

# **Releases of Dioxins and Furans to Land and Water in Europe**

Final Report

**Report produced for  
Landesumweltamt Nordrhein-Westfalen, Germany  
on behalf of  
European Commission  
DG Environment**

September 1999

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<b>Customer</b>	Landesumweltamt Nordrhein-Westfalen
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# Executive Summary

This study on releases of PCDD/Fs to land and water in Europe was commissioned by the North Rhine-Westphalia State Environment Agency (LUA NRW) as part of a study for the European Commission (DG XI). It is designed to complement the study by LUA 'Identification of Relevant Industrial Sources of Dioxins and Furans in Europe' published in 1997 which concentrated on releases of PCDD/Fs to air. Together the two studies constitute the first integrated inventory of PCDD/F releases to the environment across Europe.

An integrated inventory of pollutant releases to air, land and water has the benefit that it indicates the overall burden of emission sources on the environment. This enables policy-makers to have a complete understanding of the relative significance of processes that could release dioxins and furans (PCDD/Fs) and helps in the development of policy that works towards a more sustainable environment.

This default inventory for PCDD/F releases to land and water in 1994 is mainly based on information which has been assembled for previous studies for the UK, Germany, Sweden and The Netherlands. Though this study has identified the majority of relevant published reports on releases of PCDD/Fs, there is likely to be much measurement data that has not been published.

The draft of this report was distributed to international experts on PCDD/F emissions within the countries covered by the study. These experts checked the inventory and provided country-specific information where available. The draft inventory has therefore been improved since it was distributed in March 1999.

There are very limited quantities of data available relating to PCDD/F releases to land and water and the best estimates in this inventory (see table 1) are therefore very uncertain. These uncertainties are demonstrated by the very wide ranges in estimated emissions (see figure 1). There is a particular lack of information on releases to water and, therefore, few quantitative estimates have been made for this medium.

However, this inventory of releases of PCDD/F to land and water, together with the inventory of releases of PCDD/F to air (LUA 1997), represents a good starting point for improvement of the integrated inventory.

The inventory of releases to land and water is too uncertain to act as a reliable indicator in the development of further appropriate policy for emission reduction and control. It is therefore recommended that further research and data collection are carried out to verify the scale of releases from the source sectors which have a high potential for release. These sectors are :

- Chemical production and use
- Pesticide production and use
- Accidental fires
- Disposal of MSW to landfill
- Non-ferrous metal industry

While not quantified, total releases to water are likely to be significantly less than both releases to land and to air. This is because any waste water treatment applied is likely to concentrate the PCDD/Fs in sludge. Reduction of releases to water is still important as this is a key route for PCDD/Fs to enter the aquatic environment.

Further work to improve the inventory should concentrate on a balance between sources with a high potential emission (eg pesticide production, MSW incineration) and sources which are important in terms of environmental impact/exposure (eg pesticide use, sludge disposal). The prioritisation of further work should also take into account likely future trends in PCDD/F release - for many sources there is likely to have been a decrease in release since the 1994 base year.

To improve the inventory of PCDD/F releases to land it is not just measurements of concentrations that are required. Further research is needed on details of activity and processes – this should involve contacting the industry trade associations and other relevant organisations in individual countries.

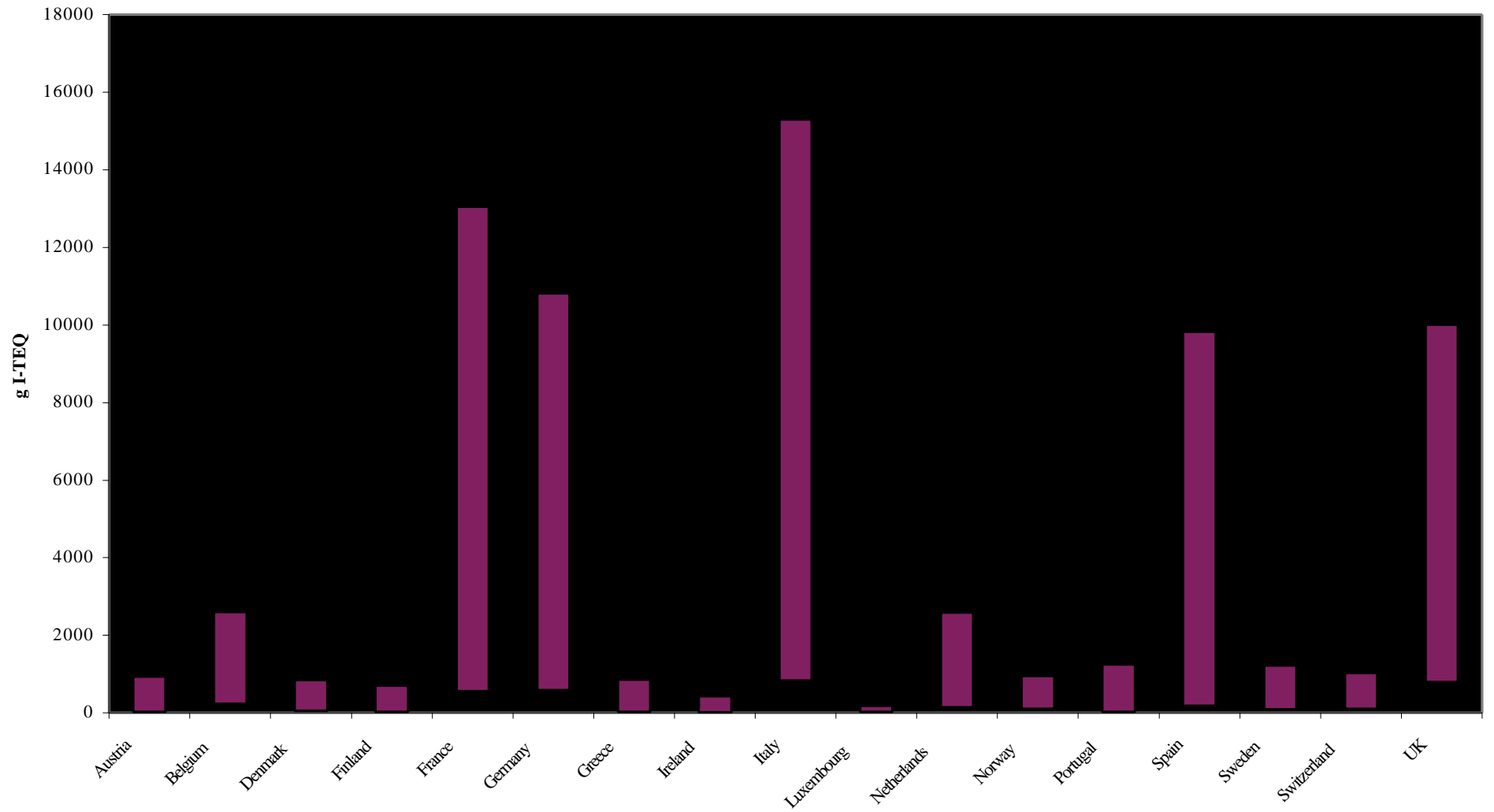
**Table 1 - Summary of ‘Best Estimates’ of Releases of PCDD/F to land from SNAP Level 1 Sources (g I-TEQ)**

		Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Lux	The Neth
<b>SNAP</b>												
<b>Group</b>												
<b>1</b>	Public power, cogen. & district heating	2	11	7	5	31	83	15	2	32	0	9
<b>2</b>	Comm., instit. & residential combustion	26	8	2	20	233	59	37	10	142	1	10
<b>3</b>	Industrial combustion	37	148	3	13	310	735	2	8	339	2	63
<b>4</b>	Industrial processes	145	387	152	91	3333	1142	14	73	3342	10	437
<b>5</b>	Extraction & distribution of fossil fuels											
<b>6</b>	Solvent use											
<b>7</b>	Road transport											
<b>8</b>	Other mobile sources & machinery											
<b>9</b>	Waste treatment & disposal activities	98	601	160	125	1282	1821	121	45	2614	82	475
<b>10</b>	Agriculture activities	15	45	17	6	388	127	36	8	388	1	49
<b>11</b>	Nature											
<b>12</b>	Fires and other sources	168	214	112	107	1226	1725	219	76	1211	9	326
	<b>TOTAL</b>	<b>490</b>	<b>1410</b>	<b>450</b>	<b>370</b>	<b>6800</b>	<b>5700</b>	<b>440</b>	<b>220</b>	<b>8070</b>	<b>110</b>	<b>1370</b>

**Table 1 - Summary of ‘Best Estimates’ of Releases of PCDD/F to land from SNAP Level 1 Sources (g I-TEQ) (Continued)**

		Norway	Portugal	Spain	Sweden	Switz	UK	Total release	% Total release
<b>SNAP Group</b>									
<b>1</b>	Public power, cogen. & district heating	2	7	41	5	3	46	<b>300</b>	<b>1 %</b>
<b>2</b>	Comm., instit. & residential combustion	17	42	55	34	7	24	<b>730</b>	<b>2 %</b>
<b>3</b>	Industrial combustion	12	11	105	73	7	402	<b>2270</b>	<b>6 %</b>
<b>4</b>	Industrial processes	43	229	3073	126	5	1088	<b>13690</b>	<b>36 %</b>
<b>5</b>	Extraction & distribution of fossil fuels								
<b>6</b>	Solvent use								
<b>7</b>	Road transport								
<b>8</b>	Other mobile sources & machinery								
<b>9</b>	Waste treatment & disposal activities	362	120	544	228	399	2482	<b>11560</b>	<b>30 %</b>
<b>10</b>	Agriculture activities	0	26	357	8	0	122	<b>1590</b>	<b>4 %</b>
<b>11</b>	Nature								
<b>12</b>	Fires and other sources	92	209	829	183	148	1236	<b>8090</b>	<b>21 %</b>
	<b>TOTAL</b>	<b>530</b>	<b>640</b>	<b>5000</b>	<b>660</b>	<b>570</b>	<b>5400</b>	<b>38230</b>	

**Figure 1 - Min - Max Range of Estimated Releases of PCDD/Fs to Land**



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Ireland	EPA	Colman Concannon
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UK	AEA Technology Environment	Peter Coleman
Europe	Eurostat	Maila Puolamaa/ Wolfgang Jenseit
Europe	European Crop Protection Association	Roger Parker

# 1. Introduction

## 1.1 BACKGROUND

This study on releases of PCDD/Fs to land and water in Europe was commissioned by the North Rhine-Westphalia State Environment Agency (LUA NRW) as part of a study for the European Commission (DG XI). It is designed to complement the study by LUA 'Identification of Relevant Industrial Sources of Dioxins and Furans in Europe' published in 1997 which concentrated on releases of PCDD/Fs to air. Together the two studies constitute an integrated inventory of PCDD/F releases to the environment across Europe.

The LUA (1997) study is available from :

North Rhine-Westphalia State Environment Agency (LUA NRW)  
Wallneyer Str. 6  
D-45133 Essen  
Germany

## 1.2 STRUCTURE OF THIS REPORT

Section 1 of this report gives the background and the purpose of this study.

Section 2 describes the method used to compile the inventory of dioxin releases to land and water. The methods for handling and demonstrating data quality are also described.

Section 3 presents the results for individual sectors, including the solid and liquid wastes arising and the resulting PCDD/F release to land and water. Where there is potential for a significant change in release following 1994 or in future then this is discussed in these sections.

Section 4 gives the conclusions and recommendations.

The bibliography / references and a glossary of terms can be found at the back of the report.

## 1.3 PCDD/FS

There is considerable public, regulatory and scientific concern about the potential effects of persistent organic pollutants (POPs) on the health of human populations and ecosystems. Much attention has been focused on chlorinated organic compounds including polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). In this report these compounds are referred to collectively as PCDD/Fs.

Although there are 210 congeners of PCDD/Fs, only the 17 which have chlorine substitution in at least all of the 2, 3, 7, 8 positions are of great concern, owing to their toxicity, stability and persistence in the environment. In general, concentrations of PCDD/Fs are expressed as a toxic equivalent value (TEQ) which is derived from analysis of the 17 toxic congeners and the

application of a system of toxic equivalent factors (TEF). There are a number of schemes, but the scheme proposed in the NATO/CCMS (NATO Committee on the Challenges of Modern Society) report, known as the International Toxic Equivalent Scheme (I-TEQ), has been adopted within the EU. In the I-TEQ scheme the 2, 3, 7, 8-TCDD congener is assigned a value of 1, and other congeners a value less than 1. Appendix 1 gives the TEF of the 17 toxic congeners. The emission estimates in this report are for the sum of these 17 congeners calculated in terms of the I-TEQ scheme.

PCDD/Fs can be released from a number of different sources, such as :

- chemical manufacturing, especially of herbicides and chlorinated phenols;
- combustion processes, especially incinerators;
- metallurgical processes;
- paper and pulp processing.

The details of potential mechanisms for formation of PCDD/Fs are discussed in many other reports (e.g. HMIP 1995). More details of the toxicity and consequences of PCDD/Fs, and of the different TEQ schemes, are given in LUA (1997).

## 1.4 BENEFITS OF AN INTEGRATED INVENTORY

Releases of PCDD/Fs to land occur through the disposal of dusts and sludges from gas cleaning devices associated with combustion and industrial plant, disposal of grate ash from combustion plant, disposal of unwanted chemicals, disposal of sludges from effluent treatment, disposal of other contaminated wastes, pesticide use etc. Releases to water occur through discharges of effluent from industrial processes, improper disposal of waste oil, pesticide use, etc.

The integrated inventory has the benefit that it indicates the overall environmental release from emission sources, so that policy makers have a complete understanding of the most important processes that could release PCDD/Fs into the environment. This enables appropriate policies to be developed to control and/or reduce releases. In this way information is made available to assist implementation of regulations such as Council Directive 96/61/EC on Integrated Pollution Prevention and Control (IPPC). Control of emissions to air might, for example, lead to a release to land through disposal of dusts or sludges from gas cleaning equipment, and an integrated approach covers all the major routes of release to the environment.

More specifically, integrated emission inventories have a number of uses :

- to build a coherent picture of present and future impacts on the environment, including exposure to humans and the ecosystem;
- to identify emission sources requiring an integrated abatement strategy, and to monitor progress against emission reduction targets;
- to identify any trends across different countries;
- to assist forecasting, including the prediction of the likely effects of future policy scenarios, for which reliable emission factors will be required;

- as starting points for the modelling of dispersion and transport of pollutants in the environment.

For persistent and semi-volatile pollutants, such as PCDD/Fs, integrated inventories are particularly important. This is because there is the potential for the pollutants to be re-emitted from the media to which they were initially released, potentially resulting in greater exposure and certainly greater mobility than would otherwise be expected.

### 1.5 RELATED WORK AND SUPPLEMENTARY DOCUMENTS

There has been considerable activity at national and international levels over recent years to develop emission inventories of PCDD/F releases to air. However, there has been limited activity on PCDD/F releases to land and water.

AEA Technology Environment (1997) produced a report 'A Review of Dioxin Releases to Land and Water in the UK'. No measurements were made for this study, but a robust methodology was developed and estimates of emissions were based on reported measurements from several countries. The methodology used in this present report had therefore been previously tested.

A significant amount of work on PCDD/F releases to land and water has been carried out as part of the Swedish Dioxin Survey (de Wit 1998).

Some work on PCDD/F releases to land and water has also been carried out in Denmark (Jensen et al. 1995), Germany (LUA 1997), and The Netherlands (Bremmer et al. 1994). However, in these cases, the main emphasis of the work has been on releases to air.

More recently, Environment Canada (1999) has published a report on an inventory of releases of PCDD/Fs and HCB.

The reports by LUA (1997) on PCDD/F releases to air in Europe and by AEA Technology Environment (1997) on PCDD/F releases to land and water in the UK are referred to at several points in this report and should be used as supplementary documents for more detailed information.

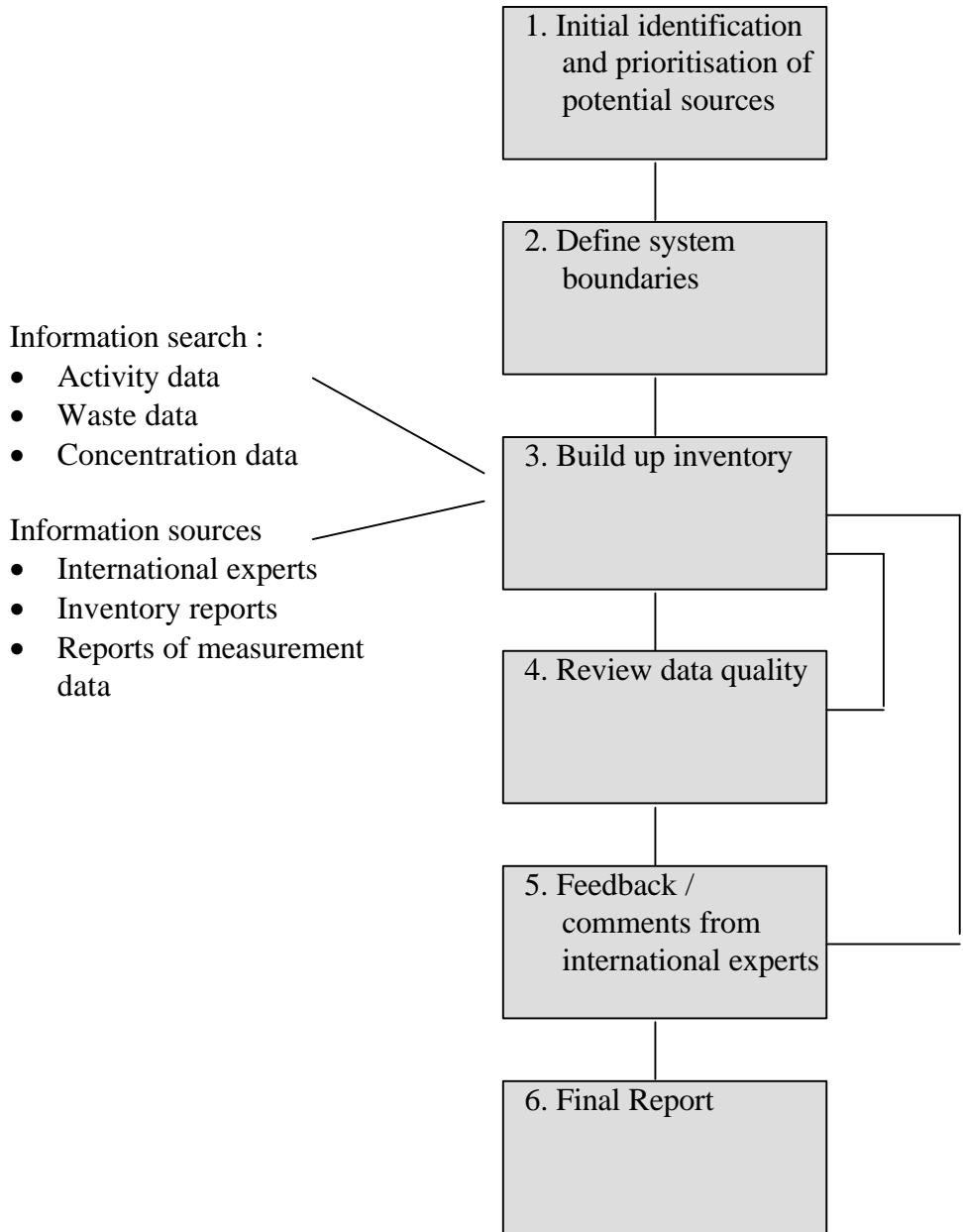
## 1.6 COUNTRIES INCLUDED IN THIS STUDY

This report covers releases of PCDD/Fs for the following countries :



## 2. Method

### Summary of Method to Develop PCDD/F Inventory of Releases to Land and Water



## 2.1 PRIORITISATION OF SOURCES

This study has concentrated on the sources that were regarded to have the greatest potential to release PCDD/Fs to the environment, and at the start of the project these were prioritised in terms of the likely magnitude of releases. This process was carried out through expert opinion and using the large amount of literature on PCDD/F emissions from various sources, particularly AEA Technology Environment (1997) and LUA (1997).

The emphasis of this work has been on the high priority sources, and these are discussed in detail in Section 3 of this report. Less work has been carried out on the lower priority sources although these are briefly discussed in Section 3. In many cases the detail of work depended on the amount of data available.

## 2.2 SYSTEM BOUNDARIES

The inventory of releases to land and water is not as straight-forward as the inventory of releases to air, with respect to system boundaries. For example, many effluents are treated before discharge to a sewer. This treatment produces a sludge, which could be disposed to land. In many cases the effluent treatment plant will capture the majority of the PCDD/Fs in the waste water, but these would then be released to land in the sludge. The estimates of releases in this study attempt to represent releases directly to land (including disposal to landfill) or directly to a water course after any relevant treatment. However, the complications regarding system boundaries present a source of uncertainty in estimates of releases as there is potential for double counting.

In order to determine whether PCDD/Fs are released to land in waste, it is necessary to know the destinations of the waste. For example, it might be sent to either a well controlled or a poorly controlled landfill, recycled, destroyed by incineration etc. Where the waste from a process is recycled or re-used in another process, PCDD/Fs might be transferred to products or to wastes from the second process.

Releases to land can potentially lead to contamination of ground water or water courses in future, or to PCDD/Fs being transported by air if resuspension occurs. Where releases to land are into a well controlled landfill, the chances of exposure are greatly reduced. It is beyond the scope of this study to attempt to quantify the transfer of PCDD/Fs between media or to review potential exposure routes.

## 2.3 DEVELOPMENT OF DEFAULT EMISSION INVENTORY

### 2.3.1 Basic Integrated Emission Inventory Methodology

Site-specific data on releases of PCDD/Fs to land and water are not widely available. Therefore we have used a top-down methodology to develop the inventory.

To estimate the release of PCDD/Fs in solid wastes, the following information is generally required :

- quantity and types of solid wastes arising
- proportion of solid wastes disposed to land, recycled etc.
- PCDD/F concentration in the type of waste specified.

The following equations illustrate the general methodology for estimating releases, in this case releases to land from MSW incinerators.

Release of PCDD/Fs	=	solid waste arising (e.g. amount of filter dust from MSW incinerator)	x	proportion of waste disposed to land (%) (eg 90 % f dust to land, 10% recycled)	x	PCDD/F concentration in waste (e.g. PCDD/F concentration per tonne of filter dust)
Solid waste arising (e.g. amount of filter dust from MSW incinerator)	=	waste factor (e.g. amount of filter dust arising per tonne of MSW incinerated)	x	activity statistic (e.g. tonnes of MSW incinerated)		

Similarly, for releases to water, the following information is generally required :

- quantity of water discharged to water courses
- PCDD/F concentration in the effluent discharge

### 2.3.2 Main Information Sources for Default Inventory

A default inventory was built up from the main information sources on releases to land and water. It was mainly based on the information on waste factors and PCDD/F concentrations which has been assembled for the UK study (AEA Technology Environment 1997). Activity data used in the default inventory was taken from the LUA (1997) study where appropriate for consistency, and from various other information sources (e.g. World Mineral Statistics, Eurostat Yearbook) for sectors not covered by LUA (1997).

### 2.3.3 Base Year for Inventory

As for the LUA (1997) study, the base year for this inventory is nominally 1994. Whereas the majority of the activity data used in our estimations is from 1994, most of the concentration

data is not specific to 1994. In the sector-specific sections of this report any potentially significant changes in releases that have occurred since 1994 or changes that are likely to occur in the near future, for example changes resulting from new legislation, will be highlighted.

## 2.4 DATA QUALITY

### 2.4.1 Sources of Uncertainty

There is a great deal of uncertainty in the estimates of PCDD/F releases to land and water. The main sources of uncertainty relate to :

- limited data on the quantities of solid and liquid waste arisings;
- limited information on the fate of products;
- limited information on waste treatment and disposal (e.g. on the proportions of solid waste disposed to landfill);
- limited available data on PCDD/F concentrations in solid wastes, effluent discharges and products;
- the data available on waste factors and PCDD/F concentrations are generally based on measurements at a small number of sources, and the applicability of the data to other sources within the same sector is often unreliable. This is because practices and processes vary significantly across Europe for many source sectors.

In many cases each of these uncertainties in the input data is multiplied up in the development of the inventory to give a very significant overall uncertainty in the final estimate.

Information is particularly scarce for releases to water and, for this reason, for many sectors estimates of releases to water have not been made. In these cases, a qualitative indication has been given of whether the sector is likely to generate a significant release to water.

Additional sources of uncertainty include the potential double counting of releases because of complications with system boundaries (Section 2.2). In addition, the concentration data from measurements is often reported using different TEQ schemes. In these cases, in this report, it is assumed that other TEQ ratings (e.g. Nordic TEQ) are broadly equivalent to I-TEQ. At this stage in the development of the inventory this assumption is justified by the fact that other uncertainties are much greater than the uncertainty associated with the different TEQ schemes.

### 2.4.2 Demonstrating Uncertainty

It is essential that inventories are reported in a manner which demonstrates the uncertainty for the estimates for different sectors. Demonstrating the uncertainty, for example, helps policy makers decide whether the inventory is reliable enough for control policies to be developed for the major sources, or helps prioritise measurement work so that inventories can be improved. For many inventories a data quality rating is used (e.g. A for high quality to E for very uncertain emission estimates). For this inventory a similar data quality rating would be inappropriate, as nearly all sources would be the lowest rating (e.g. E) and this would not help prioritise future measurements. Instead, ranges of emission estimates have been developed to show the uncertainty. In many cases the results show that the release is likely to vary

considerably between sources in the same sector, and the total release is likely to lie within a very wide range.

### **2.4.3 Best Estimates**

For all sources for which a min-max range has been quantified, best estimates have also been made. This would ideally be done by reviewing the distribution of data points within the min-max range. However, for many sources the lack of data points has resulted in the best estimate being the mid-point of the range. Where only one data point is available, the range of uncertainty has been assumed to be a factor of 10 to represent worst case.

## **2.5 FEEDBACK ON AND IMPROVEMENT OF DEFAULT EMISSION INVENTORY**

The draft report was prepared and distributed to identified experts across EU countries in February 1999. Feedback was received from 12 countries and the European Crop Protection Association and Eurostat. The experts within these countries / organisations are listed in the Acknowledgements section.

Some of the comments received were general – many of these were about the boundaries to this report (Section 2.2).

Some of the comments were more specific. Experts provided some information on emission factors from sources. Most of the specific comments, however, related to production / use statistics in different countries, and the activity data in this report has been considerably improved through the comments received.

The European Crop Protection Association were specifically approached because pesticide production and use are potentially significant sources, about which very limited data are available. The feedback from the European Crop Protection Association confirmed the lack of publicly available data, both on production of the types of pesticides which might be contaminated and on their use. The feedback did indicate that the actual emissions might be nearer the lower bound of the ranges estimated in this report.

## 3. Results

### 3.1 SNAP GROUP 1 - PUBLIC POWER, COGENERATION AND DISTRICT HEATING

#### 3.1.1 Combustion of Coal - Power Stations

##### Process Description

Power station furnaces vary in detail and factors that could affect PCDD/F releases, such as the types of furnace, the nature of the fuels burned, the combustion conditions and the abatement technologies employed also vary between plant.

Low levels of PCDD/Fs have been found in the solid residues from some coal-fired plant.

##### Activity Data

Activity data for power generated have been taken mainly from TNO (1997). The fact that most of these data are for 1990 introduces uncertainties in the emission estimates.

Country	Power generated in coal-fired power stations (TJ/yr) - 1990
Austria <sup>1</sup>	42 000
Belgium <sup>1</sup>	155 000
Denmark <sup>1</sup>	229 000
Finland <sup>2</sup>	127 044
France <sup>3</sup>	108 000
Germany <sup>1</sup>	1 778 000
Greece <sup>1</sup>	478 000
Ireland <sup>4</sup>	21 240
Italy <sup>1</sup>	273 980
Luxembourg <sup>1</sup>	0
Netherlands <sup>5</sup>	280 700
Norway <sup>1</sup>	17
Portugal <sup>1</sup>	97 800
Spain <sup>1</sup>	655 000
Sweden <sup>1</sup>	17 400
Switzerland <sup>1</sup>	18
UK <sup>1</sup>	2 020 000
TOTAL	6 283 000

(1) TNO (1997), (2) Sandell (1999) (note 1995 data), (3) Pernin (1999), (4) Concannon (1999) (note 1994 data), (5) Bremmer et al (1994)

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Abatement technologies employed vary between power plant. The driver behind technologies is mainly the control of atmospheric emissions of pollutants such as SO<sub>2</sub>, NO<sub>x</sub> and particulates. Some of these are likely to control PCDD/F releases to air at the same time.

The main solid waste from power stations is ash, including furnace bottom ash (FBA) and pulverised fuel ash (PFA) from particle emission control plant.

A significant proportion of the ash generated at power stations is likely to be sold commercially. The remainder is likely to be disposed to landfill. Releases to land are calculated for the whole quantity of ash produced as it is expected that the ash that is sold is not subjected to any treatment likely to alter the PCDD/F content and eventually this will constitute a release. The quantity of grate ash and PFA produced per unit of power generated in different countries is assumed to be constant and equal to that for the UK (4.15 tonnes of ash per TJ of energy produced, 19% of which is grate ash and 81% is PFA, (AEA Technology Environment 1997)).

Other solid wastes include sludge or gypsum from flue gas desulphurisation plant where these are employed.

The main use of water is for cooling. No information is available on the treatment of liquid discharges. In the UK ash lagoons are used to separate ash that can be used in building materials. This is a potential release to water, although the quantity of PCDD/F released is likely to be low. The extent of use of ash lagoons in other countries is unknown.

### **Emission Factors**

There are limited data available on contamination of soil residues and no data have been found for liquid wastes.

The concentrations used in AEA Technology Environment (1997), taken from measurements by CRE (1994), have been adopted for this report. These are 0.02-13.5 ng I-TEQ/kg for grate ash and 0.23-8.7 ng I-TEQ/kg for PFA. These data are from measurements on smaller furnaces than typical coal-fired power stations and, therefore, there is some uncertainty in their application for this sector.

Bremmer et al. (1994) also suggest that releases to land and water from coal-fired power stations are likely to be low.

**Emission Estimates**

Country	Release to land	
	Min.	Max.
	g I-TEQ	G I-TEQ
Austria	0.03	1.7
Belgium	0.12	6.2
Denmark	0.18	9.2
Finland	0.1	5.1
France	0.09	4.3
Germany	1.4	71
Greece	0.38	19
Ireland	0.017	0.8
Italy	0.22	11
Luxembourg	0	0
Netherlands	0.22	11
Norway	0.00001	0.0007
Portugal	0.08	3.9
Spain	0.52	26
Sweden	0.014	0.7
Switzerland	0.00001	0.0007
UK	1.6	81
TOTAL	5.0	250

Assuming a best estimate of about 130 g I-TEQ, this represents 0.3 % of the estimated total release of PCDD/F to land in Europe.

Releases to water have not been estimated because there are no data available. It is likely that releases to water are low because, although the quantities of effluent will be large, the potential for contamination is small as PCDD/Fs will be associated with particles.

**Future Changes in Release**

The amount of coal consumed in power stations is likely to decrease in many countries and, therefore, the release of PCDD/Fs from this source will also decrease. In some cases it is possible that improved control of emissions of other pollutants to air (eg FGD) might increase the release of PCDD/Fs to land, but this increase is unlikely to be significant in terms of the total inventory.

**Conclusions / Recommendations**

The estimated release to land resulting from disposal of ash from coal-fired power stations is significant, although much lower than the estimates from several other sources.

There is a need to improve the reliability of the estimates by obtaining more reliable activity data. Activity data for 1994 is required for all countries. In addition, the emission factors used introduce further uncertainty because they are derived from measurements at smaller furnaces. Emission factors for larger plant are required.

The release to water has not been estimated but is likely to be low.

### **3.1.2 Combustion of Coal - Industry**

#### **Process Description**

Industrial furnaces vary in the type and size of furnace, the nature of the coals burned, the combustion conditions and the abatement technologies employed. PCDD/F releases to the environment from industrial furnaces will therefore vary greatly.

#### **Activity Data**

Activity data for power generated have been taken from TNO (1997) and for The Netherlands estimated from Bremmer et al. (1994).

Country	Power generated in coal-fired industrial furnaces (TJ/yr) – 1990
Austria	22490
Belgium	57120
Denmark	13900
Finland	37300
France	274500
Germany	1275800
Greece	34240
Ireland	13105
Italy	55212
Luxembourg	4885
Netherlands	27600
Norway	19600
Portugal	20300
Spain	64009
Sweden	26100
Switzerland	12100
UK	186000
TOTAL	2144000

## **SNAP 1 – Public Power, Cogeneration & District Heating**

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

The main solid waste from furnaces is ash, including furnace bottom ash (FBA) and ash from particle control plant.

The quantity of grate ash and ash from particle control produced per unit of power generated in different countries is assumed to be constant and equal to that for the UK (1.8 tonnes of ash per TJ of energy produced, 88 % of which is grate ash and 12 % is ash from particle control (AEA Technology Environment 1997).

Only small volumes of water are likely to be discharged. Wet abatement systems are unusual in this sector. No information is available on the treatment of waste water.

### **Emission Factors**

There are limited data available on contamination of solid residues and no data has been found for liquid wastes.

The concentrations used in AEA Technology Environment (1997), taken from measurements by CRE (1994), have been adopted for this report. These are 0.02-13.5 ng I-TEQ/kg for grate ash and 0.23-8.7 ng I-TEQ/kg for ash from particle control.

### **Emission Estimates**

Country	Release to land	
	Min. g I-TEQ	Max. g I-TEQ
Austria	0.002	0.5
Belgium	0.005	1.3
Denmark	0.001	0.3
Finland	0.003	0.9
France	0.02	6.3
Germany	0.1	29
Greece	0.003	0.8
Ireland	0.001	0.3
Italy	0.004	1.3
Luxembourg	0	0
Netherlands	0.002	0.6
Norway	0.002	0.4
Portugal	0.002	0.5
Spain	0.01	1.5
Sweden	0.002	0.6
Switzerland	0.001	0.3
UK	0.015	4.3

TOTAL	0.2	49
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Assuming a best estimate of 25 g I-TEQ, this represents <0.1 % of total releases in Europe.

Releases to water have not been estimated because there are no data available. It is likely that releases to water are low (Bremmer et al. 1994).

### **Future Changes in Release**

The amount of coal consumed by industry is likely to decrease in many countries and the releases of PCDD/Fs will, therefore, also decrease.

### **Conclusions / Recommendations**

There is a need to improve the reliability of the estimates by obtaining more reliable activity data. The activity data used to estimate the emissions from this source are for 1990, and data for 1994 is required. However, this work is a low priority, compared to the work required to improve the inventory for other sectors, because releases from industrial coal combustion are likely to be low.

### **3.1.3 Combustion of Wood - Industry**

#### **Process Description**

Wood is burned for power generation and for heating by some industries. The wood production and processing industry, for example, uses a considerable quantity of wood waste to generate energy for heating.

#### **Activity Data**

Data on the quantity of wood burned are only available for some countries from national inventories (LUA 1997). For countries where no activity data are available the wood burned in each country has been estimated on a tonnes burned per capita basis.

Treated wood is likely to be contaminated with chemicals that could act as precursors to PCDD/F formation. For the UK 75% of wood burned is assumed to be treated (AEA Technology Environment 1997). For this report it is assumed that the same proportion of treated wood is burned for all countries. This is probably an over estimate for the countries with a greater forestry resource and for those in which the control of chlorinated pesticides has been stricter than in the UK.

Country	Treated wood burned (kt) 1994	Untreated wood Burned (kt) 1994
Austria <sup>3</sup>	190	960
Belgium <sup>1</sup>	490	160
Denmark <sup>2</sup>	140	50
Finland <sup>2</sup>	140	50
France <sup>2</sup>	1610	540
Germany <sup>1</sup>	2050	680
Greece <sup>2</sup>	290	100
Ireland <sup>2</sup>	100	30
Italy <sup>2</sup>	1590	530
Luxembourg <sup>2</sup>	11	4
Netherlands <sup>1</sup>	170	60
Norway <sup>2</sup>	120	40
Portugal <sup>2</sup>	280	90
Spain <sup>1</sup>	1660	550
Sweden <sup>2</sup>	240	80
Switzerland <sup>2</sup>	190	70
UK <sup>1</sup>	150	50
<b>TOTAL</b>	<b>9400</b>	<b>4000</b>

(1) From national inventories (LUA 1997) (2) Estimated (per capita) (3) UBA (1999)

Feedback from Ireland suggests this country's figure is an overestimate (Concannon 1999), although no additional data are available. Also, feedback from Sweden (de Wit 1999) indicates that since pentachlorophenol is banned in Sweden, this activity is overestimated.

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

The rates for production of ash from wood burning of 3.4 kg/t of waste burned for grate ash, and 3.3 kg/t of waste burned for grit ash from gas-cleaning, have been used to estimate the emissions below. It is assumed that all ash is released to land.

### **Emission Factors**

Some concentration data are available for ash produced from burning of treated and untreated wood. For treated wood the range of concentrations used for estimating PCDD/F releases are 22.3-1090 ng I-TEQ/kg (grate ash) and 722-7620 ng I-TEQ/kg (filter or grit ash), and for untreated wood the concentrations reported are much lower at 0.23-1.12 ng I-TEQ/kg (grate ash) and 117-372 ng I-TEQ/kg (filter/grit ash), (ETSU 1993a, Oehme and Muller 1995).

**Emission Estimates**

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.2	1.6
Belgium	1.3	14
Denmark	0.4	4.2
Finland	0.4	4.1
France	4.2	47
Germany	5.3	60
Greece	0.8	8.5
Ireland	0.3	2.9
Italy	4.1	47
Luxembourg	0.03	0.3
Netherlands	0.4	5.0
Norway	0.3	3.5
Portugal	0.7	8.1
Spain	4.3	49
Sweden	0.6	7.1
Switzerland	0.5	5.7
UK	0.4	4.4
TOTAL	24	270

Assuming a best estimate of 150 g I-TEQ total release to land from industrial wood combustion in Europe, this represents 0.4% of the total release of PCDD/F estimated from all known sources in Europe.

No data are available on the release of PCDD/Fs to water from these plant but any release is expected to be small.

**Future Changes in Release**

The fact that the use of PCP is being phased out means that the above releases from combustion of treated wood are likely to either be an overestimate for 1994 or to have significantly reduced since 1994. However, increasing controls on landfill are leading to a higher fraction of waste wood being burned.

**Conclusions / Recommendations**

A large proportion of the release to land arises from the burning of wood that has been treated. The main uncertainty in the emission estimates for this section relates to the quantity of treated wood burned and country-specific data needs to be obtained on this.

Although the estimated releases to land are significant, these are more likely to be an overestimate and the improvement in these estimates is a lower priority than for many other sectors.

Emissions to water are likely to be low.

### **3.1.4 Combustion of Oil - Industry**

Oil is burned in large scale power plant, industrial plant and domestic heaters.

There is expected to be little solid or liquid waste arising other than periodic wastes such as from boiler cleaning. Soot may be contaminated with PCDD/Fs and released during cleaning operations.

No data are available to enable releases from oil combustion to be estimated, but they are expected to be low.

Combustion of waste oil is discussed under SNAP 090208.

### **3.1.5 Combustion of Refuse-Derived Fuel**

Municipal waste can be processed to recover recyclable components and produce refuse-derived fuel (RDF). The RDF can then be pelletised and burned in purpose-built or modified equipment to produce heat or power.

The combustion of RDF will lead to production of grate ash and residues from pollution abatement plant.

The combustion of RDF is unlikely to be a major source of PCDD/Fs as the quantities burned are likely to be relatively small. Information on quantities of RDF burned needs to be obtained in order to estimate releases and verify this assumption.

### **3.1.6 Straw Combustion**

Straw combustion plant for heating are likely to be small furnaces. Straw contains small amounts of chlorine and therefore combustion has the potential to produce PCDD/Fs. However, the combustion of straw is unlikely to be a major source of PCDD/Fs. Information on quantities of straw burned needs to be obtained in order to estimate releases and verify this assumption.

## 3.2 SNAP GROUP 2 - COMMERCIAL, INSTITUTIONAL & RESIDENTIAL COMBUSTION

### 3.2.1 Combustion of Coal - Domestic

#### Process Description

Coal is burned on domestic premises in a range of open fires and closed stoves / boilers. The emissions of PCDD/Fs to the environment from domestic coal combustion are likely to increase significantly when types of domestic waste are introduced to the fire.

#### Activity Data

Activity data for the quantity of coal burned has been taken from national inventories (LUA 1997) and checked using information on energy production from TNO (1997). For countries where LUA had no reliable data then the estimates were made from the TNO data by scaling relative to the UK consumption on a per capita basis (it was assumed that the energy production per unit of coal burned is the same for all countries).

Country	Estimated coal burned in domestic appliances (kt) (1994)
Austria <sup>1</sup>	620
Belgium <sup>1</sup>	580
Denmark <sup>2</sup>	85
Finland <sup>1</sup>	160
France <sup>2</sup>	1690
Germany <sup>1</sup>	13500
Greece <sup>1</sup>	160
Ireland <sup>3</sup>	450
Italy <sup>1</sup>	4.0
Luxembourg <sup>1</sup>	10
Netherlands <sup>1</sup>	63
Norway <sup>1</sup>	140
Portugal <sup>2</sup>	1.4
Spain <sup>1</sup>	1850
Sweden <sup>4</sup>	0
Switzerland <sup>1</sup>	410
UK <sup>1</sup>	5250
TOTAL	25000

(1) LUA (1997), (2) TNO (1997), (3) Concannon (1999), (4) De Wit (1999)

**Solid and Liquid Waste Arisings, Treatment and Disposal**

The main solid waste is grate ash. There are likely to be periodic collections and disposal of soot from chimney cleaning operations. It is assumed that all ash and soot is disposed to land.

The ash content of coal ranges from 5-16% (AEA Technology Environment 1997).

From UK data, the quantity of soot collected and disposed is estimated at 0.57 kg/t burned. It should be noted that this soot includes that collected from wood fires.

No arisings of waste liquid are likely.

**Emission Factors**

The concentration data for soot is from Dumler-Gradl et al. 1995 and is a very wide range of 53-10,065 ng I-TEQ/kg. This range has been used to estimate the PCDD/F release in the soot.

The concentration range for ash of 0.22-0.41 ng I-TEQ/kg used for ash is lower than for soot and is based on UK data covering bituminous, anthracite and manufactured smokeless coal (CRE 1992). This range has been adopted to estimate the release in the ash although, from comparisons with the range for soot, it is likely that in reality the range is wider than this.

**Emission Estimates**

The emission estimates for release to land have been calculated by adding the releases from soot and ash.

The minimum and maximum releases in the table below have been calculated using the following method :

Min release	=	[kt of coal burned	x	min. ash content %	x	min emission factor (ash)]		
			+	[kt of coal burned	x	soot collected per kt	x	min emission factor (soot)]
Max release	=	[kt of coal burned	x	max. ash content %	x	max emission factor (ash)]		
			+	[kt of coal burned	x	soot collected per kt	x	max emission factor (soot)]

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.03	3.6
Belgium	0.02	3.3
Denmark	0.004	0.5
Finland	0.01	0.9
France	0.07	9.9
Germany	0.6	79
Greece	0.01	0.9
Ireland	0.02	2.6
Italy	0.0002	0.02
Luxembourg	0.0013	0.19
Netherlands	0.003	0.4
Norway	0.01	0.8
Portugal	0.0001	0.008
Spain	0.08	11
Sweden	0	0
Switzerland	0.02	2.4
UK	0.2	31
TOTAL	1.0	150

Assuming a best estimate of 75 g I-TEQ released to land, this sector contributes about 0.2% of total emissions of PCDD/F to land.

No releases to water are expected.

### Future Changes in Release

The quantity of coal burned in domestic appliances might rise in some countries and fall in others. The general trend is expected to be a fall in quantity burned and therefore a reduction in emission.

### Conclusions / Recommendations

The estimated releases to land are based on emission factors for disposal of ash and soot. The single study on emission factors from soot indicates these are much higher than concentrations in ash. The figures above for releases to land might therefore be an overestimate because they are dominated by the release from soot.

This sector is a low priority for inventory improvement relative to other sectors with a higher estimated release.

### 3.2.2 Combustion of Wood - Domestic

#### Process Description

Wood, like coal, is burned on domestic premises in a range of open fires and closed stoves / boilers. The emissions of PCDD/Fs to the environment from domestic wood combustion are likely to increase significantly when treated wood is burned because of the presence of PCDD/F precursors.

#### Activity Data

Activity data for the quantities of wood burned has been taken from LUA (1997). The data was obtained from national inventories and from the Eurostat (1993) document on energy consumption of private households. As these data had been collected in 1988 it had to be assumed that no considerable change occurred in quantity of wood burned within the last decade. Where LUA had no reliable data then the estimates were made using average per capita wood consumption.

For the UK, about 11% of wood burned in domestic appliances is estimated to be treated wood, and, in the absence of other data, it has been assumed that this is the case in other countries.

Country	Treated wood burned (kt) 1994	Untreated wood Burned (kt) 1994
Austria <sup>3</sup>	0	2450
Belgium <sup>1</sup>	73	590
Denmark <sup>1</sup>	23	190
Finland <sup>1</sup>	220	1810
France <sup>1</sup>	2570	20800
Germany <sup>1</sup>	220	1750
Greece <sup>1</sup>	410	3320
Ireland <sup>2</sup>	98	790
Italy <sup>1</sup>	1580	12800
Luxembourg <sup>2</sup>	11	89
Netherlands <sup>1</sup>	110	900
Norway <sup>1</sup>	190	1540
Portugal <sup>1</sup>	470	3810
Spain <sup>1</sup>	560	4520
Sweden <sup>1</sup>	390	3120
Switzerland <sup>1</sup>	66	530
UK <sup>1</sup>	99	800
TOTAL	7100	59800

(1) LUA (1997), (2) Estimated (per capita) (3) UBA (1999)

Feedback from Ireland suggests this country's figure is an overestimate (Concannon 1999), although no additional data are available. Also, feedback from Sweden (de Wit 1999) indicates that since pentachlorophenol (PCP) is banned in Sweden, this activity is overestimated.

### Solid and Liquid Waste Arisings, Treatment and Disposal

The main solid waste is grate ash. There are likely to be periodic collections and disposal of soot from chimney cleaning operations. It is assumed that all ash and soot is disposed to land. The releases of PCDD/Fs in soot is covered within the estimates made for domestic coal combustion (Section 3.2.1).

The ash content of wood ranges from 0.4-3.4% (AEA Technology Environment 1997).

No arisings of waste liquid are likely.

### Emission Factors

The concentration range of 75-500 ng I-TEQ/kg for grate ash from burning untreated wood has been taken from Dumler-Gradl et al. (1993). For treated wood no data are available specifically for domestic appliances and the concentration range for industrial combustion of wood has been used (22.3-1090 ng I-TEQ/kg).

### Emission Estimates

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria <sup>1</sup>	0.7	47
Belgium	0.2	13
Denmark	0.06	4.0
Finland	0.6	39
France	6.5	450
Germany	0.5	38
Greece	1.0	72
Ireland	0.3	17
Italy	4.0	280
Luxembourg	0.03	1.9
Netherlands	0.3	20
Norway	0.5	33
Portugal	1.2	82
Spain	1.4	98
Sweden	1.0	67

Switzerland	0.2	12
UK	0.3	17
TOTAL	19	1280

Assuming a mid-range best estimate of about 650 g I-TEQ, this represents about 1.7% of total emissions of PCDD/F to land.

### **Future Changes in Release**

The fact that the use of PCP has now been phased out means that the estimated releases from combustion of treated wood are likely to either be an overestimate for 1994 or to have reduced since 1994. The increased controls on landfill and increased interest in sustainability means that the quantity of wood burned might be increasing.

### **Conclusions / Recommendations**

Disposal of ash from domestic combustion of wood is potentially a high priority source as the estimated emissions are relatively high. However, the main uncertainty in the estimates is the proportion of wood that is treated. This proportion is likely to be decreasing. Further work should initially focus on reducing the uncertainty in activity data by obtaining country-specific information on the quantity of wood that is treated.

No releases to water are expected.

### 3.3 SNAP GROUP 3 - INDUSTRIAL COMBUSTION

#### 3.3.1 Sinter Plant

SNAP 30301

#### Process Description

The draft European BAT (BREF) report of the European IPPC Bureau contains a significant amount of detail on the sinter plant process, and the BREF report should be referred to for more information (European IPPC Bureau 1998a).

Sinter plant are used in the iron-making process to pre-treat materials fed to the blast furnace. The pre-treatment involves the agglomeration of a mixture of fine ores, coke breeze, additives, recycled materials from downstream operations, mill scale, casting scale etc.). In Europe, the sintering process is exclusively performed as down-draft sintering on continuously working travelling grates (European IPPC Bureau 1998a).

#### Activity Data

Activity data for sinter production have been taken from LUA (1997), based on data from national inventories and from annual production statistics.

Country	Sinter production (Mt) (1994)
Austria <sup>1</sup>	2.7
Belgium <sup>2</sup>	9.8
Denmark <sup>3</sup>	0
Finland <sup>1</sup>	1.9
France <sup>1</sup>	18.4
Germany <sup>2</sup>	25.5
Greece <sup>3</sup>	0
Ireland <sup>3</sup>	0
Italy <sup>1</sup>	12.8
Luxembourg <sup>1</sup>	4.6
Netherlands <sup>1</sup>	4.1
Norway <sup>3</sup>	0
Portugal <sup>1</sup>	0.4
Spain <sup>1</sup>	6.2
Sweden <sup>1</sup>	1.0
Switzerland <sup>3</sup>	0
UK <sup>2</sup>	15.1
TOTAL	102

(1) annual production statistics (LUA 1997) (2) national inventories (LUA 1997) (3) no sinter plants

#### Solid and Liquid Waste Arisings, Treatment and Disposal

The majority of solid wastes arising from sinter plant are dusts from dedusting devices and sieving fractions. Most of these are recycled to the strand.

Although many sinter plants in Europe operate with fully closed dust cycles, filter dust from the last field of electrostatic precipitators (ESPs) is not always recycled. AEA Technology Environment (1997) estimate that about 0.05 kg of dust per tonne of sinter is landfilled. The draft BREF note of the European IPPC Bureau (1998) suggests that dust arisings range from 1-2 kg/t. For this study the range of 0.05-2 kg/t has been adopted.

Sludge from wet waste gas treatment systems could also lead to a release of PCDD/Fs. There are only two plant operating such a system in Europe.

Depending on the process, releases to water could include rinsing water, cooling water and waste water from waste gas treatment (European IPPC Bureau 1998a).

**Emission Factors**

Concentration data for PCDD/Fs in ESP dust of 29-90 ng I-TEQ/kg has been taken from AEA Technology Environment (1997), based on information from UK sinter plant. Data from Germany measured in 1993/94 were in the range 196-488 ng I-TEQ/kg (LUA 1999). The range of 29-488 ng I-TEQ/kg has been used to estimate the releases below.

No concentration data are available for releases to water.

**Emission Estimates**

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.004	2.7
Belgium	0.01	9.6
Denmark	0	0
Finland	0.003	1.9
France	0.02	18
Germany	0.03	25
Greece	0	0
Ireland	0	0
Italy	0.02	12
Luxembourg	0.006	4.5
Netherlands	0.006	4.0
Norway	0	0
Portugal	0.001	0.39
Spain	0.008	6.1
Sweden	0.001	0.94

Switzerland	0	0
UK	0.02	15
TOTAL	0.1	100

A best estimate release to land of 50 g I-TEQ is about 0.1% contribution to total estimated emissions in Europe.

Negligible releases of PCDD/Fs to water are expected from sinter plant. The two plant with wet gas treatment have more potential to release PCDD/Fs to water than other plant.

### Future Changes in Release

Future sinter production will depend on market conditions. The steel industry is under pressure to reduce emissions of PCDD/F to air. This might have resulted in an initial increase of release to land, but the general trend is likely to be a decrease in releases to land as combustion conditions and technologies are improved.

In many sectors flue gas cleaning technology is continuously being tested and developed, and there is an example of this a sinter plant in Germany where activated charcoal as an absorbent following catalytic PCDD/F destruction is being tested. If this technology were to prove feasible and used at other plant, there might be an increase of PCDD/F-laden charcoal disposed to land. This would depend on the proportion of charcoal recycled to the sintering process or burned in hazardous waste incinerators.

### Conclusions / Recommendations

The estimated releases to land from disposal of dust from flue gas treatment show that this source is less significant. The release depends on the proportion of dusts that are recycled into the sinter process, and the first task to improve these estimates is therefore to investigate recycling practices at different plant in different countries.

Releases to water have not been estimated because of the lack of data, but are likely to be low, depending on the extent of use of wet scrubbers.

#### 3.3.2 Primary Lead / Zinc Production

SNAP 030304 (Primary Lead Production)

SNAP 030305 (Primary Zinc Production)

Limited information has been found on the extent of primary lead and primary zinc production in Europe. Based on assumptions in the UK study (AEA Technology Environment 1997), the PCDD/F releases to land and water from these processes in Europe are likely to be low.

In the UK only one primary lead/zinc smelter exists, producing lead bullion and metallic zinc from bulk lead/zinc concentrates using the Imperial Smelting Process. This process involves the smelting of a sinter, produced from zinc/lead materials with coke in a blast furnace. Most

solid wastes at the UK plant are recycled and wet scrubbing systems are used to treat liquid effluents. The Imperial Smelting Process and other types of primary lead and primary zinc smelters are likely to exist in different countries.

Although the PCDD/F releases at the UK plant are assumed to be low, there is not enough information available to enable reliable emission estimates to be made from this plant or any other European plant.

Activity data and information on the types of plant and waste disposal practices are needed so that the assumption that releases to land and water from these processes are low can be reviewed.

### 3.3.3 Primary Copper Production

SNAP 030306

#### Process Description

Primary copper production is carried out in smelters, which are likely to vary in detail between countries. The process generally has 3 stages :

- roasting
- smelting
- converting

#### Activity Data

Activity data for primary copper production have been taken from the World Mineral Statistics (British Geological Survey 1998).

Country	Primary copper production (Mt) - 1994
Austria	
Belgium	0.15
Denmark	
Finland	0.13
France	
Germany	0.29
Greece	
Ireland	
Italy	
Luxembourg	
Netherlands	
Norway	0.04
Portugal	
Spain	0.19
Sweden	0.10
Switzerland	

## SNAP 3 – Industrial Combustion

UK	
TOTAL	0.9

## **Solid and Liquid Waste Arisings, Treatment and Disposal**

Sludges and filter dusts are the most relevant wastes that arise from copper production with respect to potential PCDD/F releases. Information on plant in Sweden indicates that all filter dust, and the venturi sludge, is recycled, although the sludge from waste water treatment is disposed to land (de Wit 1998). However, recycling practices are likely to vary in different countries.

Waste waters from scrubbers are likely to be treated.

## **Emission Factors**

The emission factor data below, from Sweden (de Wit 1998), indicates that concentrations in the venturi sludge and filter dust are most significant :

- venturi sludge 1500 ng N-TEQ/kg
- filter dust 440 ng N-TEQ/kg
- sludge from waste water treatment 25 ng N-TEQ/kg

For our estimates it is assumed that Nordic TEQ is broadly equivalent to I-TEQ.

## **Emission Estimates**

The best estimates below represent <0.1% of total emissions. However, the only emissions data available are from Sweden (de Wit 1998) for sludge from effluent treatment. The emissions estimates below are based on emission factors derived from the Swedish data and the transfer of emission factors between processes generates uncertainty. If other processes do not recycle venturi sludge or filter dust, then the release is likely to be much higher.

The estimated emissions (best estimates) are based on a single data point, and the minimum and maximum range has been estimated assuming an uncertainty factor of 10.

Country	Release to land	Release to land	Release to land
	Best estimates	Min	Max
	g I-TEQ	g I-TEQ	g I-TEQ
Austria			
Belgium	0.5	0.05	5.0
Denmark			
Finland	0.4	0.04	4.4
France			
Germany	1.0	0.10	9.9
Greece			
Ireland			
Italy			
Luxembourg			
Netherlands			
Norway	0.1	0.01	1.4
Portugal			
Spain	0.6	0.06	6.4
Sweden	0.4	0.04	3.5
Switzerland			
UK			
TOTAL	3.1	0.31	31

### Future Changes in Release

Future changes in emissions will depend on market demand for non-ferrous metals and on technological advances in abatement.

### Conclusions / Recommendations

Although the estimated emissions are low, there is a high uncertainty in the estimated releases to land from disposal of sludges from waste water treatment. The estimates are based on data from Sweden, where dusts from flue gas cleaning are recycled into the process. If this recycling does not occur at plant in other countries then the releases of PCDD/Fs are likely to be much higher.

No data has been found on releases to water, although waste water treatment is likely to be comprehensive and the PCDD/Fs are likely to concentrate in the sludge.

### 3.3.4 Secondary Lead Production

SNAP 030307

#### Process Description

There is a substantial industry reprocessing many different types of lead scrap in most European countries. The thermal processes used to process lead and the introduction of carbonaceous compounds and contamination with scrap material provide the conditions for potential production of PCDD/Fs.

Lead acid battery reprocessing plant are also covered by this sector.

#### Activity Data

Activity data have been taken from the World Mineral Statistics (British Geological Survey 1998). However, it should be noted that there are uncertainties in the applicability of emission factors across different processes - there are several types of process which could be covered within secondary lead production.

Country	Secondary lead production (Mt) - 1994
Austria	0.017
Belgium	0.12
Denmark	
Finland	
France	0.26
Germany	0.33
Greece	
Ireland	0.01
Italy	0.22
Luxembourg	
Netherlands	0.03
Norway	
Portugal	0.013
Spain	0.07
Sweden	0.08
Switzerland	0.006
UK	0.35
TOTAL	1.52

#### Solid and Liquid Waste Arisings, Treatment and Disposal

The UK study (AEA Technology Environment 1997) found limited data on the types and amounts of solid and liquid wastes arising from secondary lead operations. The wastes have

the potential to be contaminated with PCDD/Fs, particularly the dusts from flue gas cleaning operations.

It is assumed that the dusts and flue gas cleaning residues are produced at the same rate (8% of production) as for secondary aluminium plant for which data on waste arisings are available.

It is assumed that all the dusts and flue gas cleaning residues are disposed in landfill, although this will not necessarily be the case in all countries.

No data are available on effluent discharges from secondary lead processes, although the widespread use of wet scrubbers is a potential source of release to water.

**Emission Factors**

PCDD/F contamination data from Bremmer et al. (1994) suggest that the dust collected from the fabric filters of a secondary lead plant with lime injection contains 7700-17,700 ng I-TEQ / kg. From LUA (1997) the concentration range in filter dust is 2,600 - 12,000 ng I-TEQ/kg. No other contamination data have been found.

**Emission Estimates**

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	3.5	24
Belgium	26	176
Denmark		
Finland		
France	54	370
Germany	69	470
Greece		
Ireland	2.1	14
Italy	46	316
Luxembourg		
Netherlands	5.2	35
Norway		
Portugal	2.7	18
Spain	15	99
Sweden	17	118
Switzerland	1.2	8.1
UK	73	500
TOTAL	315	2150

The estimated release from secondary lead plant (best estimate 1200 g I-TEQ) represent over 3% of the total estimated release to land.

No data are available on releases to water.

### **Future Changes in Release**

Future changes in release are likely to depend on the amount of recycling of dusts into the process. They will also depend on market demand for non-ferrous metals and on technological advances in abatement.

### **Conclusions / Recommendations**

Limited data are available on waste arisings and their disposal. The quantity of dusts and gas cleaning residues has been assumed to be a similar rate per unit production to other non-ferrous processes. This assumption, and the lack of information on the quantity of dust recycled, gives the main uncertainty in the estimated releases. The estimated releases are high and this sector is a high priority for inventory improvement.

No data are available on releases to water. Contamination in waste waters could be significant, but the PCDD/F are likely to concentrate in the sludges from waste water treatment.

### **3.3.5 Secondary Zinc Production**

SNAP 030308

#### **Process Description**

Zinc is often recovered from lead blast-furnace slag by rotary kiln or submerged combustion slag fuming (LUA 1997). Zinc oxide in the slag is reduced to metallic zinc (vapour) by carbon, oxidised in secondary air, and carried out in the furnace gases for the recovery of zinc oxide dust. Further details on the process are given in LUA (1997). The process is a potential source of PCDD/F releases to the environment.

#### **Activity Data**

Activity data have been taken from LUA (1997), based on data from national inventories and from statistics. In some cases the activity rates for zinc were related to different kinds of applications and an overall total was calculated by LUA for two countries (Germany and UK).

Country	Secondary zinc production (Mt) - 1994
Austria	0.002
Belgium	0.02
Denmark	
Finland	
France	0.02
Germany	0.27
Greece	
Ireland	0.0003
Italy	0.007
Luxembourg	
Netherlands	
Norway	0.016
Portugal	
Spain	0.015
Sweden	0.0005
Switzerland	
UK	0.047
TOTAL	0.40

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Abatement technologies to control atmospheric releases from secondary zinc plant usually consist of baghouses (LUA 1997). These are likely to result in the disposal to land of filter ash that is contaminated with PCDD/Fs. It is estimated that the dusts and flue gas cleaning residues are produced at the same rate (8% of production) as for secondary aluminium plant for which data on waste arisings have been found.

### **Emission Factors**

No data on emission factors in solid and liquid wastes from secondary zinc production have been found. The emission factor range of 480 - 17,700 ng I-TEQ/kg has been used for the emission estimates below. This has been taken from the data for secondary lead and secondary aluminium production.

### Emission Estimates

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.08	2.8
Belgium	0.8	28
Denmark		
Finland		
France	0.8	28
Germany	10	382
Greece		
Ireland	0.01	0.4
Italy	0.3	9.9
Luxembourg		
Netherlands		
Norway	0.6	23
Portugal		
Spain	0.6	21
Sweden	0.02	0.7
Switzerland		
UK	1.8	67
TOTAL	15	560

The best estimate for release of PCDD/F to land from secondary zinc production of 290 g I-TEQ represents about 0.8% of total emissions.

No data are available on emissions to water.

### Future Changes in Release

Future changes in emissions will depend on market demand for non-ferrous metals and on technological advances in abatement.

### Conclusions / Recommendations

Emission estimates are very uncertain as they are based on waste arisings and emission factor data from other secondary non-ferrous metal processes. As the estimated releases to land are relatively high, further work is a high priority to improve the inventory for this sector – information specific to waste arisings and contamination is required to improve the estimates.

### 3.3.6 Secondary Copper Production

SNAP 030309

#### Process Description

Copper is recovered from many secondary materials. There are a number of operations that are used to recover copper depending on the quality of the scrap.

The nature of the thermal processes in the secondary copper industry means that they have the potential to release PCDD/Fs to the environment.

Details of the processes in the European secondary copper sector are given in LUA (1997).

#### Activity Data

There are inconsistencies between different sources of activity data for secondary copper production. This could be because of uncertainties in the definitions of 'primary' and 'secondary' categories.

The activity data for this study have been taken from information in LUA (1997), based mainly on data from annual production statistics and on national inventories for Austria, Belgium and The Netherlands.

Country	Secondary copper production (Mt) - 1994
Austria	0.048
Belgium	0.1
Denmark	
Finland	0.025
France	0.13
Germany	0.62
Greece	0
Ireland	0
Italy	0.33
Luxembourg	
Netherlands	0.052
Norway	
Portugal	0
Spain	0.064
Sweden	0.021
Switzerland	
UK	0.12
TOTAL	1.51

**Solid and Liquid Waste Arisings, Treatment and Disposal**

Many of the solid wastes arising can be sold for recycling or reuse elsewhere. The solid wastes arising are principally slags and dusts. Slag is likely to be either sold or further refined. Dusts are sold if rich in metals or metal oxides or, if this is not the case, they are likely to be disposed to landfill. In some cases dusts are recycled into the process. Other solid wastes include dross, sludges from neutralisation of pickling effluents and sand from foundries.

From information from the UK Environment Agency (AEA Technology Environment 1997), it is estimated that 43 kg of potentially contaminated dusts and residues are disposed to land per tonne of secondary copper produced.

Liquid wastes from secondary copper operations arise from swarf contaminated with oils, coolant water and effluents from scrubbers. Spent pickling liquors, soluble oils, hydraulic and lubricating oils are usually tankered off-site for disposal or recovery in the UK and this is likely to be the case at other European plant.

The volume of liquid discharges is likely to vary significantly between plant and where large quantities of effluent are released there is a potential for a significant discharge of PCDD/Fs to water.

**Emission Factors**

The amount of data on PCDD/F concentrations in solid waste from secondary copper plant is limited. A single data point, from a single test (Strandell et al. 1994) gives a concentration of 12,000 ng Nordic TEQ/kg in smoke stack filter powder.

Data from Germany (Quaß 1999) give PCDD/F concentrations in fabric filter dust from a shaft furnace in the range 9000-20000 ng I-TEQ/kg (measured in 1990) and 140-390 ng I-TEQ/kg (measured in 1993 on a plant with some oxygen injection to improve waste gas burn-out), and concentrations of 48 ng I-TEQ/kg (1992) and 175 ng I-TEQ/kg (1995) in filter dust from a conversion furnace. There are no data on concentrations in slags.

For our estimates it is assumed that Nordic TEQ is broadly equivalent to I-TEQ and that uncertainties introduced through this assumption will be minor compared with the other uncertainties. The range in emission factors used to estimate the emissions in this report is 48-12000 ng I-TEQ/kg.

In Sweden the filter dust is recycled back into the process (de Wit 1999).

No data are available on concentrations of PCDD/Fs in liquid discharges from these plant.

### Emission Estimates

Country	Release to land	
	Min	Max
	g I-TEQ	g I-TEQ
Austria	0.1	25
Belgium	0.2	53
Denmark	0	0
Finland	0.1	13
France	0.3	67
Germany	1.3	321
Greece	0	0
Ireland	0	0
Italy	0.7	170
Luxembourg	0	0
Netherlands	0.1	27
Norway	0	0
Portugal	0	0
Spain	0.1	33
Sweden	0	0
Switzerland	0	0
UK	0.2	59
TOTAL	3.0	770

Assuming a best estimate of 390 g I-TEQ, this represents a significant release of about 1% of total estimated release to land in Europe.

No data are available on releases to water from secondary copper production processes.

### Future Changes in Release

Future changes in emissions will depend on market demand for non-ferrous metals and on technological advances in abatement.

### Conclusions / Recommendations

The emissions depend on several factors, for example whether the filter dusts are recycled back into the process, which is the case in Sweden (de Wit 1999). The priority for improving the estimated release from this source is to investigate the extent of dust recycling.

There are also uncertainties related to the solid dust/residue production rate, which is based on UK data. Further work to improve the inventory in this sector should be a medium/high priority.

### 3.3.7 Primary Magnesium Production

No information is available to enable estimates of PCDD/F releases to land and water from primary magnesium production to be made.

It is believed that the only significant primary magnesium plant in the countries covered by this report is the Porsgrunn Plant in Norway. Emission control technology at this plant is now more comprehensive and the emission to water had decreased to 2.8 g I-TEQ in 1994 (Breivik 1999).

### 3.3.8 Secondary Magnesium Production

#### Process Description

In the secondary magnesium industry, magnesium-based scraps, such as automotive components, die casting scrap, turnings etc., are remelted in pots or furnaces. Cover fluxes are usually used to avoid oxidation losses and prevent burning. These fluxes often include chlorides. In the past grain refining might have been carried out during the melting using hexachlorobenzene or hexachloroethane (AEA Technology Environment 1997).

The use of thermal processes coupled with the presence of chlorine-containing compounds provide the potential conditions for PCDD/F formation.

#### Activity Data

Limited activity data have been found for production of secondary magnesium.

#### Solid and Liquid Waste Arisings, Treatment and Disposal

Solid wastes produced are likely to include melting dross, sludge from wet scrubbers, etc. Residues from gas cleaning are likely to be the main potential source of PCDD/F contamination.

Releases to water might include wash water from magnesium plating, water used to remove slag from crucibles and scrubber effluent.

#### Emission Factors

No contamination data are available for PCDD/F concentrations in solid residues of effluent.

**Emission Estimates**

Using a range of emission factors similar to those for secondary aluminium it is estimated that the releases to land in the UK from secondary magnesium are 0.4-3.2 g I-TEQ.

Releases to land and water have not been estimated for other countries. Releases are likely to be significant for those countries producing significant amounts of magnesium. However, releases from several other sectors are likely to be much higher and therefore this sector is not a priority for further work. Activity data needs to be obtained to enable releases to be estimated.

**Future Changes in Release**

Future changes in emissions will depend on market demand for non-ferrous metals and on technological advances in abatement.

**Conclusions / Recommendations**

Although there are limited data available on potential releases from secondary magnesium plant, the estimates for the UK show that the releases are likely to be low relative to other sources.

**3.3.9 Secondary Aluminium Production**

SNAP 030310

**Process Description**

Aluminium is recovered and recycled from scrap using many different types of furnace. The type of melting furnace used depends on the type of scrap to be melted, the method of fluxing, the tonnage of aluminium to be recycled and the type of fuel to be used.

Frequently the charge to the furnace is contaminated with lubricating or cutting oils and/or grease and other non-metallic materials such as paints, plastics and varnishes which can give rise to PCDD/F emissions during the operation of the furnace.

For some secondary aluminium plant chlorinated or fluorinated compounds are introduced deliberately as part of the process requirements. For example, reduction in the magnesium content of the metal to improve its ductility is carried out using fluxing agents such as aluminium fluoride, hexachloroethane (HCE), chlorine or a mixture of chlorine and an inert gas. The use of HCE is likely to release the necessary precursors to cause emissions of PCDD/Fs. However, the use of HCE is likely to have decreased significantly at secondary aluminium plant – an EC Directive limits its use to smaller plant.

More details of the secondary aluminium production processes are given in LUA (1997).

### Activity Data

The activity data in this report have been taken from LUA (1997), based on data from annual production statistics and for five countries on activity in their national inventories or other publications (Austria, Belgium Germany, Luxembourg and The Netherlands).

There are uncertainties in secondary aluminium production statistics because there are several stages to production process (e.g. remelting, casting, alloying) and there is the potential for double counting of production for this sector and others such as casting operations (SNAP 040309).

Country	Secondary aluminium production (Mt) - 1994
Austria	0.044
Belgium	0.003
Denmark	0.015
Finland	0.028
France	0.23
Germany	0.54
Greece	0.009
Ireland	0
Italy	0.35
Luxembourg	0
Netherlands	0.15
Norway	0.0008
Portugal	0.002
Spain	0.097
Sweden	0.022
Switzerland	0.011
UK	0.25
TOTAL	1.75

### Solid and Liquid Waste Arisings, Treatment and Disposal

Solid wastes arising from all aluminium operations are likely to include :

- dross from furnaces
- slag from furnaces (approximate arisings of slag ~25% of metal produced (UK Environment Agency 1993)
- dusts from cyclones and bag filters (approx. arisings of dust ~8% of metal produced (UK Environment Agency 1993)
- waste sand from casting operations
- sludge from neutralisation of pickling effluent

(AEA Technology Environment 1997).

The dusts from cyclones / bag filters and possibly the slags are likely to be the only solid waste which could be significantly contaminated with PCDD/Fs.

Releases to water from secondary aluminium operations are likely to include :

- effluents from pickling operations
- effluents from wet scrubbers
- surface water run-off

No data are available on the quantity of effluent released from secondary aluminium production processes.

### **Emission Factors**

The PCDD/F concentration range for dusts from cyclones / bag filters is taken as 480-4000 ng I-TEQ/kg (Lexen et al 1993, de Wit 1998, Bremmer et al. 1994, Laue et al 1994).

Only one data point has been found for PCDD/F contamination in slags from secondary aluminium production which is a concentration of 11 ng Nordic TEQ/kg (de Wit 1996).

For the estimates in this report it is assumed that Nordic TEQ is broadly equivalent to I-TEQ and that uncertainties introduced through this assumption will be minor compared with other uncertainties.

It is assumed that all dusts and slags are landfilled, although it is likely that this is not the case in all countries.

No data are available on the concentration of PCDD/Fs in effluent released, although the contamination in waste water could be significant and the releases depend on the extent of waste water treatment.

### Emission Estimates

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	1.7	14
Belgium	0.1	1.0
Denmark	0.6	4.8
Finland	1.1	8.8
France	8.8	74
Germany	21	170
Greece	0.3	2.9
Ireland	0	0
Italy	14	110
Luxembourg	0	0
Netherlands	5.8	48
Norway	0.03	0.3
Portugal	0.1	0.6
Spain	3.7	31
Sweden	0.8	7.0
Switzerland	0.4	3.5
UK	9.4	78
TOTAL	67	560

A best estimate of 310 g I-TEQ represents a contribution to total emissions to land of about 0.8%.

Releases of PCDD/Fs to water from secondary aluminium processes could be significant but there are currently no data available from which reliable emission estimates can be made.

### Future Changes in Release

Future changes in emissions will depend on market demand for non-ferrous metals and on technological advances in abatement. The EC legislation restricting the use of HCE to smaller plant is likely to have resulted in a decrease in emissions of PCDD/F.

### Conclusions / Recommendations

Although more data are available on waste arisings and PCDD/F concentrations for secondary aluminium processes than for most other non-ferrous metal processes, the estimated releases to land are still fairly uncertain. Improvement to the inventory for this sector should be a medium priority.

### **SNAP 3 – Industrial Combustion**

Contamination in waste waters has the potential to be significant. No data are available on releases to water, but these will depend on the extent of waste water treatment.

More specific information on processes and control technologies in different countries is required to improve the estimated releases from secondary aluminium production.

## 3.4 SNAP GROUP 4 - INDUSTRIAL PROCESSES

### 3.4.1 Petroleum Processes

Catalytic reforming of refinery products is a process used to improve the performance of gasoline fuels. PCDD/Fs could be formed during the regeneration of catalysts used in the process.

No data are available on quantities of solid or liquid waste arising from catalytic reforming or other petroleum processes. Waste waters are likely to be treated prior to discharge, creating a potential discharge to land in the sludge from treatment.

From Canadian data (Manff and Lewis (1988), quoted in US EPA (1994)), it is assumed that releases of PCDD/Fs to land and water are likely to be small.

### 3.4.2 Electric Furnace Steel Plant

SNAP 40207

#### Process Description

The draft European BAT (BREF) report of the European IPPC Bureau contains a significant amount of detail on the electric arc steel-making process (European IPPC Bureau 1998a).

The close control of the reaction that can be achieved in electric arc furnaces means that low grade scrap can be refined to meet the close specifications of the various steel alloys. The major feed stock for the electric arc furnace is ferrous scrap (e.g. automobile scrap). Other material is added depending on the required composition of steel. Current is applied through electrodes and the charge is melted.

#### Activity Data

Activity data has been taken from LUA (1997), based on statistical information on steel production.

Country	Steel production in electric arc furnaces (Mt) 1994
Austria	0.43
Belgium	1.67
Denmark	0.62
Finland	0.7
France	6.15
Germany	8.89
Greece	0.89
Ireland	0.27
Italy	26.1
Luxembourg	0.45
Netherlands	6.17
Norway	0.46
Portugal	0.72
Spain	13.7
Sweden	1.79
Switzerland	0.8
UK	4.3
TOTAL	74.1

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

The most important source of solid waste with respect to PCDD/F releases from electric arc furnaces is the treatment of effluent gases, which produces significant quantities of dusts. The amount of this dust that is recycled varies between 0 and 85 % and the quantities disposed to land in the table below have been taken from European IPPC Bureau (1998a). In total in the EU, about 64 % of dust is recycled.

Country	Estimated amount of dust landfilled (t)
Austria	1780
Belgium	3510
Denmark	5820
Finland	3980
France	60300
Germany	45000
Greece	7970
Ireland	2420
Italy	100800
Luxembourg	950
Netherlands	13000
Norway	2740
Portugal	4810
Spain	91190
Sweden	19690
Switzerland	3320
UK	66500
TOTAL	433800

In addition, during the steel-making process, a slag is formed from the use of lime to collect undesirable components in the steel. It is estimated that 77-150 kg of slag per tonne of steel are produced (based on data from de Wit (1998) and European IPPC Bureau (1998a)), except for Sweden where the waste factor is taken from the Swedish study as 77-99 kg/t (de Wit 1998). It is assumed that between 34 % (European IPPC Bureau 1998a) and 100 % is landfilled.

Other solid wastes include refractory bricks, which are likely to be disposed to landfill.

Waste water arisings include effluent from gas scrubbing operations, cooling water from continuous casting, and drainage water from scrap yards. No information is available on the quantities of waste water arising or on the extent of effluent treatment.

### Emission Factors

Concentrations of PCDD/Fs in dust from gas-cleaning operations have been taken as 74-1,470 ng I-TEQ/kg, based on German data (LUA 1997), Swedish data (de Wit 1998) and UK data (AEA Technology Environment 1997).

The concentrations in slag from electric arc steel-making of 0.4-3.4 ng I-TEQ/kg have been taken from Swedish data (de Wit 1998).

### Emission Estimates

Country	Release to land		Release to land		Total	
	Release via dusts		Release via slags			
	Min.	Max.	Min.	Max.	Min.	Max.
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0.1	2.6	0.004	0.2	0.1	2.8
Belgium	0.3	5.2	0.02	0.9	0.3	6.1
Denmark	0.4	8.5	0.006	0.3	0.4	8.8
Finland	0.3	5.9	0.007	0.4	0.3	6.3
France	4.5	89	0.06	3.1	4.6	92
Germany	3.3	66	0.09	4.5	3.4	70
Greece	0.6	12	0.009	0.5	0.6	12
Ireland	0.2	3.6	0.003	0.1	0.2	3.7
Italy	7.5	150	0.3	13	7.5	163
Luxembourg	0.07	1.4	0.005	0.2	0.07	1.6
Netherlands	1.0	19	0.06	3.1	1.1	22
Norway	0.2	4.0	0.005	0.2	0.2	4.2
Portugal	0.4	7.1	0.01	0.4	0.4	7.5
Spain	6.7	130	0.1	7.0	6.8	137
Sweden	1.5	29	0.02	0.6	1.5	30
Switzerland	0.2	4.9	0.01	0.4	0.2	5.3
UK	4.9	98	0.04	2.2	4.9	100
TOTAL	32	640	0.8	37	33	680

From country-specific data provided by Denmark, the emission of PCDD/F via dust was measured in 1995 and found to emit about 7.5 g I-TEQ/y, which lies within the ranges estimated in this report (Vikelsøe, 1999).

A best estimate of 350 g I-TEQ released to land represents a significant contribution of 0.9% to total estimated releases in Europe.

No information is available to enable reliable estimates of releases to water from electric arc furnaces to be made.

### Future Changes in Release

Future changes in emissions will depend on market demand for steel and on technological advances in abatement.

## Conclusions / Recommendations

There is a relatively large amount of information on electric arc furnaces from the BREF note (European IPPC Bureau 1998a). Releases to land from this source are likely to be relatively high.

The amount of filter dust recycled in different plant varies significantly. This is one of the most significant factors influencing the emissions.

Contamination in waste water from wet scrubbers has the potential to be high if this technology is used, but waste water treatment is likely to result in these PCDD/Fs concentrating in the sludge. No information is available to enable releases to water to be estimated and this is the priority area for improvement of the inventory for this sector.

### 3.4.3 Aluminium Production (electrolysis)

SNAP 040301

#### Process Description

There are two main types of process for the production of primary aluminium : the pre-baked anode process and the Soderberg process (Horizontal Stud Soderberg (HSS) or Vertical Stud Soderberg (VSS)).

The main difference between the pre-baked and Soderberg processes is the method of preparation of the anode, which is made up of pitch and petroleum coke. In the Soderberg process the electrode paste is added periodically to a steel shell, which is immersed in the electrolyte bath and baked by the heat of the reduction cell. The heat drives off the lower boiling point organic compounds and the new anode material is baked to the old anode. In this way the anode is continually replenished.

For the pre-baked process the anode is manufactured prior to placing it in the reduction cell.

Primary aluminium production is unlikely to be a significant source of PCDD/F releases although contamination is possible through the graphite-based electrodes. It is unlikely that the different processes (Soderberg and pre-baked) release significantly different emissions per tonne of aluminium produced.

#### Activity Data

Activity data have been taken from the World Mineral Statistics (British Geological Survey 1998).

Country	Primary aluminium production (Mt) - 1994
Austria	
Belgium	
Denmark	
Finland	
France	0.39
Germany	0.51
Greece	0.14
Ireland	
Italy	0.18
Luxembourg	
Netherlands	0.22
Norway	0.86
Portugal	
Spain	0.34
Sweden	0.11
Switzerland	0.02
UK	0.23
TOTAL	3.0

### Solid and Liquid Waste Arisings, Treatment and Disposal

The extent of control at European primary aluminium production plant is likely to vary considerably. Many plant which use pre-baked electrodes are likely to remove fumes from the electrolysis process and pass them through a dry scrubbing system with alumina feedstock. The main aim of this scrubber is to remove gaseous fluorides, and the alumina entrained by the cleaned gas is then removed, for example by fabric filter.

Typical production of spent sludge is about 44 kg/tonne of aluminium (de Wit 1996). This waste factor is assumed to be an average for all plant across Europe.

It is assumed that all the spent sludge is landfilled, although this will not necessarily be the case in all countries.

### Emission Factors

The only PCDD/F contamination data identified is from Sweden and suggests that the spent sludge from cells may contain 7.8 ng Nordic TEQ / kg (de Wit 1996).

For the estimates in this report it is assumed that Nordic TEQ is broadly equivalent to I-TEQ and that uncertainties introduced through this assumption will be minor compared with other uncertainties.

### Emission Estimates

The estimated emissions (best estimates) are based on a single data point, and the minimum and maximum range has been estimated assuming an uncertainty factor of 10.

Country	Release to land	Release to land	Release to land
	Min	Best estimates	Max
	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0	0	0
Belgium	0	0	0
Denmark	0	0	0
Finland	0	0	0
France	0.01	0.1	1.3
Germany	0.02	0.2	1.7
Greece	0.005	0.05	0.5
Ireland	0	0	0
Italy	0.01	0.06	0.6
Luxembourg	0	0	0
Netherlands	0.01	0.08	0.8
Norway	0.03	0.3	2.9
Portugal	0	0	0
Spain	0.01	0.1	1.2
Sweden	0.004	0.04	0.4
Switzerland	0.001	0.01	0.08
UK	0.01	0.08	0.8
TOTAL	0.1	1.0	10

The best estimate total release of 1 g I-TEQ from aluminium production is <0.1% of total releases to land.

No information is available on releases to water.

### Future Changes in Release

The likely improvements to waste water treatment at aluminium plant will be decreasing releases to water, but might be resulting in an increase in release to land via sludge. However, other technological advances in environmental control are likely to mean an overall decrease in release of PCDD/Fs.

## Conclusions / Recommendations

The estimated releases to land are based on single data points. The data quality of these estimates is poor. However, these initial estimates suggest that this source is unlikely to release significant quantities of PCDD/Fs.

### 3.4.4 Installations for Smelting and Casting of Non-Ferrous Metals

SNAP 40309

Installations for smelting and casting non-ferrous metals mainly use the following types of furnace :

- rotary kiln
- crucible furnace
- reverberatory furnace
- multichamber furnace
- cupola furnace

Some of these furnaces are described in more detail in the LUA (1997) report.

The thermal nature of these operations could give rise to PCDD/F emissions, especially where chloride-based fluxes are added to the melt to protect the molten metal surface and to remove impurities.

Activity data are available in LUA (1997), covering mould / die castings of aluminium, lead, copper and zinc.

No estimates of PCDD/F releases have been made because of the lack of data on solid and liquid wastes and on PCDD/F contamination.

The releases from casting are likely to be less significant than from the processes to produce secondary metals, which have high potential for scrap containing chlorinated precursors.

### 3.4.5 Chemical Production - PVC

SNAP :

40504 Vinylchloride (except 040505)

40405 1,2 Dichloroethane + Vinylchloride (balanced process)

40508 Polyvinylchloride

#### Process Description

The processes involved in the manufacture of polyvinyl chloride (PVC) have been identified as a possible source of PCDD/Fs (Evers et al. 1989). In Germany, prior to the implementation of abatement measures, river sediments in the vicinity of production sites at Marl, Rheinberg and Wilhelmshafen were found to be contaminated with PCDD/Fs (LUA 1999).

The manufacture of PVC involves a number of inter linked processes. PVC is manufactured by the polymerisation of vinyl chloride monomer (VCM) in the ‘balanced process’. This involves the production of ethylene dichloride (EDC) by direct chlorination of ethylene and oxychlorination of ethylene with hydrogen chloride (HCl). The oxychlorination stages of the production of EDC have the potential to produce PCDD/Fs particularly from the quenching process. The EDC is purified prior to the next stage of the process and the bulk of the PCDD/F contamination is likely to end up in the heavy ends from the purification. The release of PCDD/Fs from the manufacture of PVC will mainly depend on the treatment and/or disposal of the heavy ends. The heavy ends can be used to produce by-products such as chlorinated solvents.

The EDC is thermally cracked to produce VCM. This part of the process also has the potential to produce PCDD/Fs.

VCM is polymerised at low temperatures, under conditions that do not favour the formation of PCDD/Fs.

### **Activity Data**

Limited activity data has been found on the quantities of EDC, VCM and PVC produced in Europe. In Germany, about 10,800 kt/y of EDC and 6,000 kt/y of Vinyl Chloride are produced annually (LUA 1999). UK capacity for EDC production is about 965 kt/year and for VCM about 360 kt/year.

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

The main releases to land will be from the disposal of the waste heavy ends from the purification of EDC, where these are not used in by-products.

Spent catalyst from the oxychlorination process, lime from the final polishing of vinyl chloride product and residues from plants for treatment of quenching and other effluents are also sources of contaminated solid wastes.

Liquid wastes also arise from the production process. Some of these are likely to be incinerated, and some pass to waste water treatment plant, from which an effluent is discharged and a sludge arises.

### **Emission Factors**

According to EVCM (European Association of Vinyl Chloride Manufacturers) the emission factor for input of PCDD/F into the (river) water is about 1 ng I-TEQ/kg of product (Dichloroethane) (LUA 1999).

### **Emission Estimates**

Estimated releases to land in Germany are 6.2-618 g I-TEQ (LUA 1997) and 25-80 g I-TEQ in the UK (AEA Technology Environment 1997).

Releases to water are estimated as 0.15-51 g I-TEQ (Germany (LUA 1997)) and 0.07-0.4 g I-TEQ (UK (AEA Technology Environment 1997)).

Initial estimates of releases for other countries could be made if production data for EDC and VCM were obtained. The estimated releases to land in Germany and the UK suggest that the total releases to land in Europe could represent >1% of total releases of PCDD/F to land, and that this source could therefore be significant.

### **Future Changes in Release**

Regulatory controls on the chemical industry and pressure from the public / environmental groups are likely to result in a continued decrease in releases of PCDD/F from these plant.

### **Conclusions / Recommendations**

Some data are available, particularly from Germany, on wastes arising and emission factors. However, activity data are difficult to obtain, mainly for commercial reasons, and estimates for other countries cannot be made at this stage. This source is likely to release significant quantities of PCDD/Fs so further inventory work is a high priority.

## **3.4.6 Chemical Production - PCE / TCE**

### **Process Description**

Perchloroethylene (PCE) and trichloroethylene (TCE) can be produced by an oxychlorination process. The process is linked to the production of ethylene dichloride (EDC), described above as some of the by-products of EDC production can be fed into the PCE/TCE production process.

### **Activity Data**

No activity data has been found on the quantities of PCE / TCE produced in Europe.

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Residues from PCE / TCE production arise from sources such as the purification of the product streams, as well as spent catalyst. The wastes have significant potential to be contaminated with PCDD/Fs.

### **Emission Factors**

Emission factors could be estimated from AEA Technology Environment (1997).

### **Emission Estimates**

No emission estimates have been made at this stage.

### **Future Changes in Release**

The reduced acceptability of chlorinated chemicals across the EU is likely to cause a continued decrease in emissions from this sector.

### **Conclusions / Recommendations**

Activity data on production is required to enable preliminary estimates of PCDD/F release to be made. However, production statistics are difficult to obtain from chemical industries for commercial reasons.

There is a potential for significant releases of PCDD/F from this process.

## **3.4.7 Pesticide Production**

SNAP 040425

### **Process Description**

The production of some pesticides, and of some of the active ingredients used in them, has significant potential for releasing PCDD/Fs to the environment (because of the presence of chlorine, aromatic structures, etc).

The production of pesticides usually involves a number of organic chemical syntheses which are carried out in batch reactors. Formulation then takes place to provide the pesticide products, which are then packed for sale.

### **Activity Data**

Europe has a successful pesticide production industry. As well as the straight import and export of pesticides, reformulation of imported products occurs in Europe. There are many different pesticide formulations produced, and these have varied uses. Reliable activity data on production of pesticides is therefore difficult to obtain.

The production of a number of pesticides that involve chlorination or have chlorinated phenols in their synthesis have been identified as likely to lead to the formation of PCDD/Fs. Most attention has been focused on the production of phenoxy herbicides and pentachlorophenol. The US EPA has identified a list of pesticides which could be contaminated with PCDD/Fs if synthesised under conditions which favour PCDD/F formation (Appendix 2).

Although there are limited activity data available, figures on sales of active ingredients are given in the Eurostat Yearbook (1996). For the table below, if no data for the year 1994 were available in the Eurostat Yearbook, then the most recent available data were used. The figure for 1994 sales in Norway is from Breivik (1999).

The quantity of potentially contaminated active ingredients used in pesticides in different countries has been estimated to be in the same proportion of total sales as in the UK (AEA Technology Environment 1997).

Country	Total sales of pesticides (tonnes) 1994	Estimated quantities of potentially contaminated active ingredients used in pesticides (tonnes) 1994
Austria	3620	170
Belgium	10630	500
Denmark	4100	195
Finland	1320	62
France	91950	4350
Germany	29770	1400
Greece	8590	0
Ireland	1940	92
Italy	91680	4330
Luxembourg	250	12
Netherlands	11760	560
Norway	870	41
Portugal	6120	290
Spain	84340	4000
Sweden	1960	93
Switzerland	no data	no data
UK	28750	1360
TOTAL	377700	17900

There is clearly significant uncertainty in these activity data. For comparison with other data sources, the 1998 UK sales of Active Ingredients by British Agrochemical Association members were 24,400 tonnes (European Crop Protection Association (1999)).

No pesticide manufacture takes place in Greece (Kyrtopoulos (1999)).

### Solid and Liquid Waste Arisings, Treatment and Disposal

A wide variety of solid and liquid wastes are likely to arise from active ingredient and pesticide manufacture. Solid wastes include organic and inorganic residues, solvents and a range of materials such as dusts from gas purification, sludges from water treatment and residues from cleaning operations. Liquid wastes arise from cleaning process vessels, from aqueous phase reactions and from purification operations.

The treatment and disposal of solid and liquid wastes produced from pesticide production is tightly controlled, and therefore any emissions are likely to fall within agreed licence conditions. It is assumed that a high proportion of solid wastes are incinerated.

For the UK study (AEA Technology Environment 1997), it was estimated that 12,000 tonnes per year of solid waste arises from pesticide production processes. For this study, the solid wastes arising from other countries has been estimated on a pro rata basis relative to the quantity of active ingredient produced.

For the UK study (AEA Technology Environment 1997) it was assumed that 1% of solid wastes from pesticide production was contaminated at concentrations estimated below. Also, it was assumed that 75% of these wastes were incinerated and the remainder disposed to landfill. These assumptions have been applied to other European countries for this study.

### **Emission Factors**

There are limited data on the concentration of PCDD/Fs in wastes from pesticide production operations. The process conditions and active ingredients vary greatly from one process to another and for this reason the concentration of PCDD/Fs in wastes are expected to vary from zero to quite high levels.

The concentration data used to estimate PCDD/F releases in solid wastes for this study has been taken as the range 296,000 - 67,400,000 ng I-TEQ/kg (NATO 1988, Kaune 1991). This is likely to be representative of the most contaminated wastes.

No reliable concentration data are available on releases to water.

### **Emission Estimates**

The estimates for releases to land are based on a number of assumptions described above, and the uncertainty in the estimates is high.

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	1.1	260
Belgium	3.3	750
Denmark	1.3	290
Finland	0.4	90
France	28	6470
Germany	9.2	2090
Greece	0	0
Ireland	0.6	140
Italy	28	6450
Luxembourg	0.1	18
Netherlands	3.6	830
Norway	0.3	61
Portugal	1.9	430
Spain	26	5930
Sweden	0.6	140
Switzerland	no data	no data
UK	8.9	2020
TOTAL	116	26500

A best estimate of 13,000 g I-TEQ released to land represents 34 % of total estimated releases. Feedback from international experts indicates that this might be an overestimate but further data are required to confirm this.

The estimated releases to water have not been quantified, but could be high.

### Future Changes in Release

According to the European Crop Protection Association (1999) the pesticide industry is generally moving away from highly chlorinated pesticides, and under IPC and similar legislation, it is developing processes which mitigate against PCDD/F formation. Under IPPC in Europe further reductions in releases would be expected. In addition, total tonnages of pesticides used will decrease, for a number of reasons :

- industry support for environmentally-friendly farming;
- pesticide use minimisation strategies encouraged by Governments;
- biotechnology;
- phasing out of older active ingredients;
- tighter laws on emissions.

## Conclusions / Recommendations

The estimated releases to land indicate that pesticide production is likely to represent a high contribution to total PCDD/F release. There is a very high uncertainty associated with the estimated releases from pesticide production. This sector should be the highest priority for further work to improve the whole inventory. There are major uncertainties with both the quantity of potentially contaminated pesticides produced and with the concentrations.

The concentration data used are likely to represent the most contaminated wastes and the actual emissions are more likely to be towards the lower half of the estimated range.

Although the above method to estimate the emissions is very uncertain, it does provide a starting point for the inventory, which urgently needs improving.

Emissions are likely to continue to decrease with time.

### 3.4.8 Chemical Production - Chlorophenols

SNAP 040526 Production of POPs

#### Process Description

Chlorophenols have a variety of uses in the chemical industry as intermediates for the synthesis of compounds such as dyes or pesticides, or direct use as biocides.

The production of chlorophenols is usually carried out by direct chlorination (by chlorine gas and aluminium chloride catalyst) or basic hydrolysis of chlorobenzenes. There is a high potential for PCDD/F formation during the production process.

#### Activity Data

No activity data are available on the production of chlorophenols, although in most countries production is likely to have been banned or be decreasing because of environmental concerns.

#### Solid and Liquid Waste Arisings, Treatment and Disposal

Solid residues and effluents arising from chlorophenol production processes have a high potential to be contaminated with PCDD/Fs.

#### Emission Factors

No emission factor data are available.

#### Emission Estimates

No estimates of emissions can be made with confidence because of the lack of data.

### **Future Changes in Release**

Releases are likely to have decreased significantly as production decreased and environmental control has tightened. This trend is likely to continue.

### **Conclusions / Recommendations**

Further work should first check whether production is still occurring in significant enough quantities for PCDD/F emissions to be high.

### **3.4.9 Other Chemical Production / Processes**

Other chemical production processes, such as the production of chlorobenzenes, metal chlorides etc., and production processes using chlorinated compounds as intermediates, have the potential to release PCDD/Fs.

However, limited activity data are available for the relevant chemical production processes and limited data are also available on solid and liquid waste quantities and on PCDD/F contamination. Therefore no estimates of releases to land and water can be made.

Some data are available on PCDD/F releases from the chloralkali process which produces chlorine. Most solid wastes from the process are recycled, although some sludge could be disposed to land. Liquid effluent arisings depend on the process details and the extent of recycling. The estimated release to land for the UK is 6 g I-TEQ. This sector is unlikely to be a major contributor to total releases of PCDD/Fs, although activity data on chlorine production is required so that preliminary estimates can be made to verify this.

Under certain conditions, PCDD/Fs may be generated in the course of oxidative waste water treatment (high pressure or low pressure wet oxidation) (LUA 1999). However, the potentially low number of sites with this process means the emissions are unlikely to be significant.

### **3.4.10 Paper and Pulp Production**

SNAP :

- 40601 Chipboard
- 40602 Paper Pulp (kraft process)
- 40603 Paper Pulp (acid sulphite process)
- 40604 Paper Pulp (neutral sulphite semi-chemi)
- 30321 Paper Mill Industry (Drying Processes)

### **Process Description**

PCDD/Fs have been detected in waste water and sludges from paper and pulp mills, and in the final pulp and paper products. The release of PCDD/Fs greatly depends on the type of manufacturing process and the degree of treatment applied to the discharges.

The draft European BAT (BREF) report of the European IPPC Bureau contains a significant amount of detail on paper and pulp production (European IPPC Bureau 1998b).

A paper mill might reconstitute pulp made elsewhere or might be integrated with the pulping operations on the same site.

The main operations within the paper and pulp sector are :

- pulping;
- recycled paper processing;
- paper-making and related processes.

The pulping process involves the break down of raw cellulose-bearing material into different fibres, and can be carried out chemically or mechanically. Different pulping processes are used :

- Kraft (sulphate) chemical pulping;
- sulphite chemical pulping;
- mechanical and chemi-mechanical pulping.

There is often a need to bleach pulp. The use of pulp that has been bleached with elemental chlorine is likely to be the major cause of PCDD/F release from the pulp and paper industry. However, the use of chlorine for bleaching has been phased out in recent years and chlorine dioxide, or non-chlorinated bleaches, are used as alternatives (Sandell 1999).

Paper is made from the pulp of cellulose fibres. The paper making process uses chemicals such as biocides, de-foamers, drainage and retention aids, and product chemicals to control the performance of the final product.

A large proportion of paper production is from recycled paper. For some of the recycled paper, chemicals are used for de-inking and cleaning. Although these chemicals are unlikely to be precursors to PCDD/F formation, the de-inking process could be a source of PCDD/F releases because of PCDD/Fs that are already present in the inks that are removed from the recycled paper.

### Activity Data

A significant amount of the paper and pulp production in Europe occurs in Sweden and Finland. Activity data have been estimated from the BREF report (European IPPC Bureau 1998b). The data in the BREF report is for 1996, but it is assumed that the uncertainties this causes in the estimates of PCDD/F releases in 1994, are minor compared to other uncertainties (eg concentration data).

Country	Pulp production (Mt) 1994	Paper production (Mt) 1994
Austria	1.3	3.5
Belgium	0	1.2
Denmark	0.1	0.3
Finland	10	10.6
France	2.5	8.8
Germany	1.9	15
Greece	0.05	0.4
Ireland	0	0
Italy	0.3	7.2
Luxembourg	0	0
Netherlands	0.2	3
Norway	2.3	2.1
Portugal	1.6	1.1
Spain	1.5	3.5
Sweden	10	9.3
Switzerland	no data	no data
UK	0.6	6.4
TOTAL	32.4	72.4

### Solid and Liquid Waste Arisings, Treatment and Disposal

The main solid wastes arising are sludges from :

- the de-inking process;
- the pulping process;
- the paper-making process;
- the effluent treatment plant.

In the paper-making process water is used as a transportation medium and a solvent for raw materials, for sealing and other duties as well as for washing and cleansing. Some water is recycled to different stages in the process.

AEA Technology Environment (1997) estimated that 50 kg sludge is generated per tonne of paper produced. The BREF report (European IPPC Bureau 1998b) gives information on different rates of sludge production for different parts of the processes. Based on this information the waste factor range used for this study has been taken as 25-75 kg sludge per tonne of paper or pulp produced. It is assumed that these sludges are disposed to landfill.

Detailed estimates of sludge quantities arising from different parts of the processes in different countries could be made using the information in the BREF report. However, detailed concentration data are not available to go with the waste data so it is only worthwhile for this study to estimate a total quantity of sludge arising.

The BREF note (European IPPC Bureau 1998b) gives some information on typical quantities of water used in different parts of the paper and pulp process, and on quantities discharged. It is likely that most sites will have effluent treatment, following which large volumes of water would be discharged. The PCDD/Fs in the waste water are, therefore, likely to concentrate in the sludge from the effluent treatment plant.

### Emission Factors

Limited data are available on PCDD/F concentrations. It is estimated that the concentration of PCDD/Fs in sludge from paper and pulp production processes to be 11-44.4 ng I-TEQ/kg. This range is based on one study from Germany (Santl et al. 1994).

Data in the Swedish PCDD/F survey (de Wit 1998) suggest a similar range of 2.4-54 ng Nordic TEQ/kg.

Limited information is available on concentrations of PCDD/Fs in effluent discharges. Some data is available from de Wit (1998), where it is estimated that releases to water are in the range 1.5-5 g Nordic TEQ. From this information, approximate emission factors per tonne of paper and pulp produced have been estimated and applied to other countries.

### Emission Estimates

The estimates for the total release to land via the sludge from all paper and pulp production processes are given below.

Country	Release to land		Release to water	
	Min.	Max.	Min.	Max.
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0.3	19	0.4	1.2
Belgium	0.1	4.9	0.09	0.3
Denmark	0.02	1.6	0.03	0.1
Finland	1.2	83	1.6	5.3
France	0.7	46	0.9	2.9
Germany	1.0	68	1.3	4.4
Greece	0.03	1.8	0.03	0.1
Ireland	0	0	0	0
Italy	0.5	30	0.6	1.9
Luxembourg	0	0	0	0
Netherlands	0.2	13	0.3	0.8
Norway	0.3	18	0.3	1.1
Portugal	0.2	11	0.2	0.7
Spain	0.3	20	0.4	1.3
Sweden	1.2	78	1.5	5.0

Switzerland	no data	no data	no data	no data
UK	0.4	28	0.5	1.8
TOTAL	6.3	420	8.1	27

A best estimate release to land of 210 g I-TEQ represents about 0.6 % contribution to total estimated releases in Europe.

Although the majority of any PCDD/Fs in waste water are likely to concentrate in the sludge from effluent treatment, the large volumes of water discharged present a potentially significant release of PCDD/Fs. The estimates for releases to water, based on data from Sweden, are very uncertain but give an indication of the potential scale of releases.

### Future Changes in Release

Emissions of PCDD/F from pulp and paper production have been decreasing since the early 1990s because of changes such as the phase-out of chlorine bleaching. The rate of decrease in emissions is likely to have slowed in more recent years.

### Conclusions / Recommendations

Detailed estimates of sludge quantities arising from different parts of the processes in different countries could be made using the information in the BREF report. However, detailed concentration data are not available to go with the waste data so it is only worthwhile for this study to estimate a total quantity of sludge arising.

Measurements of releases to water are needed so that the significance of releases of PCDD/Fs to water from paper and pulp processes can be identified.

Use of chlorine bleaching has decreased or stopped in recent years and releases of PCDD/Fs have greatly reduced as a result.

### 3.4.11 Cement and Lime Production

SNAP

040612 (Cement)

040613 (Lime)

#### Process Description

The draft European BAT (BREF) report of the European IPPC Bureau contains a significant amount of detail on cement and lime production (European IPPC Bureau 1998c).

The cement-making process is based on high temperature calcination in a kiln to produce clinker. The main raw materials are limestone and clay. There are four main processes for the manufacture of cement : the dry, semi-dry, semi-wet and wet processes. Lime is manufactured

by the high temperature calcination of limestone. The production processes are described in detail in the BREF report (European IPPC Bureau 1998c).

The long residence times in cement and lime kilns and the high temperatures (up to 1500°C) mean that PCDD/F formation is generally low during steady kiln conditions.

There has been much attention on the potential environmental effects of the use of waste fuels in cement and lime kilns.

### Activity Data

Activity data for cement production has been taken from LUA (1997) and for lime production from LUA (1997) and European IPPC Bureau (1998c). In the case of cement production, the LUA (1997) report took the data from annual production statistics. For lime production, the LUA (1997) report gave activity data from national inventories and production statistics.

Country	Cement production (kt) 1994	Lime production (kt) 1994
Austria	4940	730 <sup>1</sup>
Belgium	7500	1850 <sup>1</sup>
Denmark	1700	100 <sup>2</sup>
Finland	1100	250 <sup>2</sup>
France	20500	3000 <sup>2</sup>
Germany	32500	7900 <sup>2</sup>
Greece	12600	500 <sup>2</sup>
Ireland	1500	100 <sup>2</sup>
Italy	35	3500 <sup>2</sup>
Luxembourg	1040	0 <sup>2</sup>
Netherlands	3300	0 <sup>2</sup>
Norway	1200	no data
Portugal	7300	200 <sup>2</sup>
Spain	23900	1000 <sup>2</sup>
Sweden	2000	420 <sup>1</sup>
Switzerland	4500	no data
UK	11400	2000 <sup>1</sup>
<b>TOTAL</b>	<b>137000</b>	<b>21600</b>

(1) LUA (1997), (2) European IPPC Bureau (1998c)

### Solid and Liquid Waste Arisings, Treatment and Disposal

The main waste from cement production, of relevance to PCDD/F releases, is cement kiln dust. This is collected in the electrostatic precipitators or bag filters which are used to control dust emissions to the atmosphere. The dust is either recycled into the cement-making process, disposed to landfill, or a small proportion might be used for agriculture because of its lime content.

There is limited information available on the proportion of cement kiln dust that is recycled. For example, according to de Wit (1998), all cement kiln dust collected at plant in Sweden is recycled. The trend in most cases is an increase in the proportion of dust that is recycled. It is estimated that the amount of material landfilled is in the range 0-35 kg of dust per tonne of cement, for countries other than Sweden. It is assumed that the same waste factors (ie quantity of dust arising per tonne of production) apply to lime production.

Solid waste is also likely to arise from processes which employ wet scrubbers, but no information is available on the extent of use of wet scrubbers or on the quantity of sludge arising. It is expected that the PCDD/F release through this route is much smaller than from disposal of cement kiln dust.

Other solid waste that arises, such as the small amounts of waste from kiln maintenance, are unlikely to be relevant with respect to PCDD/F emissions.

Waste water arises mainly from the raw material preparation stages of the semi-wet process and from cooling operations. The amounts of water arising are likely to vary from one site to another, and contamination in discharges is likely to be low, particularly because some form of waste water treatment is probable.

The potential exists for the release of PCDD/Fs in the cement and lime products, although concentrations are likely to be low.

### **Emission Factors**

Limited data are available on PCDD/F concentrations in solid and liquid wastes from cement and lime production.

The concentration of PCDD/Fs in dust from cement and lime kilns, based on various tests carried out on UK kilns, has been taken as 0.001-30 ng I-TEQ/kg (AEA Technology Environment 1997).

## Emission Estimates

Country	Release to land		Release to land	
	Cement production		Lime production	
	Min.	Max.	Min.	Max.
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0	5.2	0	0.8
Belgium	0	7.9	0	1.9
Denmark	0	1.8	0	0.1
Finland	0	1.2	0	0.3
France	0	22	0	3.2
Germany	0	34	0	8.3
Greece	0	13	0	0.5
Ireland	0	1.6	0	0.1
Italy	0	0.04	0	3.7
Luxembourg	0	1.1	0	0
Netherlands	0	3.5	0	0
Norway	0	1.3	no data	no data
Portugal	0	7.7	0	0.2
Spain	0	25	0	1.1
Sweden	0	0	0	0
Switzerland	0	4.7	no data	no data
UK	0	12	0	2.1
TOTAL	0	140	0	22

A best estimate release of 80 g I-TEQ to land from cement and lime production represents about 0.2% contribution to total estimated emissions.

Releases of PCDD/Fs to water have not been estimated but are not expected to be significant.

### Future Changes in Release

Future changes in emissions will depend on market demand and on technological advances in abatement. There is unlikely to have been a significant change in technology since 1994. Future changes in fuel might need to be taken into account when improving these emission estimates.

### Conclusions / Recommendations

The releases of PCDD/F to land through the disposal of dusts from cement and lime production have some potential to be significant, but this sector is less important relative to many others. The release for each country will depend on the extent of recycling of dusts in the cement and lime plant.

The main uncertainties are associated with the concentration data; the estimates in this report are based on UK data only.

### **3.5 SNAP GROUP 5 - EXTRACTION AND DISTRIBUTION OF FOSSIL FUELS**

The processes within SNAP Group 5 are unlikely to be significant sources of PCDD/F release because they mainly do not involve conditions that lead to PCDD/F formation.

## 3.6 SNAP GROUP 6 - SOLVENT USE

### 3.6.1 Dry Cleaning

SNAP 60202

Some machines for the dry cleaning of clothes makes use of chlorinated organic solvents, such as perchloroethylene. The process involves the cleaning of the clothes in a solvent bath followed by drying in hot air. The solvents are regenerated and the dirt and grease from the cleaning process are removed as a waste product.

Information on the amount of dry cleaning that takes place in different countries, and on whether chlorinated solvents are used, has not been found. Although concentration data are available, estimates of releases cannot be made with confidence at this stage. For the UK, releases to land were estimated to be 0.7-9.8 g I-TEQ, and releases to water estimated to be low. For Germany, releases to land have been estimated as 0.3-31.5 g I-TEQ (LUA 1997).

Further work to generate estimated releases from this sector is a lower priority than for many other sectors, although if activity data were obtained then initial estimates could be made with the available data.

### 3.6.2 Pharmaceutical Products Manufacture

SNAP 60306

The pharmaceutical industry covers a very wide range of processes. Pharmaceutical products might be chlorinated and production might involve use of chlorinated chemicals, some of which could be contaminated.

Production is carried out at low temperatures and is considered to have low potential for PCDD/F formation.

### 3.6.3 Manufacture and use of dyestuffs, printing ink and coating materials

This sector is covers various SNAP categories, including :

60307 Paints Manufacturing

60308 Inks Manufacturing

A wide range of chemicals are produced to serve as dyes, inks and coating materials, but few data have been found on their production and use. Dyes which could be contaminated with PCDD/Fs include dioxazin dyes, carbazole violet and other dyes. Both the manufacture and use of dyes could lead to release of PCDD/Fs into the environment.

Residues from the production of dyes have the potential to be contaminated with PCDD/Fs. This sector requires further study to determine the release of PCDD/Fs. However, limited data are available on the types and quantities of dyes produced, the quantities of sludge and waste waters produced, and on PCDD/F contamination. The only information is an estimation of

105 g I-TEQ per year released in Germany through contaminated 'Violet 23' until 1990. Since then, production was changed to the hydroquinone process and emissions decreased to about 3 g I-TEQ per year (BGA/UBA 1993).

### **3.6.4 Textile Finishing 060312**

A number of the chemicals and dyes, such as dioxazin dyes, used in the textile industry are known to have the potential to be contaminated with PCDD/Fs. The chemicals are used for coating textiles to provide specialist finishes, and for preservation.

Pentachlorophenol and pentachlorophenyl laureate have been used in the textile industry to prevent fungal and bacterial attack. It is likely, however, that the use of these chemicals has decreased because of environmental concerns.

#### **Activity Data**

The annual consumption of new textiles for Germany of 23 kg per capita could be used to estimate activities for other countries.

No reliable data are available on the use of chemicals and dyes during textile finishing.

#### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Releases to land could occur from chemical residues and treatment plant sludges, and releases to water could occur through discharges of the effluents from the process.

#### **Emission Factors**

Although some data are available on PCDD/F concentrations, the range of chemicals used means that it is difficult to apply these emission factors to the whole textile industry with any confidence. In addition, no data are available on the quantities of chemicals used and the extent of waste water treatment in the textile industry across Europe.

However, data from Germany are available on PCDD/F concentrations in household waste waters from cleaning new textiles. The concentrations in the textiles are 0.05-369 ng I-TEQ/kg (LUA 1997).

#### **Emission Estimates**

No estimates of PCDD/F releases to land and water from textile finishing plant have been made at this stage.

Releases in waste water from washing in households could be estimated. However, a large proportion of these PCDD/Fs will be transferred to sewage sludge at waste water treatment plant. Releases to the environment through this route are covered by estimations for disposal of sewage sludge (SNAP 090205 and 090300).

### **Future Changes in Release**

It is likely that releases of PCDD/Fs have been decreasing since 1994 and will continue to decrease because of controls on the types of dyes and chemicals used.

### **Conclusions / Recommendations**

Releases of PCDD/Fs to land and water from the textile industry have the potential to be significant, but not enough information is available to make initial estimates of releases. It would be a considerable task to identify the extent of use of different dyes and chemicals to enable estimates of PCDD/F release from textile processes to be made.

The quantity of many of the wide range of chemicals and dyes used will have decreased in recent years because of concerns over contamination of persistent organic pollutants such as PCDD/Fs.

### **3.6.5 PCP Use in Wood Preservation**

PCP has a number of uses, one of the main ones being preservation of wood (SNAP 60406). The chemical also has been used in agriculture (section 3.10) and in textile industry (section 3.6.4).

Pentachlorophenol (PCP) and related compounds, sodium pentachlorophenoxide (NaPCP) and pentachlorophenyl laureate (PCPL) have had widespread use as strong biocides.

Releases to the environment can occur as a result of volatilisation, spillages and disposal of treated products. Wood treated with PCP is likely to be processed, with the result of the PCP-contaminated shavings and off-cuts becoming a potential discharge to land. There is potential for release to land and water from the timber treatment process, and from the disposal of timber that has previously been treated.

The use of PCP has decreased significantly because of environmental concerns leading to regulatory controls and due to development of active ingredients at competitive prices.

There has been in the past a high risk of PCDD/F release, before PCP use was reduced. In Finland for example, contaminated land has been found at many sawmills which used a PCP based pesticide before it was banned in 1985 (Sandell 1999).

No reliable data have been found on the quantities of PCP used for timber treatment. For this reason no estimates have been made.

It has been estimated that releases of PCDD/Fs to land in the UK from PCP use in timber treatment were 0.01-0.32 g I-TEQ (AEA Technology Environment 1997). Although this is low compared with other sources, and that the trend is likely to be for a decrease in releases, further work on this sector is needed to verify these estimates.

### 3.7 SNAP GROUP 7 - ROAD TRANSPORT

Although vehicles can emit PCDD/Fs, they are unlikely to do so in significant quantities directly to land or water.

### **3.8 SNAP GROUP 8 - OTHER MOBILE SOURCES AND MACHINERY**

Although vehicles can emit PCDD/Fs, they are unlikely to release PCDD/Fs in significant quantities directly to land or water.

## **3.9 SNAP GROUP 9 - WASTE TREATMENT AND DISPOSAL ACTIVITIES**

### **3.9.1 Incineration of Domestic/Municipal Wastes**

SNAP 090201

#### **Process Description**

A wide variety of approaches are used in the combustion of waste, employing a variety of pre-treatment and sorting processes. The most widely used technology is mass burn incineration, with minimal pre-treatment and no sorting.

MSW incineration has long been recognised as a source of PCDD/F and extensive programmes have been conducted to investigate and control releases. The main emphasis has been on air emissions. The changes made to modern plant can result in both reduced production of PCDD/F and increased capture of PCDD/F formed, which may then increase the burden in discharges to land.

#### **Activity Data**

Amounts of MSW incinerated have been taken from LUA (1997), recategorised into old plant (previously the low abatement quality category used in the TNO study (Rijkema, 1993)) and new plant (medium and high abatement quality in TNO study). The LUA (1997) report obtained data from national inventories but also completed the data using the TNO study on PCDD/F emissions from MSW Incineration (Rijkema, 1993).

Country	Quantity of MSW incinerated in old plant	Quantity of MSW incinerated in new plant
	Mt	Mt
Austria	0	0.460
Belgium	0.95	0.03
Denmark	0	1.250
Finland	0.05	0
France	0	10.3
Germany	0	9.3
Greece	0	0
Ireland	0	0
Italy	2.8	0
Luxembourg	0.14	0
Netherlands	0	2.8
Norway	0.44	0
Portugal	0	0
Spain	0	0.8
Sweden	0	1.7
Switzerland	0	2.4
UK	2.5	0.42
<b>TOTAL</b>	<b>6.9</b>	<b>29.4</b>

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Grate residues account for the bulk of the solid wastes arising. These are usually disposed to landfill but may be used as an aggregate. Boiler ash, grate ash and fly ash (from particle abatement systems) are also disposed to landfill.

The amount of grate residues depends on the nature of combustion. A quantity of 300 kg/tonne of waste is reported in an international study (IAWG 1995). Releases from particulate controls in older plant are on average 30 kg/tonne of waste (IAWG 1995, ETSU 1996). In new plant there is also a release of gas cleaning residue, which can vary according to the systems in place. It is estimated that for an average semi-dry system, the release is 38 kg/tonne of waste (ETSU 1996). Other systems may produce more residue.

Some MSW incinerators employ wet scrubbing systems. Rijpkema (1993) indicate that 10-15 kg of sludge is produced by incinerators with wet scrubbers per tonne of waste burned and this range has been used in this report. Data obtained from the European Commission report (1997) show little differences. The data is a little higher; 40 kg residue/tonne of waste for the dry systems and less than 25 kg residue/tonne of waste for the wet systems. However, feedback from France suggests 10-15 kg sludge/tonne might be an overestimate (Pernin 1999).

The quantity of waste burned in incinerators with wet scrubbing systems has been taken from Rijpkema (1993).

It is assumed that all disposal routes for ash/slag solid waste represent a release to land.

Waste waters from MSW incinerators are likely to require treatment before discharge to the sewer. Wet scrubbing systems are a source of water. Other sources of water are from quenching of grate residues, wash water and surface runoff. Limited quantitative data are available on liquid wastes arising although total emissions of liquid effluent range from 6 kt/y for the 25 kt capacity plants to 192 kt/y for the 800kt/y capacity plant are reported by the European Commission (1997).

### **Emission Factors**

A range of 12-72 ng I-TEQ/kg, based on UK measurements for DETR, is taken as representative of levels in grate residues. ESP ash in old plant has a range of levels of 6,600-31,100 ng I-TEQ/kg. The emission factors used by Bremmer et al. (1994) lie within these ranges. In new plants the gas cleaning residue has a range of 810-1,800 ng I-TEQ/kg.

Sludge from wet scrubbers used at MSW plant is assumed to have a concentration in the range 680 - 12,200 ng I-TEQ/kg (WSL (1992a), Bremmer et al. (1994)).

Emission factors for other solid wastes and for liquid wastes are not available. In the report published by the European Commission (1997), the PCDD/F concentration in liquid discharges is assumed to be low.

**Emission Estimates**

Country	Old plant release to land		New plant release to land		Plant with wet scrubbers - release to land in sludge		Total - all plant release to land	
	min	max	min	max	Min	max	min	max
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0	0	16	41	0	0	16	41
Belgium	190	910	1	3	0.8	32	195	945
Denmark	0	0	43	110	2.8	110	46	220
Finland	10	48	0	0	0	0	10	48
France	0	0	350	930	9.7	370	360	1300
Germany	0	0	320	830	29	1120	349	1950
Greece	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0
Italy	560	2670	0	0	2.8	110	563	2780
Luxembourg	28	130	0	0	0	0	28	130
Netherlands	0	0	95	250	7.4	280	102	530
Norway	89	420	0	0	2.2	81	91	500
Portugal	0	0	0	0	0	0	0	0
Spain	0	0	27	72	0	0	27	72
Sweden	0	0	58	150	3.3	126	62	280
Switzerland	0	0	83	220	11	430	94	650
UK	500	2390	14	38	0	0	514	2430
<b>TOTAL</b>	<b>1390</b>	<b>6570</b>	<b>1010</b>	<b>2640</b>	<b>69</b>	<b>2650</b>	<b>2470</b>	<b>11900</b>

A best estimate release of 7,200 g I-TEQ represents 19% contribution to total estimated releases to land.

Releases to water have not been estimated because there are no data available. Although quantities of liquid discharge are expected to be small, there is potential for contamination if the degree of treatment is not appropriate. Estimates of discharge to water in effluents from wet scrubbers after treatment, based on information in Bremmer et al. (1994), indicate that the releases to water are likely to be low from new plants.

**Future Changes in Release**

The incineration of MSW is undergoing considerable development in order to meet the requirements of EC Directives. Improvements in pollution controls will mean that a greater proportion of the PCDD/F formed in the process is captured and not released to air. Improvements in combustion will lead to reductions in ash going to landfill, whereas improvements in the efficiency of gas cleaning technologies could lead to increased amounts of residues being collected. The overall release of PCDD/Fs to the environment is decreasing from MSW incinerators.

Some countries will have more potential to further decrease emissions than others. The TNO study (Rijpkema 1993) found that Austria, Denmark, Germany, The Netherlands and Sweden generally had the more advanced standard of emission control with widespread use of wet and dry systems for acid gas removal and dust control, whereas countries such as Spain, France and Italy were dominated by small-scale facilities.

### **Conclusions / Recommendations**

Releases of PCDD/Fs to land through disposal of ash from MSW incinerators were significant in 1994. However, reductions in releases will continue because of national and international regulations. The ranges in estimated emissions are fairly wide, and the inventory needs to be updated through further measurements of PCDD/F contamination in ash.

### **3.9.2 Incineration of Industrial Wastes**

SNAP 090202

#### **Process Description**

Industrial or chemical incineration covers a wide variety of wastes, and consequently a number of different types of equipment are used. The main incinerators employed are rotary kilns, liquid injection furnaces, fluid grate furnaces and fixed grate furnaces.

#### **Activity Data**

Activity data for the quantity of industrial and chemical wastes incinerated have been taken from LUA (1997). This report took the data from national inventories and from OECD statistics. For some countries no data were available.

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Country	Quantity of Chemical / Industrial waste incinerated
	Mt
Austria <sup>1</sup>	0.076
Belgium <sup>1</sup>	0.44
Denmark	
Finland <sup>2</sup>	0.044
France <sup>2</sup>	1.04
Germany <sup>1</sup>	2.00
Greece	
Ireland <sup>3</sup>	0.027
Italy	
Luxembourg	
Netherlands <sup>2</sup>	0.16
Norway <sup>2</sup>	0.003
Portugal <sup>2</sup>	0.01
Spain	
Sweden <sup>1</sup>	0.031
Switzerland <sup>2</sup>	0.27
UK <sup>1</sup>	0.29
<b>TOTAL</b>	<b>4.38</b>

(1) Data from national inventories, (2) Data from OECD, (3) Concannon (1999) (note 1996 data)

In Spain there is no incineration of industrial wastes at present. The first incinerator is being built in Catalunya.

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Solid wastes include bottom ash from the furnace, fly ash and residues from gas cleaning operations, and filter cakes and collected dusts from flue gas cleaning. We assume a solid waste production rate of 20% of throughput.

Releases to water arise mainly from the use of wet scrubbers, which are common on hazardous waste incinerators. Data from one UK plant indicate that the discharge is about 6.2 m<sup>3</sup> per tonne of waste.

### **Emission Factors**

There are limited data on concentrations in solid and liquid releases. Data for the UK are given in AEA Technology Environment (1997), and these are used as default emission factors for

## SNAP 9 –Waste Treatment and Disposal Activities

this inventory. The range of levels in bottom ash and composite solid wastes is 0.1 - 34 ng I-TEQ/kg. The range of levels for liquid discharges is 0.01 - 0.6 ng I-TEQ / l.

### Emission Estimates

Country	Release to land		Release to water	
	min	max	min	max
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0.002	0.5	0.005	0.3
Belgium	0.009	3.0	0.03	1.6
Denmark	no data	no data	no data	No data
Finland	0.0009	0.3	0.003	0.2
France	0.02	7.1	0.07	3.9
Germany	0.04	14	0.1	7.5
Greece	no data	no data	no data	No data
Ireland	0.0005	0.2	0.002	0.1
Italy	no data	no data	no data	No data
Luxembourg	no data	no data	no data	No data
Netherlands	0.003	1.1	0.01	0.6
Norway	0.00006	0.02	0.0002	0.01
Portugal	0.0002	0.07	0.0006	0.04
Spain	no data	no data	no data	No data
Sweden	0.0007	0.2	0.002	0.1
Switzerland	0.005	1.8	0.02	1.0
UK	0.006	2.0	0.02	1.1
TOTAL	0.09	30	0.3	16

A best estimate release to land of 15 g I-TEQ represents <0.1% contribution to total emissions.

### Future Changes in Release

The EC Directive on Incineration of Hazardous Wastes will result in a reduction in emissions. Solid waste discharges may also fall as combustion conditions are improved. Lower releases to water are expected as re-use rates increase. There is also a proposed EC Directive on Water Pollution from Hazardous Waste Incinerators, which seeks to restrict emissions of toxic substances discharged by incineration plants by setting limit values for certain substances in waste water.

### Conclusions / Recommendations

There is limited information available on concentration data and waste arisings. The estimates are based on UK data only. However, these incinerators are tightly regulated and the estimated emission is low.

## **SNAP 9 –Waste Treatment and Disposal Activities**

### **3.9.3 Incineration of Sludges from Waste Water Treatment**

SNAP 090205

#### **Process Description**

The sludge from waste water treatment is de-watered prior to incineration. Plants vary in terms of releases depending on their specification, which has improved with time, and for the purpose of this study we have assumed that 50% of the sludge incinerated is in ‘old’ plant, and 50% in ‘new’ plant in 1994.

#### **Activity Data**

Activity data from Hall (1995) is given below (the same original data is used in section 3.9.10 Sludge Spreading). Hall (1995) states that on average 11% of sludge is incinerated, therefore this has been used as a default assumption where other data are not available. Schnurer (1997) states that 13% of sludge is incinerated in Germany.

Country	Sludge production (total)	Total sewage sludge burned
	t dry solids per year	t dry solids per year
Austria	no data	
Belgium	59200	6500
Denmark	170300	40900
Finland	no data	
France	852000	176000
Germany	2681200	370000
Greece	48200	5300
Ireland <sup>1</sup>	36700	0
Italy	816000	81600
Luxembourg	7900	870
Netherlands	322900	35500
Norway	no data	
Portugal	25000	2750
Spain	350000	38500
Sweden	no data	
Switzerland	no data	
UK	1107000	84000
<b>TOTAL</b>	<b>6480000</b>	<b>842000</b>

(1) Concannon (1999)

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

Plants vary according to their age: older style plants have multiple hearths and usually have electrostatic precipitators for dust control. Newer plants have fluidised bed combustion technology and comprehensive pollution controls. The main wastes are residual ashes either from the grate or pollution control equipment.

For older plants, it is estimated that 430kg of grate ash and 13kg of ESP ash are produced per tonne of dry waste. For new plant, about 373 kg/t of ESP ash are produced, with no grate ash (AEA Technology Environment (1997) - personal communication D Scott).

Liquid discharges are from wet scrubbers in new plant. It is estimated that 44-62 m<sup>3</sup> is discharged per tonne of sludge burned (AEA Technology Environment (1997) - personal communication D Scott), although these figures are uncertain and in reality the volume could be lower. The discharges are likely to be collected and returned to the sewage treatment works, and therefore might not be released into the environment.

### **Emission Factors**

The emission factors for old plant are: 39 ng I-TEQ/kg in grate ash and 473 ng I-TEQ/kg in ESP ash (WSL 1992b). For new plant, ESP ash has a level of <1 ng I-TEQ/kg, and the range of values for scrubber effluent is 0.0012 - 0.0065 ng I-TEQ/l (WSL 1992b).

**Emission Estimates**

Country	Old plant	New plant			Total - all plant
		Release to land	Release to water	Release to water	
		max	min	max	max
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	no data				
Belgium	0.08	0.001	0.0002	0.001	0.08
Denmark	0.5	0.008	0.001	0.008	0.5
Finland	no data				
France	2.0	0.03	0.005	0.04	2.0
Germany	4.2	0.07	0.01	0.08	4.3
Greece	0.06	0.001	0.0001	0.001	0.06
Ireland	0	0	0	0	0
Italy	0.9	0.015	0.002	0.016	0.9
Luxembourg	0.01	0.0002	0.00002	0.0002	0.01
Netherlands	0.4	0.007	0.001	0.007	0.4
Norway	no data				
Portugal	0.03	0.001	0.0001	0.001	0.03
Spain	0.4	0.007	0.001	0.008	0.4
Sweden	no data				
Switzerland	no data				
UK	1.0	0.02	0.002	0.02	1.0
<b>TOTAL</b>	<b>9.6</b>	<b>0.16</b>	<b>0.02</b>	<b>0.17</b>	<b>9.8</b>

A best estimate of 10 g I-TEQ represents 0.1% contribution to total releases to land. This best estimate is based on a single data point, and a range of uncertainty of a factor of 10 gives a potential range in release to land of 1-100 g I-TEQ.

**Future Changes in Release**

Releases to land are likely to increase in future as a result of increasing amounts of secondary treatment of sewage, and the prevention of disposal to the sea resulting in an increase in the quantity of sludge incinerated.

**Conclusions / Recommendations**

Limited data are available. The estimated emissions are based on solid and liquid arisings and emission factors from the UK only. However, releases are likely to be low.

### **3.9.4 Incineration of Hospital Wastes**

SNAP 090207

#### **Process Description**

The most widely used hospital waste incineration technology is high temperature incineration, but there is a wide variety of sizes of installation, with some centralised plants and many smaller hospital based plants. In some European countries the on-site incineration of hospital waste has been banned (LUA 1997).

Abatement technologies also vary according to the age and size of the plant. Most new plant have a moving hearth, an after-burner chamber and a boiler followed by comprehensive gas cleaning equipment (either a wet or dry scrubber). Older plants typically had static hearths and no pollution controls other than a secondary combustion chamber. Three types of plant are considered: new plant with wet scrubbers; new plant with dry scrubbers; and old plant with no gas cleaning. It is assumed that 50% of new plant has wet scrubbers and 50% has dry.

#### **Activity Data**

Activity data for the quantity of hospital wastes incinerated have been taken from LUA (1997), based on data either from national inventories or from publications of DG XI or OECD.

Country	Quantity of clinical waste incinerated
	M tonnes
Austria <sup>1</sup>	0.003
Belgium <sup>1</sup>	0.04
Denmark <sup>2</sup>	0.01
Finland <sup>4</sup>	0.004
France <sup>2</sup>	0.11
Germany <sup>2</sup>	0.03
Greece <sup>2,4</sup>	0.02
Ireland <sup>3</sup>	0.009
Italy <sup>5</sup>	0.1
Luxembourg <sup>3</sup>	0.0004
Netherlands <sup>3</sup>	0.001
Norway <sup>3</sup>	0
Portugal <sup>5</sup>	0.014
Spain <sup>2</sup>	0.02
Sweden <sup>1</sup>	0.002
Switzerland <sup>3,4</sup>	0.003
UK <sup>1</sup>	0.26
<b>TOTAL</b>	<b>0.62</b>

(1) Data from national inventories, (2) Data from DGXI (Analysis of priority waste streams - healthcare waste: information document summary, August 1994), (3) Data from OECD Europe's Environment: Statistical

## SNAP 9 –Waste Treatment and Disposal Activities

Compendium, (4) Data from OECD Environmental Data Compendium 1995, (5) Data from OECD Environmental Performance Reviews [Details of all these data sources are in LUA (1997)].

### Solid and Liquid Waste Arisings, Treatment and Disposal

The main solid wastes arising are grate ash, in all plants, and also scrubber residues in new plants. There is a wide range of grate ash generation rates across the variety of plants and we assume an average of 150 kg per tonne of waste burned for all plants (based on UK Environment Agency (1991 and 1995).

In wet scrubber plants an estimated 40 kg of solid residue is produced per tonne of waste. In dry scrubber plants the figure is 80 kg (based on UK Environment Agency (1991 and 1995).

No data are available for quantities of liquid wastes.

### Emission Factors

Concentration ranges for the various solid wastes arising are as follows:

grate ash	15-300 ng I-TEQ/kg
dry scrubber residue	1800-4500 ng I-TEQ/kg
wet scrubber residue	680 ng I-TEQ/kg

These concentrations are based on data in ETSU (1992) and WSL (1992a and 1992c).

## SNAP 9 –Waste Treatment and Disposal Activities

### Emission Estimates

Estimated quantities of PCDD/Fs released are shown below.

Country	Release to land from grate ash		Release to land from wet scrubber residue	Release to land from dry scrubber residue		Total release to land	
	min	max		min	max	min	max
	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ	g I-TEQ
Austria	0.01	0.1	0.04	0.2	0.5	0.3	0.7
Belgium	0.09	1.9	0.6	3.0	7.6	3.7	10
Denmark	0.02	0.5	0.1	0.7	1.8	0.9	2.4
Finland	0.01	0.2	0.05	0.3	0.7	0.4	1.0
France	0.2	4.7	1.4	7.6	19	9.2	25
Germany	0.07	1.5	0.5	2.4	5.9	3.0	7.9
Greece	0.03	0.7	0.2	1.1	2.7	1.3	3.6
Ireland	0.02	0.4	0.1	0.7	1.6	0.8	2.2
Italy	0.2	4.5	1.4	7.2	18	8.8	24
Luxembourg	0.001	0.02	0.01	0.03	0.07	0.04	0.1
Netherlands	0.002	0.05	0.01	0.07	0.2	0.09	0.2
Norway							
Portugal	0.03	0.6	0.2	1.0	2.5	1.2	3.3
Spain	0.05	1.0	0.3	1.7	4.1	2.0	5.5
Sweden	0.00	0.09	0.03	0.1	0.4	0.3	0.5
Switzerland	0.01	0.1	0.04	0.2	0.5	0.2	0.7
UK	0.6	12	3.5	19	47	23	62
TOTAL	1.4	28	8.5	45	110	55	150

A best estimate release of 100 g I-TEQ represents 0.3% contribution to total emissions.

More details on plant types and abatement control are needed to improve these estimates.

In some countries, eg Denmark, the major part of hospital waste is co-incinerated together with MSW in large plants. According to an investigation carried out in Denmark, no measurable increase in PCDD/F flue gas emission was found when co-incineration took place, compared with incineration of MSW alone (Vikelse, 1999).

### Future Changes in Release

There are many changes in activity in incineration of hospital wastes. Many incinerators are being closed or upgraded. For example, many hospital waste incinerators have been closed down in Germany and much of the clinical waste is incinerated in larger hazardous waste facilities.

## **SNAP 9 –Waste Treatment and Disposal Activities**

## **Conclusions / Recommendations**

The estimated releases to land from disposal of ash and residues from hospital waste incinerators is significant. However, the estimates are based on waste arisings data and concentrations from the UK only, and measurements from other countries are needed to improve the inventory.

### **3.9.5 Waste Oil Disposal**

SNAP 090208 (Incineration of Waste Oil)

#### **Process Description**

Waste oils arise from domestic and industrial sources. Waste oils are often burned in small boilers, for example a number of car workshops burn their waste oil for heating. Waste oils could contain contaminants which can act as precursors to PCDD/F formation.

The main source of PCDD/F releases from waste oil could be improper disposal down drains. The PCDD/Fs might end up in sewage sludge from waste water treatment.

The disposal practices for waste oil are likely to vary between countries depending on waste management practices.

#### **Activity Data**

The amount of waste oil collected from industrial, commercial or domestic premises is likely to vary significantly between countries.

Limited data has been found on waste oil disposal, and the amounts disposed improperly into drains are unlikely to be known. In 1993, the waste oil generation in UK was about 402,000 tonnes (Poll 1995); most waste oils come from commercial sources, but it is estimated that 10% of arisings are generated by motorists who change their own oil and it is estimated that less than 20% of this volume is recovered.

#### **Solid and Liquid Waste Arisings, Treatment and Disposal**

The solid arisings from the combustion of waste oil will depend on the nature of the appliance in which it is burned. In larger plant particulate control technology is likely to be used and ESP or filter dusts are likely to be generated.

The disposal of waste oil into drains results in a release to water.

#### **Emission Factors**

## SNAP 9 –Waste Treatment and Disposal Activities

It is estimated that the concentrations of PCDD/Fs in waste oils could be in the range 14-60 ng I-TEQ/kg (based on NATO 1988).

### Emission Estimates

#### a) Combustion of waste oil

No concentration data have been found for solid or liquid discharges from waste oil combustion plant. No emission estimates have therefore been made. Emissions to water are likely to be negligible.

#### b) Improper disposal of waste oil

For releases to water from improper disposal into drains, the estimates below have been made by scaling UK estimates in relation to population.

Country	Release to water	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.04	0.2
Belgium	0.05	0.2
Denmark	0.02	0.1
Finland	0.02	0.1
France	0.3	1.2
Germany	0.4	1.7
Greece	0.05	0.2
Ireland	0.02	0.07
Italy	0.3	1.2
Luxembourg	0.002	0.01
Netherlands	0.07	0.3
Norway	0.02	0.09
Portugal	0.05	0.2
Spain	0.2	0.8
Sweden	0.04	0.2
Switzerland	0.03	0.1
UK	0.3	1.2
<b>TOTAL</b>	<b>1.8</b>	<b>7.9</b>

Releases from waste oil disposal are unlikely to represent a major contribution to total emissions – a best estimate of 5 g I-TEQ represents <0.1% of total emissions.

### **Future Changes in Release**

Releases from the improper disposal of waste oil are unlikely to increase significantly as awareness is raised on the environmental impact of this practice.

### **Conclusions / Recommendations**

There is significant uncertainty in the estimates of releases to water from disposal of waste oil into drains. This is because the estimates have been made by scaling the UK estimate on a per capita basis.

### **3.9.6 Incineration of Scrap Tyres**

#### **Process Description**

Tyres have a high calorific value and they may be burned to recover energy. Tyres may be burned in purpose-built plant or co-fired with other fuels, for example in cement kilns or power stations.

#### **Activity Data**

Activity data for quantities of tyres burned in Europe have not been found, except for the UK where 60,000-94,000 tonnes of tyres are incinerated (AEA Technology Environment 1997, Silke 1995).

#### **Solid and Liquid Waste Arisings, Treatment and Disposal**

The AEA Technology Environment (1997) report describes two plants in the UK, where combustion is controlled and abatement measures are applied to reduce atmospheric emissions. One plant uses dry scrubbing and fabric filters and the other uses a wet scrubber. There may be other plant types across Europe.

In purpose-built plant there will be grate ash and solid residues from the pollution control devices. Tyres have a high ash content (10%). It is assumed that 90% of the ash is recovered as grate ash, and the remainder as pollution control residue (ETSU 1993).

No discharges to water are expected other than surface runoff and cooling waters. For plant using wet scrubbers a discharge would be expected, but there are no data on the quantities produced.

#### **Emission Factors**

## **SNAP 9 –Waste Treatment and Disposal Activities**

Emission factors are available for the grate ash produced, of 6-8 ng I-TEQ/kg, and for grit ash from pollution control devices, of 1970-2750 ng I-TEQ/kg. This data originates from an industrial boiler modified to burn shredded tyres, and therefore it is not representative of large purpose-built plant (ETSU 1993).

### **Emission Estimates**

Releases to land for the UK were estimated to be 1.9-2.7 g I-TEQ/year. Estimates for other countries can be made when activity data are obtained.

### **Future Changes in Release**

Future changes in emissions will depend on market demand for this technology and waste management strategies.

### **Conclusions / Recommendations**

Only UK data are available on releases from this source. Scrap tyre combustion is unlikely to be a significant source of PCDD/F release in Europe, except for the accidental or other open burning of scrap tyres, which is covered in Section 3.12.

#### **3.9.8 Combustion of Poultry Litter**

The litter collected from the floors of sheds used to raise chickens can be used as a fuel for electricity generation or heat production. The litter consists of mainly straw and other bedding, and droppings and other residue from the birds.

The UK has two large-scale poultry litter fired power plants, burning 246,600 t in 1993, but this is not representative of the rest of Europe, where this energy resource is not often exploited.

Combustion of chicken litter leads to the production of grate ash and fly ash. The ash content is approximately 10%, giving 100 kg of grate ash per tonne of litter combusted. Fly ash is produced at a rate of 26 kg/t litter combusted (ETSU 1995). These residues are thought to be applied to farmland as a fertiliser.

No releases to water are expected.

Grate ash has been found to contain <5 ng I-TEQ/kg ash, and fly ash to have a levels of 28 ng I-TEQ/kg. In the UK the release to land is estimated to be about 0.3 g I-TEQ/year (ETSU 1995). This sector is therefore unlikely to be a significant source of PCDD/Fs in Europe.

### **3.9.9 Disposal of Municipal Solid Waste (MSW) to Landfill**

SNAP 90400

#### **Process Description**

Domestic waste is taken to landfill in varying quantities across Europe. This section covers just MSW, rather than total waste disposal to landfill, although the SNAP classification covers all waste. Disposal of ash from incinerators is covered by earlier sections.

#### **Activity Data**

Activity data are from Eurostat (1996), except for the UK which is from DETR (1995).

Country	total MSW to landfill
	Mt/y
Austria	1.7
Belgium	0.50
Denmark	0.47
Finland	2.4
France	9.5
Germany	14
Greece	3.0
Ireland	1.1
Italy	23
Luxembourg	0.07
Netherlands	3.6
Norway	1.7
Portugal	2.8
Spain	12
Sweden	1.4
Switzerland	0.7
UK	23
<b>TOTAL</b>	<b>101</b>

#### **Solid and Liquid Waste Arisings**

The total MSW landfilled is considered here as a release to land. Releases to water can also be considered in terms of leachate produced. Leachate is increasingly managed on modern sites. It may be treated or recycled to the landfill. On older sites leachate discharge constitutes a release to water. Eduljee et al. (1995) give an estimate of 200-500 l per tonne, but this is regarded as very uncertain. Our estimates only cover a release to land because releases to water occur subsequently.

**Emission Factors**

MSW has been found to contain on average 6.3 ng I-TEQ/kg wet basis (based on information from UK Environment Agency (AEA Technology Environment 1997)) and 73 ng I-TEQ/kg wet basis average in Germany (Greiner et al. 1991).

**Emission Estimates**

Country	Release to land	
	Min	Max
	g I-TEQ	g I-TEQ
Austria	11	124
Belgium	3	36
Denmark	3	34
Finland	15	175
France	60	694
Germany	90	1038
Greece	19	217
Ireland	7	80
Italy	140	1664
Luxembourg	0	5
Netherlands	23	264
Norway	11	122
Portugal	18	206
Spain	74	855
Sweden	9	102
Switzerland	4	47
UK	150	1708
TOTAL	640	7370

A best estimate of 4000 g I-TEQ represents a 10% contribution to total releases to land.

**Future Changes in Release**

Amounts of MSW disposed to landfill will change in future as a result of changing disposal practices, for example increased recycling and incineration, as well as a potential continued increase in total arisings. The changes in PCDD/F release will depend on the amount and type of waste disposed.

## **Conclusions / Recommendations**

The potential release of PCDD/Fs to land from disposal of MSW is high. There is significant uncertainty associated with the estimates, which are based on single concentration figures from Germany and UK. There is potential for double counting of releases from this section and other relevant sections and this is a potential source of uncertainty.

Improvements to these estimates are required through generation of more data on contamination.

### **3.9.10 Open Burning of Agricultural Wastes**

SNAP 90700

Open burning of agricultural wastes has the potential to release PCDD/Fs to the environment, especially where the wastes that are burned include plastic bags which contained pesticides. However, no information is available on the types and quantities of wastes burned, the residues produced and the PCDD/F contamination.

### **3.9.7 Crematoria**

SNAP 90901

#### **Process Description**

Combustion in crematoria is usually a two stage process with a furnace and an afterburner. Poor combustion conditions, the use of some coffin materials and poor emission controls result in these being potential sources of PCDD/Fs.

#### **Activity Data**

LUA (1997) provide data on the number of cremations across Europe, based on the total deaths per year and the percentage of funerals which are cremations, with estimates made where actual data were not available. Estimates are based on the assumption that 50% of funerals are cremations, calculated from national death rate data.

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Country	Number of Cremations
Austria	11 970
Belgium	32 000
Denmark	31 500
Finland	25 500
France	265 000
Germany	292 000
Greece	48 500
Ireland	15 500
Italy	270 500
Luxembourg	2 000
Netherlands	59 100
Norway	no data
Portugal	53 000
Spain	169 500
Sweden	61 200
Switzerland	415 000
UK	437 000
TOTAL	2 189 000

### Solid and Liquid Waste Arisings

Data from The Netherlands (LUA 1997) suggests 75g filter dust arises per cremation.

### Emission Factors

In the same study from The Netherlands (LUA 1997), the PCDD/F concentration is assumed to be comparable with values found at non-ferrous metal works; 17.8 ng I-TEQ/g at maximum.

**Emission Estimates**

Country	Release to land
	g I-TEQ
Austria	0.02
Belgium	0.04
Denmark	0.04
Finland	0.03
France	0.35
Germany	0.39
Greece	0.07
Ireland	0.02
Italy	0.36
Luxembourg	0.003
Netherlands	0.08
Norway	No data
Portugal	0.07
Spain	0.23
Sweden	0.08
Switzerland	0.55
UK	0.58
<b>TOTAL</b>	<b>2.9</b>

The estimated releases to land of 2.9 g I-TEQ from crematoria represent <0.1% of total PCDD/F releases.

**Future Changes in Release**

The potential for increase or decrease in activity in crematoria is unpredictable and depends on social factors. Emissions are not expected to change significantly.

**Conclusions / Recommendations**

Emissions from crematoria are unlikely to be significant, although further data are required to confirm this.

**3.9.11 Waste Water Treatment in Residential / Commercial Sector**

SNAP 091002

It is likely that the large majority of PCDD/Fs in domestic waste water are removed at sewage treatment works and contaminate the sludge. The method of disposal of the sludge is therefore

the key issue. The release of these PCDD/Fs to the environment is largely covered under the section on sludge spreading (SNAP 091003).

The extent of waste water treatment is likely to vary significantly between countries and the quantity of PCDD/F released through effluent or sludge will vary.

### **3.9.12 Sludge Spreading**

SNAP 091003

#### **Process Description**

Sewage sludge arises from the treatment of waste waters. The sludge can be applied to agricultural land as a fertiliser.

#### **Activity Data**

Hall (1995) provides data for the whole of Europe concerning amounts of sewage sludge produced and methods of disposal. A total of 6.5 million tonnes of sludge were produced per year in 1991-92. Methods of disposal and relative proportions are as follows: landfill (40%), incineration (11%), agriculture (37%) (checked against 35% for Germany (Schnurer, H.L. (1997)), other beneficial (2%), other disposal (4%) and to the sea (6%). These figures have been used to estimate total applications of sludge to land across Europe where actual data are not available. However, in reality there are large variations in disposal methods across Europe.

<b>Country</b>	<b>Sludge production (total)</b>	<b>Sludge used in agriculture</b>
	t dry solids per year	
Austria	no data	
Belgium <sup>1</sup>	59 200	21 900
Denmark <sup>1</sup>	170 300	63 010
Finland	no data	
France	852 000	511 200
Germany	2 681 200*	730 000
Greece	48 200	4 820
Ireland	36 700	3 670
Italy <sup>1</sup>	816 000	301 920
Luxembourg <sup>1</sup>	7 900	2 920
Netherlands <sup>1</sup>	322 900	119 470
Portugal <sup>1</sup>	25 000	9 250
Spain <sup>1</sup>	350 000	129 500
Sweden	no data	
UK	1 107 000	465 000
<b>TOTAL</b>	<b>6 480 000</b>	<b>2 260 000</b>

(1) Data estimated considering 37% of the total sludge production  
 (\*) compared to 2.3 million tonnes published by Schnurer, H.L. (1997)

**Emission Factors**

Typical concentrations of PCDD/Fs in sewage sludge are given in AEA Technology Environment (1997), based on UK data, as 20-80 ng I-TEQ/kg dry solids, Bremmer et al. (1994) as 26 ng I-TEQ/kg, Jenseit (1999) as 33 ng I-TEQ/kg, Vikelsoe (1999) as 3-54 ng I-TEQ/kg with an average of 10 ng I-TEQ/kg and as 9-144 ng I-TEQ/kg from German studies (LUA 1997).

The range of 9-144 ng I-TEQ/kg has been used to make the emission estimates below.

**Emission Estimates**

Estimates of releases to land as a result of agricultural spreading are as follows:

Country	Release to land	
	Min	Max
	g TEQ	g TEQ
Austria	no data	no data
Belgium	0.2	3.2
Denmark	0.6	9.1
Finland	no data	no data
France	4.6	74
Germany	6.6	105
Greece	0.04	0.7
Ireland	0.03	0.5
Italy	2.7	43
Luxembourg	0.03	0.4
Netherlands	1.1	17
Norway	no data	no data
Portugal	0.08	1.3
Spain	1.2	19
Sweden	no data	no data
Switzerland	no data	no data
UK	4.2	67
TOTAL	21	340

Estimates for Denmark give releases of 0.6 g I-TEQ/y, which is the same value as our minimum estimate (Vikelsoe, 1999).

A best estimate of 180 g I-TEQ represents 0.5% of total estimated emissions.

### **Future Changes in Release**

Applications of sludge to land are likely to increase in the near future as a result of the EU Directive on urban waste water treatment, which will result in a greater quantity of sludge produced and also in the banning of disposal to sea at the end of 1998. Continued improvements in waste water treatment technology is also likely to increase sludge production.

### **Conclusions / Recommendations**

The extent of waste water treatment and the types of sludge disposal practised varies between countries. The estimated emissions show that this source has the potential to release PCDD/Fs in lower quantities than several other sources. However, this source is important because it represents a significant route to the food chain.

### **3.9.13 Compost Production from Waste**

SNAP 091005

#### **Process Description**

Part of the putrescible fraction of the municipal waste stream is composted in some countries. The compost may be used for landfill cover, agricultural or horticultural purposes. Compost can contain PCDD/Fs.

#### **Activity Data**

Activity data have been taken from Eurostat (1996), except for the UK which is from AEA Technology Environment (1997) and for Germany (Quaß 1999). However, the available activity data vary greatly and there are large uncertainties in the data below. For example, Border (1997) published activity data that are different from those presented above.

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Country	Total Compost Production
	t/y
Austria	85 000
Belgium	96 000
Denmark	206 000
Finland	50 000
France	1 300 000
Germany	3 500 000
Greece	
Ireland	
Italy	
Luxembourg	5 000
Netherlands	475 000
Norway	15 000
Portugal	444 000
Spain	1 468 000
Sweden	100 000
Switzerland	
UK	90 000
TOTAL	7 830 000

### Emission Factors

The level of PCDD/Fs in compost has been estimated in various studies. A range of 1.8 to 19 ng I-TEQ/kg has been assumed (based on AEA Technology Environment (1997), Wilken et al. 1990, Schafer et al. 1993 and Jenseit (1999)).

**Emission Estimates**

Country	Release	Release
	to land	to land
	min	max
	g I-TEQ	g I-TEQ
Austria	0.2	1.6
Belgium	0.2	1.8
Denmark	0.4	3.9
Finland	0.1	1.0
France	2.4	25
Germany	6.5	66
Greece		
Ireland		
Italy		
Luxembourg	0.0	0.1
Netherlands	0.9	9.0
Norway	0.0	0.3
Portugal	0.8	8.4
Spain	2.7	28
Sweden	0.2	1.9
Switzerland		
UK	0.2	1.7
<b>TOTAL</b>	<b>14</b>	<b>150</b>

The best estimate of 80 g I-TEQ is about 0.2 % of total emissions.

**Future Changes in Release**

Composting rates may increase in future, and there might therefore be increased releases from this sector.

**Conclusions / Recommendations**

The main uncertainty in the above estimates relates to the production statistics. Further work should first focus on improving these statistics. Although this source has low potential to release PCDD/Fs, it represents a significant route to the food chain.

## 3.10 SNAP GROUP 10 - AGRICULTURE ACTIVITIES

### 3.10.1 Stubble Burning

SNAP 100300

The residues from stubble burning are likely to be contaminated with PCDD/Fs. However, limited information is available on the quantity of stubble burned, the amount of residues produced and on typical PCDD/F concentrations. It is therefore not possible to confidently estimate the release of PCDD/Fs.

Stubble burning is banned in most of the UK, but it is unclear whether this is the case of the rest of Europe.

### 3.10.2 Pesticide Use

SNAP 100600

#### Process Description

Many different pesticide formulations are used as fungicides, herbicides, insecticides and for other purposes. This section covers the use of pesticides; their production is covered in section 3.4.7 (SNAP 040425).

#### Activity Data

Reliable activity data on use of pesticides is therefore difficult to obtain.

The US EPA has identified a list of pesticides which could be contaminated with PCDD/Fs if synthesised under conditions which favour PCDD/F formation (Appendix 2).

Information on sales of pesticides is available in Eurostat (1996). This information is summarised in the section on SNAP 040425. The activity statistics in the table below, for the use of active ingredients identified as potentially contaminated with PCDD/Fs in pesticides, have been scaled up from the figure for the UK on a pro rata basis relative to the sales of pesticides.

Country	Tonnes of potentially contaminated active ingredients used 1994
Austria	170
Belgium	500
Denmark	190
Finland	62
France	4350
Germany	1410
Greece	410
Ireland	92
Italy	4340
Luxembourg	12
Netherlands	560
Norway	
Portugal	290
Spain	3990
Sweden	93
Switzerland	
UK	1360
TOTAL	17 800

### **Solid and Liquid Waste Arisings, Treatment and Disposal**

It is assumed that all the active ingredients used are released to land. In reality, a significant proportion could be released to water.

### **Emission Factors**

From a number of different sets of contamination data, for a number of different pesticides, we estimate that the range of concentrations of PCDD/Fs in active ingredient (identified as potentially being contaminated by US EPA) is 3,500-175,000 ng I-TEQ/kg (AEA Technology Environment 1997).

### Emission Estimates

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.6	30
Belgium	1.8	88
Denmark	0.7	34
Finland	0.2	11
France	15	760
Germany	4.9	250
Greece	1.4	71
Ireland	0.3	16
Italy	15	760
Luxembourg	0	2.0
Netherlands	1.9	97
Norway		
Portugal	1.0	51
Spain	14	700
Sweden	0.3	16
Switzerland		
UK	4.8	240
TOTAL	62	3120

A best estimate of 1600 g I-TEQ is over 4% of total releases to land in Europe.

There is significant uncertainty associated with these estimates, particularly related to the activity data for tonnes of potentially contaminated pesticide used. For example, estimates for Germany in the LUA (1997) report give a release to land of 0.03-29 g I-TEQ. Comparison of this with the above estimates illustrates the high uncertainty in this sector.

In addition to the use of pesticides potentially contaminated (identified by US EPA), releases from the use of PCP as pesticides have the potential to be high. These releases, however, will have been decreasing. The use of PCP in wood treatment is discussed in section 3.6.5.

There is a high potential for release to water courses from open use of chemicals.

### Future Changes in Release

The reduced acceptability of chlorinated chemicals across the EU is likely to cause a continued decrease in emissions from pesticide use.

**Conclusions / Recommendations**

Statistics on use of potentially contaminated pesticides and information on levels of contamination are difficult to obtain. Improvements to these estimates rely on better activity data on types of pesticides used.

PCP use has been largely phased out and all pesticide products in Europe have to undergo approval under 91/4/4 EC (European Crop Protection Association, 1999). Many other potentially contaminated pesticides have also been phased out. It is therefore possible that actual releases are nearer the lower end of the above range in estimated emissions to land, although data are not available to confirm this.

There is a high potential for release to water courses from open use of chemicals.

### **3.11 SNAP GROUP 11 - NATURE**

No significant releases of PCDD/Fs are expected from nature.

## 3.12 FIRES AND OTHER SOURCES

### 3.12.1 Accidental Fires

#### Process Description

The poor combustion conditions and the wide variety of materials that can be burned in an accidental fire can lead to the formation and release of varying quantities of a wide range of pollutants including PCDD/Fs. Fires involving certain chemicals (e.g. PCBs or PCP) could potentially release significant quantities of PCDD/Fs.

The releases from a fire will depend on the materials involved, the nature and duration of the fire, and the extent of methods to control the fire.

Many types of fire are relevant to this ‘accidental fires’ section, including fires in houses, other buildings, cars, tyre dumps etc. In countries with hotter climates these could include large-scale forest fires which are a regular summer feature for Mediterranean countries. Such fires may well turn out to constitute an important additional source of PCDD/F releases.

Potential fires at PCB-containing transformers have been a major concern, but since most transformers containing PCB oil have been changed, the risk of PCDD/Fs release from electrical fires has been reduced. Electrical wiring and PVC materials still give a high formation of PCDD/Fs in fires (Sandell 1999).

#### Activity Data

There are limited comprehensive data on the incidence of fires and that which does exist is not designed for the purposes of estimating pollution.

#### Solid and Liquid Waste Arisings, Treatment and Disposal

The principal release to land is expected to be the residual material that is not fully combusted, and other solid material that could have become contaminated during a fire and is subsequently removed. It is likely that this material will be handled and disposed as waste.

In AEA Technology Environment it is estimated that 12,770 t/y of contaminated ash and other material are removed from the remains after accidental fires and disposed to land in the UK.

The quantity of solid waste has been estimated by scaling the figure for the UK on a pro rata basis relative to the population of countries.

Country	Tonnes of solid waste removed after accidental fires 1994
Austria	1760
Belgium	2210
Denmark	1140
Finland	1110
France	12660
Germany	17820
Greece	2280
Ireland	780
Italy	12520
Luxembourg	88
Netherlands	3360
Norway	950
Portugal	2170
Spain	8570
Sweden	1920
Switzerland	1530
UK	12770
TOTAL	83600

Releases to water are most likely to occur as a result of fire-fighting operations and surface run-off. The quantity of water discharged is not known.

### Emission Factors

It is difficult to obtain concentration data for accidental fires and limited data are available specific to these types of fire. It is estimated that the concentrations of PCDD/Fs in solid material from accidental fires are likely to be within the range 584-190,000 ng I-TEQ/kg, (ETSU 1993, Carroll 1996 (quoting Christmann 1989).

Bremmer et al. (1994) quote concentration data in a lower range of 40-28,000 ng I-TEQ/kg. LUA (1997) estimate the range of PCDD/F contamination in residues to be 200-1000 ng I-TEQ/kg.

### Emission Estimates

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.1	330
Belgium	0.1	420
Denmark	0.0	220
Finland	0.04	210
France	0.5	2410
Germany	0.7	3390
Greece	0.1	430
Ireland	0.03	150
Italy	0.5	2380
Luxembourg	0.004	17
Netherlands	0.1	640
Norway	0.04	180
Portugal	0.1	410
Spain	0.3	1630
Sweden	0.1	360
Switzerland	0.1	290
UK	0.5	2430
TOTAL	3.3	15900

A best estimate of 7,950 g I-TEQ represents 21% of total estimated emissions.

### Future Changes in Release

There is unlikely to be a clear trend in the number and size of fires and therefore in the scale of release. It is possible that the wider use of smoke detectors and improved emergency services is leading to a reduction.

### Conclusions / Recommendations

The wide range in emission factors shows the uncertainty in the estimates from this significant source. The uncertainty in data on number and size of fires is also very high. Scaling the UK estimate on a per capita basis is an uncertain method but is appropriate to give a starting point.

The estimated releases for Mediterranean countries might be underestimated as these are likely to have more forest fires during summer.

### 3.12.2 Bonfires and Other Incidental Fires

#### Process Description

Like accidental fires, the poor combustion conditions and the wide variety of materials that can be burned in a bonfire can lead to the formation and release of varying quantities of a wide range of pollutants including PCDD/Fs.

The releases from a fire will depend on the materials involved, the nature and duration of the fire, and the extent of methods to control the fire.

#### Activity Data

There are limited data on the number of bonfires and other incidental fires. The number of fires in each country has been estimated from the UK estimate of 2 million per year in AEA Technology Environment (1997) by scaling relative to population.

#### Solid and Liquid Waste Arisings, Treatment and Disposal

The principal release to land is expected to be the residual material that is not fully combusted.

We estimate that on average 0.5 kg of residue is produced per bonfire and this estimate has been used for all countries.

#### Emission Factors

No data are available on concentrations in residue from these fires. It is assumed that an appropriate range of concentrations will be 75 ng I-TEQ/kg (from data on ash from a wood stove) to 42,048 ng I-TEQ/kg (from data from soot from a stove burning coal, wood and waste). These concentration data were reported by Dumler-Gradl et al. (1993 and 1995).

**Emission Estimates**

Country	Release to land	
	Min.	Max.
	g I-TEQ	g I-TEQ
Austria	0.01	5.8
Belgium	0.01	7.3
Denmark	0.007	3.7
Finland	0.007	3.7
France	0.07	42
Germany	0.1	59
Greece	0.01	7.5
Ireland	0.005	2.6
Italy	0.07	41
Luxembourg	0.001	0.3
Netherlands	0.02	11
Norway	0.006	3.1
Portugal	0.01	7.1
Spain	0.05	28
Sweden	0.01	6.3
Switzerland	0.009	5.0
UK	0.08	42
TOTAL	0.5	275

A best estimate of 140 g I-TEQ represents 0.4% of total emissions.

**Future Changes in Release**

There is unlikely to be a clear trend in the number and size of bonfires and other incidental fires. It is possible that restrictions on these fires, for example in urban areas, is leading to a reduction in release.

**Conclusions / Recommendations**

The wide range in emissions demonstrates the uncertainty in the source.

### 3.12.3 Other Sources

From a brief review of the following sources, it has been assumed that releases of PCDD/Fs from these sources are likely to be relatively low.

SNAP	Source
03 03 26	Metal reclamation from cables
03 03 14/15/17	Flat, container and other glass
03 03 20	Fine ceramic materials
04 02 01	Coke oven
09 10 09	Regeneration processes (eg. Regeneration of activated carbon)
03 02 04	Plaster furnaces
03 03 13	Asphalt concrete plants
03 03 19	Bricks and tiles
04 02 10	Shredder installations
04 03 07	Galvanising
04 06 01	Clipboard
04 06 17	Smoke curing
03 02 03	Blast furnaces cowpers
03 03 26	Green feed drying
04 02 03	Pig iron tapping
04 02 06	Basic oxygen furnace steel plant
04 03 09	Drossing facilities
	Heating of houses, gas oil
	Combustion of peat

Some emission factor data are given in LUA (1997) for some of these sources.

### 3.13 SUMMARY OF ESTIMATES OF PCDD/F RELEASES TO LAND FOR 1994 (g I-TEQ)

SNAP	Sector	Austria		Belgium		Denmark		Finland		France		Germany		Greece		Ireland		Italy		Lux		The Neth		
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	Combustion of Coal - Power Stations	0.03	1.7	0.12	6.2	0.18	9.2	0.1	5.1	0.09	4.3	1.4	71	0.38	19	0.017	0.8	0.22	11	0	0	0.22	11	
	Combustion Coal – Industry	0.002	0.5	0.005	1.3	0.001	0.3	0.003	0.9	0.02	6.3	0.1	29	0.003	0.8	0.001	0.3	0.004	1.3	0	0	0.002	0.6	
	Combustion of Wood – Industry	0.2	1.6	1.3	14	0.4	4.2	0.4	4.1	4.2	47	5.3	60	0.8	8.5	0.3	2.9	4.1	47	0.03	0.3	0.4	5.0	
0202/0203	Combustion of Coal – Domestic	0.03	3.6	0.02	3.3	0.004	0.5	0.01	0.9	0.07	9.9	0.6	79	0.01	0.9	0.002	2.6	0.0002	0.02	0.0013	0.19	0.003	0.4	
0202/0203	Combustion of Wood – Domestic	0.7	47	0.2	13	0.06	4.0	0.6	39	6.5	450	0.5	38	1.0	72	0.3	17	4.0	280	0.03	1.9	0.3	20	
30301	Sinter Plant	0.004	2.7	0.01	9.6	0	0	0.003	1.9	0.02	18	0.03	25	0	0	0	0	0.02	12	0.006	4.5	0.006	4.0	
030304	Primary Lead / Zinc Production																							
030305																								
030306	Primary Copper Production			0.05	5.0			0.04	4.4			0.10	9.9											
030307	Secondary Lead Production	3.5	24	26	176					54	370	69	470			2.1	14	46	316			5.2	35	
030308	Secondary Zinc Production	0.08	2.8	0.8	28					0.8	28	10	382			0.01	0.4	0.3	9.9					
030309	Secondary Copper Production	0.1	25	0.2	53	0	0	0.1	13	0.3	67	1.3	321	0	0	0	0	0.7	170	0	0	0.1	27	
	Primary Magnesium Production																							
	Secondary Magnesium Production																							
030310	Secondary Aluminium Production	1.7	14	0.1	1.0	0.6	4.8	1.1	8.8	8.8	74	21	170	0.3	2.9	0	0	14	110	0	0	5.8	48	
	Petroleum Processes																							
040207	Electric Furnace Steel Plant	0.1	2.8	0.3	6.1	0.4	8.8	0.3	6.3	4.6	92	3.4	71	0.6	12.5	0.2	3.7	7.8	163	0.1	1.6	1.1	22	
040301	Aluminium Production (electrolysis)	0	0	0	0	0	0	0	0	0.01	1.3	0.02	1.7	0.005	0.5	0	0	0.01	0.6	0	0	0.01	0.8	
040309	Installations for Smelting and Casting of Non-Ferrous Metals																							
	Chemical Production - PVC																							
	Chemical Production - PCE / TCE																							
040425	Pesticide Production	1.1	260	3.3	750	1.3	290	0.4	90	28	6470	9.2	2090	0	0	0.6	140	28	6450	0.1	18	3.6	830	
040526	Chemical Production - Chlorophenols																							
	Other Chemical Production																							
	Paper and Pulp Production	0.3	19	0.1	4.9	0.02	1.6	1.2	83	0.7	46	1.0	68	0.03	1.8	0	0	0.5	30	0	0	0.2	13	
040612	Cement and Lime Production	Cement	0	5.2	0	7.9	0	1.8	0	1.2	0	22	0	34	0	13	0	1.6	0	0.04	0	1.1	0	3.5
040613		Lime	0	0.8	0	1.9	0	0.1	0	0.3	0	3.2	0	8.3	0	0.5	0	0.1	0	3.7	0	0	0	0
060202	Dry Cleaning																							

NB – a blank entry indicates no data available

## Summary Table of Releases to Land

SNAP	Sector	Austria		Belgium		Denmark		Finland		France		Germany		Greece		Ireland		Italy		Lux		The Neth	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
060306	Pharmaceutical Products Manufacture																						
	Manufacture and use of dyestuffs, printing ink and coating materials																						
060312	Textiles																						
060406	Preservation of Wood																						
090201	Incineration of Domestic/Municipal Wastes	16	41	195	945	46	220	10	48	360	1300	349	1950	0	0	0	0	563	2780	28	130	102	530
090202	Incineration of Industrial Wastes	0.002	0.5	0.009	3.0			0.0009	0.3	0.02	7.1	0.04	14			0.0005	0.2					0.003	1.1
090205	Incineration of Sludges from Water Treatment				0.08		0.5				2.0		4.2		0.06		0		0.9		0.01		0.4
090207	Incineration of Hospital Wastes	0.3	0.7	3.7	10	0.9	2.4	0.4	1.0	9.2	25	3.0	7.9	1.3	3.6	0.8	2.2	8.8	24	0.04	0.1	0.09	0.2
	Waste Oil Disposal	0.04	0.2	0.05	0.2	0.02	0.1	0.02	0.1	0.3	1.2	0.4	1.7	0.05	0.2	0.02	0.07	0.3	1.2	0.002	0.01	0.07	0.3
	Incineration of Scrap Tyres																						
	Combustion of Poultry Litter																						
090400	Disposal of MSW to Landfill	11	124	3	36	3	34	15	175	60	694	90	1038	19	217	7	80	140	1664	0	5	23	264
090700	Open Burning of Agricultural Wastes (except 100300)																						
090901	Crematoria	0.02		0.04		0.04		0.03		0.35		0.39		0.07		0.02		0.36		0.003		0.08	
091002	Waste Water Treatment																						
091003	Sludge Spreading			0.2	3.2	0.6	9.1			4.6	74	6.6	105	0.04	0.7	0.03	0.5	2.7	43	0.03	0.4	1.1	17
091005	Compost Production from Waste	0.2	1.6	0.2	1.8	0.4	3.9	0.1	1.0	2.4	25	6.5	66							0	0.1	0.9	9
100300	Stubble Burning																						
100600	Pesticide Use	0.6	30	1.8	88	0.7	34	0.2	11	15	760	4.9	250	1.4	71	0.3	16	15	760	0	2.0	1.9	97
	Accidental Fires	0.1	330	0.1	420	0	220	0.04	210	0.5	2410	0.7	3390	0.1	430	0.03	150	0.5	2380	0.004	17	0.1	640
	Bonfires and Other Incidental Fires	0.01	5.8	0.01	7.3	0.007	3.7	0.007	3.7	0.07	42	0.1	59	0.01	7.5	0.005	2.6	0.07	41	0.001	0.3	0.02	11
Total		36	940	240	2600	55	850	30	710	560	13050	580	10810	25	860	12	440	840	15300	28	180	150	2590

NB – a blank entry indicates no data available

## Summary Table of Releases to Land

SNAP	Sector	Norway		Portugal		Spain		Sweden		Switz		UK		TOTAL		Total Best Estimate		
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	g I-TEQ	% total	
	Combustion of Coal - Power Stations	0	0	0.08	3.9	0.52	26	0.014	0.7	0	0	1.6	81	5.0	250	130	0.3	
	Combustion Coal - Industry	0.002	0.4	0.002	0.5	0.01	1.5	0.002	0.6	0.001	0.3	0.015	4.3	0.2	49	25	<0.1	
030101-03/06	Combustion of Wood - Industry	0.3	3.5	0.7	8.1	4.3	49	0.6	7.1	0.5	5.7	0.4	4.4	24	270	150	0.4	
0202/0203	Combustion of Coal - Domestic	0.01	0.8	0.0001	0.008	0.08	11	0	0	0.02	2.4	0.2	31	1.0	150	75	0.2	
0202/0203	Combustion of Wood - Domestic	0.5	33	1.2	82	1.4	98	1.0	67	0.2	12	0.3	17	19	1280	650	1.7	
30301	Sinter Plant	0	0	0.001	0.39	0.008	6.1	0.001	0.9	0	0	0.02	15	0.1	100	50	0.1	
030304 030305	Primary Lead / Zinc Production																	
030306	Primary Copper Production	0.01	1.4			0.06	6.4	0.04	3.5					0.3	31	3	<0.1	
030307	Secondary Lead Production			2.7	18	15	99	17	118	1.2	8.1	73	500	315	2150	1200	3.2	
030308	Secondary Zinc Production	0.6	23			0.6	21	0.02	0.7			1.8	67	15	560	290	0.8	
030309	Secondary Copper Production	0	0	0	0	0.1	33	0	0	0	0	0.2	59	3.0	770	390	1	
	Primary Magnesium Production																	
	Secondary Magnesium Production																	
030310	Secondary Aluminium Production	0.03	0.3	0.1	0.6	3.7	31	0.8	7.0	0.4	3.5	9.4	78	67	560	310	0.8	
	Petroleum Processes																	
040207	Electric Furnace Steel Plant	0.2	4.2	0.4	7.5	6.8	137	1.5	30	0.2	5.3	4.9	100	33	680	350	0.9	
040301	Aluminium Production (electrolysis)	0.03	2.9	0	0	0.01	1.2	0.004	0.4	0.001	0.08	0.01	0.8	0.1	10	1	<0.1	
040309	Installations for Smelting and Casting of Non-Ferrous Metals																	
	Chemical Production - PVC																	
	Chemical Production - PCE / TCE																	
040425	Pesticide Production	0.3	61	1.9	430	26	5930	0.6	140			8.9	2020	116	26500	13000	34	
040526	Chemical Production - Chlorophenols																	
	Other Chemical Production																	
	Paper and Pulp Production	0.3	18	0.2	11	0.3	20	1.2	78			0.4	28	6.3	420	210	0.6	
040612	Cement and Lime Production	Cement	0	1.3	0	7.7	0	25	0	0	0	4.7	0	12	0	140	70	0.2
040613		Lime			0	0.2	0	1.1	0	0			0	2.1	0	22	10	<0.1
060202	Dry Cleaning																	

NB – a blank entry indicates no data available

## Summary Table of Releases to Land

SNAP	Sector	Norway		Portugal		Spain		Sweden		Switz		UK		TOTAL		Best Estimate	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	g I-TEQ	% total
060306	Pharmaceutical Products Manufacture																
	Manufacture and use of dyestuffs, printing ink and coating materials																
060312	Textiles																
060406	Preservation of Wood																
090201	Incineration of Domestic/Municipal Wastes	91	500	0	0	27	72	62	280	94	650	514	2430	2470	11900	7200	19
090202	Incineration of Industrial Wastes	0.0001	0.02	0.0002	0.07			0.0007	0.2	0.005	1.8	0.006	2.0	0.09	30	15	< 0.1
090205	Incineration of Sludges from Water Treatment				0.03		0.4						1.0	1	100	10	< 0.1
090207	Incineration of Hospital Wastes			1.2	3.3	2.0	5.5	0.2	0.5	0.3	0.7	23	62	55	150	100	0.3
	Waste Oil Disposal	0.02	0.09	0.05	0.2	0.2	0.8	0.04	0.2	0.03	0.1	0.3	1.2	1.8	7.9	5	< 0.1
	Incineration of Scrap Tyres																
	Combustion of Poultry Litter																
090400	Disposal of MSW to Landfill	11	122	18	206	74	855	9	102	4	47	150	1708	640	7370	4000	10
090700	Open Burning of Agricultural Wastes (except 100300)																
090901	Crematoria			0.07		0.23		0.08		0.55		0.58		0.3	30	2.9	< 0.1
091002	Waste Water Treatment																
091003	Sludge Spreading			0.08	1.3	1.2	19					4.2	67	21	340	180	0.5
091005	Compost Production from Waste	0	0.3	0.8	8.4	2.7	28	0.2	1.9			0.2	1.7	14	150	80	0.2
100300	Stubble Burning																
100600	Pesticide Use			1.0	51	14	700	0.3	16			4.8	240	62	3120	1600	4.2
	Accidental Fires	0.04	180	0.1	410	0.3	1630	0.1	360	0.1	290	0.5	2430	3.3	15900	7950	21
	Bonfires and Other Incidental Fires	0.006	3.1	0.01	7.1	0.05	28	0.01	6.3	0.009	5.0	0.08	42	0.5	275	140	0.4
Total		100	960	29	1260	180	9830	95	1220	100	1040	800	10010	3870	73190	38 230	

NB – a blank entry indicates no data available

## 4. Conclusions and Recommendations

### 4.1 RELEASES TO LAND

The following table shows the sources with a high potential for release to land. The 'best estimates' have generally been taken as the mid-point of the min-max estimates.

Source	Release to land (best estimate) g I-TEQ (1994)	% of Total Release	Uncertainty (High/ Medium/ Low)	Likely trends in release from 1994
Pesticide Production	13000	34 %	High	-
Accidental Fires	7950	21 %	High	?
Incineration of MSW	7200	19 %	Medium	-
Disposal of MSW to Landfill	4000	10 %	High	?
Pesticide Use	1600	4.2 %	High	-
Secondary Lead Production	1200	3.2 %	Medium	?
Combustion of Wood - Domestic	650	1.7 %	High	?
Secondary Copper Production	390	1.0 %	Medium	?
Electric Furnace Steel Plant	350	0.9 %	Medium	?
Secondary Aluminium Production	310	0.8 %	Medium	?

The releases from 3 of the 5 highest emitting sources are likely to be decreasing. Emissions from pesticide production and use will be decreasing because of improved control and reductions in the use of production of chlorinated pesticides and intermediates. Emissions from incineration of MSW are decreasing because of improved combustion and control technology.

The estimated releases from 4 of the 5 highest emitting sources have a high uncertainty. There is a particularly high uncertainty regarding the estimated releases from accidental fires and from the disposal of MSW to landfill. The estimated releases to land as a result of accidental fires range from 3 to 15,900 g I-TEQ. This demonstrates the very high uncertainty in this release.

Releases to land from non-ferrous metal processes greatly depend on the proportion of dust from gas-cleaning technology that is recycled into the process instead of being disposed to land.

The disposal of sewage sludge to land has an estimated total release of PCDD/F of 180 g I-TEQ. It is a significant source for which releases to land have the potential to increase, because of improvements in waste water treatment and reduction in sewage sludge disposal to sea. Releases are likely to continue to be much lower than those from most of the sources in the above table, but sludge disposal presents a significant route for PCDD/Fs to enter food chains.

#### **Recommendations**

- ***The results indicate that the highest release to land is from pesticide production and that this source should be the highest priority for further work to improve the whole inventory.***

- *To improve the inventory of PCDD/F releases to land it is not just measurements of concentrations that are required. Further research is needed on details of activity and processes – this should involve contacting the industry trade associations and other relevant organisations in individual countries. For example, work to investigate the details of the extent of recycling of dusts at non-ferrous metal plant in different countries would greatly improve the reliability of these estimated releases.*

## 4.2 RELEASES TO WATER

There are far less data available to enable releases to water to be estimated and for most sources an indication of whether the source is likely to release a high, medium or low emission to water has been given, rather than an estimate of the release quantified.

Source	Potential release to land (min. – max.) g I-TEQ (1994)	Likely trends in release from 1994	Additional notes
Pesticide Production	High (no data)	-	
Chemical Production	High (no data)	-	Estimated release from PVC processes in Germany 0.15-51 g I-TEQ
Accidental Fires	High (no data)	?	
Disposal of MSW to Landfill	High (no data)	?	
Pesticide Use	High (no data)	-	
Paper & Pulp Production	Medium (8 – 27)	-	
Incineration	Medium (0.3 – 16)	-	Estimated release for industrial waste incineration only
Waste oil disposal	Medium (1.8 – 7.9)	?	
Textile treatment	Medium (no data)	?	
Non-ferrous metal production	Medium (no data)	?	
Iron & steel industry	Medium (no data)	?	
Sinter plant	Medium (no data)	?	
Waste water treatment	Low (no data)	-	

Whereas the release to land from accidental fires is difficult to control, there is potential for control of releases to water which occur through fire fighting practices.

As mentioned, the releases from pesticide and chemical production and use are likely to be decreasing because of the reduction in chlorinated chemical use. Releases from paper and pulp production have decreased with the phase out in chlorine bleaching. Releases from industrial processes (eg metals) will depend on the extent of use of scrubbers and the quality of effluent treatment. As with the treatment of municipal waste water, the PCDD/Fs from industrial waste waters are likely to concentrate in the sludge.

### **Recommendations**

- *As much of the PCDD/F contamination in waste waters is likely to be removed at treatment plant, and the PCDD/Fs therefore concentrate in the sludge, further work should focus on investigating the extent of waste water treatment and then on the concentration of PCDD/Fs in sludge as well as the sludge disposal practices.*
- *However, releases to water from chemical and pesticide production and use, from accidental fires and from MSW disposal to landfill, should be researched further through appropriate measurements and identification of more reliable activity data.*

### 4.3 UNCERTAINTY

There are very limited quantities of data available relating to PCDD/F releases to land and water and the estimates in this inventory are therefore very uncertain. For all the estimated releases there are significant uncertainties with one or more of the following :

- the activity / production data;
- the quantity of solid or liquid waste arising;
- the extent of control of releases;
- the concentration of PCDD/Fs in solid and liquid wastes.

These uncertainties are demonstrated by the very wide ranges in estimated emissions for sources where sufficient data were available to make estimates.

There is a particular lack of information on releases to water and, therefore, few quantitative estimates have been made for this medium.

However, this inventory of releases of PCDD/F to land and water, together with the inventory of releases of PCDD/F to air (LUA 1997), is the first integrated inventory for releases of any POP in Europe. It represents a good starting point for improvement of the inventory and ultimately for appropriate development of future policy to further reduce or control releases of PCDD/Fs into the environment.

#### ***Recommendation :***

- ***As the inventory of releases to land and water is too uncertain to act as a reliable indicator in the development of further appropriate policy for emission reduction and control, it is recommended that further research and data collection are carried out to verify the scale of releases from the source sectors which have a high potential for release. These sectors are :***
  - ***Chemical production and use***
  - ***Pesticide production and use***
  - ***Accidental fires***
  - ***Disposal of MSW to landfill***
  - ***Non-ferrous metal industry***

## 4.4 GENERAL CONCLUSIONS AND RECOMMENDATIONS

Estimated releases to land from known sources for which estimates have been made are significantly higher than releases to air, as shown below :

	Release (g I-TEQ)		
	Min.	Max.	Best estimate
Land	3,850	72,600	38,200
Air <sup>(1)</sup>	1,320	20,000	3,270 – 5750 <sup>(2)</sup>

(1) LUA 1997. (2) The best estimate of 3270 g I-TEQ is from available national inventories, and 5750 is a re-estimate by LUA for all countries.

While not quantified, total releases to water are likely to be significantly less than both releases to land and to air. This is because waste water treatment is likely to concentrate the PCDD/Fs in sludge. However, the extent of waste water treatment is likely to vary between sectors and between countries. Reduction of releases to water is still important as this is a key exposure route.

This default inventory for PCDD/F releases to land and water in 1994 has been built up from the main information sources on releases to land and water. At this stage it is mainly based on information which has been assembled for previous studies for the UK, Germany, Sweden and The Netherlands. Though this study has identified the majority of relevant published reports on releases of PCDD/Fs, there is likely to be much measurement data that has not been published.

The draft of this report was distributed to various international experts on PCDD/F emissions within the countries covered by the study. These experts checked the inventory and provided country-specific information where available. The draft inventory has therefore been improved since it was distributed in March 1999.

Some of the uncertainty in the inventory relates to the likelihood that techniques to measure PCDD/F concentrations do not always give comparable results.

### **Recommendations**

- ***Further work to improve the inventory should concentrate on a balance between sources with a high potential emission (eg pesticide production, MSW incineration) and sources which are important in terms of environmental impact/exposure (eg pesticide use, sludge disposal).***
- ***Despite the likelihood of releases to water being less than to land and air, this release route represents a key exposure route and improvements to the inventory are required so that the scale of releases can be assessed in different countries.***
- ***It is recommended that the EU encourages the measurement and reporting of PCDD/F releases to the environment so that the inventory can be updated with more reliable data.***
- ***As the integrated inventory is improved, it is important that the network of experts around Europe is maintained so that new information is taken into account. The large existing network within the UNECE Task Force on Emission Inventories provides an excellent base for raising awareness of new data.***

- *The EU is also encouraged to continue the standardisation of sampling and analytical techniques. This will improve the comparability of data.*

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## 6. Glossary

DETR	Department of Environment, Transport and the Regions, UK
EDC	Ethylene dichloride
ESP	Electrostatic Precipitator
FBA	Furnace Bottom Ash
HCB	Hexachlorobenzene
IPPC	Integrated Pollution Prevention and Control
LUA	North Rhine-Westphalia State Environment Agency (LUA NRW)
MSW	Municipal Solid Waste
PCB	Polychlorinated Biphenyls
PCDD/F	Polychlorinated dibenzo- <i>p</i> -dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) - in this report these compounds are referred to collectively as PCDD/Fs.
PCP	Pentachlorophenol
PFA	Pulverised Fuel Ash
POPs	Persistent Organic Pollutants
PVC	Polyvinyl chloride
TEF	Toxic equivalent factor
TEQ	Toxic Equivalent (I-TEQ is International Toxic Equivalent)
UNECE	United Nations Economic Commission for Europe
US EPA	United States Environmental Protection Agency
VCM	Vinyl Chloride Monomer
WHO	World Health Organisation

# Appendix 1

## I-TEQ

### NATO/CCMS International Toxic Equivalent (I-TEQ) scheme

Compound	TEF
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	0.5
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.001
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.001

# Appendix 2

## Potentially Contaminated Pesticides

The following pesticides have been identified by the US EPA to have the potential to be contaminated with PCDD/Fs if synthesised under conditions that favour PCDD/F formation (US EPA (1994):

0-(4-Bromo-2,5-dichlorophenyl) 0,0-dimethyl phosphorothioate  
 Dimethylamine 2,3,5-triiodobenzoate  
 Neburon  
 Crufomate  
 4-(2-Methyl-4-chlorophenoxy)butyric acid  
 Sodium 4-(2-methyl-4-chlorophenoxy)butyrate  
 4-Chlorophenoxyacetic acid  
 Chloroxuron  
 Dichlobenil  
 3',4'-Dichloropropionanilide  
 Dichlofenthion ( 0-(2,4-Dichloropheny) 0,0-diethyl phosphorothioate)  
 Dichloro diphenyl trichloroethane  
 Dichlone ( 2,3-dichloro-1,4-naphthoquinone)  
 Ammonium chloramben ( 3-amino-2,5-dichlorobenzoic acid)  
 Sodium chloramben ( 3-amino-2,5-dichlorobenzoic acid)  
 Sodium 2-(2,4-dichlorophenoxy)ethyl sulfate  
 2,6-Dichloro-4-nitroaniline  
 2-(2-Methyl-4-chlorophenoxy)propionic acid  
 Potassium 2-(2-methyl-4-chlorophenoxy)propionate  
 Diethanolamine 2-(2-methyl-4-chlorophenoxy)propionate  
 Dimethylamine 2-(2-methyl-4-chlorophenoxy)propionate  
 Isooctyl 2-(2-methyl-4-chlorophenoxy)propionate  
 Dicapthon (0-(2-chloro-4-nitrophenyl) 0,0-dimethyl phosphorothionate)  
 Monuron trichloroacetate (3-(4-chlorophenyl)-1,1-dimethylurea trichloroacetate)  
 Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea  
 Metobomuron (3-(p-bromophenyl)-1-methoxy-1-methylurea  
 0,0-Dimethyl 0-p-nitrophenyl phosphorothioate  
 5-Chloro-2-(2,4-dichlorophenoxy)phenol  
 Dichlorophene  
 Sodium 2,2'-methylenebis(4-chlorophenyl)  
 1,2,4,5-Tetrachloro-3-nitrobenzene  
 Parathion (0,0-diethyl 0-p-nitrophenyl phosphorothioate)  
 Carbophenothion (S-(((p-chlorophenyl)thio)methyl) 0,0-diethyl phosphorodithioate)  
 Ronnel (0,0-dimethyl 0-(2,4,5-trichlorophenyl) phosphorothioate)  
 Sodium 5-chloro-2-(4-chloro-2-(3-(3,4-dichlorophenyl)ureido)phenoxy)benzenesul fonate  
 Orthodichlorobenzene  
 Paradichlorobenzene  
 2-Benzyl-4-chlorophenol  
 Potassium 2-benzyl-4-chlorophenylate  
 Sodium 2-benzyl-4-chlorophenylate  
 2-Chlorophenol  
 2-Chloro-4-phenylphenol

## Potentially Contaminated Pesticides

Potassium 2-chloro-4-phenylphenate  
4-Chloro-2-phenylphenol  
4-Chloro-2-phenylphenol, potassium salt  
6-Chloro-2-phenylphenol  
6-Chloro-2-phenylphenol, potassium salt  
4-Chloro-2-phenylphenol, sodium salt  
6-Chloro-2-phenylphenol, sodium salt  
4 and 6-Chloro-2-phenylphenol, diethanolamine salt  
2-Chloro-4-phenylphenol, sodium salt  
4-Chloro-2-cyclopentylphenol  
2,2'-Thiobis(4-chloro-6-methylphenol)  
2,2'-Thiobis(4-chlorophenol)  
4-Chloro-2-cyclopentylphenol, potassium salt  
4-Chloro-2-cyclopentylphenol, sodium salt  
Chlorophacinone  
Alkyl\* dimethyl benzyl ammonium chloride \*(50% C14, 40% C12, 10% C16)  
Alkyl\* dimethyl 3,4-dichlorobenzyl ammonium chloride \*(61% C12, 23% C14, 11% C16, 5% C18)  
2-Aminoethanol salt of 2',5-dichloro-4'-nitrosalicylanilide  
5-Chlorosalicylanilide  
Tetradifon (4-chlorophenyl 2,4,5-trichlorophenyl sulfone)  
Chloranil (tetrachloro-p-benzoquinone)  
Endosulfan (hexachlorohexahydromethano-2,4,3-benzodioxathiepin-3-oxide)  
6-Chlorothymol  
2,4-Dichloro-6-(o-chloroanilino)-s-triazine  
Chlorothalonil (tetrachloroisophthalonitrile)  
Chlorfenvinphos  
0-(2-Chloro-1-(2,5-dichlorophenyl)vinyl) 0,0-diethyl phosphorothioate  
4-Chloro-3,5-xlenol  
3-(2-Methylpiperidino)propyl 3,4-dichlorobenzoate  
p-Chlorophenyl diiodomethyl sulfone  
Metribuzin  
Bifenox (methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate)  
Methazole (2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione)  
Diflubenzuron (N-(((4-chlorophenyl)amino)carbonyl)-2,6-difluorobenzamide)  
Oxadiazon (2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- delta 2-1,3,4-oxadiazoline-5-one)  
Fenvalerate  
N- 2-Chloro-4-trifluoromethyl)phenyl-DL-valine ( $\pm$ )-cyano(3-phenoxy-phenyl)methyl ester  
3-(3,5-Dichlorophenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide(9CA)  
1-(4-Chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4-triazol-1-yl)-2-butanone  
Diclofop – methyl (methyl 2-(4-(2,4-dichlorophenoxy)phenoxy)propanoate)  
0-(4-Bromo-2-chlorophenyl)-0-ethyl S-propyl phosphorothioate  
Oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene)  
1-(2-(2,4-Dichlorophenyl)-2-(2-propenyloxy)-1H-imidazole  
N-Methyl-2,4-dinitro-n-(2,4,6-tribromophenyl)-6-(trifluoromethyl)benzenamine  
3-(3,5-Dichlorophenyl)-5-ethenyl-5-methyl-2,4-oxazolidinedione (9CA)  
Potassium 1-(p-chlorophenyl)-1,4-dihydro-6-methyl-4-oxo-pyridazine-3-carboxylate  
2-(3,5-Dichlorophenyl)-2-(2,2,2-trichloroethyl) oxirane  
Paclbutrazol  
Linalool  
Fenarimol (a-(2-chlorophenyl)-a-(4-chlorophenyl)-5-pyrimidinemethanol)