via waste and water;
sensitivity of ecosystem, incl. existing status;
stress on risk reduction



complexity and clearness:

facility specific results
→ non-uniform decision basis, results not transferable



analytical requirements:

highly specific technological and site-related environmental expertise
for evaluation of alternatives, no-action alternative demanded



assessment cost:

relevant if assessment to be performed for every single facility



treatment of knowledge gaps:

gaps addressed explicitly, but decision based on available information

Figure 10-2: The suitability of the EIA method for the environmental preferability assessment

⁴⁴ For a demonstrative illustration of the overall procedure see the Commission guidance documents at <http://europa.eu.int/comm/environment/eia/eia-support.htm>.

Technology Assessment (TA)⁴⁵

The methodology of Technology Assessment usually compares innovative technologies to a status quo ante, which would be difficult to define in our case, though. A 100% incineration, or concrete stabilised landfilling of hazardous waste comes into question, it is, however, not representative for the current situation. A suchlike assumption would therefore neglect the existing state of the art treatment routines.

Strengths and drawbacks of Technology Assessment (TA)

-  **coverage of environmental burdens and risks:**
qualitative assessment only, no framework for resource consumption or emission data processing
-  **complexity and clearness:**
screening and scoping tool designed for enterprise level, explicitly NOT applicable for regulatory decision making
-  **analytical requirements:**
compilation of available information as a simple pro-con list;
basis is technological knowledge
-  **treatment of knowledge gaps:**
precise description of technological impacts, economic and ecological status quo required for comparison
-  **assessment cost:**
no cost-intensive measurement activities or data conversion required

Figure 10-3: The suitability of the TA methodology for the environmental preferability assessment

⁴⁵ A discussion on the method in the context of various environmental assessment tools can be found at <http://www.unep.or.jp/ietc/Publications/Integrative/EnTA/AEET/3.asp>.

Risk Assessment (RA)⁴⁶

A state-of-the-art risk assessment provides a comprehensive image of the risk attached to a process. It processes wide-ranging information on toxicological properties of the substances involved, and distinctly addresses hazard and exposure elements of risk. For the valuation of risk information as a basis for recommended procedures, it establishes a benchmark concept.

Strengths and drawbacks of Risk Assessment (RA)

-  **coverage of environmental burdens and risks:**
 -  multitude of toxicological attributes regarded, NOAEL assessed; but no regard of resource use
-  **complexity and clearness:**
 -  very precise but extensive data requirements
-  **analytical requirements:**
 - highly specific technological and site-related environmental expertise for evaluation of alternatives; no-action alternative demanded
-  **assessment cost:**
 - detailed measurements required at all levels
-  **treatment of knowledge gaps:**
 - hazard assessment in cases of uncertainty
 - accident and normal case scenarios

Figure 10-4: The suitability of the RA method for the environmental preferability assessment

⁴⁶ Comprehensive information and a first overview on the methodology can be found in the Technical Guidance Document on Risk Assessment published by the European Chemicals Bureau, EUR 20418 EN/1.

Multi-Criteria Analysis (MCA)⁴⁷

To combine the factual elements identified as relevant for the decision, and to facilitate their proceeding, a Multi-criteria analysis can be useful. It supplies methods for the decision making procedure, the compilation and appreciation of conflicting arguments.

Its basic element is the performance matrix that juxtaposes different options for action with all decision criteria mentioned as relevant by the affected persons or stakeholder groups. It provides a clear view on the singularities and drawbacks of each option, and can lay the grounds for a scoring model to yield a precise recommendation.

Strengths and drawbacks of Multi-Criteria Analysis

-  **coverage of environmental burdens and risks:**
free choice of performance criteria and degree of aggregation
-  **complexity and clearness:**
clearly arranged arguments, decision following a simple procedure
-  **analytical requirements:**
level of detail adjusted to information needs for application of each performance criterion
-  **treatment of knowledge gaps:**
inclusion into valuation against a “risk” criterion, or decision on the basis of available information
-  **assessment cost:**
monetary as well as physical data can be processed directly as available
directly translated into a credit point system;
qualitative information included in go/no-go criteria

Figure 10-5: Suitability of Multi-Criteria Analysis as an overarching method for the assessment

⁴⁷ An illustrative presentation of the method is provided by the British ODPM's Multi-criteria analysis manual available at http://www.odpm.gov.uk/stellent/groups/odpm_about/documents/source/odpm_about_source_608524.doc

10.1.4 *Definition of assessment methodology*

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 10-6.
- 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 10-6 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 in Figure 10-2. Environmental preferability is given if the sum of the credits obtained by an option is above 0.

Performance Criteria	Benchmark	Option X	Relation	Credits	Weight	Total Performance	Verbal justification
① POP emissions • air • water • waste							
② Other emissions, (e.g. heavy metals, GHG, ozone pre- cursors, acidifying substances)							
③ Risks, uncertainties							
Total					3		

Figure 10-6: 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 following:

1. Generally describe waste, intended disposal route, and benchmark:
 - Waste code and waste designation
 - Origin
 - Contamination
 - Amount
 - Intended disposal route ("Option X")
 - Benchmark
 - Period of disposal
 - Transport (distance to disposal site, means of transport)
 - Handling
2. Describe technology and precautionary measures applied for intended disposal, and confirm necessary pre-treatments and stabilisation or solidification activities.
3. Fill in table with data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range. Use checklists to obtain performance values for the different criteria.
4. Establish relations between performance values for Option X and benchmark. Attribute credits justified with regard to severity and possible propagation of effects. If data are missing, make a justified expert judgement.
5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor
7. Take the decision based on the performance outcome
 - Total > 0 → The intended waste treatment option is environmentally preferable
 - Total < 0 → The benchmark option is environmentally preferable
 - Total = 0 → Make a justified expert judgement

In order to make clear how the method can be applied in praxis, several exemplary cases show how the evaluation scheme can be applied (see chapter 10.2)

10.1.5 Waste management technologies to compare

The default benchmark option for the management of POP containing wastes is high temperature incineration. This widely used option leads to the destruction of the pollutants,

and can serve as a benchmark for alternative treatment measures in this methodology. If desired, any other treatment option may be used as benchmark for the application of the evaluation scheme.

As environmental preferability has to be assessed for waste exceeding the low POP content limits and classified as POP waste according to European POP regulation (2004/850/EC) only a limited number of alternative treatment options – as listed in Annex V to the regulation⁴⁸ – may be authorised by Member States and exemplarily will be assessed in chapter 10.2.

The environmental implications of these alternative disposal pathways depend largely on the barrier formation of natural and synthetic/technical sealing layers (base and surface seal) which prevent the pollutants from entering the adjacent soil and groundwater and inhibit superficial evaporation or erosion resulting in atmospheric transport.

Furthermore they depend on the physico-chemical properties of the waste and the relevant pollutants defining the leaching properties and the environmental transport and fate.

Whereas leaching is not of relevance for destruction or irreversible transformation methods and has been calculated to be of negligible relevance for underground storage/storage in salt mines it is a crucial factor for the risk assessment of over ground landfilling.

As long-term leaching behaviour besides intrinsic substance characteristics may potentially be influenced by specific pre-treatment measures, this issue is further discussed in chapter 10.1.6.

For certain waste types (e.g. dusts or slags from metallurgical processes) recovery of the waste for use of valuable raw material (metals) in secondary high temperature thermal processes can be a reasonable management option which not yet mentioned in Annex V to the POP regulation, even for waste exceeding the low POP content limit as contained POPs will be largely destroyed during the process and scarce raw material will be saved.

10.1.6 Specifications for solidification and stabilisation measures

If the POP content of a waste lies above low POP content limits but below maximum POP content limit values the question has to be answered which solidification or stabilisation methods, including relevant pre-treatment methods, qualify a waste for disposal in landfills.

The qualifying requirements have to be outlined in a way that disposal in landfills after solidification and/or stabilisation and relevant pre-treatment is environmentally preferable compared to destruction or irreversible transformation.

⁴⁸ hazardous waste landfill or underground stowage in salt mines as well as hard rock formations

Solidification and stabilisation methods aim to reduce possible emissions to the environment depending on the physical condition of the waste. The decision on the environmental preferability of the disposal option should thus regard the management of the waste treated in such way. Figure 10-7 illustrates this point.

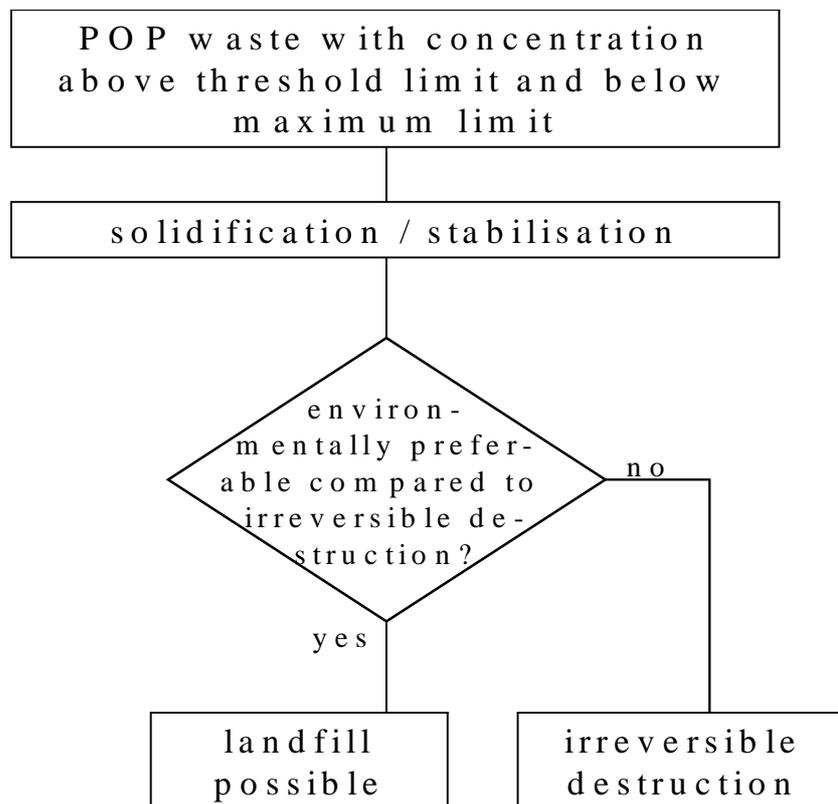


Figure 10-7: Decision scheme related to the environmental preferability of solidified or stabilised waste

The assessment has to take regard of the methods available for the pre-treatment, stabilisation and solidification of waste, and the leachate pollutant concentrations to be expected of a waste that is landfilled. The evaluation of environmental drawbacks and risks shall enable to decide on possible requirements and restrictions, such as the appropriateness of limit values and the necessity of possible pre-treatment measures.

Solidification and stabilisation are both designed to limit possible emissions of POPs from waste however there is an important difference in the definition of both terms:

1. Solidification: According to Commission Decision 2000/532 solidification processes only change the physical state of a waste, e.g. a liquid into a solid, by use of additives. This does not include a change in the chemical properties of the waste. Possible emission of POPs from waste are thus reduced by limiting the solubility and mobility of POP constituents in the waste.

2. **Stabilisation:** According to the same Commission Decision, stabilisation processes change the dangerousness of the waste constituents and thus transform hazardous to non-hazardous waste. In the case of POPs, the transformation into non-toxic or less toxic substances would e.g. consist of a de-halogenation. Consequently stabilisation measures have to be considered as destruction method as the POP content of a waste is destroyed.

Stabilisation can be performed by means of chemical or thermal processes.

Thermal treatment methods aim at reducing the volume of a waste and the mobility of the pollutants contained. Three different thermal treatment methods are being operated; these are melting, vitrification, and sintering. Especially, vitrification renders the physical encapsulation of the pollutants. Like the melting process, it is carried out at temperatures between 1300 and 1500°C. Sintering requires a temperature of about 900°C. Due to the high temperatures, POPs in the waste are usually destroyed during treatment. Therefore also thermal treatment is a method of destruction.

Chemical stabilisation and thermal treatment methods are both methods of destruction. POP waste that has been stabilised or thermally treated in order to destroy its POP content should not contain any POPs. As a consequence expected leakage of POPs from stabilised or thermally treated waste is zero. The decision on the environmental preferability of stabilisation and thermal treatment options has to be taken on the basis of the general method for decision on the environmental preferability of treatment options for POP wastes exceeding low POP content limits but below maximum POP content limits. Therefore stabilisation and thermal treatment are not considered in the following which is consequently restricted to stabilisation.

The Principle of solidification methods for POPs is limiting the solubility or mobility of the POPs in hazardous waste by physical containment which leads to decreased hydraulic conductivity and increased durability [UNEP BAT-BEP 2004].

The following solidification methods are commonly used for the containment of POPs

- Cement and pozzolanic applications use inorganic binders, such as cement, lime and other pozzolanic materials, e.g. fly ash).
- Thermoplastic encapsulation makes use of organic binders, as are bitumen or asphalt, paraffins, or polyethylene.

10.1.7 Specification of pre-treatment measures

A variety of pre-treatment measures shall improve the waste properties before disposal to landfill. Commonly used pre-treatment methods are listed in the UNEP General Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants to the Basel Convention [UNEP GTGESM 2000]. Depending on the waste properties, several pre-treatment methods may contribute to an optimised solidification and thus contribute to reduced or

controlled leaching:

- Screening and crushing improves the homogeneity of the waste and ensure homogeneous leaching properties of the waste
- Ageing before solidification can positively affect the leaching properties of a solidified waste
- Acid extraction serves the same purpose by reducing the leachability of POPs
- Dewatering is performed to increase the density and physical stability of the waste.
- Thermal desorption may reduce the POP concentration in the contaminated waste.
- pH-adjustment raises the pH of the waste material, thereby increasing the buffer capacity and improving its leaching properties.

Even provided an appropriate pre-treatment and solidification of a waste, some risks remain associated with its disposal in a landfill. Generally the risks are related to the long term safety of the solidified waste i.e. the question if solidification enables appropriate reduced leakage of POPs over hundreds or thousand of years. In the long term several conditions may alter the properties of the solidified waste. Weathering can mechanically destroy the solidified waste matrix and alter its leakage properties. As a consequence also emissions of POPs via dust into air or via the discharge of particles to water are possible. Other effects that may affect the leakage properties are pH-alterations that may occur due to acid precipitation, contact with atmospheric CO₂, or the uptake of organic acids from plants. Also acids, oils, tensides or other organics can increase the solubility of POPs in the waste.

As a consequence of these consideration two decisive requirements remain for the solidification of waste to be disposed to landfill:

- appropriate leakage rate
- appropriate long term safety

The remaining questions are consequently

- what is an appropriate leakage rate for solidified POP wastes?
- what is an appropriate long term safety ensuring reduced mobility of the POPs in the long run?

Both requirements should enable environmental preferability of solidified and disposed POP waste compared to its destruction.

Experience with leaching properties and long term behaviour of solidified waste is mainly

available for inorganic pollutants⁴⁹. Information on the leachate of organic compounds is generally scarce. Generally it can be stated that the presence of dissolved organic carbon can mobilise organic contaminants and the leaching behaviour of dissolved organic carbon from waste is relevant for the assessment of potential impacts. The quantities of DOC released from different materials depends on the waste material (usually increase with the organic content of the material) and the pH (usually increase with the pH value) [see LN 2005]. As a consequence, high pH-values need to be avoided in order to prevent mobilisation of DOC which goes in hand with mobilisation of POPs. According to expert information, the negative effects of a rise of pH can be adjusted by use of specific binding agents.

According to leaching tests performed for PCDD/PCDF annual leaching rates for solidified waste (fly ash) are expected in an order of magnitude of approximately 10^{-6} for cement or pozzolanic solidification⁵⁰ and of 10^{-7} in the case of thermoplastic solidification [LCA AVI 2002]. Expected leaching rates are documented in Table 10-2.

Results from leaching tests for dioxins ⁶⁾	without treatment	cement and pozzolanic solidification	thermoplastic solidification
Leaching [%] under varying test conditions	0.001 ¹⁾ 0.001-0.0001 ²⁾ 0.002 ³⁾ 2.5 ⁴⁾		
Estimated 100 year leaching rate ⁵⁾	1%	0.01%	0.001%

Source 1) to 6): LCA AVI fly ash, 2002 (all values are applicable to a 100 year period)

- 1) RIVM, Acid percolate, column test, A total fatty acid content of 20.000 mg/l (acetic acid, propanoic acid, butyric acid, valeric acid); based on the assumption that the fly ash contains approximately 3 µg TEQ/kg ds
- 2) RIVM, demineralised water, column test (both o-NVN 7344); The first value is an average derived from a retest, the final value was set after having eliminated a probable maverick
- 3) Sakai, 200 mg/l humic acid in -demineralised water, shaking test. 24h
- 4) Schramm, 1500 mg/l LAS (linear alkyl benzene sulphonate), shaking test
- 5) worst case estimation for fly ash; applicable for dioxins and PCBs (justification given in the literature reference, appendix 8, dioxins memorandum)
- 6) A leaching test used by the RIVM for dioxins was later validated for PCBs, and proved useable; in view of the limited amount of results on the leaching of dioxins, the results should be considered as an order of magnitude

Table 10-2: Leaching rates expected following state of the art solidification

⁴⁹ see e.g. several contributions at the 9th international waste management and landfill symposium, Sardinia, October 2003

⁵⁰ note: an annual leaching rate of 10^{-6} corresponds to a 100 year leaching rate of 0.01%

As regards the minimum requirement concerning the leaching behaviour of a waste foreseen for landfill, the project team suggests that an annual leakage rate of 10^{-6} be considered appropriate. Leaching should be tested by means of appropriate leaching tests as required in directive 2003/33/EC for other pollutants already. Appropriate tests are currently not available for all POPs. Thus CEN might be mandated with the standardisation process. Experiences from related projects with respect to modelling and leaching assessment could be used (projects GRACOS and HORIZONTAL).

The minimum requirements for long term safety have to be seen in the context of existing long term estimations. The analytical results presented above (see Table 10-2) indicate the proposed leakage rate as a worst case estimation for the time frame of 100 years. It is difficult to assess how valid or realistic such estimations are because practical long term experience with up-to-date technologies is not available yet. Tests for long term leaching properties have only limited significance for long-run developments, in spite of considerable effort invested. Consequently, uncertainty remains on whether established long-term test methods (including the simulation of different weather conditions such as freeze and thaw cycles) can represent realistic conditions for several centuries. Solidified materials, in particular cement and pozzolanic matrices, have been considered to exhibit only limited long-term stability under disposal conditions [Wienberg 2004]. On the other hand, assessment of the alkaline buffer capacity hampering leaching of POPs from landfill indicate a satisfying long-term buffer activity spanning roughly 400 thousand years [SDR 2004].

Considering that if a solidification method allows appropriate low leakage rates over a time frame of 100 years with a high probability and taking into account that

- POP concentrations are decreasing according to the leaching rate and according to the half-lives of the corresponding POPs in its specific matrix within this time frame due to decomposition processes,
- the starting concentration of POPs in solidified waste is already below specific maximum levels (maximum POP content limit values; see chapter 9.5) and
- (if at all) that leakage rates are expected to increase only slowly after the 100 year time frame

it seems appropriate to require a solidification that guarantees low leakage rates (i.e. 10^{-6}) over a time frame of at least 100 years. Due to the uncertainty for the long term safety a justified assessment of the long term safety is necessary (e.g. with the support of appropriate testing methods).

Finally the requirements for solidification depend on the leakage rate of the original (i.e. not solidified) waste and the concentration of the POP waste in question.

If the leakage rate of the original waste is below the requirements for solidified waste (i.e. annual leakage below 10^{-6}) a solidification is not required. At POP concentrations above the established maximum POP content limit, the leakage rate loses its relevance because any

waste exceeding the maximum POP content limit must be destroyed or irreversibly transformed. Solidification is no longer reasonable. In any other case appropriate solidification is necessary in order to ensure an acceptable leaching behaviour.

To conclude, the following overall picture results:

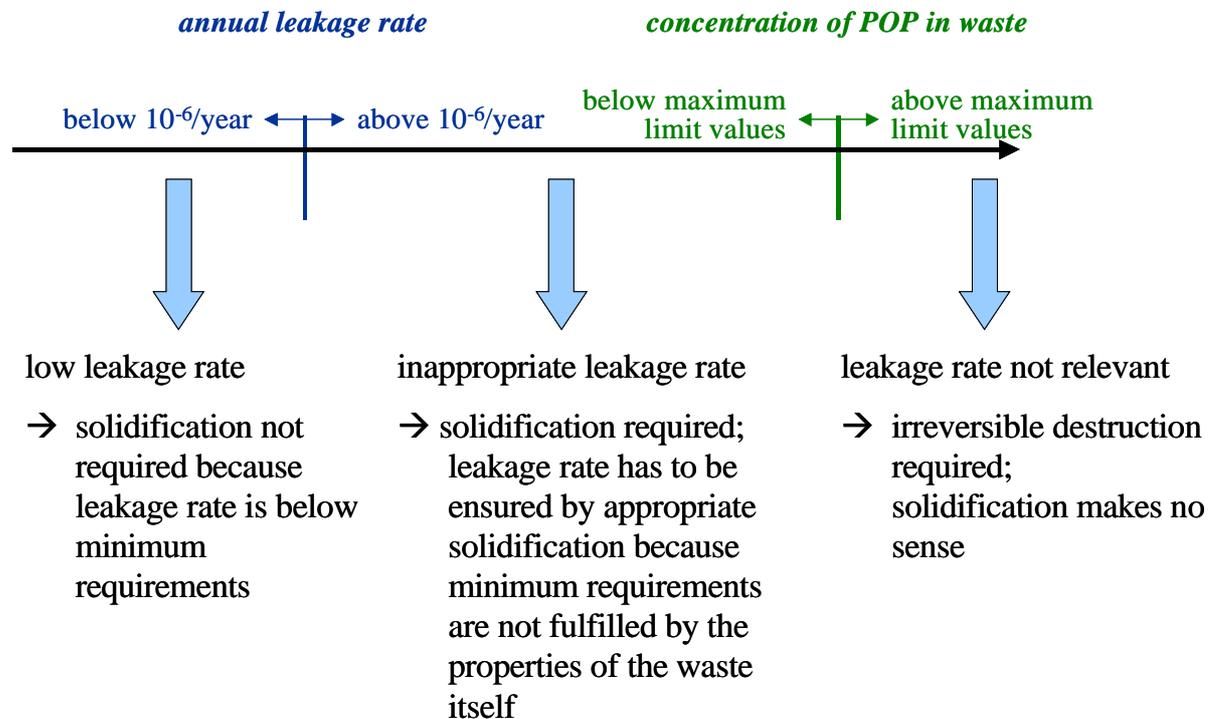


Figure 10-8: Schematic illustration of conditions related to solidification requirements

As a result the following requirements for solidification can be proposed:

- annual leakage rate of the original (not solidified) waste above 10^{-6}
- POP concentration below maximum POP content limit values according to chapter 9.5
- annual leakage rate of the solidified waste below 10^{-6}
- long term safety for a time frame of at least 100 years

In order to achieve the leakage rates not only solidification but also any other appropriate pre-treatment method may be applied.

Not every solidification process is suited for immobilisation of POPs. As a consequence, testing of the solidified waste is necessary. Even if in single cases testing methods are established⁵¹ it has to be stressed that at European scale no standard leaching tests are

⁵¹ E.g. In the Netherlands, a leakage test was especially designed for measuring the emission of POPs from

existing for organic compounds. As pre-condition for an appropriate implementation of corresponding legislation there is definitely a need to develop appropriate standards for POP containing waste (solidified and not solidified) that enable to estimate (a) the leakage of POPs and (b) the correlated long term safety.

10.2 Exemplary application of assessment methodology

In the following, the method developed in chapter 10.1.4 is applied to selected exemplary cases. They represent choices between different disposal/recovery options under conditions likely to be incurred by decision makers, who may be authorities or owners of waste. Even if invented, the examples shall represent realistic situations. The evaluation of the exemplary cases is based on several assumptions such as contamination level, transport distance etc. in order to demonstrate how the method may be applied in practice.

The following considerations are basic elements for the calculations in the case studies:

The high temperature incineration of POPs features a destruction removal efficiency of 99.9999% [UNEP GTGESM 2005 final]. Accordingly, emissions to air from POP incineration can be estimated to be approximately 0.0001% of the POP input. The destruction efficiency of alternative waste treatment options can be compared to the high temperature incineration destruction removal efficiency (based on existing information without the necessity to measure it in any case).

The new formation of PCDDF in the course of the incineration is estimated to correspond to a ratio of 40 µg/ton waste incinerated. This estimation is based on data for incineration of municipal solid waste. Even a lower reformation ratio around 5 µg/ton waste is realistic. The reformation ration of alternative waste treatment options can be compared to this.

For the leaching behaviour of POPs from solidified waste, a leaching factor of 10^{-6} per year has been measured (see chapter 9). The leakage from non solidified waste is a factor 2 higher and thus approximately 10^{-4} .

The energy demand for the incineration of wastes with a low intrinsic heating value lies in between 0.7 and 1.0 MWh / tonne. The calculations in the examples are based on an average value of 0.85 MWh / tonne. The corresponding greenhouse gas emissions amount to ~ 230 kg CO₂/t waste (266 kg CO₂ / MWh thermal energy from waste) [Johnke 2002]). The solidification of waste in a cement matrix, assuming a cement/waste relation of 1:4, requires an energy input of 0.2 MWh per tonne of waste treated, corresponding to a CO₂ emission of 624 kg/t cement or ~156 kg/t waste [Deutsche Zementindustrie 2003]. Further CO₂ emissions arise from road transport, in the amount of 2 kg per tonne waste transported over 100 km.

solidified products (Dutch standard NVN 7376). According to expert opinion this method will enable a good prediction of the emissions as far as the conditions in the waste don't change too much.

The assessment of different cases, following the seven step procedure laid out in chapter 10.1.4 is demonstrated in exemplary cases in the following.

Exemplary case no 1:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	19 01 13* Fly ash containing dangerous substances
Origin	Municipal solid waste incineration
Contamination	15 ppb PCDD/PCDF
Amount	100 t, total PCDD/PCDF content 1.5 g
Intended disposal route ("Option X")	Disposal in hazardous waste landfill
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 100 km road transport to hazardous waste landfill Benchmark: 200 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Hazardous waste landfill according to BAT standards
- Solidification with cement;
addition of binding reagent (~250 kg/t) and water (~100 l/t)

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data are missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	1.5 µg	0
leachate	0	< 1.5 µg / year
waste	< 4000 µg	0
Credits for criterion ①:	+1	
<i>Justification:</i> Option X is considered environmentally preferable because emission to air is given higher priority with respect to environmental impact as it has a direct, uncontrolled impact on soil contamination, thus affecting the food chain, whereas leachate and waste are further controlled and treated..		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	23 t CO ₂	15.6 t CO ₂
CO ₂ emission for transport	0.02 t CO ₂	0.01 t CO ₂

Credits for criterion ②: +1		
<i>Justification:</i> Option X is considered environmentally preferable due to the following reasons: Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, with respect to emissions other than POPs, greenhouse gas emissions constitute the most important argument. The intended treatment causes less CO ₂ emissions compared to the benchmark technology. Also lower emission from transport due to lower distance are in favour to the intended option.		
③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	uncertain
Credits for criterion ③: -1		
<i>Justification:</i> Even if several estimations indicate that the disposal of solidified waste may be safe for centuries, uncertainty with respect to long-time safety of landfilling is the crucial factor in view of comparable performance.		

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	+1	1	+1
③ Risks, uncertainties	-1	1	-1
Total		3	+1

7. Decision based on the performance outcome:

The intended waste treatment option is environmentally preferable.

Exemplary case no 2:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	19 01 13* fly ash containing dangerous substances
Origin	Municipal solid waste incineration
Contamination	15 ppb PCDD/PCDF
Amount	100 t, total PCDD/PCDF content 1.5 g
Intended disposal route ("Option X")	Disposal in hazardous waste landfill
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 100 km road transport to hazardous waste landfill Benchmark: 200 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Hazardous waste landfill according to BAT standards (no solidification)

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

① POP emissions	benchmark	option X
air	1.5 µg	0
leachate	0	< 150 µg / year
waste	< 4000 µg	0
Credits for criterion ①: 0		
<i>Justification:</i> A decision is difficult because a non-recurring one-time emission of 1.5 µg to air (uncontrolled; potential to enter the environment/food chain) plus a one time discharge to waste < 4000 µg (controlled; low probability to enter the environment/food chain) on the side of the benchmark treatment option has to be evaluated against a recurring annual emission to leakage < 150 µg/y (controlled) on the side of the intended treatment option. After a mid to long term period the emissions from option X will exceed the emissions from the benchmark technology. However the emissions are to leakage and the potential to enter the environment is comparatively limited. A clear decision against or in favour of the one or the other option is not possible.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction	23 t CO ₂	0 t CO ₂
CO ₂ emission for transport	0.02 t CO ₂	0.01 t CO ₂
Credits for criterion ②: +1		

Justification:

Option X is considered environmentally preferable due to the following reasons:

Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways.

Therefore, with respect to emissions other than POPs, greenhouse gas emissions constitute the most important argument.

The intended treatment causes practically no CO₂ emissions in contrast to the benchmark technology. Also emissions from transport are in favour of the intended treatment.

③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k. ⁵²
long term safety	assured	uncertain

Credits for criterion ③: -1

Justification:

Even if several estimations indicate that disposal sites are safe in the long term, uncertainty with respect to long-time safety of landfilling is the crucial factor in view of comparable performance.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing make a justified expert judgement.
5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	0	1	0
② Other emissions	+1	1	+1
③ Risks, uncertainties	-1	1	-1
Total		3	0

7. Decision based on the performance outcome:

Need for a justified expert judgement:

As a clear decision on the environmental preferability can not be taken, the waste has to be either treated with the benchmark treatment option or the waste has to be solidified. As shown above, solidification leads to environmental preferability.

⁵² If the proposed annual leakage rate of 10⁻⁶ will be taken up into legislation as a low POP content limit that requires solidification before landfill, option X would not be legally compliant. This would be a k.o. criterion for the intended option.

Exemplary case no 3:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	Waste code 19 01 05* Filter cake from gas treatment
Origin	Municipal solid waste incineration
Contamination	30 ppb PCDD/PCDF
Amount	5 t, PCDD/PCDF content 150 mg
Intended disposal route ("Option X")	Disposal in hazardous waste landfill
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 100 km road transport to hazardous waste landfill Benchmark: 200 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Hazardous waste landfill according to BAT standards
- Solidification with cement;
addition of binding reagent (~250 kg/t) and water (~100 l/t)

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	0.15 µg	0
leachate	0	< 0.15 µg / year
waste	< 200 µg	0
Credits for criterion ①: +1		
<i>Justification:</i> Emission to air is given higher priority with respect to environmental impact as it has a direct, uncontrolled impact on soil contamination, thus affecting the food chain, whereas leachate and waste are further controlled and treated.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	1.2 t CO ₂	0.8 t CO ₂
CO ₂ emission for transport	0.02 t CO ₂	0.01 t CO ₂
Credits for criterion ②: +1		

<i>Justification:</i> Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, greenhouse gas emissions constitute the most important argument. The intended treatment causes less CO ₂ emissions compared to the benchmark technology. Also emissions from transport are in favour of the intended treatment.		
③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	uncertain
Credits for criterion ③: -1		
<i>Justification:</i> Even if several estimations indicate that the disposal of solidified waste may be safe for centuries, uncertainty with respect to long-time safety of landfilling is the crucial factor in view of comparable performance.		

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	+1	1	+1
③ Risks, uncertainties	-1	1	-1
Total		3	+1

7. Decision based on the performance outcome:

The intended waste treatment option is environmentally preferable.

Exemplary case no 4:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	Waste code 17 09 02* Construction and demolition wastes containing PCB
Origin	Demolition of an industrial facility
Contamination	300 ppm PCB
Amount	50 t, PCB content 15 kg
Intended disposal route ("Option X")	Disposal in hazardous waste landfill
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 200 km road transport to hazardous waste landfill Benchmark: 200 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Hazardous waste landfill according to BAT standards

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	15 mg	0
leachate	0	< 15 mg / year
waste	< 2 mg	0
Credits for criterion ①: +1		
<i>Justification:</i> Emission to air is given higher priority with respect to environmental impact as it has a direct, uncontrolled impact on soil contamination, thus affecting the food chain, whereas leachate and waste are further controlled and treated.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	11.6 t CO ₂	0 CO ₂
CO ₂ emission for transport	0.2 t CO ₂	0.2 t CO ₂
Credits for criterion ②: +2		

<i>Justification:</i> Incineration leaves heavy metals etc. in solid residues. Disposal follows, both options lead these pollutants to the same waste treatment options. No difference is to be expected regarding their emissions. Greenhouse gases are decision relevant. Assuming equal distances to disposal facilities with appropriate capacities for large-volume waste, CO ₂ emissions depend entirely on the treatment process. Due to the physical properties and volume, stabilisation of demolition waste is not assumed necessary and feasible.		
③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	uncertain
Credits for criterion ③: -1		
<i>Justification:</i> Even if construction and demolition waste is considered inert and no adverse effects must be expected, uncertainty with respect to long-time safety of landfilling is the crucial factor in view of comparable performance.		

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	+2	1	+2
③ Risks, uncertainties	-1	1	-1
Total		3	+2

7. Decision based on the performance outcome:

The intended waste treatment option is environmentally preferable.

Exemplary case no 5:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	17 04 10* glass, plastic and wood containing or contaminated with dangerous substances
Origin	Demolition of an industrial facility (Waste cable residues as plastic granulate)
Contamination	40 ppm PCB
Amount	10 t, PCB content 0.4 kg
Intended disposal route ("Option X")	Disposal in hazardous waste landfill
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 200 km road transport to hazardous waste landfill Benchmark: 100 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Hazardous waste landfill according to BAT standards
- Solidification with cement;
addition of binding reagent (~250 kg/t) and water (~100 l/t)

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	0.4 mg	0
leachate	0	< 0.4 mg / year
waste	< 2 mg	0
Credits for criterion ①: +1		
<i>Justification:</i> Emission to air is given higher priority with respect to environmental impact as it has a direct, uncontrolled impact on soil contamination, thus affecting the food chain, whereas leachate and waste are further controlled and treated.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	2.3 t CO ₂	1.6 t CO ₂
CO ₂ emission for transport	0.02 t CO ₂	0.04 t CO ₂
Credits for criterion ②: -1		

Justification:

Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, greenhouse gas emissions constitute the more important argument. As plastic granulate possesses a relatively high heating value (3.36 MWh/t), usable energy can be derived and thus CO₂ emissions can be reduced. Therefore the benchmark is considered to be preferable.

③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	uncertain
Credits for criterion ③:	-1	

Justification:

Even if several estimations indicate that the disposal of solidified waste may be safe for centuries, uncertainty with respect to long-time safety of landfilling is the crucial factor in view of comparable performance.

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	-1	1	-1
③ Risks, uncertainties	-1	1	-1
Total		3	-1

7. Decision based on the performance outcome:

The intended waste treatment option is not environmentally preferable.

Exemplary case no 6:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	13 03 01* insulating or heat transmission oils containing PCB
Origin	Electric equipment
Contamination	100% PCB
Amount	5 t
Intended disposal route ("Option X")	Underground stowage in a salt mine
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 500 km road transport to salt mine Benchmark: 100 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Underground stowage in a salt mine

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	5 g	0
leachate	0	0 mg / year
waste	< 0.2 mg	0
Credits for criterion ①: +1		
<i>Justification:</i> No emissions are expected from an underground site.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	1.2 t CO ₂	0 CO ₂
CO ₂ emission for transport	0.01 t CO ₂	0.05 t CO ₂
Credits for criterion ②: -1		
<i>Justification:</i> Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, greenhouse gas emissions constitute the more important argument. As pure PCB possesses a relatively high heating value (3.1 MWh/t), usable energy can be derived and thus CO ₂ emissions can be reduced. Therefore the benchmark is considered to be preferable.		
③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.

long term safety	assured	uncertain
Credits for criterion ③: -1		
<i>Justification:</i> Even if studies indicate underground stowage in salt mines to be safe, the persistence of PCB is the crucial factor in view of comparable performance.		

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	-1	1	-1
③ Risks, uncertainties	-1	1	-1
Total		3	-1

7. Decision based on the performance outcome:

The intended waste treatment option is not environmentally preferable.

Exemplary case no 7:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	10 03 23* solid wastes from gas treatment containing dangerous substances
Origin	Secondary aluminium production
Contamination	25 ppb PCDD/PCDF
Amount	5 t, PCDD/PCDF content 0.13 kg
Intended disposal route ("Option X")	Treatment for use in landfill construction
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 5 km road transport to recycling site Benchmark: 150 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Treatment for use as a landfill construction material
- Solidification with cement;
addition of binding reagent (~250 kg/t) and water (~100 l/t)

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	0.13 mg	0
leachate	0	< 0.13 mg / year
waste	< 0.2 mg	0
Credits for criterion ①: +1		
<i>Justification:</i> Emission to air is given higher priority with respect to environmental impact as it has a direct, uncontrolled impact on soil contamination, thus affecting the food chain, whereas leachate and waste are further controlled and treated.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	1.2 t CO ₂	1.2 t CO ₂
CO ₂ emission for transport	15 kg CO ₂	0.5 kg CO ₂
Credits for criterion ②: +1		

Justification:

Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, greenhouse gas emissions constitute the more important argument. The advantage of the intended treatment over the benchmark in terms of CO₂ emissions is entirely due to the different transport distances.

③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	uncertain

Credits for criterion ③: -1

Justification:

Even if several estimations indicate the use of solidified waste to be safe, uncertainty with respect to long-time safety of landfill sites is the crucial factor in view of comparable performance.

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	+1	1	+1
③ Risks, uncertainties	-1	1	-1
Total		3	+1

7. Decision based on the performance outcome:

The intended waste treatment option is environmentally preferable.

Exemplary case no 8:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	02 01 08* agrochemical waste containing dangerous substances
Origin	Agriculture (POP pesticides)
Contamination	3000 ppm
Amount	10 t, POP content 10 kg
Intended disposal route ("Option X")	Disposal in hazardous waste landfill
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 100 km road transport to hazardous waste landfill Benchmark: 500 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Hazardous waste landfill according to BAT standards
- Solidification with cement;
addition of binding reagent (~250 kg/t) and water (~100 l/t)

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	30 mg	0
leachate	0	< 30 mg / year
waste	< 0.4 mg	0
Credits for criterion ①:	+1	
<i>Justification:</i> Emission to air is given higher priority with respect to environmental impact as it has a direct, uncontrolled impact on soil contamination, thus affecting the food chain, whereas leachate and waste are further controlled and treated.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	2.3 t CO ₂	1.6 t CO ₂
CO ₂ emission for transport	0.05 t CO ₂	0.02 t CO ₂
Credits for criterion ②:	+1	

<i>Justification:</i> Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, greenhouse gas emissions constitute the more important argument. The intended treatment causes less CO ₂ emissions compared to the benchmark technology. Also lower emission from transport due to lower distance are in favour to the intended option.		
③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	uncertain
Credits for criterion ③: -1		
<i>Justification:</i> Even if several estimations indicate that the disposal of solidified waste may be safe for centuries, uncertainty with respect to long-time safety of landfilling is the crucial factor in view of comparable performance.		

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	+1	1	+1
② Other emissions	+1	1	+1
③ Risks, uncertainties	-1	1	-1
Total		3	+1

7. Decision based on the performance outcome:

The intended waste treatment option is environmentally preferable.

Exemplary case no 9:

1. Waste, intended disposal route, and benchmark:

Waste code and waste designation	10 06 03* flue-gas dust
Origin	Secondary copper production
Contamination	15 ppb PCDD/PCDF
Amount	10 t, PCDD/PCDF content 0.15 kg
Intended disposal route ("Option X")	Retrieval of metal components for recycling
Benchmark	Thermal destruction
Period of disposal	February and March 2005
Transport	Intended option: 50 km road transport to recycling site Benchmark: 50 km to thermal destruction facility
Handling	Safe handling and compliance with occupational exposure limits guaranteed

2. Technology and precautionary measures, pre-treatments and stabilisation or solidification:

- Treatment for retrieval of metal components, at temperatures comparable to incineration, off the production site

3. Data for criteria ① to ③ for the benchmark option and "Option X". If precise data missing, fill in an estimated range.

4. Establish relations between performance values for Option X and benchmark. Attribute credits. If data are missing, make a justified expert judgement.

① POP emissions	benchmark	option X
air	0.15 mg	0.15 mg
leachate	0	0
waste	< 0.4 mg	< 0.4
Credits for criterion ①:	0	
<i>Justification:</i> Emission to air and waste is assumed equal for the two high temperature processes, as both are conducted according to legal requirements regarding the treatment of exhaust air and residues.		
② Other emissions	benchmark	option X
CO ₂ emission for destruction/solidification	2.3 t CO ₂	2.3 t CO ₂
CO ₂ emission for transport	10 kg CO ₂	10 kg CO ₂
Credits for criterion ②:	+1	
<i>Justification:</i> Heavy metals released during incineration are adsorbed to a large extent to flue gas treatment residues. Thus, no important difference exists in potential emissions from the two alternative disposal pathways. Therefore, greenhouse gas emissions constitute the more important argument. If transport distances are equal, CO ₂ emissions and energy demand do not differ between the two options. The relevant decision criterion is the recovery of heavy metals as a secondary raw material. They remain in incineration residues if the waste is incinerated. Therefore the intended option is preferable.		

③ Risks, uncertainties	benchmark	option X
legal compliance	o.k.	o.k.
long term safety	assured	assured
Credits for criterion ③: 0		
<i>Justification:</i> Both processes are run at temperatures sufficient to destroy PCDD/PCDF.		

5. If appropriate, weigh the criteria according to the local situation and the quality of the data background. Make sure that weighting criteria are fulfilled (Sum = 3; min = 0.5; max = 2)
6. Calculate the total performance by multiplying the credits with the weighting factor

Performance\Criteria	Credits	Weight	Total Performance
① POP emissions	0	1	0
② Other emissions	+1	1	+1
③ Risks, uncertainties	0	1	0
Total		3	+1

7. Decision based on the performance outcome:

The intended waste treatment option is environmentally preferable.

Findings from the case studies:

Destruction by thermal treatment is being suggested by European legislation as a standard option to minimise environmental threats from dangerous substances. However, the destruction of POPs during the incineration process is not complete. Emissions to air persist, which entangle a widely uncontrollable dissemination of the POPs. Dispersing in ecosystems, they can be attributed a high potential to enter the food chain.

Landfill of POP waste can thus be advantageous, and so can recycling and recovery, especially if dangerous substances like heavy metals are retrieved and subjected to a controlled use. Only the thermal destruction of substances with an elevated calorific value is clearly preferable. In this case, it can be assumed that energy gains from the combustion over-compensate the detriment.

Trading off emissions against energy consumption actually is an ambitious task. The result will never be unambiguous but must express a well-founded opinion. Still, environmental objections to thermal destruction are strong whenever the associated resource consumption is high. This suggests landfilling of non-combustible waste if it is inert or can be stabilised and solidified. As the energy consumption for the solidification process is still remarkably inferior to the energy input required to incinerate substances with low calorific values, the overall environmental burden expected is still smaller. Even in case no solidification is conducted, landfilling may be justified. Its preferability is less clear, though, than in the case of waste with leakage rates minimised by a solidification matrix. If solidification is carried out, even the use of POP wastes for landfill construction is justifiable.

Indeed this judgement relies on an equal weighting of the performances related to POP emissions, other emissions, and long-term risk, respectively. It is imaginable that aspects of uncertainty, as reflected by Criterion ③, be weighted stronger than emissions from regular operation. As well, a political preference for the specific aim of resource conservation may exist. In both cases, the rating of option can differ from the case results presented.

11 Categorisation and reporting tools

11.1 Categorisation of existing waste codes

According to Article 1 (a) of the Council Directive on waste (75/442/EC) and Article 1, paragraph 4 of Council Directive on hazardous waste (91/689/EC) a harmonised list of European waste codes (EWC) has been established by Decision 2000/532/EC allowing a specific classification of each type of waste by means of a six-digit code in one of the 20 chapters of the list.

Any waste marked with an asterisk (*) is considered as a hazardous waste pursuant to Directive 91/689/EC and is considered to display one or more of the properties (H) listed in Annex III to the Directive. The classification of a waste as hazardous follows the provisions of 91/689/EC.

If a waste is classified as hazardous by a specific or general reference to dangerous substances, it is only hazardous if the concentration of these substances exceed the limits set. For PCB specific regulations have been set in addition in the PCB disposal Directive⁵³

A categorisation of the waste codes in view of their potential to contain POPs in concentrations exceeding the limit values to be established under the European POP Regulation shall help to facilitate the implementation of the Regulation and focus monitoring and control to the relevant sectors.

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
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)

While only little testing effort is foreseen for wastes from group B group C waste codes will require more testing effort, in particular if disposal or recovery as non POP waste is intended The testing approach for the different groups is discussed in chapter 12.

It has to be stated that the group allocation is based on available data and takes into account uncertainty with respect to contamination levels in certain waste codes. This is especially important for all codes compiled under group C. For these waste codes the uncertainty with respect to the effective contamination in the specific waste sample is especially high. This can happen either because the reported data show a extremely wide range of contamination, the

⁵³ Council Directive 96/59/EC

data base is extremely poor or the contamination is a function of “hot spot” situations. This applies namely for C&D wastes.

In addition the allocation of certain waste codes is not always unambiguous and clear-cut. This can be due to a coding not exactly fitting to the specific waste type or it is not always clear whether a waste with a moderate POP content will in practice be reported as asterix code or the corresponding non-asterix code.

As according to the POP regulation a general monitoring for POPs will be necessary in order to identify wastes exceeding the established low POP content limits a broader data base for precise group allocation will be available in future.

11.1.1 Group allocation for PCDD/PCDF contaminated waste

In view of a low POP content limit of 10 ppb for PCDD/PCDF most waste codes show a low likelihood to exceed the low POP content limit which would classify them as POP waste.

Only a small number of waste types, such as fly ashes and FGT residues from secondary aluminium production, metal loaded dusts used as raw material in the secondary copper production and filter cakes from wet flue gas treatment in waste incineration are likely to exceed the limit value for a number of samples/batches. (< 50%)

APC residues from MSWI incineration, chimney soot from domestic burning and ashes from Biomass plants may exceed the limits in some cases (probably less than 10%). Insufficient information is available to assess the potential contamination for combustion residues from lead, precious metal and manganese (other non-ferrous) thermal metallurgy, which according to the latest draft of the UNEP BAT/BEP document and the BREF document on non-ferrous metal industry may have a certain potential to emit/discharge PCDD/PCDF as well.

In the following table a compilation of EWC codes sorted in accordance to their likelihood with respect to exceedance of a low POP content limit of 10 ppb TEQ PCDD/PCDF is given.

group A (low likelihood)	EWC 01-09, 11-18 all categories of 10, 19 and 20 with exception of those mentioned below
group B (high likelihood)	10 02 07* solid wastes from gas treatment containing dangerous substances (iron and steel industry) 10 03 19* flue-gas dust containing dangerous substances (aluminium thermal metallurgy) 10 03 23* solid wastes from gas treatment containing dangerous substances 10 06 03* flue-gas dust (copper thermal metallurgy) 19 01 05* filter cake from gas treatment (waste incineration)
group C (uncertain)	10 01 03 fly ash from peat and untreated wood 19 01 07* solid wastes from gas treatment (waste incineration) 20 01 41 wastes from chimney sweeping
no data (allocation not yet possible)	10 04 wastes from lead thermal metallurgy 10 07 wastes from silver, gold and platinum thermal metallurgy 10 08 wastes from other non-ferrous thermal metallurgy

*dangerous waste

Table 11-1: Group allocation of EWC in view of a low POP content limit of 10 ppb ($\mu\text{g}/\text{kg}$) I-TEQ PCDD/PCDF

A rough estimation for the overall sum of all noted group B waste codes leads to a volume of 2 million tons per year. Waste codes allocated to group C amount for 1.3 million tons per year.

11.1.2 Group allocation for PCB contaminated waste

In view of a limit of 30 ppm (mg/kg) for total PCB⁵⁴ most waste codes show a low likelihood to exceed the low POP content limit which would classify them as POP waste.

Only a small number of waste types, such as hydraulic and insulation oils or equipment containing or contaminated with PCB, waste adhesives and sealants, waste cables and C&D wastes containing or contaminated with PCB are likely to exceed the limit value for a number of samples/batches. (>50%)

Mineral-based oils, other fractions of C&D waste containing dangerous substances and shredder light-fluff and dust may exceed the limits in some cases (probably less than 10%).

In the following table a compilation of EWC codes sorted in accordance to their likelihood with respect to exceedance of a low POP content limit of 30 ppm for total PCB is given.

⁵⁴ Sum 6 Congener x 5 according to German standards

group A (low likelihood)	EWC 01-06, 09-12, 14, 15, 18-20 all categories of 07, 08, 13, 16, 17 with exception of those mentioned below
group B (high likelihood)	13 01 01* hydraulic oils, containing PCBs 13 03 01* insulating or heat transmission oils containing PCBs 16 02 09* transformers and capacitors containing PCBs 16 02 10* discarded equipment containing or contaminated by PCBs other than those mentioned in 16 02 09 08 04 09* waste adhesives and sealants containing organic solvents or other dangerous substances 17 04 10* cables containing oil, coal tar and other dangerous substances 17 09 02* construction and demolition wastes containing PCB (for example PCB containing sealants, PCB-containing resin-based floorings, PCB-containing sealed glazing units, PCB-containing capacitors)

group C (uncertain)	12 01 06* mineral-based machining oils containing halogens (except emulsions and solutions) 13 02 04* mineral-based chlorinated engine, gear and lubricating oils 13 02 05* mineral-based non-chlorinated engine, gear and lubricating oils 17 01 06* mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances 17 02 04* glass, plastic and wood containing or contaminated with dangerous substances (construction and demolition waste) 17 05 03* soil and stones containing dangerous substances 17 06 03* other insulation materials consisting of or containing dangerous substances 17 08 01* gypsum-based construction materials contaminated with dangerous substances 17 09 03* other construction and demolition wastes (including mixed wastes containing dangerous substances) 19 10 03* fluff-light fraction and dust containing dangerous substances 19 10 04 fluff-light fraction and dust other than those mentioned in 19 10 03
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Table 11-2: Group allocation of EWC in view of a low POP content limit of 30 ppm (mg/kg) for total PCB (Sum 6 x 5)

A rough estimation for the overall sum of all noted group B waste codes leads to a volume of 5.5 million tons per year. Waste codes allocated to group C amount for 2.8 million tons per year.

It has to be stated that the group allocation is based on available data and takes into account uncertainty with respect to contamination levels in certain waste codes. This is especially important for all codes compiled under group C. The fact that shredder residues have been classified in Group C is due to the extremely wide range of contamination that has been reported. However it should be expected that the implementation of the related directives ELV and WEEE will lower the range of contamination to levels corresponding to group A. Further data will be needed to trace the effect of the directives.

11.1.3 Group allocation for waste containing or contaminated with POP pesticides⁵⁵

In view of a limit of 10 ppm (mg/kg) for POP pesticides most waste codes show a low likelihood to exceed the low POP content limit which would classify them as POP waste.

Only stocks of obsolete POP pesticides are likely to exceed by far the limit value.

Mixed C&D wastes such as concrete, bricks and tiles, wood, glass and plastic or soils and stones are likely to exceed the limit in locations where POP pesticides have been produced, dumped or stored improperly or without sufficient safety measures.

In the following table a compilation of EWC codes sorted in accordance to their likelihood with respect to exceedance of a low POP content limit of 10 ppm for POP pesticides is given.

group A (low likelihood)	EWC 01-16, 18-20 17 with exception of those mentioned below
group B (high likelihood)	/
group C (uncertain)	17 01 concrete, bricks, tiles and ceramics (construction and demolition wastes) 17 02 wood, glass and plastic (construction and demolition wastes) 17 05 soil (including excavated soil from contaminated sites), stones and dredging spoil

Table 11-3 : Group allocation of EWC in view of a low POP content limit of 10 ppm (mg/kg) for POP pesticides

11.1.4 Group allocation for waste containing or contaminated with other POPs⁵⁶

In view of a limit of 10 ppm (mg/kg) for other POP most waste codes show a low likelihood to exceed the low POP content limit which would classify them as POP waste.

Only stocks of obsolete products are likely to exceed by far the limit value.

Besides this mixed C&D wastes such as concrete, bricks and tiles, wood, glass and plastic or soils and stones are likely to exceed the limit in locations where POP pesticides have been produced, dumped or stored improperly or without sufficient safety measures.

In the following table a compilation of EWC codes sorted in accordance to their likelihood with respect to exceedance of a low POP content limit of 10 ppm for POP pesticides is given.

⁵⁵ Aldrin, Chlordane, Chlordecone, Dieldrin, DDT, Endrin, Heptachlor, Toxaphene,

⁵⁶ HCH including Lindane, HCB, HxBB

group A (low likelihood)	EWC 01-16, 18-20 17 with exception of those mentioned below
group B (high likelihood)	/
group C (uncertain)	17 01 concrete, bricks, tiles and ceramics (construction and demolition wastes) 17 02 wood, glass and plastic (construction and demolition wastes) 17 05 soil (including excavated soil from contaminated sites), stones and dredging spoil

Table 11-4: Group allocation of EWC in view of a low POP content limit of 10 ppm (mg/kg) for other POPs

11.2 Testing approach for group allocation

In order to minimise efforts and costs for sampling and analysis of waste samples only waste types where the allocation as POP waste or non Pop waste is uncertain (group C) should be tested regularly if a disposal/recovery as non POP waste is intended.

In order to prevent unacceptable monitoring burdens and taking into account mass aspects which are relevant for the overall risk to the environment the following testing approach seems to be reasonable from economic and ecological points of view:

Group C (uncertain likelihood):

- ◆ testing is requested from the owner of the waste if he wants to have quantities > 100 t of his waste disposed of or recovered as non-POP waste
- ◆ it is requested that disposal/recovery companies make a test if more than 1,000 t of a waste category are disposed of / used for operations other than foreseen for POP wastes
- ◆ testing can be requested by the disposal/recycling company from the owner of the waste if there are doubts on possible exceedance of the low POP content limit

Waste types pertaining to group A and B generally do not require testing if disposal/recovery according to the provisions of the POP regulation is intended for group B wastes

Testing is requested from owners of waste types classified in group B if it is intended to dispose of the waste as non POP waste.

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, internationally agreed standards for measurement methods as described in chapter 7. The framework document for the sampling of waste adopted by CEN TC 292 applicable for all waste types and the sampling standard established for PCB should be used as reference documents for the sampling procedure.

To facilitate implementation of the testing and reduce costs sampling and testing should be integrated into the regime developed for the landfill acceptance criteria directive (2003/33/EC) and testing regimes established e.g. for co-incineration of wastes (R1) or for underground disposal.

11.3 European reporting format for authorisation of alternative waste management operations for Annex V wastes

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 which is discussed below.

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

Details on the requirements regarding the assessment method for environmental preferability are discussed in chapter 11 and are therefore not explained in detail here.

However, it can be stated that the following aspects have to be covered in 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.)

Following a draft reporting format is presented:

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): Contact person: Tel.: Fax: e-mail	Date:
Waste generator (Name, address) Contact person: Tel.: Fax: e-mail	Waste disposer (Name, address) Contact person: Tel.: Fax: e-mail
Site of generation and process:	Actual site of disposal/recovery:
General description of waste: Waste code: Origin: Contamination: Amount:	Intended disposal route: Intended date or period of disposal
Measurement information: Measurement data: Measurement methods	Technology and precautionary measures applied, incl. pre-treatment and/or solidification or stabilisation measures: Tests on leakage rate available: Measurement data: Measurement methods:
Transport to disposal/recovery site (distance, means):	Considered benchmark: Specifications:
Additional specification regarding waste handling:	

Table 11-5: Draft reporting format

Environmental Preferability against benchmark

	<i>Performance related to benchmark</i>			
	<i>credits</i>	<i>weight</i>	<i>total performance</i>	<i>evidence and verbal justification</i>
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, etc.				
③ Risks, uncertainties				
legal compliance				
long term safety				

Table 11-6: 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 on POP quantities and concentrations

New waste legislation covers only such parts of the mass flow which are related to production of waste and its management via recovery or disposal operations. It does not cover emissions and POP quantities already spread to the environment or already disposed of in former times.

In order to facilitate decisions on feasible limit values and measures to be taken in the waste sector with respect to POPs an evaluation of the investigated mass flows in view of existing environmental burdens and potential impacts of the regulation has been performed in this report in order to assess the relative importance of current waste streams and used disposal/recovery methods in relation to existing environmental burdens and in order to assess the environmental effects of the POP regulation.

As information on cumulated amounts in environment and landfills are limited the overall mass flows can not be more than rough estimations. However they help to identify the relative importance of different sectors and pathways and allow conclusions on environmental and economic effects of the POP regulation.

Emissions and discharges are quoted on an annual basis based on the results of the detailed mass flows (see chapter 5) whereas the environmental load has been calculated as a minimum estimate on the basis of available production figures, literature data and emission data bases.

Overall flow of PCDD/PCDF

As illustrated in Figure 12-1 the PCDD/PCDF flow is characterised by relatively small amounts which are constantly formed and discharged while remarkable stocks awaiting elimination do not exist. Air emissions account for only 20% of the overall discharge from anthropogenic sources. Therefore, 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.

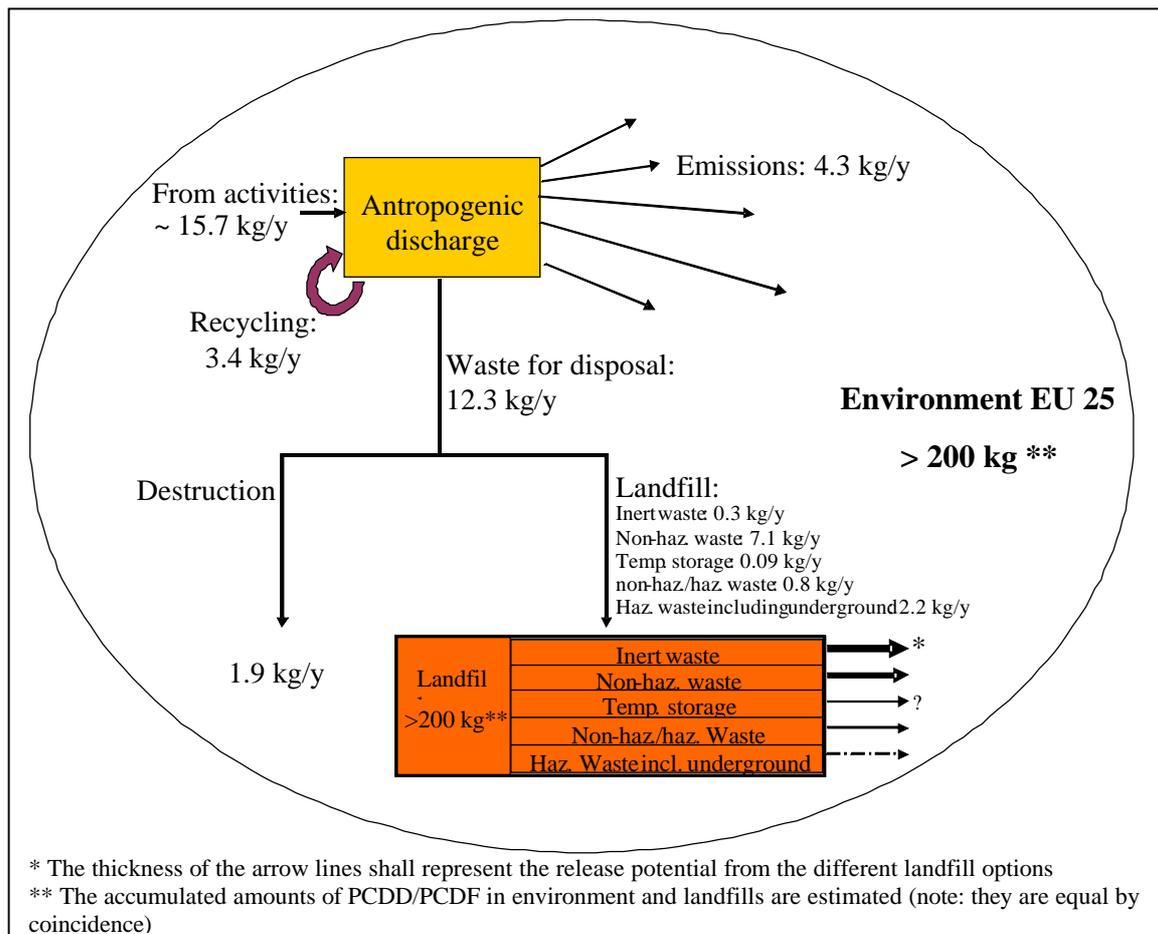


Figure 12-1: Major pathways and amounts of PCDD/PCDF distributed in EU 25

The share of landfill is high in comparison with 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 can not be allocated 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 that are recycled and recovered 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 0.8 kg/y which is further reduced in the processes.

To conclude it can be stated that the waste sector would add annually ~7% to the calculated environmental load of 200 kg, whereas air emissions would add ~2%. However the major share of PCDD/PCDF discharge via waste is due to high volume but low contaminated

wastes – mainly MSW, but also bottom ashes, slags, sewage sludge and 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 and only 2 kg/y contained in wastes that may in part be disposed of or be used as secondary construction material at non-hazardous waste landfills may be influenced by the POP regulation.

Lastly it can be stated that destruction methods are currently only used for destruction of ~2 kg of PCDD/PCDF TEQ. This seems to be insufficient even more as MSW which discharges much of the PCDD/PCDF to waste is largely combustible. However concentrations are so low that MSW will and shall not be affected by the low POP content limit for POP waste.

As the landfill directive (1999/31/EC) requires national strategies to reduce to amount of biodegradable waste going to landfills, the importance of PCDD/PCDF discharge via non hazardous waste landfilling of MSW will probably decline in future, increasing the importance of other pathways such as MBT, incineration and hazardous waste disposal.

As illustrated in Table 12-1 discharge of PCDD/PCDF from the investigated sources in Europe is about 20 kg/y with an overall distribution of the discharge of about 20% to air and around 80% to solid process residues (waste).

Activity	air emission [g TEQ/y]	product [g TEQ/y]	waste [g TEQ/y]	total [g TEQ/y]
municipal solid waste incineration	21.5	0	1,977	1,999
hazardous waste incineration	2.3	0	76	78
hospital waste incineration	111	0	32	143
power production (coal)	38	0	1,613	1,651
power production (biomass)	1.7	0	604	606
FM sinter plants	524	0	70	1,400
FM EAF	167	0	1,234	594
FM iron smelting	21	0	122	143
NFM secondary copper	84	95	47	225
NFM secondary aluminium	58	0	443	500
NFM secondary zinc	2.5	94	85	182
chem. industry	8	0	0.8	9
sewage sludge	0	0	297	297
compost	0	160	0	160
road traffic	56	0	0	56
domestic burning coal and derivatives	3,133	0	241	3,374
domestic burning wood	125	0	157	282
Sum non-industrial sources	3,314	160	695	4,169
Sum industrial sources	1,039	190	6,308	7,531
Sum household (MSW)			8,404	8,404
Total	4,300	350	15,400	20,090

Table 12-1: Emissions of PCDD/PCDF to air and discharge to products and solid residues (waste) from investigated sectors in EU 25

It can be stated that (under BAT conditions) air emissions are dominated by non-industrial sources in particular domestic burning and other open fires. 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 (0.4%) are important sectors for discharge of PCDD/PCDF via residues.

The overall PCDD/PCDF flow from industrial sources is about two times as high as from investigated non-industrial sources, however it has to be noted, that it is focused on residues which are well controllable whereas the dominating air emissions from the non-industrial sources lead to an uncontrolled deposition of the pollutants on soil and water surfaces thus directly affecting the food chain.

Table 12-2 summarises average concentrations and contamination ranges reported for major waste types from the investigated sectors.

anthropogenic sector	waste	PCDD/PCDF concentration ng TEQ/g		
		mean	min	max
MSW		0.037	0.002	0.06
MSWI	Fly ash, filter dust and other FGT residues	1.46	0.00	35.7
	Bottom ash	0.02	0.00	0.4
HWI	Fly ash and residues from FGT	0.31	0.0002	2.4
	Bottom ash	0.01	0.0001	5.8
PP coal	ashes	0.02	0.00005	0.06
PP biomass	fly ash and other solid residues	1.13	0.001	16.2
HospWI (EU10)	bottom ash	0.16	0.015	0.3
	fly ash	2.3	0.68	4.5
sinter plants	Residues from FGT	1.1	0.0001	3.1
electric arc furnaces	Slag	0.001	0.0002	
	Filter dust	1.1	0.1	10
iron smelting	Slag and dross (furnace residues)	0.005	0.0002	0.05
	Residues from FGT	1.7	0.18	4.9
secondary copper	Filter dust	6		23
	Slag	0.02		
	Furnace-oxide	1		
secondary aluminium	Filter dust	10	0.5	34
	Sludge from WWT	1.58		
secondary zinc	Slag	0.02		
	Absorption and filter material	0.68	0.002	1.4
	Waelz oxide	0.1		<0.2
sewage Sludge	Sewage Sludge	0.03	0.00002	1.77
compost	Compost	0.01	0.0008	0.036
domestic burning	ash (fossil fuels)	0.056	0.00022	0.15
	ash (wood)	0.11	0.0001	0.5
	soot (fossil fuels)	6.15	0.05	10
	soot (wood)	3.99	0.02	14.4

Table 12-2: Average contamination levels and concentration ranges for PCDD/PCDF in different waste types in EU 25

Concentration of PCDD/PCDF in residues vary. However a categorisation of waste types into low contaminated and higher contaminated classes can be made.

Concentrations of PCDD/PCDF in bottom ashes, slags, compost, sewage sludge and MSW are in a range of contamination usually below 0.05 ppb and comparable with or only one order of magnitude higher than levels that are currently detected in the soil compartment. A second group (APC residues, metallic dusts) contamination levels in average range from 0.5-5 ppb which is 1-2 orders of magnitude higher than current soil levels and can even peak at 30 ppb. These wastes should be precluded from direct contact to soils (e.g. use as fertiliser) in order to prevent negative impact on environment and health.

Overall flow of PCB

In relation to the PCDD/PCDF flow the PCB mass flow is of significantly higher importance even if the different toxicity of the substances and the difference in reporting (TEQ and total sum) is taken into consideration.

As illustrated Figure 12-2 the overall PCB mass flow is still clearly dominated by remaining stocks from former production, which step by step have to be destroyed and so eliminated from the environment.

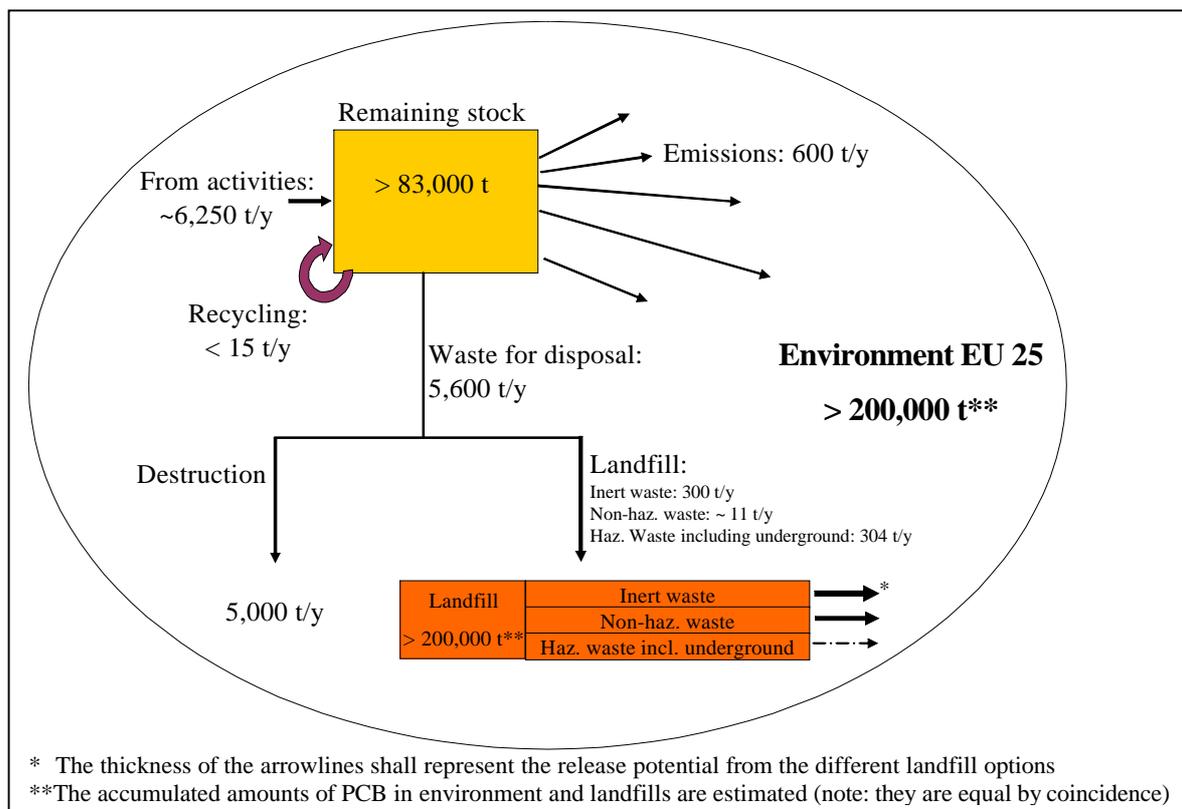


Figure 12-2: Major pathways and amounts of PCB distributed in EU 25

In relation to the remaining stocks recycling operations currently can not be regarded as of high importance as they account for only 0.2 % of the total discharge, however they may get

a higher importance when the stocks will be eliminated and they have a higher 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, so that there will be no additional benefit 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 take 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 might not be sufficient for the C&D sector.

As illustrated in Table 12-3 annual discharge of PCB from the investigated sources in Europe is about 6,250 t/y with an overall distribution of the discharge of about 10% to air and around 90% to waste. 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. Substance recovery from waste oil and shredder non-metallic fraction are less important sectors, however both sectors can contribute to a prolonged cycling of PCB in the production process.

activity	waste (t/y)	total (t/y)
electrical and electronic equipment	4,690 (7 – 9,370)	5,210 (7.8 – 10,410)
construction and demolition	900	1,000
shredder non-metallic fraction	17	18
waste oil	5.3	14.9
sewage sludge	4.8	4.8
compost	0	4.5
Sum EU 25	5,617	6,252

Table 12-3: Emissions of PCB to air and discharge to products and solid residues (waste) from investigated sectors in EU 25

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. Comparable ranges of discharge can be expected for other combustion/incineration processes.

On the other hand municipal solid waste, due to large annual quantities represents a PCB flow which can not be completely 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, which exceeds the shares of shredder and waste oil, although it represents only 1% of the total discharge of PCB to waste.

Table 12-4 summarises average contamination and concentration ranges reported for major waste types from the investigated sectors.

anthropogenic sector	waste	Contamination data mg/kg		
		mean	min	max
WEEEs	large equipment (condensers, transformers)	500,000	500	1,000,000
	household equipment	25	0	50
C&D waste	Demolition & Construction waste	4.6		
	mixtures containing dangerous substances	70	0.01	6,135
	waste wood d.w.	0.05	0.02	3,086
	soil & stones d.w.	27.5	0.0005	9,700
	C&D waste containing PCB	17,000	4.5	147,300
Waste oils	higher contaminated	15		50
	lower contaminated	2.5	0	5
Shredder	white goods and vehicles	3	0.5	>50
	waste cables	30	0	>500
Compost		0.3	0.005	0.8
Sewage sludge		0.6	0.003	1.5
HWI	bottom ash	0.038	0.0001	0.09
	boiler ash	0.005	0.001	0.01
	fly ash		0.001	0.04

Table 12-4: Average contamination levels and concentration ranges for PCB in different waste types in EU 25

As illustrated in the table concentration of PCB in residues vary. However a categorisation of waste types into low contaminated and higher contaminated classes can be made.

With respect to PCB concentrations in a first group of wastes i.e. ashes, sewage sludge, compost range from 0.01-0.6 ppm. This is comparable or only moderately (1 order of magnitude) above levels observed in the soil compartment in Europe. In a second group of waste types e.g. waste oil, shredder residues from ELV and white goods levels in most cases are below 10 ppm. For the plastic fraction of cable shredding and for ashes from domestic burning levels range from 10-30 ppm and are thus 2-3 orders of magnitude higher than background concentrations observed in the environment. In a last group, which consists of C&D waste and PCB containing equipment concentration levels might easily exceed 50 ppm and can reach concentrations of several thousands of ppm.

Overall flow POP pesticides

POP pesticides are no longer produced in significant amounts. Therefore anthropogenic discharge mainly results from stocks remaining. As pesticides are either destroyed or applied in open systems, recycling can be excluded.

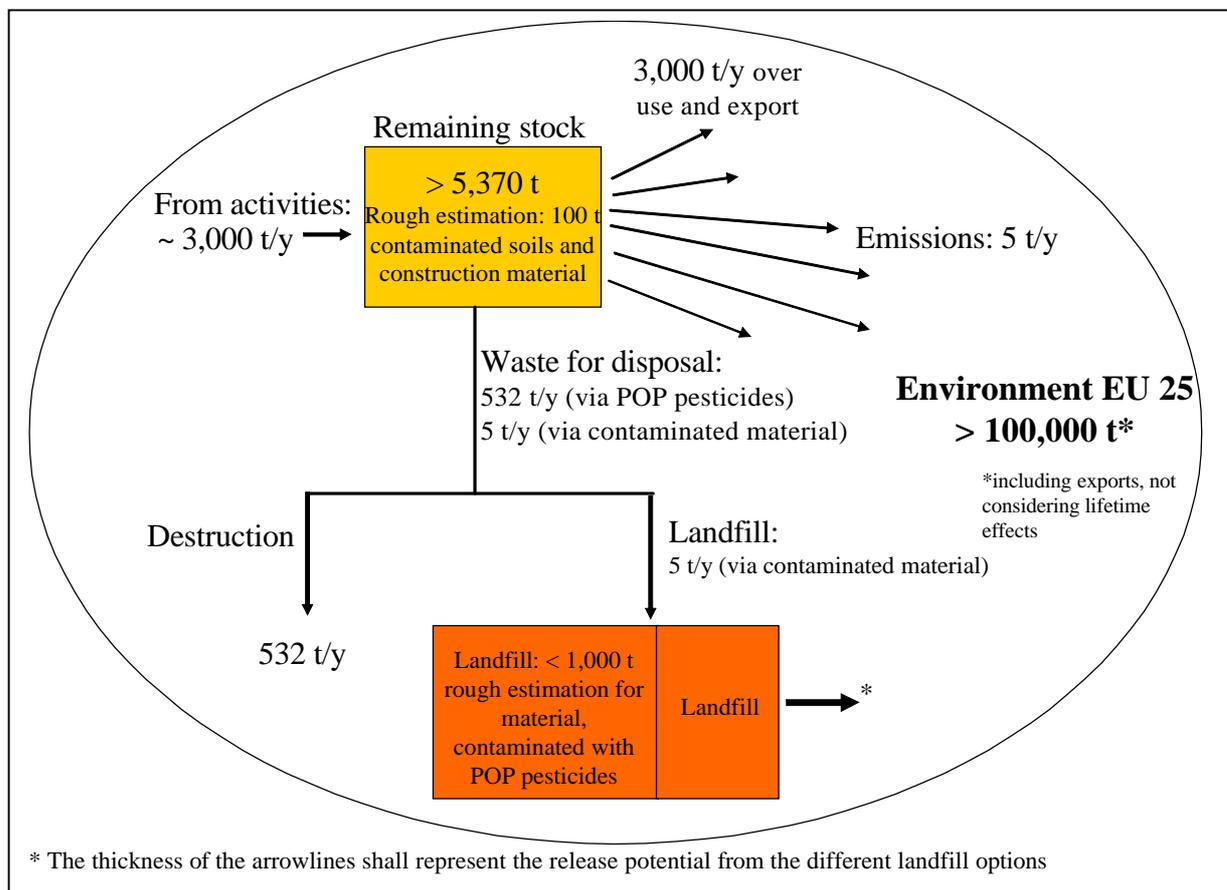


Figure 12-3: Major pathways and amounts of POP pesticides distributed in EU 25

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 Regulation⁵⁷ 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.

To conclude it can be stated that - based on the limited data available for POP pesticides - the destruction of remaining stockpiles and the controlled disposal/recovery of contaminated soils

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

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 lie above the low POP content limit.

Two types of sources have to be distinguished for the mass flow: One flow starting with intentional production and use, the other starting with reduction of stock piles of former production. Via ongoing production an estimated amount of >3,000 t DDT per year is discharged to products, however discharge to the waste regime is hard to assess.

On the other hand about 537 tons of POP pesticides enter the waste regime each year via reduction of POP pesticides stockpiles, provided a linear reduction of remaining stockpiles over a 10 year period (2000-2010) and an unknown amount enters the waste regime via contaminated soil and C&D waste. Air emissions may only arise from volatilisation and airborne erosion from stored products and soils and are assumed to reach about 5 tons /y.

Data for POP pesticides suggest either high contamination in wastes or soil from contaminated sites or quite low levels in the range of environmental contamination. However the number of data is too small to draw final conclusions.

Overall flow other POPs

As illustrated in Figure 12-4 the mass flow to waste is dominated by stocks of HCH from former production. Formation of other POPs (HCB) in combustion processes accounts only for ~5t/y. As these are included in FGT residues they are mainly directed to hazardous waste landfills or and up in thermal recovery operations where they are destroyed..

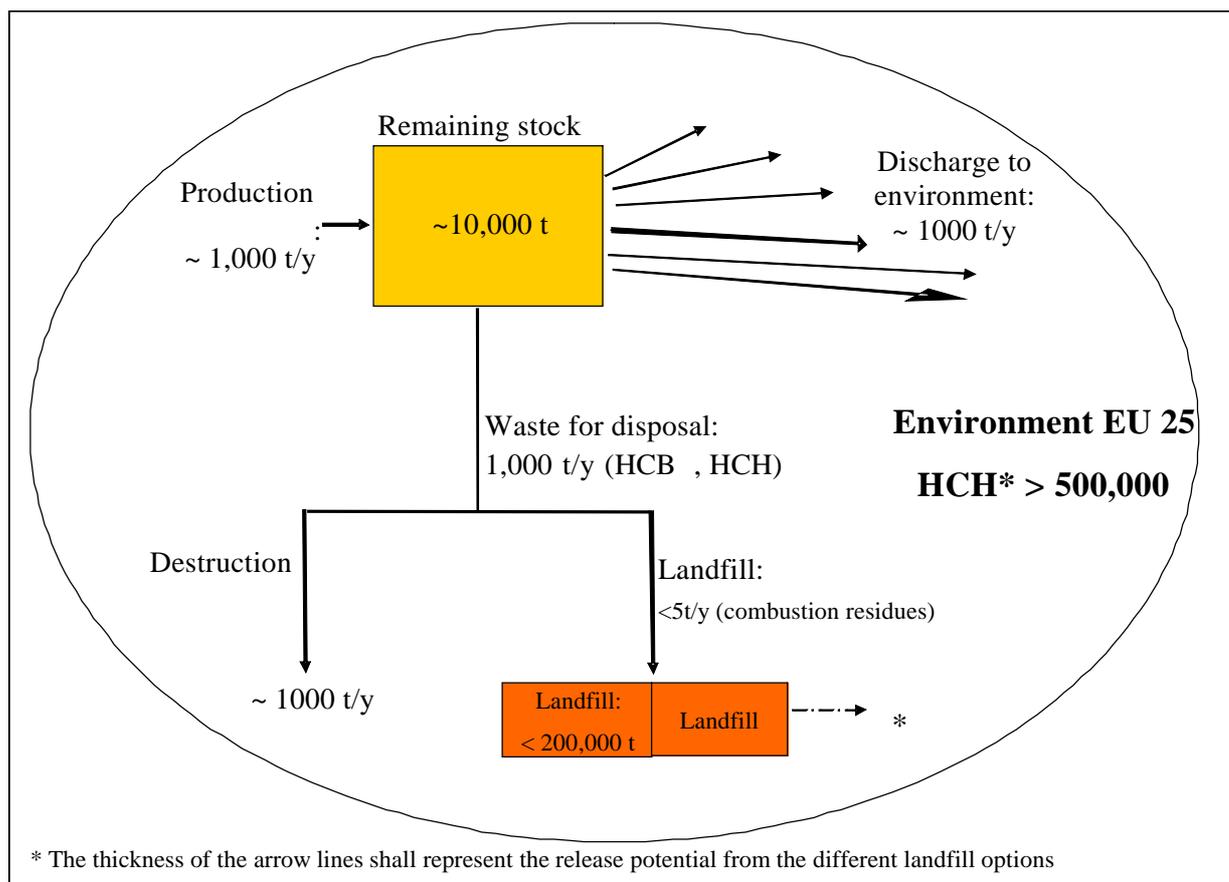


Figure 12-4: Major pathways and amounts of other POPs distributed in EU 25

Due to the high share of landfilling currently used for the management of shredder residues, non-hazardous waste landfill can be assumed as the most important management option for other POPs. In addition a non-quantifiable amount of other POPs is directed to landfill via contaminated C&D waste. Limit values for other POPs can thus be assumed to have a remarkable effect on the overall flow.

Current production of HCH (Lindane) is estimated to account for >1,000 t/y in products. In addition HCB is known to be formed through the same processes that create PCDD/PCDF. However, the dimension of these sources is relative small (~ 5t/y). Stocks of HCH from former production amount to estimated 10,000 t. Provided a linear reduction over 10 years that will correspond to a annual flow of 1,000 t which is directed to destruction operations mainly. Thus an annual mass flow of about 1,000 t to waste results for other POPs.

Data on concentrations in wastes suggest either high contamination (up to several hundred ppm) in C&D wastes or soil from contaminated sites or low levels in the range of environmental contamination.

A weakness of the current state of knowledge can be seen in the wide range of POP concentrations in certain wastes and the corresponding uncertainty how to properly treat significant volumes in practice. This obviously will result in remarkable difficulties to enforce the POP Regulation. As an important next step it is therefore recommended to do

measurements and collect corresponding information about concentration ranges of POP contamination in most important wastes (e.g. C&D waste, waste oils, metal dusts, waste wood, domestic burning). This can then result in guidelines to support enforcement of the POPs regulation with respect to testing, measurements, suspicious waste and a general awareness of problematic wastes at enforcement authorities .

12.2 Conclusions on and recommendations for concentration limits of the POPs Regulation

The assessment of low POP content limits for the classification of wastes as POP wastes has been based on a methodology taking into account environmental and health aspects as well as technical feasibility, economic impacts and existing commitments..

The basic principles of the developed methodology are on the one hand "lower limitation criteria" that indicate the lower boundary for possible limit values and on the other hand "upper limitation criteria" that indicate the upper boundary for possible limit values In addition target functions (e.g. precautionary principle) have been used to condense the resulting range of possible limits to precise proposals for limit values as two options.

The following low POP content limit values or their combinations are recommended, based on the developed methodology:

PCDD/PCDF	1 ppb	+ amendment of annex V, part 1 (include R4)
	10 ppb	+ ban of unsolidified application to land if PCDD/PCDF concentration of 1 ppb is exceeded and precautionary principle is applied strictly
	15 ppb	+ ban of unsolidified application to land if PCDD/PCDF concentration of 1 ppb is exceeded and precautionary principle is applied less strictly
PCB	30 ppm	expressed as sum 6 of congener multiplied by 5 strict application of precautionary principle
	50 ppm	expressed as sum 6 of congener multiplied by 5 less strict application of precautionary principle
POP pesticides	10 ppm	strict application of precautionary principle
	50 ppm	less strict application of precautionary principle
other POPs	10 ppm	strict application of precautionary principle
	50 ppm	less strict application of precautionary principle

Table 12-5: Options for low POP content limits

Based on the developed methodology, results from leaching tests and target levels for agricultural soils established in Member States have been used to calculate maximum POP

content limits are proposed for hazardous and non-hazardous waste landfills:

PCDD/PCDF (expressed as I-TEQ):	5,000 ppb
PCB (expressed as Sum 6 of congeners multiplied by 5):	2,000 ppm
POP pesticides:	5,000 ppm
Other POPs:	5,000 ppm

Table 12-6 Proposal for maximum POP content limits

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 long-time leaching behaviour and long-term safety of landfills in order to derive leachate based limits for POPs that can be 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 on and recommendations for environmental preferability

Essential parameters for an assessment methodology on environmental preferability covering elements of LCA, RA, EIA, TA and MCA⁵⁸ 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.

The results are foreseen to be visualised 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.

⁵⁸ LCA: Life Cycle Analysis; RA: Risk Assessment; EIA: Environmental Impact Assessment; TA: Technical Assessment; MCA: Multi Criteria Analysis

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 list⁵⁹ 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.

To support implementation of the method to define environmental preferability 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): Contact person: Tel.: Fax: e-mail	Date:
Waste generator (Name, address) Contact person: Tel.: Fax: e-mail	Waste disposer (Name, address) Contact person: Tel.: Fax: e-mail
Site of generation and process:	Actual site of disposal/recovery:
General description of waste: Waste code: Origin:	Intended disposal route: Intended date or period of disposal

⁵⁹ Decision 2000/532/EC

Contamination: Amount:	
Measurement information: Measurement data: Measurement methods	Technology and precautionary measures applied, incl. pre-treatment and/or solidification or stabilisation measures: Tests on leakage rate available: Measurement data: Measurement methods:
Transport to disposal/recovery site (distance, means):	Considered benchmark: Specifications:
Additional specification regarding waste handling:	

Table 12-7: Draft reporting format

Environmental Preferability against benchmark

	<i>Performance related to benchmark</i>			
	<i>credits</i>	<i>weight</i>	<i>total performance</i>	<i>evidence and justification</i>
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 12-8: Draft reporting format - Performance matrix for justification of alternative waste management operations under Annex V to the EU POP regulation

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.

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15 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	<i>BALTIC Project: environmental cycling of selected persistent organic pollutants (POPs)</i>
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

16 References

[6th Pesticides Forum]

6th International HCH and Pesticides Forum, Poznan 2001; Forum Book, www.iarpa.org/library

[4th Pesticides Forum]

4th Forum HCH and unwanted Pesticides, Poznan 1997; Forum Book, www.iarpa.org/library

[ABAD 2000]

Abad, E.; Adrados M.A.; Caixach, J.; Fabrellas, B.; Rivera, J.: Dioxin mass balance in a municipal solid waste incinerator, Chemosphere 40, 2000, S. 1143-1147

[ABAD 2002]

Abad, E.; Adrados M.A.; Caixach, J.; Rivera, J.: Dioxin Abatement Strategies and Mass Balance at a Municipal Waste Management Plant. Environmental Science & Technologies 36, 2002, 1, S. 92-99

[AEA1999]

AEA: Compilation of EU Dioxin Exposure and Health Data Task 2 – Environmental Levels 1999

[ASSURE]

Energy from waste fact sheets, <http://www.assurre.org/downloads/archive/71d92c53-dc76-4758-9b78-25135038af33.pdf>, access, December 10, 2004

[AVN Abfallverwertung]

Die Reststoffe aus der thermischen Abfallverwertung
<http://www.avn.at/reststoffe.html>

[Arbeitsgemeinschaft Bau 2000]

Arbeitsgemeinschaft Kreislaufwirtschaftsträger Bau; 3. Monitoring-Bericht Bauabfälle, 2000

[B.U.S.]

B.U.S, Umwelterklärung 2004, Zinkrecycling Freiberg GmbH & Co. KG

[Baumgartner 2005]

Baumgartner, A.: Ergänzung der Umweltverträglichkeitserklärung 2005

[Bewend 2000]

Bewend: Bewertung abfallwirtschaftlicher Maßnahmen mit dem Ziel der nachsorgefreien Deponierung. Studie der GUA Gesellschaft für umfassende Analysen GmbH, des Institutes für Wassergüte und Abfallwirtschaft der TU Wien und des Institutes für Finanzwirtschaft und Infrastrukturpolitik der TU Wien 2000

[EFR 2005]

Bureau of International Recycling, plastic coated cable scrap 2005

www.bir.org/aboutrecycling/cable/index.asp

[BMU 2001]

Dr.Lepom/Fricke, Novelle der Altölverordnung; PCB-Grenzwert, 2001

[BMU 2002]

BMU: Verwertung, Beseitigung und Verwertung von Abfällen im Jahr 2002

[BMU 2003]

BMU, Abfallwirtschaft-Altöl-Kurzinfo 2004

[Brinton 2000]

COMPOST QUALITY STANDARDS & GUIDELINES: Brinton, W.F., Ph.D. Project Manager: An International View Report, Dec. 2000

[CEWEP SE 2004]

Confederation of European Waste to Energy Plants, Country Report Sweden, CEWEP Congress, Amsterdam, September 2004

[COM 2003]

Report from the Commission to the Council and the European Parliament on the implementation of community waste legislation for the period 1998-2000 May 2003

[COWI 2000]

COWI, Substance Flow Analysis for dioxins in Denmark; Erik Hansen; Environmental Project No. 570 2000 Miljøprojekt; Danish EPA

[COWI 2002]

COWI, Obsolete Pesticides Status in Candidate Countries; Final report 2002; European Commission, DG Environment

[DAMIEN 1998]

Damien A, Etude des caractéristiques intrinsèques de certains déchets des usines d'incinération d'ordures ménagères et de déchets industriel spéciaux, Ministère de l'Environnement / DPPR – TIRU, 1997

[DANCEE 2004]

DANCEE, Ministry of the Environment of the Republic of Lithuania, Implementation of the EU requirements for disposal of PCB, waste oils and batteries, February 2004

[Defra Health Report 2004]

Defra, Enviro, Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes, 2004, www.defra.gov.uk

[DEMEX 2003]

DEMEX, Study on the different open uses of Polychlorinated Biphenyls and Polychlorinated Terphenyls in products and determination of best available technology for the disposal of

Polychlorinated Biphenyls., European Commission DG Environment; Ref.: Study Contract, B4-3040/2001/329152/MAR/A2; Draft final report; January 2003

[Deutsche Zementindustrie 2003]

Verein Deutscher Zementwerke e.V., Umweltdaten der deutschen Zementindustrie 2003

[Dioxinähnliche PCB in der Umwelt 2003]

Dioxinähnliche PCB in der Umwelt; Quellen, Verbleib, Exposition und gesundheitliche Bewertung Fachtagung am 13./14. Januar 2003

[Dioxins 1997]

Working document: Dioxins – Sources, Levels and Exposures in Denmark Danish Environmental Protection Agency 1997

<http://irptc.unep.ch/pops/DENDIOX.html>

[Dioxin and Furan Inventories 1999]

DIOXIN AND FURAN INVENTORIES, National and Regional Emissions of PCDD/PCDF United Nations, Environment Programme, Prepared by UNEP Chemicals Geneva, Switzerland May 1999

<http://www.oztoxics.org/ipepweb/library/DioxinInventory.pdf>

[Dioxin Inventory 1997]

Dioxin Inventory stage 1 volume 1 Part B: Evaluation of Emission Estimates 1997

[DYKE 1997]

Dyke PH, Wenborn MJ, Coleman PJ, Woodfield MJ and Rose CL (1997): A Review of Dioxin Releases to Land and Water in the UK. Research & Development Publication 3., Environment Agency, Bristol UK

[EEA 2002]

EEA Hazardous waste generation in EEA member countries Nr. 14/2001, J. Brodersen, M. Crowe, H. Jacobsen, EEA, Copenhagen 2002

[EC 2001]

European Commission, DG Environment: Critical Review of Existing Studies and Life Cycle Analysis on the Regeneration and Incineration of Waste Oils, December 2001

[ECB 2003]

European Chemicals Bureau [Technical Guidance Document on Risk Assessment] Institute of Health and Consumer Protection, April 2003, ecb.jrc.it/php-bin/reframer.php?B=/TGD

[ECN 2002]

BIOLOGICAL WASTE TREATMENT IN EUROPE -TECHNICAL AND MARKET DEVELOPMENTS, European Compost Network 2002

[ECN 2002]

European Country Network, Barth, J.: Biological Waste Treatment in Europe -Technical and

Market Developments, 2002

[EFR 2004]

European Ferrous Recovery & Recycling Federation, answer questionnaire 2004

[ELICC 2004]

BiPRO GmbH, Dioxins & PCB: Environmental Levels and Human Exposure in Candidate Countries, on behalf of the European Commission, DG Environment, June 2004

[EPA 2000]

EPA Information sheet 1- 5 on Dioxins, US, 2000

[EURITS 2002]

EURITS "Overview of information on Eurits members" in WI BREF 2004

[EuroChlor 2000]

Euro Chlor: Chlorine flow in Europe 1998, Brussels, November 2000

[EUROFER 2004]

Production Statistics for the year 2003, EUROFER, 2004

[European dioxin inventories]

UNEP Chemicals 1999; www.chem.unep.ch/pops/pdf/dioxinfuran/difurpt.pdf

[EUROSTAT 2001]

www.europa.eu.int/comm/eurostat/

[Fiedler 2000]

Fiedler, H., Hutzinger, O., Welsch-Pausch, K., Schmiedinger, A., Evaluation of the occurrence of PCDD/PCDF and POPs in wastes and their potential to enter the food chain, on behalf of the European Commission, DG Environment, Brussels, September 2000

[GEIR 2002]

GEIR, www.geir-regeneration.org/en/key_figures key figures-waste oil collection 2002

[Handbuch Abbrucharbeiten 2004]

Abbrucharbeiten; Grundlagen, Verarbeitung, Durchführung Verlagsgesellschaft Rudolf Müller GmbH & Co. KG, April 2004

[Harmsen 2004]

Horizontal Standardisation of Polychlorinated Biphenyls (PCB). Report on the desk study on PCB for the European project HORIZONTAL, Final Report, January 2004

including:

ANNEX 1: Harmsen, Win, Lepom, Lehnik-Habrink 2004: PCB in sludge, waste, soil and sediment

ANNEX 2: Brüll 2004: Determination of PCB in solid materials

[HCB Tech Guidelines 2005]

Draft technical guidelines on environmental sound management of wastes consisting of, containing or contaminated with HCB; 1 draft; www.basel.int/techmatters

[HEINZOW 2004]

Heinzow, Birger G.J.; Mohr, Siegfried; Ostendorp, Guido; Kerst, Melanie; Körner, Wolfgang: Dioxin-like PCB in indoor air contaminated with different sources, External and internal human exposure, Organohalogen compounds – Volume 66, 2004

[HORIZONTAL DRAFT 2004]

Horizontal standardisation for soil, sediment, sludge and bio-waste. Report of the final desk study on the determination of PCDD/PCDF and DL-PCB for the European project HORIZONTAL, DRAFT, October 2004

[IEA Energy Statistics]

International Energy Agency, statistics from 2001 <http://www.iea.org/dbtw-wpd/Textbase/stats/coalresult.asp>

[IEP 2003]

IEP, Stockholm Convention Focal Point, Warsaw, Poland; inventory of persistent organic pollutants in Poland

[INERIS 2002]

Caractérisation des Mâchefers d'Incinération d'Ordures Menageres, Rapport final; INERIS, January 2002

[INSERM 2000]

INSERM, Dioxines dans l'environnement: quelles risques pour la santé, 2000

[Inventory EE 2002]

National sector emissions: Persistent organic pollutants-Version 2002; <http://countries.eea.eu.int/SERIS>

[Inventory LT 2002]

National sector emissions: Persistent organic pollutants-Version 2002; <http://countries.eea.eu.int/SERIS>

[Inventory LV 2002]

National sector emissions: Persistent organic pollutants-Version 2002; <http://countries.eea.eu.int/SERIS>

[Johnke 2003]

Johnke, B.: Statusbericht zur Einsparung von CO₂-Emissionen durch verbesserte Energienutzung in Siedlungsabfall-Verbrennungsanlagen – Stand Juli 2002
Umweltbundesamt Berlin

[IS BREF 2001]

European Commission, Best Available Techniques Document on the Production of Iron and

Steel, December 2001

[ISWA report 2004]

ISWA International Solid Waste Association, international waste information, October 2004
<http://www.iswa.org/index.php?option=content&task=view&id=136&Itemid=135>

[KWTB 2003]

Arbeitsgemeinschaft Kreislaufwirtschaftsträger Bau KWTB
3. Monitoring Bericht Baubranche, October 2003;

[LAGA 2004]

Bericht der LAGA zur 62. Umweltministerkonferenz: Umsetzung der Abfallverordnung 2004

[Launhardt]

Launhardt, T., Formation of Dioxins and PAH in Domestic Wood Furnaces – Contamination of Flue Gas, Ashes and Chimney Soot, Munich University of Technology

[LCA-AVI 2002]

Environmental impact Report – National Waste Management Plans; LCA-AVI-vliegass, final report, TAUW Netherlands, 2002

[LCP BREF 2004]

European Commission, Draft Reference Document on Best Available Techniques for Large Combustion Plants, Draft November 2004

[LFU 1998]

Untersuchung von Altholz aus Altholzaufbereitungsanlagen in Bayern; E. Reichle, Bayerisches Landesamt für Umweltschutz 1998; www.bayern.de/Lfu

[LFU 2003]

Zusammensetzung und Schadstoffgehalt von Siedlungsabfällen; Bayerisches Landesamt für Umweltschutz (Hrsg.), Augsburg 2003

[LN 2005]

Leaching.net, material properties, www.leaching.net/leaching/database/materialproperties , accessed 16.02.2005

[LUA NRW 2000]

The European Dioxin Emission Inventory Stage II, North Rhine-Westphalia State Environment Agency (LUA NRW), Prof. Dr. Bröker, Dr. Quass, Dr. Fermann, December 2000

[LVOC BREF 2003]

European Commission, Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry, February 2003

[Margni 2003]

M. Margni, Evaluating multimedia/multipathway model intake fraction estimates using POP

emission and monitoring data; Elsevier 2003

[www.cheforhealth.org]

Mercury emissions from crematoria, Consultation on an assessment by the Environment Agency's Local Authority

Unit <http://www.cheforhealth.org/resources/background%20resources/Mercury%20Resources/cremationreport.pdf>

[Nouwen et al 2004]

Johan Nouwen, Jeroen Provoost, Christa Cornelis, Jan Bronders, Raf De Fré, Rudy Van Cleuvenbergen: Health risk assessment of exposure to dioxinlike PCB and Dioxins in the City of Menen (Belgium), Flemish Institute for Technological Research (Vito), Organohalogen Compounds, Vol 66, 2004

[National Swedish Environmental Protection Board 1995]

National Swedish Environmental Protection Board, 1995 cit in PAULSRUD et al.,: Organic Contaminants in Sewage Sludge for Agricultural Use, 2000

http://europa.eu.int/comm/environment/waste/sludge/organics_in_sludge.pdf

[NFM BREF 2001]

European Commission, Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001

[P&P BREF 2001]

Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Pulp and Paper Industry, Draft December 2001

[Partial RIA 2001]

Partial Regulatory Impact Assessment Dioxins and dioxin-like PCB in the UK Environment Department for Environment, Food & Rural Affairs 2001

http://www.defra.gov.uk/environment/consult/dioxins/pdf/dioxins_partial_ria.pdf

[PCB Tech Guidelines 2005]

Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Polychlorinated Biphenyls (PCB), Polychlorinated Terphenyls (PCTs) or Polybrominated Biphenyls (PBBs), 2005

(http://www.basel.int/pub/techguid/pcb_guid_final.pdf)

[PCB network 1999]

PCB network, A., Åsterbro: PCB in building material –a short presentation of a proposed application to the fifth framework programme in the European Union 1999

[Pless-Mulloli et al 2003]

Pless-Mulloli, T., Air, V., Schilling, B., Paepke, O., Foster, K. 2003: Follow-up Assessment of PCDD/PCDF in Eggs from Newcastle Allotments. University of Newcastle, Ergo, Newcastle City Council, July 2003.

[Pless-Mulloli et al 2001a]

Pless-Mulloli, T., Schilling, B., Paepke, O., Griffiths, N., Edwards: Transfer of PCDD/PCDF and Heavy Metals from Incinerator Ash on Footpaths in Allotments into Soil and Eggs, 2001.

[Pless-Mulloli et al 2001b]

Pless-Mulloli, T., Edwards, R., Paepke, O., Schilling, B. 2001: Full technical report. PCDD/PCDF and heavy metals in soil and egg samples taken from Newcastle allotments: assessment of the role of the Byker incinerator. Newcastle upon Tyne: University of Newcastle, 2001

[Polden 1998]

Institut National des Sciences Appliquées, Lyon, 1998

[Reimann 2000]

Reimann O., Dioxin removal and destruction technologies; Second conference on solid waste management; perspective of the twenty first century (2000)

[Ritter 1995]

Ritter, Persistent organic pollutants] an assessment report on DDT,-Aldrin-Dieldrin-Endrin-Chlordane Heptachlor-Hexachlorobenzene, Mirex-Toxaphene, PCB, PCDD/PCDF; IPCS; www.pops.int/documents/background/assessreport/en/ritteren.pdf

[Rösch 2001]

Rösch, C.: nachhaltige Nutzung von Biomasse als Energieträger, TA-Datenbank-Nachrichten, Nr. 3, 10. Jg., September 2001

[RVF 2000]

RVF Swedish Association of Waste management, Waste to energy, an inventory and review about dioxins, 2000

[SDR 2004]

S.D.R. Biotec Verfahrenstechnik GmbH, Beitrag zum Workshop zur Verordnung über die Verwertung von Abfällen auf Deponien über Tage, März 2004, BMU, Bonn

[SF BREF 2004]

European Commission, Reference Document on Best Available Techniques in the Smitheries and Foundries Industry, July 2004

[Sludge use acceptance report 2001]

European Commission, Disposal and recycling rout for sewage sludge – sludge use acceptance report, 2001

[Statistics Finland 2002]

http://www.stat.fi/tup/suoluk/taskue_energia.html

[Statistics Netherlands 2002]

<http://statline.cbs.nl>

[Statistics Sweden 2002]

<http://www.ssd.scb.se/databaser/makro/start.asp>

[Stockholm Convention]

www.pops.int/documents/convtext/convtext_en.pdf

[SWS/UEV 2004]

Analytical results for POP contamination levels of several waste materials disposed of in underground disposals in Germany, Communication from Südwestdeutsche Salzwerke AG, 2004

[Taniyasu 2004]

Taniyasu, Sachi; Falndysz, Jerzy; Swietojska Agnieszka; Flisak, Magdalena; Horii, Yuichi; Hanari, Nobuyasu; Yamashita, Nobuyoshi; Petrick, Gert: Composition and content of CBs, CDFs and CNs of Clophen A60, - Nonthermal sources and source inventories, Organohalogen Compounds – Volume 66, 2004

[Thanner 2002]

Umweltbundesamt Österreich, Thanner G., Moche, W. Emissionen von Dioxinen, PCB und PAHs aus Kleinf Feuerungen, Monographien, Band 153, Wien 2002

[TIRU 1997]

TIRU; Etude des Caractéristiques intrinsèques de certains déchets des usines d'incinération d'ordures menageres et de déchets industriels spéciaux; 1997

[TNO 2004]

TNO interim report, Dioxin emissions in candidate countries, February 2004

[TNO 2005]

TNO draft final report, Dioxin emissions in candidate countries, February 2005

[UBA 2003]

UBA: data on environmental pollution by dioxins third report of the Government/Laender working group on Dioxins (DE) 1999

[UBA 2003A]

Dioxin reference measuring program 4th Report of the Government/Laender working group on Dioxins, Federal Ministry for the Environment, Nature and Nuclear Safety, Bonn

[UBA 2001]

Draft of a German Report for the creation of a BREF-document "waste incineration", Umweltbundesamt, Berlin, 2001

[UK 1994]

Waste Management Paper No 6; Polychlorinated Biphenyls; Department of the Environment

[UK EA 2002]

Solid residues from MSWI in England and Wales, UK Environment Agency, May 2002

[UMEG 2001]

UMEG, Erhardt, Prüeß, Organic contaminants in sewage sludge for agricultural use, 2001;
http://europa.eu.int/comm/environment/waste/sludge/organics_in_sludge.pdf

[UMK AG 2000]

UMK AG: mean PCB-concentration in sewage sludge in Germany; Organic Contaminants in Sewage Sludge for Agricultural Use, 2000
http://europa.eu.int/comm/environment/waste/sludge/presentations/11_pruess.pdf

[Umwelterklärung 2004]

B.U.S. Zink Recycling Freiberg GmbH & CoKG: Umwelterklärung 2004 (Basis: Bilanzjahr 2003/2004)

[UNEP BAT-BEP 2004]

Guidelines on Best Available Techniques (BAT) and Guidance on Best Environmental Practice (BEP) relevant to the provisions of Article 5 and Annex C of the Stockholm Convention, Draft, July 2004

[UNEP GTGESM final 2005]

General Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of, Containing or Contaminated with Persistent Organic Pollutants to the Basel Convention, 2005 (www.basel.int/techmatters/pops/pops_guid_final.doc)

[UNEP Regional Report Europe]

UNEP, Regionally Based Assessment of Persistent Toxic Substances EUROPE REGIONAL REPORT, 2002

[UNEP Regional Report Mediterranean]

UNEP, Regionally Based Assessment of Persistent Toxic Substances MEDITERRANEAN REGIONAL REPORT, 2002

[UNEP Toolkit 2003]

Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases, United Nations Environment Programme, 2003

[UNFCCC CRF 2004]

Data from Common Reporting Formats for the provision of inventory information by Annex I Parties to the UNFCCC, country specific submission for 2004

[US EPA 1988]

Environmental Protection Agency, Federal Register, Part V, 40 CFR Part 761, Polychlorinated Biphenyls; Exclusions, Exemptions and Use Authorisations; Final Rule, 27.06.1988

[US EPA 2004]

Database of Sources of Environmental Releases of dioxin-like Compounds in the United States, US Environmental Protection Agency, <http://www.epa.gov/ncea/dioxindb.htm> (access december 7, 2004).

[VAW IMCO 2003]

VAW IMCO Guß und Recycling GmbH, Umwelterklärung 2003 (für die Jahre 1999-2002)

[VCI 2004]

Chemiewirtschaft in Zahlen, Verband der Chemischen Industrie e.V., Frankfurt, Juli 2004

[Vehlow 2002]

Vehlow, "Bottom ash and APC residue management" Power production from waste and biomass IV, Helsinki, 2002

[WI BREF 2004]

European Commission, Draft Reference Document on the Best Available Techniques for Waste Incineration, Draft, March 2004

[Wienberg 2004]

Dr. Reinhard Wienberg, Beitrag zum Workshop zur Verordnung über die Verwertung von Abfällen auf Deponien über Tage, März 2004, BMU, Bonn

[WMCN 2004]

Waste Management Council Netherlands, The future of hazardous waste incineration, July 2004

[WMO 2001]

Waste management options and climate change 2001

http://www.environmental-center.com/articles/article1200/waste_climate_change.pdf

[ZDB-Leitfaden]

Zentralverband des deutschen Baugewerbes, Februar 1997