Environmental RTDI Programme 2000–2006

Inventory of Dioxin and Furan Emissions to Air, Land and Water in Ireland for 2000 and 2010 (2000–DS–2–M1)

Synthesis Report

(Please note that the main report relating to this project can be downloaded from the Research and Development webpages of the EPA website www.epa.ie)

Prepared for the Environmental Protection Agency

by

URS Dames & Moore, Dublin

Authors:

Fergus Hayes and Ian Marnane

ENVIRONMENTAL PROTECTION AGENCY

An Ghníomhaireacht um Chaomhnú Comhshaoil

PO Box 3000, Johnstown Castle, Co. Wexford, Ireland

Telephone: +353-53-60600 Fax: +353-53-60699

Email: info@epa.ie Website: www.epa.ie

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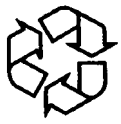

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Details of Project Partners

Fergus Hayes & Ian Marnane
URS Dames & Moore
4th Floor
Iveagh Court
6–8 Harcourt Road
Dublin 2
Telephone: +353 1 4155100
Fax: +353 1 4155101

E-mail: fergus_hayes@urscorp.com
Website: http://www.urscorp.com/europe

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1 Introduction

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), commonly referred to as 'dioxins' have received significant attention in the press in recent years, mainly due to public concern over potential dioxin emissions from municipal waste incineration as proposed by local and regional authorities in their Waste Management Plans. Several of these Waste Management Plans have recommended thermal treatment as a means of waste disposal, which may result in up to 1.5 million tonnes per annum being treated by this method within the next 10–15 years, if the favoured scenario in each of the Waste Management Plans is adopted. There is currently no mass thermal treatment of municipal solid waste in Ireland.

No detailed dioxin emission inventory currently exists for Ireland, although estimates of dioxin emissions have been made in recent EU Inventories and these data are included in the main report. This emission inventory is therefore the first carried out in Ireland.

It should be noted that PCDDs and PCDFs are referred to collectively throughout this report as '**dioxins**'. The standard unit of measurement for dioxins is grams toxic equivalent (g TEQ). Toxicity equivalency factors have been developed for individual PCDD/PCDF congeners allowing the quantification of complex congener mixtures as a single numerical descriptor.

A number of polychlorinated biphenyls (PCBs) are also reported to exhibit dioxin-like behaviour. However, very little information is currently available on emission factors for dioxin-like PCBs, and consequently dioxin-like PCB emissions are not included in this inventory.

1.1 Scope and Objectives

The main objectives of the study can be summarised as follows:

- Identify the principal sources of dioxin emissions to air, land and water in Ireland;
- Quantify these emissions on the basis of reported information;
- Prepare an inventory of dioxin emissions for the calendar year 2000;
- Consider the likely future impact on the inventory resulting from the establishment of thermal treatment and other industrial plants;
- Compare the current (2000) and future (2010) dioxin emissions to permit the potential impact of new dioxin sources, in particular thermal waste treatment plants, to be estimated.

This report provides an estimate of dioxin emissions to air, land and water in the Republic of Ireland during the calendar year 2000, and also an estimate of emissions in 2010. A wide variety of sources of dioxin emissions have been identified, from heavy industry to domestic activity. It was considered that such a project could be carried out as a desk study; hence no dioxin monitoring was carried out, although some dioxin emissions data were available from IPC-licensed facilities which are required by the EPA to monitor dioxin emissions on an annual or biannual basis. Dioxin information was also available from other facilities that have voluntarily carried out dioxin monitoring.

Over the last number of years several countries have published dioxin emission inventories, identifying possible sources of dioxin emissions and estimating emissions for each of these sources. These estimates have been used to derive 'emission factors' for dioxins, i.e. the expected mass emission of dioxins to the environment per unit of industrial activity – e.g. grams of dioxins per tonne of production. Emission factors developed by individual countries have been tentatively used to estimate emissions in other countries, where measured data may not be available. It was anticipated that such national emission factors would be used during this project to estimate dioxin emissions in Ireland, where measured emissions data were not available.

However, in early 2001, the United Nations Environment Programme (UNEP) issued a draft "Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases" (UNEP Chemicals, 2001). The Toolkit has been developed by UNEP to address the lack of standardisation internationally with regard to the national

and regional inventories, and hence to facilitate the development of consistent and comparable data.

This inventory has been prepared with the aid of the methodology and suggested emission factors contained in the UNEP Toolkit. The approach and methodology adopted are described in Section 2 of this summary report.

Because dioxin emissions data were not available for the majority of the identified sources, a degree of uncertainty must be associated with the results. While the relative importance of the individual categories can be identified from the study, the actual emissions estimate from each category must be carefully interpreted.

This inventory addresses only direct releases and transfers of dioxins to air, water and land. Releases to land include the deposit of waste in landfills. The inventory has not attempted to separate land emissions data into (a) those materials that are spread or deposited on land and subject to dispersion and dilution by natural processes and (b) those wastes which contain dioxins that are disposed of in landfills. In some cases the distinction is clear, such as in the case of dioxin-containing incinerator ash, the disposal of which will take place only under controlled conditions at licensed facilities, thereby limiting any potential release of dioxins to the environment. It should be noted that for the purposes of the projections for 2010 in the inventory, it is assumed that 100% of sewage sludge will be landspread and that dioxin-containing incinerator ash will be disposed of to controlled landfill. Releases to products or contained in residues that are disposed of outside Ireland are not considered in this inventory.

2 Methodology

2.1 Introduction

The preparation of this emission inventory was based on the United Nations Environment Programme (UNEP), Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP Chemicals, 2001), which was released to the EPA in draft form in March 2001.

This toolkit was developed to assist countries in identifying sources and estimating releases of dioxins and furans. A further aim of the toolkit is to provide a common approach to the preparation of dioxin and furan emission inventories, allowing a representative comparison of inventories prepared in different countries. Current inventories are generally not directly comparable, as there was previously no internationally established listing of dioxin emission sources.

The toolkit is not designed to provide an exact estimate of emissions for each country, as general emission factors are employed. It is particularly useful as a screening tool to make initial estimates of dioxin and furan emissions where emissions data do not exist, or are limited.

In this inventory of dioxin and furan emissions, **where emissions data are available, these data have been used to improve the accuracy of the inventory**. The generic emission factors have been used for all other categories, particularly for estimating emissions to land and water, where information in Ireland is not available.

2.2 Inventory Preparation Methodology

There are five steps included in the application of the UNEP toolkit, namely:

1. Apply screening matrix to identify main source categories.
2. Check sub-categories to identify existing activities and sources in the country[1].
3. Gather detailed information on the processes and classify processes into similar groups by applying the standard questionnaire.
4. Quantify identified sources with default/measured emission factors.
5. Apply nationwide to establish a full inventory, and report results using guidance given in the standard format.

The Toolkit methodology was not adhered to strictly during this project for a number of reasons. As the toolkit was received several months after the beginning of the project, much of the screening work had already been carried out to identify potential sources of dioxin emission in Ireland. Much work had also been carried out on gathering information on available dioxin and furan emissions data, and gathering activity statistics that can be used with default emission factors in the absence of measured data. Hence, the majority of steps 1, 2 and 3, as detailed above, had already been completed upon receipt of the toolkit.

As the toolkit categories were developed specifically for sources of dioxin emissions to air, land and water it was decided to use this categorisation scheme in the current inventory. Previous inventories had employed generic categorisation schemes related to categories of industrial emissions. The default emission factors included in the toolkit were also employed in the inventory. However, the toolkit emission factors were compared to other available emission factors to assess their applicability to Irish conditions – see Table 2.2.

Information was requested from selected industrial facilities on activity and emission statistics for 2000. This required intensive and time-consuming follow-up contact with many of the facilities to ensure a satisfactory response. As the information was requested on a voluntary basis, this relied heavily on the co-operation of the individual facilities. Complete data were not received from all of the facilities contacted, though responses were generally satisfactory. Where such information was made available, revised emission estimates were calculated based on these data to allow comparison with the toolkit-based estimates. As these revised estimates based on measured data were considered more representative than the toolkit-based estimates, these emissions were employed in the final total estimated dioxin emissions for 2000.

1. Table 2.1 provides an overview of the UNEP main source and sub-categories.

Table 2.1. UNEP Main source categories and sub-categories.

No.	Description	No.	Description
1	**Waste Incineration**	**4**	**Production of Mineral Products**
1a	Municipal solid waste	4a	Cement kilns
1b	Hazardous waste	4b	Lime
1c	Medical waste	4c	Brick
1d	Light weight aggregate	4d	Glass
1e	Sewage sludge	4e	Ceramics
1f	Waste wood combustion	4f	Asphalt mixing
1g	Animal carcasses		
		5	**Transport**
2	**Ferrous and Non-ferrous Metals**	5a	4-stroke engines
2a	Iron ore sintering	5b	2-stroke engines
2b	Coke production	5c	Diesel engines
2c	Steel production	5d	Heavy fuel oil engines (ships, etc.)
2d	Copper production		
2e	Aluminium production	**6**	**Uncontrolled Combustion Processes**
2f	Lead production	6a	Fires/burning – biomass
2g	Zinc production	6b	Fires – waste burning, landfill fires, accidental fires
2h	Brass production		
2i	Magnesium production	**7**	**Production of Chemicals and Consumer Goods**
2j	Shredder (e.g. automobile)	7a	Pulp mills
2k	Wire reclamation by combustion	7b	Paper mills
		7c	Chemical industry
3	**Power Generation and Heating**	7d	Petroleum industry (refining)
3a	Fossil fuel power plants (coal, oil, gas, peat, co-combustion)	7e	Textile plants
3b	Biomass power plants	7f	Leather plants
3c	Landfill, biogas combustion		
3d	Household heating and cooking (biomass)	**8**	**Miscellaneous**
3e	Domestic heating (coal, oil, gas, peat)	8a	Drying of biomass
		8b	Crematoria
4	**Production of Mineral Products**	8c	Smoke houses
4a	Cement kilns	8d	Dry-cleaning residues
4b	Lime	8e	Tobacco smoking
4c	Brick		
4d	Glass	**9**	**Disposal**
4e	Ceramics	9a	Landfills and waste dumps
4f	Asphalt mixing	9b	Sewage/sewage treatment
		9c	Composting
		9d	Open water dumping
		9e	Waste oil disposal

Table 2.2. Ranges of emission factors employed in various inventories for a sample of different categories

Category	1*	2*	3*	4*	5*
Municipal waste incineration (µg TEQ/t)	0.5–3,500	0.8–231	NA	1.5–90.0	0.025 – 118
Iron and steel production (µg TEQ/t)	0.01–10.00	0.7–10	0.16	0.2–5.0	1.15
Coal-fired boilers (power generation) (µg TEQ/t)	10.00	0.04–4.8	5.7–9.3	NA	0.087
Cement production (µg TEQ/t)	0.15–5.00	0.02–1.08	0.20 – 1.08	0.15–5.0	0.29
Crematoria (µg TEQ/cremation)	0.40–90.00	2.4–80.0	0.5–28.0	3.0–40.0	0.5
Uncontrolled domestic waste burning (µg TEQ/t)	300	NA	1–300	75.5–3,230	140

*1: UNEP Toolkit Emission Factors (used in this study).
*2: A Review of Dioxin Emissions in the UK (HMIP, 1995).
*3: New Zealand Inventory (Buckland *et al*., 2000).
*4: European Dioxin Inventory (LUA, 1997).
*5: Draft Inventory of Sources of Dioxins in the United States (USEPA, 1998).

Prior to completion of the report, relevant excerpts from it were sent to facilities in the following industrial sectors that had provided information for the purposes of the inventory (25–30 facilities were contacted):

- Waste incineration;
- Ferrous and non-ferrous metal production;
- Power generation;
- Mineral products;
- Wood processing.

The facilities were asked to respond with any specific comments on the inventory for their given industry sector. Less than ten responses were received, mainly requesting some further information and clarification. No significant changes were requested by the facilities as a result of the consultation exercise.

UNEP recommend that the inventory should include the following information:

- A listing of all process sub-categories that are carried out in the country.
- The activity statistic for each category and a short description of how this was found or estimated.
- The range of emission factors by process sub-category and the overall range of potential emissions (mass flow multiplied by low- and high-end emission factors).
- More precise country estimates, where available, shown separately from the potential range of releases made using the toolkit default emission factors, along with an explanation of how the result was achieved.
- Potential ranges shown as a bar chart for each source based on default emission factors.
- In-country estimates shown as points or ranges overlaid on the potential range.

In the main report we have presented the following information for each sub-category that is applicable to Ireland:

- A brief description of the sub-category as it applies to Ireland.
- Available dioxin emission and sub-category activity data.
- An estimate of dioxin emissions in 2000 based on the Toolkit methodology and emission factors.
- A revised dioxin emission estimate based on dioxin measurement data where available.

For 2010, similar data are presented, with a presentation of estimated activity data and an estimate of dioxin emissions in 2010 based on emission factors from the UNEP toolkit or on emission factors generated from Irish dioxin measurements as employed in the 2000 inventory.

2.3 Format of Main Emission Inventory Report

The following sections detail estimated emissions for each of the categories as listed in Table 2.1. If the sector is not relevant in an Irish context, this is stated and no further information on dioxin emissions from such sources is presented. Those interested in such sectors should refer to the UNEP Toolkit. For all relevant sectors, a brief description of the category is presented, and any other relevant information is also detailed.

Secondly, details are discussed of activity data available for the sector, which can be used to generate dioxin emission estimates using available emission factors. In some sectors, the available activity statistics must be manipulated to generate statistics compatible with the available emission factor units. For example, in assessing the mass of wood burned in forest fires, available Irish data on the area of forest affected were employed with internationally defined mass/hectare factors to generate the total mass of wood consumed in forest fires for 2000.

Thirdly, the activity statistics are employed with the UNEP toolkit emission factors to generate a dioxin emission estimate. A range of emission estimates is normally provided, with a low, high and best estimate (BE) emission presented. The range may be based on a range of emission factors given in the toolkit or on a margin of error based on estimated variances in approximate activity statistics that have been provided or calculated.

If dioxin-monitoring data are available for a particular sector, these may be used to help generate a revised emission estimate. However, as only a small number of measurements are generally available for a given sector, the toolkit factors may still be used to aid in the generation of a potential emission range. Using the activity data and the dioxin emission data for a given sector allows calculation of a revised emission factor that can be compared to the toolkit factors. As little dioxin monitoring data are available for the identified sectors in Ireland, many of the sectors do not include a revised estimate. Where a revised estimate has been generated, this value, rather than the simple toolkit-based emission estimate is used in calculating total dioxin emissions to a given media as presented in the summary tables.

3 Summary Emissions Inventory

The following tables (Tables 3.1 and 3.2) and figures (Figs. 3.1–3.4) provide a summary emission inventory for 2000 and 2010, including the percentage of emissions from a given sector to a given media (best estimate emissions to water for 2000 and 2010 are not plotted due to the small quantities of data). More detailed tables can be found in the appendix of the main report which is available in electronic format through the EPA website (http://www.epa.ie).

For both 2000 and 2010, emissions to water are estimated to be lowest, with emissions to land and landfill being quantitatively the most important receptor of dioxin emissions. It should be noted that emissions to land include the disposal of waste to landfill under controlled conditions at licensed facilities. Any such emissions are contained and are not dispersed in the environment. Emissions to air (the pathway through which humans are most likely to be exposed to dioxins) are of the same order of magnitude as emissions to land.

Ireland-specific dioxin monitoring data were available for a small number of sources, as follows:

- hazardous waste incinerators;
- some iron and steel and aluminium producers;
- large facilities using wood as a fuel;
- electricity-generating stations.

For categories where dioxin emissions data are available a revised estimate is calculated. This revised estimate is used in preference to the Toolkit-based estimate in calculating total emissions to a given media as presented in Tables 3.1 and 3.2.

For other emission sources, the UNEP Toolkit emission factors were employed to estimate emissions.

For the majority of sources of dioxin emission, activity statistics were readily available. For some sources, the activity statistics were based on available activity statistics for previous years activities (as 2000 activity data were not available), but were considered broadly representative of 2000 emissions.

For other sources, such as the quantity of domestic waste burned, the mass of wood burned in forest fires, or the quantity of material landfilled over the last 50 years, extrapolation from available data was employed. For 2010, all activity statistics were estimated, though official predictions for some of the identified dioxin sources were available through government publications.

For both the 2000 and 2010 inventories, the majority of emissions are identified as coming from one individual sector, namely uncontrolled combustion processes. The activity statistics for this sector are uncertain, but are believed to be a conservative estimate of the potential emissions from this sector.

Table 3.1. Summary of emissions to air, land and water in Ireland for 2000 (main categories).*

	Air		Water		Land	
	Best estimate g/annum	**% Contribution to total air emissions**	**Best estimate g/annum**	**% Contribution to total water emissions**	**Best estimate g/annum**	**% Contribution to total land emissions**
Waste Incineration	0.0068	0.02	0.0034	0.16	0.0034	0.01
Ferrous and Non-ferrous Metal Production	2.0942	6.15	0.0000	0.00	1.6218	2.85
Power Generation and Heating	3.3203	9.76	0.0000	0.00	8.1066	14.22
Mineral Products	1.9969	5.87	0.0000	0.00	0.0000	0.00
Transport	0.9714	2.85	0.0000	0.00	0.0000	0.00
Uncontrolled Combustion Processes	25.6363	75.34	0.0000	0.00	42.1822	74.01
Production and Use of Chemical and Consumer Goods	0.0000	0.00	0.0000	0.00	0.9013	1.58
Miscellaneous	0.0015	0.00	0.0000	0.00	0.0047	0.01
Disposal/Landfill	0.0000	0.00	2.1762	99.84	4.1755**	7.33
Total	34.0273	100.00	2.1796	100.00	56.9953	100.00

*Data reported in grams; however, estimated emissions from some sectors are small, hence the data are reported to four decimal places to allow inclusion of this data. This does not imply an accuracy in the best estimate emissions to four decimal places. **This figure is principally composed of contributions from sewage sludge landspreading and disposal to landfill. In 2000, 40% of sewage sludge was landspread and 51% was disposed of in landfills.

Table 3.2. Summary of emissions to air, land and water in Ireland for 2010.*

	Air		Water		Land	
	Best estimate g/annum	**% Contribution to total air emissions**	**Best estimate g/annum**	**% Contribution to total water emissions**	**Best estimate g/annum**	**% Contribution to total land emissions**
Waste Incineration	0.5494	1.81	0.0060	1.83	18.0060**	22.82
Ferrous and Non-ferrous Metal Production	0.0509	0.17	0.0000	0.00	1.5705	1.99
Power Generation and Heating	2.4243	8.00	0.0000	0.00	3.9605	5.02
Mineral Products	0.6119	2.02	0.0000	0.00	0.0000	0.00
Transport	1.1697	3.86	0.0000	0.00	0.0000	0.00
Uncontrolled Combustion Processes	25.4898	84.13	0.0000	0.00	41.8518	53.05
Production and Use of Chemical and Consumer Goods	0.0000	0.00	0.0000	0.00	0.0000	0.00
Miscellaneous	0.0018	0.01	0.0000	0.00	0.0121	0.02
Disposal/Landfill	0.0000	0.00	0.3185	98.17	13.4883***	17.10
Total	30.2980	100.00	0.3245	100.00	78.8890	100.00

*Data reported in grams; however, estimated emissions from some sectors are small, hence the data are reported to four decimal places to allow inclusion of this data. This does not imply an accuracy in the best estimate emissions to four decimal places. **Incinerator bottom ash and flyash to be landfilled under controlled conditions at licensed facilities thereby limiting any potential release of dioxins to the environment. The term ‘Land emissions’ in this case means the deposit of waste in landfills. ***This figure is principally composed of contributions from sewage sludge management, in 2010, assumed to be 100% landspreading.

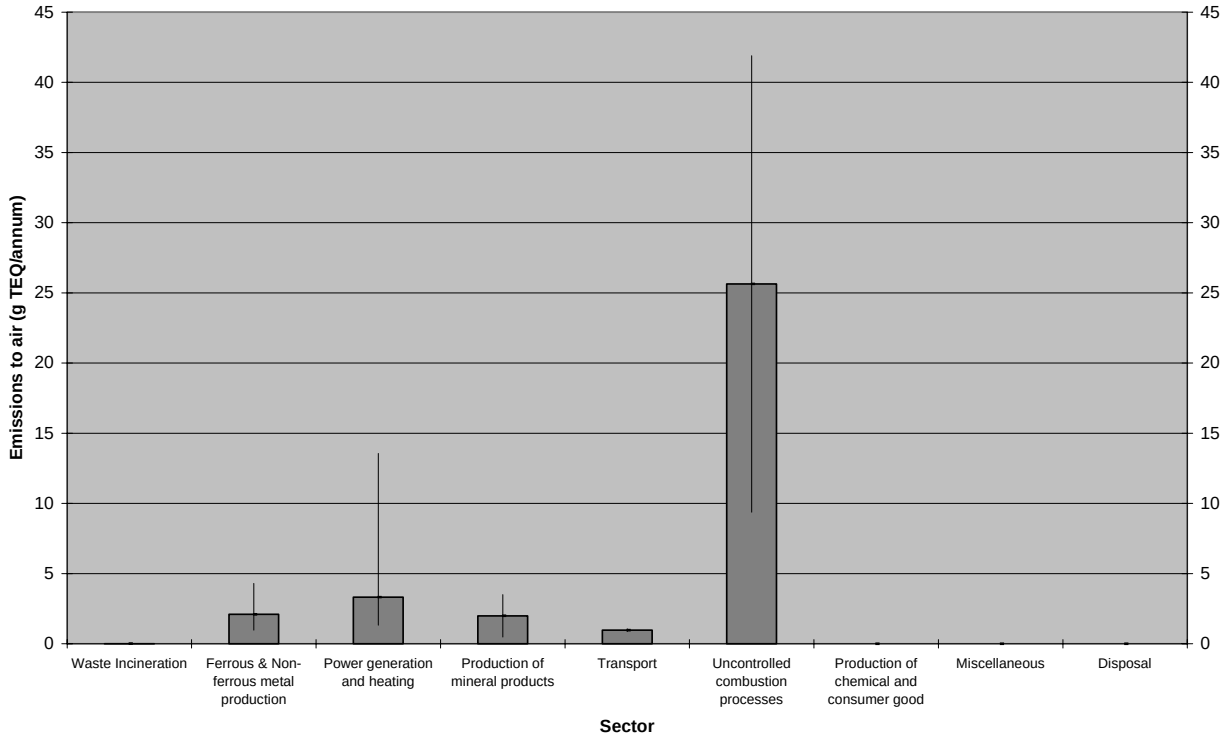

Figure 3.1. Best estimate emissions to air – 2000 (range also shown).

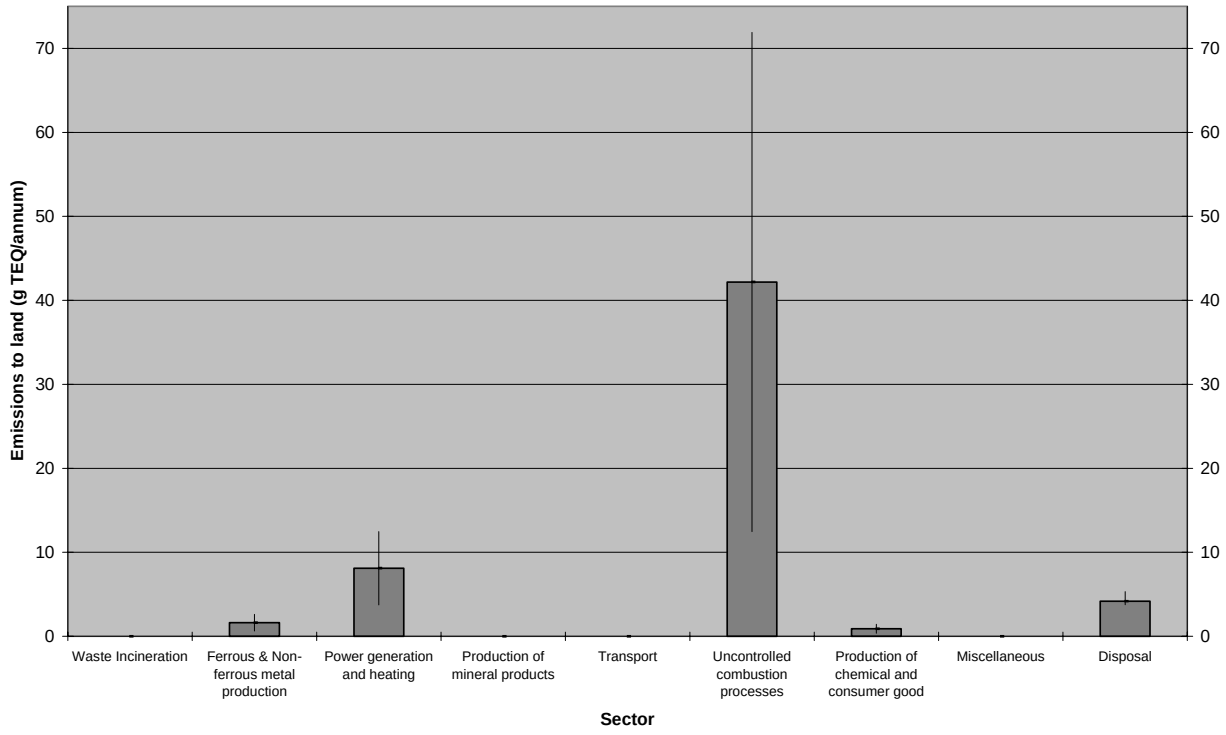

Figure 3.2. Best Estimate Emissions to land – 2000 (range also shown).

Best estimate emissions to water for 2000 not plotted due to small quantity of data.

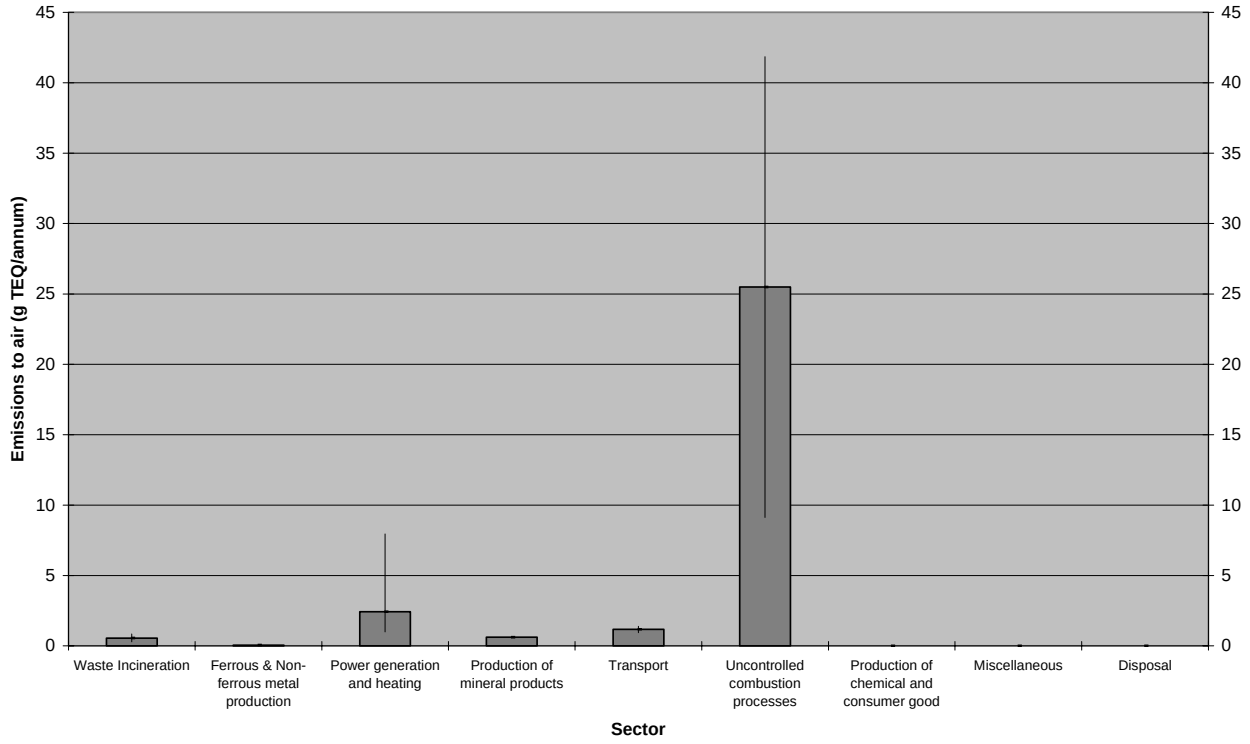

Figure 3.3. Best estimate emissions to air – 2010 (range also shown).

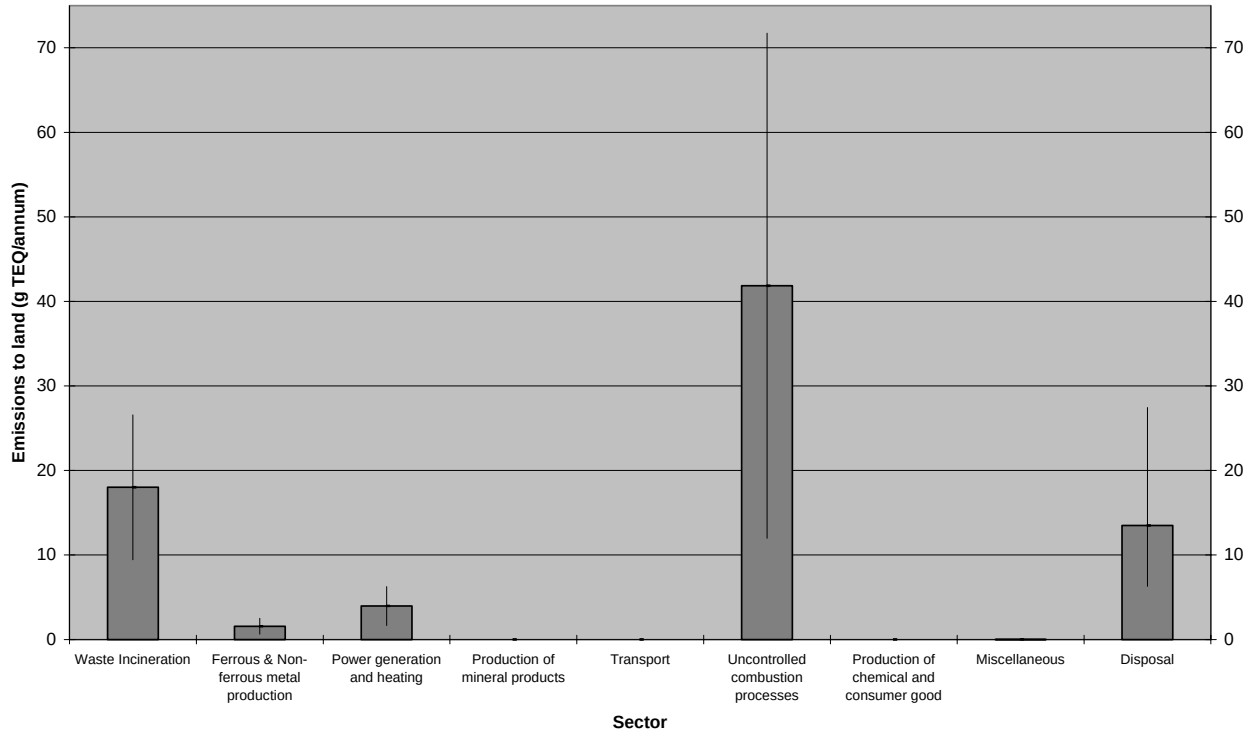

Figure 3.4. Best estimate emissions to land – 2010 (range also shown).

Best estimate emissions to water for 2010 not plotted due to small quantity of data.

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