Ministry for the
Environment
Manatū Mō Te Taiao

New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources: 2011

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for the
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The *New Zealand Inventory of Dioxin Releases to Air, Land and Water, and Reservoir Sources: 2011*, follows from a review and updating of the 2000 report of the same name. The 2000 inventory was based on 1998 data and the estimates of the 2011 inventory are based on a reference year of 2008. The updated inventory report establishes the framework for New Zealand's 5-yearly reporting requirements under the Stockholm Convention on Persistent Organic Pollutants, on the measures taken to reduce dioxin releases.

Dioxins are extremely toxic to humans and can be found throughout the world in air, soil, sediment and water. They break down very slowly in the environment, and can accumulate in the fatty tissues of birds, fish, marine mammals, domestic animals, and in people. Dioxins have never been produced intentionally, other than for research, but are formed as unintentional by-products in various chemical production processes and in most thermal processes, including combustion.

The methodology used for the inventory update involved estimates of the annual releases from each source by multiplying an activity statistic by an emission factor. Activity statistics are chosen on the basis of fuel consumption, production rates, or some other similar measure, while the emission factors are based on data for the average emissions to air, land or water, per unit of activity. This approach is consistent with current international practice.

Dioxin emissions to air

Dioxin emissions to air were identified and assessed for 40 different source categories. The total releases to air from all sources were estimated to be 32.28 g I-TEQ yr^{-1} in 1998 and 17.43 g I-TEQ yr^{-1} in 2008; a reduction of almost 50%. The most significant contributors to this reduction were as follows:

- Landfill fires were identified in the 2000 Inventory as New Zealand's most significant source of dioxin releases to air. In response to this, the deliberate lighting of fires and burning of wastes at landfills was banned through Regulations issued in 2004 under the Resource Management Act 1991 (RMA). The number of landfill fires has since dropped to about 50 per year, which is a reduction of approximately 80% since 1998.
- Emissions from clinical, pathological and quarantine waste incineration have dropped significantly, because there are now only two incinerators in operation, compared to 24 in 1998. This reduction was also driven by the 2004 Regulations under the RMA.
- The dioxin emission estimates for domestic wood burning have dropped significantly but this is almost entirely due to the use of a much lower emission factor, rather than any major changes in wood consumption. Further reductions in the dioxin emissions from wood burning might be expected in the future as a result of the policy and regulatory actions of regional councils in implementing the National Environmental Standards for Air Quality and for wood burners. Similar reductions might also be expected for domestic waste burning.
- The estimates for dioxin emissions to air from land transport have shown a significant reduction over the 10 year period. This is due to an increase in the proportion of vehicles fitted with exhaust catalysts, and this trend is expected to continue as a result of the current exhaust emission requirements on imported vehicles.

Less significant changes were recorded in the emission estimates for many other source categories. Some of these were due to changes in source activity – for example, the releases from coal-fired power generation. However, others were simply due to changes in the assessment methodology.

Dioxin releases to land

Dioxin releases to land were identified and assessed for 38 different source categories. The total releases to land from all sources were estimated to be 45.72 g I-TEQ yr^{-1} in 1998 and 70.38 g I-TEQ yr^{-1} in 2008; an increase of just over 50%. However, this is mainly due to changes in the assessment methodology, and the inclusion of sources that were not covered in 1998. The most significant changes were as follows:

- Wastewater treatment plants are the largest contributor of dioxin releases to land. The release estimate for 2008 is three times higher than that for 1998 because of the use of plant-specific data for sludge production, which was not previously available.
- The 2008 release estimate for domestic waste burning is approximately double that for 1998. While the waste quantities have dropped considerably in that time, a different method used for estimating ash production, and a different emission factor, have resulted in an overall increase in the release estimate relative to that of 1998.
- As expected, the releases to land from the incineration of clinical, pathological and quarantine wastes are significantly lower than the range reported for 1998.
- Some of the increases in releases to land were due to other source categories that were not considered in the 1998 estimates, including forest, scrub and grass fires, structural fires, vehicle fires, school incinerators, asphalt plants, and hot-dip galvanising.

Dioxin releases to water

Releases to water are a relatively minor contributor to the total dioxin releases across all media. The primary sources of releases to water are landfill leachate and the discharges from wastewater treatment plants. The total releases for 2008 were estimated to be 1.58 g I-TEQ yr^{-1} compared to 2.26 g I-TEQ yr^{-1} in 1998, with the reduction being almost entirely due to changes in the methodology used to estimate the releases.

Dioxin reservoirs

The significant known reservoir sources of dioxins in New Zealand are pulp and paper waste disposal sites, landfills, timber treatment sites, old gasworks sites, and areas contaminated by the past use of the herbicide 2,4,5-T. The estimates for 2008 show some significant increases due to the inclusion of reservoirs that were not considered in 1998. However, there have also been reductions in some of the reservoirs – for example, some of the old gasworks sites have been remediated, with much of the residual material being transferred to landfills.

Discussion

The work presented in this report provides a starting point for identifying possible actions to achieve further reductions in the releases of dioxins. The estimates for each source give an indication of the relative potential for achieving reductions. In addition, each source category was assessed for the extent of compliance with the guidelines on best available techniques and best environmental practices (BAT/BEP) adopted under the Stockholm Convention.

Significant reductions in dioxin releases have already been achieved in New Zealand through a combination of national and regional activities directed at specific sources, while further reductions have also occurred as an indirect result of other initiatives. Further incremental reductions in dioxin releases are considered possible and could be achieved by ongoing support for current initiatives, coupled with additional national and regional activities that target selected sources.

Units and Abbreviations

Units

°C	degrees Celsius or centigrade
g	gram
kg	kilogram (10^3 grams)
tonne	10^6 grams
ktonne	kilotonne (10^6 tonnes)
µg	microgram (10^{-6} grams)
ng	nanogram (10^{-9} grams)
pg	picogram (10^{-12} grams)
MJ	megajoule (10^6 joules)
GJ	gigajoule (10^9 joules)
TJ	terajoule (10^{12} joules)
PJ	petajoule (10^{15} joules)
L	litre
m^3	cubic metre
Nm^3	normal cubic metre of dry gas at 0°C and 101.3 kilopascals
ppm	parts per million
kW	kilowatt (10^3 watts)
kWh	kilowatt-hour
MW	megawatt (10^6 watts)
GWh	gigawatt-hour
TJ	terrajoule
yr	year

Abbreviations

2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
ADT	air-dry tonnes
BAT/BEP	best available techniques / best environmental practices
bw	body weight
CNG	compressed natural gas
DCNA	2,6-dichloro-4-nitroaniline
DCPA	dimethyl tetrachloroterephthalate (also known as chlorthal dimethyl)
FAO	Food and Agriculture Organization
CKD	cement kiln dust
dioxins	generic name for the PCDDs and PCDFs
HEEP	Household Energy End-use Project

IPPC	Integrated Pollution Prevention and Control
I-TEF	international toxic equivalence factor
I-TEQ	international toxic equivalents
LPG	liquefied petroleum gas
MED	Ministry of Economic Development
MDF	medium density fibreboard
NaPCP	sodium pentachlorophenate
PCBs	polychlorinatedbiphenyls
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
PCP	pentachlorophenol
PM_{10}	particulate matter less than 10 microns in size
POPs	persistent organic pollutants
PVC	polyvinylchloride
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
UNEP	United Nations Environment Programme
UK	United Kingdom
USA	United States of America
US EPA	United States Environmental Protection Agency
VKT	vehicle kilometres travelled
WHO	World Health Organization

Extended Summary

S.1 Introduction and overview

This report has been produced as part of New Zealand's obligations under the Stockholm Convention on Persistent Organic Pollutants (see http://www.pops.int). The obligations, and the proposed responses, were detailed in *New Zealand's National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants* (Ministry for the Environment, 2006). The report addresses unintentional releases of two specific groups of persistent organic pollutants: the polychlorinated dibenzo-*p*-dioxins (PCDDs) and the polychlorinated dibenzofurans (PCDFs).It was prepared in response to the following activities proposed in the National Implementation Plan:

- a review and update of a dioxin release inventory for New Zealand
- applying best available techniques and best environmental practices (BAT/BEP) to minimise dioxin releases in accordance with the Convention.

The previous inventory of PCDD and PCDF releases to air, land and water, and reservoir sources, was published in 2000, based on 1998 data (Ministry for the Environment, 2000b). This report provides an update of that inventory for a reference year of 2008. The methodology used for the inventory update was consistent with current international practice (UNEP, 2005), and was based on the emission factor approach, in which the annual releases from each source are estimated by multiplying an activity statistic by an emission factor. Activity statistics are chosen on the basis of fuel consumption, production rates or some other similar measure, while the emission factors are based on data for the average emissions to air, land or water, per unit of activity.

Table S.1: Summary of PCDD and PCDF inventory results

Source category[1]	Annual release estimates (g I-TEQ yr^{-1})[2,3]					
	Air 1998[4]	Air 2008	Land 1998[4]	Land 2008	Water 1998[4]	Water 2008
Waste incineration	3.58	0.72	2.97	0.05	–	–
Ferrous and non-ferrous metal production	1.75	0.68	7.01	10.15	0.02	0.02
Power generation and heating	7.28	3.37	5.32	1.39	–	–
Production of mineral products	0.46	0.09	0.78	0.24	–	–
Transport	0.64	0.42	nd	0.21	–	–
Open burning processes	18.30	11.95	5.7	15.85	–	–
Production of chemicals/consumer goods	0.04	0.03	0.83	0.08	0.28	
Miscellaneous sources	0.23	0.18	–	–	–	–
Waste disposal	–	–	23.11	42.41	1.96	1.56
Totals	**32.28**	**17.44**	**45.72**	**70.38**	**2.26**	**1.58**

1. The source categories shown in the table are those used in the *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases* (UNEP, 2005), which is discussed elsewhere in this report.
2. A dash (–) in the cells indicated no releases are expected for that media.
3. The entry 'nd' indicates *not determined*.
4. The release estimates shown for 1998 are based on the mid-points of the ranges of values given in the 2000 Inventory report.

A summary of the results for both the past and current inventories is given in table S.1.

There have been significant changes in many of the release estimates. Some of these, such as reductions in the emissions to air from waste incineration and landfill fires, are the result of specific regulatory actions. Others, such as increased releases from coal-fired power generation, are due to changes in source activity. But others are simply due to changes in the assessment methodology; for example, an apparent increase in the releases to land from open burning is partly due to the inclusion of sources that were not assessed in the 2000 Inventory. The reasons for specific changes will be noted in the following sub-sections of this summary, and are discussed in more detail within each section of the 2011 Inventory report.

The current status of each source or group of sources with respect to the application of BAT/BEP is discussed at the end of each section of the report, and the key findings are summarised in section S.8.

S.2 Methodology

The 2000 Inventory was based on the use of a range of emission factors for each source to indicate some of the variations in published emissions data. Uncertainty rankings were also reported for the activity statistics and emission factors used for each source. A similar approach has been taken in the current inventory, but with one major difference. Emission factors are now based on the recommendations given in the *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases* (UNEP, 2005), which is discussed in section 3.1.1.

The UNEP Toolkit was developed by UNEP Chemicals with the aim of achieving an effective and standardised approach to the compilation of PCDD/PCDF emission inventories. This was intended to ensure a reasonable degree of consistency between the inventories reported by different countries, and should also help in comparing inventory results between countries or changes over time. Two of the main issues addressed by the Toolkit are consistency in source identification and the use of a standard set of default emission factors. The first of these issues is relevant to the current work, in that a number of potential, albeit quite minor, sources were not included in the 2000 Inventory. The second is also relevant, in that many of the recommended emission factors are based on a wider range of published data than was considered previously.

Overall, the amount of data used in developing the Toolkit factors for each source subcategory is still quite limited. In addition, some of it is relatively dated. It should also be recognised that some source characteristics may vary significantly between countries; for example, the Toolkit factors for industrial coal combustion appear to be based on relatively large boilers, whereas a third of all New Zealand plants would be classified as small (< 10 MW). Local emission factors have been used, whenever available, to address this aspect.

S.3 Emissions to air

The estimates of emissions to air are summarised in table S.2. This shows the original estimates for 1998, a 1998 back-calculation based on current emission factors, the estimates for 2008, and the certainty rankings for the 2008 data. The 2008 estimates have also been plotted in figure S.1, arranged in order from highest to lowest, while figure S.2 shows the changes in emissions from 1998 to 2008. In the interests of clarity, some minor sources have not been included in figure S.2, nor have those sources that were not considered in 1998.

Table S.2: PCDD and PCDF emissions to air

Source[1]	Annual emissions to air[2] (g I-TEQ yr^{-1})			Certainty (2008)[4]	Section no.
	Original 1998 estimate	1998 back-calculation[3]	2008 estimate		
Clinical, pathological and quarantine waste incineration	0.38–3.5	(1.94)	0.657	M, L	4
Hazardous waste incineration	0.00054–0.0039	(0.00220)	0.000029	H, H	5
Wastewater solids incineration	0.009	0.000057	0.000086	H, H	6
Document destruction	Nd	nd	0.003	H, L	7
School incinerators	Nd	nd	0.021	M, L	7
Animal carcass disposal	Nd	nd	0.036	M, L	7
Crematoria	0.0080–0.45	0.159	0.183	H, L	8
Power generation – coal	0.059–0.11	0.096	0.434	H, M	9
Power generation – oil and gas	Nd	0.035	0.043	H, L	9
Industrial, commercial coal combustion	0.0337–4.0	(2.017)	0.829	H, L	10
Industrial, commercial oil and gas combustion	Nd	nd	0.019	H, L	10
Domestic coal burning	0.36–0.59	0.131	0.036	H, L	11
Domestic oil and gas burning	Nd	0.01	0.01	H, L	11
Industrial wood and biomass combustion	0.28–1.2	0.545	1.068	H, M	12
Contaminated wood wastes	0.57–1.2				
Domestic wood burning	0.71–8.7	0.90	0.84	H, L	13
Domestic waste burning	0.54–6.4	(3.5)	5.40	L, L	14
Unleaded petrol	0.010–0.59	(0.64)	0.39	M, L	15
Diesel	0.10–0.57				
Forest, scrub and grass fires	0.080–1.1	(0.59)	3.087	M, L	16
Structure fires	0.27–2.7	0.93	0.85	L, L	16
Vehicle fires	0.10–0.14	0.3	0.31	L, L	16
Cement manufacture	0.10–0.65	(0.38)	0.050	H, H/M	17
Lime manufacture	0.0030–0.16	(0.082)	0.025	H, L	17
Bricks, tiles, pottery and ceramics	Nd	nd	0.005	M, L	17
Asphalt plants	Nd	nd	0.006	H, L	17
Primary steel production	0.1	0.1	0.08	H, M	18
Secondary steel production	0.017–0.063	(0.04)	0.24	H, H	18
Hot-dip galvanising	Nd	nd	0.001	L, L	18
Metal shredding	Nd	nd	0.024	H, L	18
Iron foundries	0.10–1.3	(0.70)	0.15	M, M	20
Non-ferrous metal production			0.13	M, M	20
Secondary aluminium production	0.0091–1.8	0.102	0.058	M, M	19
Glass production	0.00024–0.0038	0.0018	0.0022	H, L	21
Pulp and paper (recovery boilers)	0.033–0.045	(0.039)	0.0325	H, H	22
Tobacco smoking	0.00029–0.0084	0.00041	0.00033	H, L	23
Used oil use and disposal	0.00068–0.024	0.016	0.022	L, L	24
Landfill gas (fugitive emissions)	0.077–0.086	0.055	0.033	H, H	26
Landfill gas combustion	0.0013–0.077	0.0011	0.011	L/M, L	26
Landfill fires	10–15	(12.5)	2.3	L, L	26
Total estimated emissions to air	**14–51**	**25.8**	**17.4**		

1. There is no significance in the order with which the different sources have been listed in this table.
2. The entry 'nd' indicates *not determined*.
3. The use of brackets in the back-calculation column indicates that no back-calculation was possible and the value shown is simply the mid-point of the range reported for 1998.
4. The certainty rankings apply to the 2008 estimates and are presented in the order *activity statistic, emission factor ranking.* The rankings applied are H = high; M = medium; L = low. See section 3.3.

Figure S.1: PCDD and PCDF emissions to air, 2008

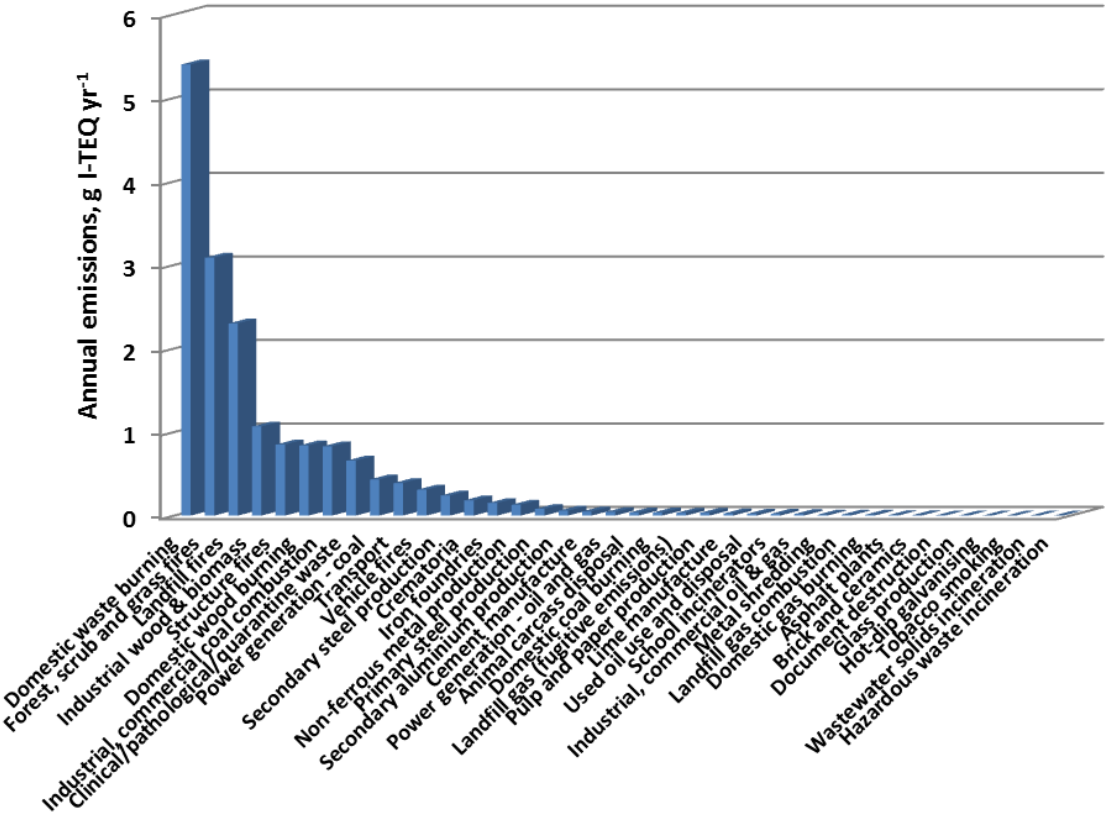
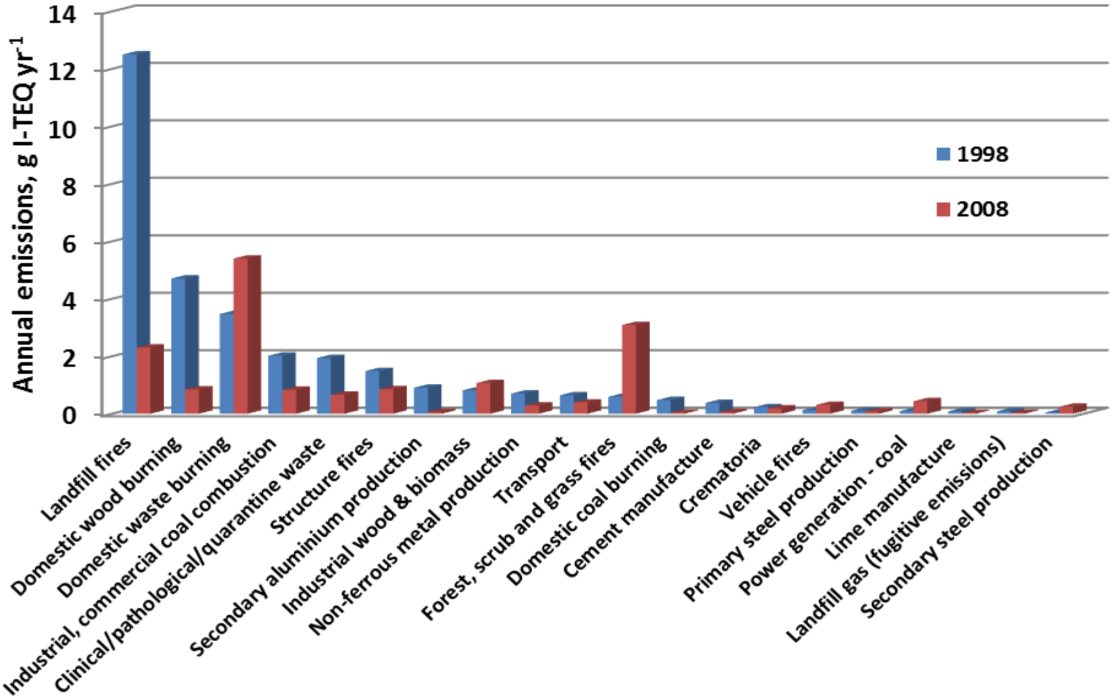


Figure S.2: Changes in PCDD and PCDF emissions to air, 1998 and 2008



The sources that are new to the 2011 Inventory (ie, that were not included in the 2000 Inventory) are:

- document destruction incinerators
- school incinerators
- animal carcass disposal
- industrial and commercial oil and gas combustion
- domestic gas combustion
- bricks, tiles, pottery and ceramics
- asphalt plants
- hot-dip galvanising
- metal shredding.

In addition, the following changes have been made.

- Ferrous and non-ferrous metal production has been subdivided into iron foundries and secondary non-ferrous metal production.
- The estimates for emissions to air from leaded petrol and diesel have been combined into a single 'transport' category.

S.3.1 Changes in emissions to air

The figures at the bottom of table S.2 indicate there has been a significant reduction in the total emissions to air over the 10-year period. The reasons for the changes in some of the more significant sources are discussed individually below, followed by a summary of the reasons for changes in other groups of sources.

Landfill fires were identified in the 2000 Inventory as the most significant source of dioxin releases to air. In response to this, the deliberate lighting of fires and burning of wastes at landfills was banned under the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004. These Regulations, and other significant improvements in landfill management practices, have been highly effective in reducing the releases from this source. The estimated annual emissions to air have dropped from 10–15 g I-TEQ yr^{-1} in 1998 (nearly 40% of the total emissions to air) to 2.3 g I-TEQ yr^{-1} in 2008 (13% of the total).

Another significant source targeted by the 2004 Regulations was the incineration of clinical, pathological and quarantine wastes. A total of 24 incinerators were identified in the 2000 Inventory, but there are now only two: one used for hospital wastes and one for quarantine wastes. The emission estimates have reduced from 0.38–3.5 g I-TEQ yr^{-1} in 1998 to 0.66 g I-TEQ yr^{-1} in 2008.

The emission estimates for domestic wood burning have also dropped significantly (0.7–8.7 g I-TEQ yr^{-1} in 1998 compared to 0.84 g I-TEQ yr^{-1} in 2008), but this is almost entirely due to the use of a much lower emission factor rather than to any major changes in wood consumption. Further reductions in the emissions from this source are expected in the future as a result of the actions currently being taken by many regional councils to improve air quality by reducing emissions of fine particulates.

The changes shown for domestic waste burning (0.54–6.4 g I-TEQ yr^{-1} in 1998 compared to 5.4 g I-TEQ yr^{-1} in 2008) are due to a combination of factors. The waste quantities are believed to have dropped considerably (estimated at 58,000 tonnes per year in 1998 and at 18,000 tonnes per year in 2008). However, the emission factor used for the current estimates is at the top end of the range of the emission factors used in 1998.

The significant increase in the emission estimates for forest, scrub and grass fires (0.08–1.1 g I-TEQ yr^{-1} in 1998 compared to 3.09 g I-TEQ yr^{-1} in 2008) is almost entirely due to changes in the estimates for the amount of biomass burned. The current estimates are based on biomass density factors used for estimating national greenhouse gas emissions, which are much higher than the factors used in the 2000 Inventory.

The primary reasons for the changes in emission estimates for the remaining source categories are listed below (excluding those sources not assessed in the 2000 Inventory):

- *changes in source activity rates:* hazardous waste incineration, coal-fired power generation, industrial wood combustion, land transport, primary steel production, secondary steel production, secondary aluminium processing, glass production, pulp and paper (recovery boilers), tobacco smoking, used oil use and disposal, landfill gas combustion
- *changes in emission factors and/or other methodology changes:* crematoria, structure fires, iron foundries, secondary non-ferrous metal production
- *changes due to a combination of both source activity and methodology:* wastewater solids incineration, domestic coal burning, vehicle fires, cement manufacture, lime manufacture.

S.3.2 Other potential emissions to air

The 2000 Inventory included an assessment of the emissions to air from the flaring of oil and gas condensates. However, this practice has now been stopped (see section 16.1.5).

School incinerators are an addition to the 2011 Inventory. The use of these was banned under the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004, unless the activity was authorised by a resource consent issued before 1 October 2006. About 90% of all school incinerators were shut down in response to these Regulations, and most of the remaining units are in small rural schools. The current emissions to air are estimated at 0.02 g I-TEQ yr^{-1}, but emissions in the past would have been substantially higher.

The potential emissions to air from oil refinery catalyst regeneration and from smokehouses are discussed in sections 29.5 and 30.1, respectively. The emissions from the former have been shown to be negligible, while a very rough estimate for the latter indicates a release rate of no more than 0.15 g I-TEQ yr^{-1}.

Finally, it should be noted that there is a brief discussion in section 16.1.4 of the potential emissions to air from the burning of construction and demolition timbers. The amount of material burned is unknown, but an initial rough estimate of the potential emissions (approximately 2.2 g I-TEQ yr^{-1}) suggests this may be a significant source.

S.4 Releases to land

The estimates of releases to land are summarised in table S.3. This shows the original estimates for 1998, a 1998 back-calculation based on current release factors, the estimates for 2008, and the certainty rankings for the 2008 data. The 2008 estimates have also been plotted in figure S.3, arranged in order from highest to lowest, while figure S.4 shows the changes in releases from 1998 to 2008. Those sources that were not considered in 1998 are not included in figure S.4.

The sources that are new to the 2011 Inventory are the same as those listed previously in section S.3.1. In addition, the following changes have been made in relation to releases to land.

- The data now includes estimated releases to land from crematoria, forest, scrub and grass fires, structure fires and vehicle fires.
- Ferrous and non-ferrous metal production has been subdivided into iron foundries and secondary non-ferrous metal production.

S.4.1 Changes in releases to land

The inclusion of additional sources and some changes in the estimation methodology have led to some significant changes in the estimates for releases to land over the 10-year period, as shown in table S.3. The reasons for these changes are discussed and summarised below.

Wastewater treatment plants are now the largest contributor of PCDD and PCDF releases to land as a result of an almost three-fold increase in the release estimate (23.4 g I-TEQ yr^{-1} in 2008, compared to a range of 0.61–5.2 g I-TEQ yr^{-1} in 1998). This increase is primarily due to changes in estimation methodology, in that the activity data is now based on plant-specific information obtained from a national database. This has resulted in a significant increase in the activity estimates (sludge production of 234,112 tonnes per year, compared to 87,800 tonnes per year in 1998).

Landfills are the second highest contributor of releases to land (19.0 g I-TEQ yr^{-1} in 2008). The differences shown in figure S.4 for the 1998 and 2008 releases are due to relatively minor fluctuations in the annual quantities of domestic and industrial waste disposed to landfill.

The increase shown for domestic waste burning (5.7 g I-TEQ yr^{-1} in 1998 compared to 10.8 g I-TEQ yr^{-1} in 2008) is due to a combination of factors. The waste quantities are believed to have dropped considerably (estimated at 58,000 tonnes per year in 1998 and 18,000 tonnes per year in 2008). However, both the method used for estimating ash production and the emission factor are significantly different from those used for 1998.

Secondary aluminium processing is the fourth-highest contributor of PCDD and PCDF releases to land. These mainly arise from the dust and fumes collected in air pollution control equipment such as bag-filters. The release estimate for 2008 (5.4 g I-TEQ yr^{-1}) is close to the top end of the range reported in the 2000 Inventory (0.67–6.8 g I-TEQ yr^{-1}), based on a different methodology.

Non-ferrous metal production is another significant source of releases to land (1.92 g I-TEQ yr^{-1}), but it is not shown in figure S.4 because the 2000 Inventory made no distinction between ferrous and non-ferrous foundries. The 2008 estimate for iron foundries and non-ferrous metal production combined is 2.01 g I-TEQ yr^{-1}, compared to the range of 0.19–2.2 g I-TEQ yr^{-1} for 1998.

Table S.3: PCDD and PCDF releases to land

Source[1]	Annual releases to land[2] (g I-TEQ yr^{-1})			Certainty (2008)[4]	Section no.
	Original 1998 estimate	1998 back-calculation[3]	2008 estimate		
Clinical, pathological and quarantine waste incineration	0.43–3.2	(1.82)	0.004	M, L	4
Hazardous waste incineration	0.25 E-6–85 E-6	0.000064	0.000019	H, H	5
Wastewater solids incineration	0.024	0.0005	0.0008	M, L	6
Document destruction	nd	nd	nd	nd	7
School incinerators	nd	nd	0.042	L, L	7
Animal carcass disposal	nd	nd	nd	nd	7
Crematoria	nd	nd	nd	nd	8
Power generation – coal	0.0016–0.12	0.135	0.608	H, L	9
Power generation – oil and gas	nd	nd	nd	nd	9
Industrial, commercial coal combustion	0.000473–0.316	(0.158)	0.291	H, L	10
Industrial, commercial oil and gas combustion	nd	nd	nd	nd	10
Domestic coal burning	0.00072	0.009	0.00020	M, L	11
Industrial wood and biomass combustion	0.0012–0.017	0.164	0.32	H, L	12
Contaminated wood wastes	0.33–1.9				
Domestic wood burning	0.48–9.7	0.18	0.17	M, L	13
Domestic waste burning	5.7	(5.7)	10.80	L, L	14
Forest, scrub and grass fires	nd	nd	4.14	M, L	16
Structure fires	nd	0.93	0.85	L, L	16
Vehicle fires	nd	0.058	0.060	L, L	16
Cement manufacture	0.000013–1.4	0.088	0.134	H, L	17
Lime manufacture	0.000005–0.15	(0.075)	0.084	M, L	17
Bricks, tiles, pottery and ceramics	nd	nd	nd	nd	17
Asphalt plants	nd	nd	0.026	M, L	17
Primary steel production	0.67	(0.67)	0.21	H, L	18
Secondary steel production	1.4	(1.4)	2.50	H, L	18
Hot-dip galvanising	nd	nd	0.025	L, L	18
Metal shredding	nd	nd	nd	nd	18
Iron foundries	0.19–2.2	(1.2)	0.094	M, L	20
Non-ferrous metal production			1.92	L, L	20
Primary aluminium production	0.0017	(0.0017)	nd	nd	19
Secondary aluminium production	0.67–6.8	6.3	5.4	M, L	19
Bleached kraft pulp production	0.56	(0.56)	0.083	H, L	22
Non-kraft mills (paper recycling)	0.005	(0.005)	nd	nd	22
Used oil use and disposal	0.012–0.53	0.325	0.207	L, L	24
Use of halogenated pesticides	0.13–0.15	(0.14)	< 0.003	H, H	25
Residential solid waste	8.9	19.1	19.0	H, L	26
Industrial solid waste	11.1				
Wastewater treatment	0.61–5.2	8.78	23.4	H, M	27
Total estimated releases to land	**26–54**	**47.8**	**70.38**		

1. There is no significance in the order with which the different sources have been listed in this table.
2. The entry 'nd' indicates *not determined*.
3. The use of brackets in the back-calculation column indicates that no back-calculation was possible and the value shown is simply the mid-point of the range reported for 1998.
4. The certainty rankings apply to the 2008 estimates and are presented in the order *activity statistic, emission factor ranking.* The rankings applied are H = high; M = medium; L = low. See section 3.3.

Figure S.3: PCDD and PCDF releases to land, 2008

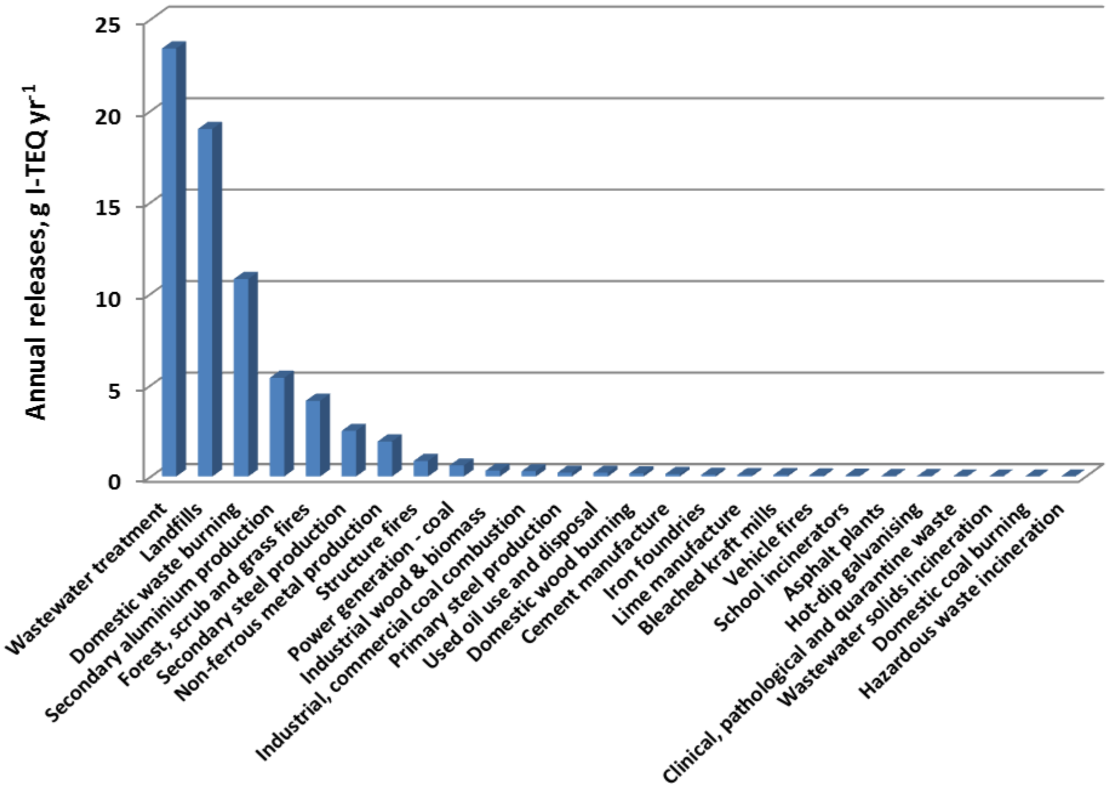
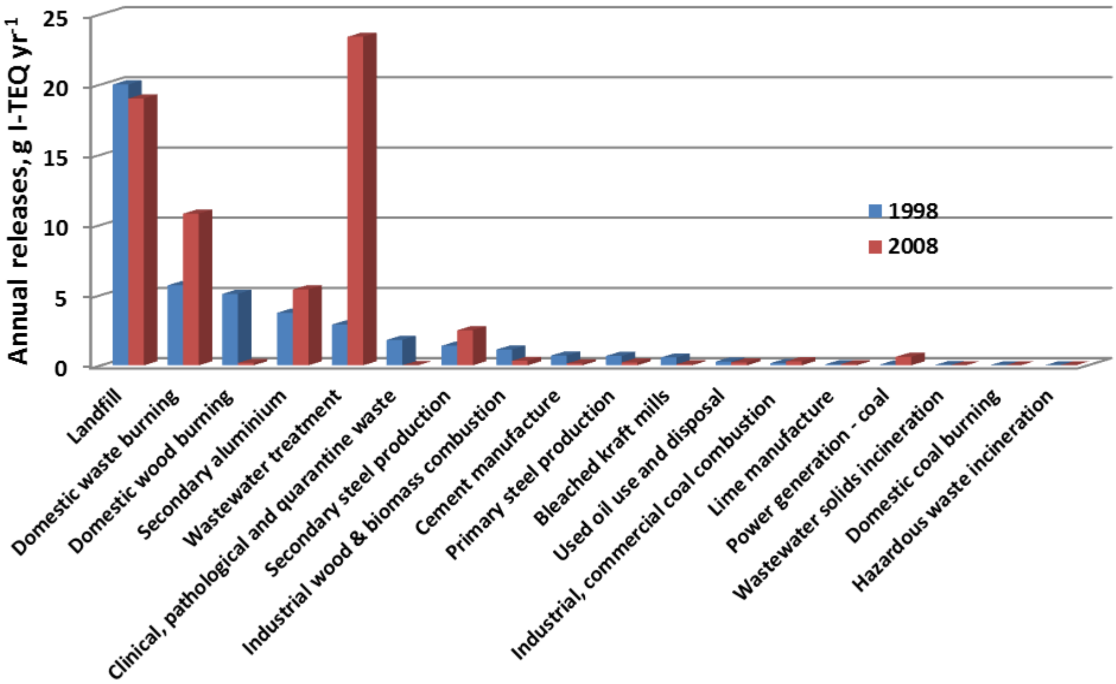


Figure S.4: Changes in PCDD and PCDF releases to land, 1998 and 2008



As expected, the releases to land from the incineration of clinical, pathological and quarantine wastes (0.004 g I-TEQ yr^{-1}) are significantly lower than the range reported in the 2000 Inventory (0.43–3.2 g I-TEQ yr^{-1}).

Estimates for the releases to land from forest, scrub and grass fires were not included in the 2000 Inventory, and have contributed an additional 4.14 g I-TEQ yr^{-1} to the total for 2008. The other new contributors to the current inventory are structural fires (0.85 g I-TEQ yr^{-1}), vehicle fires (0.060 g I-TEQ yr^{-1}), school incinerators (0.042 g I-TEQ yr^{-1}), asphalt plants (0.026 g I-TEQ yr^{-1}) and hot-dip galvanising (0.025 g I-TEQ yr^{-1}).

The primary reasons for the changes in release estimates for the remaining source categories are listed below (excluding those sources not assessed in the 2000 Inventory):

- *changes in source activity rates:* hazardous waste incineration, coal-fired power generation, industrial wood combustion, primary steel production, secondary steel production, pulp and paper (bleached kraft), used oil use and disposal
- *changes in emission factors and/or other methodology changes:* use of 2,4-D
- *changes due to a combination of both source activity and methodology:* wastewater solids incineration, domestic coal burning, cement manufacture, lime manufacture.

S.4.2 Other potential releases to land

No estimates have been reported for the releases to land from document destruction, animal carcass disposal, crematoria, metal shredding, paper recycling or tobacco smoking because the appropriate release factors are not available. However, the contributions from each of these sources are expected to be relatively minor (see sections 7.2.1, 7.2.3, 8.2, 18.4.4, 22.2.2, and 23.2).

The potential for releases to land from the use of halogenated pesticides other than 2,4-D (chlorothalonil, DCNA, DCPA and oxadiazon) and drycleaning are discussed in sections 25.1.2, and 30.2, respectively. However, no estimates have been reported because the available information on usage rates and/or PCDD/PCDF contamination levels is inadequate.

S.5 Releases to water

The estimates for PCDD and PCDF releases to water are summarised in table S.4. This shows the original estimates for 1998, a 1998 back-calculation based on current release factors, the estimates for 2008, and the certainty rankings for the 2008 data.

The most significant change in the estimates from 1998 is the reduction in releases from wastewater treatment plants. The estimates for the volumes of wastewater discharged from these plants have increased, but the PCDD/PCDF release estimates have dropped due to changes in estimation methodology, especially the use of different release factors.

The increase in the release estimates for landfill leachate is primarily due to the increases in waste quantities in the total reservoir. Releases to water from pulp and paper production are shown as *not determined* because the UNEP Toolkit methodology recommends that these be accounted for under releases to land (see section 22.3.1).

Another potential source of PCDD and PCDF releases to water is textile and leather production, which is discussed in section 29.3. On the basis of the available information there is no reason to expect any significant releases from New Zealand plants.

Table S.4: PCDD and PCDF releases to water

Source[1]	Annual release estimate[2] (g I-TEQ yr^{-1})			Certainty (2008)[4]	Section no.
	Original 1998 estimate	1998 back-calculation[3]	2008 estimate		
Primary steel production	0.015	0.015	0.015	H, L	18
Pulp and paper (bleached kraft mills)	0.20–0.35	(0.28)	nd	nd	22
Landfills – annual refuse placement	0.00074–0.0093	0.54	0.74	L, M	26
Landfills – release from the reservoir	0.0083–0.95				
Wastewater treatment	0.34–2.6	(1.47)	0.823	H, L	27
Total estimated releases to water	**0.56–3.9**	**2.3**	**1.6**		

1. There is no significance in the order with which the different sources have been listed in this table.
2. The entry 'nd' indicates *not determined*.
3. The use of brackets in the back-calculation column indicates that no back-calculation was possible and the value shown is simply the mid-point of the range reported for 1998.
4. The certainty rankings apply to the 2008 estimates and are presented in the order *activity statistic, emission factor ranking.* The rankings applied are H = high; M = medium; L = low. See section 3.3.

S.6 PCDD and PCDF reservoirs

Reservoirs are places or materials that are believed to contain significant amounts of PCDDs and PCDFs as a result of past contamination. The current and past estimates of PCDD and PCDF reservoirs in New Zealand are summarised in table S.5.

The most significant change in the reservoir estimates is for the past uses of pentachlorophenol (PCP) as a timber preservative. The changes result from a reassessment of the available data on contamination levels at sawmill sites, and from the inclusion of an estimate for the quantities remaining in treated timber (see section 28.3).

The significant increase shown for landfills and the minor increase for pulp and paper production are a result of the continuing accumulation of wastes in these reservoirs. The reduction in the estimate for past use of 2,4,5-T is due to the expected decomposition of PCDDs and PCDFs over time, while the reduction for gasworks sites is attributed to site remediation activities.

Table S.5: PCDD and PCDF reservoirs

Source[1]	Reservoir estimates (g I-TEQ)		Certainty[2]	Section
	1998 estimate	2008 estimate		
Pulp and paper production (bleached kraft mills)	24	24.8	M, L	22
Landfills	500	660	M, L	28
Historic use of 2,4,5-T[3]	620–860	390–540	M, M	28
Use of NaPCP as antisapstain – sawmill sites	80	810	L, L	28
Use of PCP in diesel sawmill sites	230	230	M, M	28
Use of PCP in diesel – treated timber		4270		28
Gasworks sites	0.028–6.4	0.022–5.2	L, M	28
Total reservoir estimates	**1450–1700**	**6385–6540**		

1. There is no significance in the order with which the different sources have been listed in this table.
2. The certainty rankings are unchanged from those reported for 1998, except for pulp and paper production. They are presented in the order *activity statistic, emission factor ranking.*
3. Reservoir estimate for 2,3,7,8-TCDD.

It should be acknowledged that there are significant uncertainties in identifying potential PCDD and PCDF reservoirs. The reservoirs considered here are those associated with known sources of PCDDs and PCDFs and/or known disposal routes. However, it is quite likely that there will be other reservoirs not yet identified, especially in association with contaminated sites.

S.7 Future projections

Each of the tables of release estimates in the inventory includes future projections for 2013 and 2018. However, changes have only been shown when one or more of the following applied:

- known changes in the source category, such as the installation of new plant.
- a continuation of existing activity trends.
- expected reductions in source activities or emissions due to current initiatives.

In all other cases it was assumed that the releases would remain at 2008 levels.

The most significant changes in future projections are summarised below, and further details can be found in each section of the inventory report.

- Reductions in future PCDD and PCDF emissions to air are expected for domestic coal, wood and waste combustion, and landfill fires, mainly as a result of current emission reduction initiatives.
- Increased emissions to air are expected for crematoria and gas-fired power generation, as a continuation of current trends in activity rates, and for glass manufacturing due to a one-off change in total production.
- Reductions in releases to land are expected for domestic wood and waste combustion and used oil use and disposal, mainly as a result of current initiatives.
- Increases in releases to land are expected for wastewater solids incineration due to a one-off change in annual activity rates.
- Increases in releases to water are expected for landfills and wastewater treatment plants as a result of continuing waste accumulation and future population trends, respectively.
- Increases in the reservoirs associated with landfills and pulp and paper wastes are expected as a result of continuing waste accumulation.

S.8 Best available techniques/best environmental practices

Article 5 of the Stockholm Convention requires parties to take measures to reduce or eliminate releases of the unintentionally produced persistent organic pollutants (POPs) listed in Annex C, Part I, of the Convention, which include PCDDs and PCDFs. One of the primary ways of reducing these releases is through the application of best available techniques and best environmental practices (BAT/BEP), in accordance with the guidance given in Annex C, Part V, of the Convention and guidelines adopted by a decision of the Conference of the Parties (UNEP, 2007).

A summary of the BAT/BEP requirements under the Convention is given in section 2 of this report. The BAT/BEP recommendations for each source category are also discussed at the end of each of the source-specific sections of the report, along with an assessment of the extent to which New Zealand sources currently comply. The term ‘Bat/BEP Guidance’ is used to refer to UNEP, 2007.

The key findings for each source category are summarised briefly in table S.6.

Table S.6: Summary of compliance with BAT/BEP guidance

Source category	Status/commentary
Clinical, pathological and quarantine waste incineration	Two operational facilities identified, neither of which comply – residence times too low, no flue gas monitoring and no emission controls. Could be addressed through resource consent process.
Hazardous waste incineration	Emission testing shows compliance with performance limit.
Wastewater solids incineration	Emission testing shows compliance with performance limit.
Document destruction	No guidance, but generally covered through resource consent process.
School incinerators	No guidance, but only permitted when no viable alternatives.
Animal carcass disposal	Newer units comply. Older ones likely be shut down over next 5–10 years.
Crematoria	General compliance with design criteria.
Power generation – coal	Past emission testing shows compliance with performance limit.
Power generation – oil and gas	Complies.
Industrial, commercial coal combustion	Wide range of facilities with a corresponding range in degrees of compliance. Could be addressed through resource consent process.
Industrial, commercial oil and gas combustion	
Domestic coal burning	Current focus on alternatives and promotion of good operating practices.
Domestic gas burning	Not a significant source.
Industrial wood and biomass combustion	Wide range of facilities with a corresponding range in degrees of compliance. Could be addressed through resource consent process.
Domestic wood burning	Supported by current moves to reduce PM_{10} emissions.
Domestic waste burning	Addressed through local restrictions and promotion of best practices.
Transport	Current national programmes will help reduce emissions.
Forest, scrub and grass fires	Addressed in regional air plans and other best practice recommendations.
Structure fires	No guidance – addressed through general fire prevention programmes.
Vehicle fires	
Construction and demolition timber	Addressed through local restrictions and promotion of best practice.
Cement manufacture	Emission testing shows compliance with performance limit.
Lime manufacture	No BAT/BEP guidance.
Brick and ceramics	No BAT/BEP guidance.
Asphalt plants	No BAT/BEP guidance.
Primary steel production	Emission testing shows compliance with performance limit.
Secondary steel production	Emission testing shows compliance with performance limit.
Hot-dip galvanising	No BAT/BEP guidance.
Metal shredding	Complies.
Iron foundries	Wide range of plants, with some in compliance but others not. The use of bag filters could be promoted across a wider range of plants, as could processing of bag-filter residues for metal recovery before disposal.
Non-ferrous metal production	
Secondary aluminium production	
Glass production	No BAT/BEP guidance.
Pulp and paper (recovery boilers)	Complies.
Pulp bleaching	Complies – no bleaching with elemental chlorine.
Tobacco smoking	No BAT/BEP guidance.
Used oil use and disposal	No BAT/BEP guidance.
Use of halogenated pesticide	No BAT/BEP guidance.
Landfill gas (fugitive emissions)	No BAT/BEP guidance.
Landfill fires	Complies – landfill fires are prohibited in New Zealand.
Solid waste disposal (landfills)	No BAT/BEP guidance.
Wastewater treatment plants	No BAT/BEP guidance.

S.9 Possible actions to further reduce dioxin releases

The work presented in this report provides a starting point for the development of a list of possible actions directed at achieving further reductions in the releases of PCDDs and PCDFs, in accordance with New Zealand's obligations under the Stockholm Convention. The release estimates for each source give an indication of the relative potential for achieving significant reductions. Similarly, the BAT/BEP assessment given in each section helps identify those sources with the greatest potential for improvement though the upgrading of process technologies, emission controls or other relevant aspects.

Significant reductions in dioxin releases have already been achieved in New Zealand through a combination of national and regional activities directed at specific sources (see section 33). Some reductions have also occurred as an indirect result of other initiatives (eg, the programmes for reducing particulate emissions to air, and upgrading landfill operation and management).

Further reductions in dioxin releases are possible and could be achieved by continuing to support current initiatives, coupled with additional national and regional activities that target selected sources. All actions could be implemented under existing laws and policies by using national regulation and guidance, combined with regional plans and consents. The objective of this project would be to establish the framework through which to achieve further incremental reductions in dioxin releases.

S9.1 National regulation

No new national regulations are proposed, on the basis that most of the significant industrial sources can be managed effectively and more appropriately through other existing control mechanisms, such as resource consents. Non-industrial sources, such as uncontrolled fires and domestic heating, are also more appropriately controlled by other means.

National regulation was considered in relation to the need to *require* BAT/BEP for the new sources listed in Annex C, Part II of the Stockholm Convention (see section 2.4). However, the only sources likely to be of any relevance in New Zealand are secondary metal production processes, and even here the number of new sources will be limited. The more appropriate approach, therefore, would be through the provision of national guidance, as discussed below.

S9.2 National guidance

Most industrial sources of PCDDs and PCDFs are controlled in New Zealand through the issuing of resource consents. However, there can be significant variations throughout the country in the level of control achieved.

The Ministry for the Environment has published a series of good practice guides on various aspects of air quality management, including dust, odour, ambient air monitoring and the assessment of industrial discharges. This approach should also be effective for those groups of sources where specific national guidance on the BAT/BEP recommendations would be appropriate, to ensure a reasonable degree of consistency in the controls applied throughout the country. In addition, it should result in a gradual reduction in releases over time, as existing resource consents come up for renewal.

The candidate sources would include the industrial and commercial combustion of coal, oil, wood and other biomass; crematoria and secondary metal production; and other minor sources such as pet cremators. The good practice guides could either be specific to dioxin release reductions, or cover a wider range of pollutants and/or discharges.

A national guidance document could also be considered for the treatment and disposal of bag-filter residues and other process wastes from iron foundries and secondary metal production. Currently, some of these wastes are exported for processing and metals recovery, but most are simply disposed to landfill. Dioxins are not specifically covered in the New Zealand waste acceptance criteria for landfills, and the application of any such limit would be cost-prohibitive (in terms of testing/monitoring requirements). However, some guidance on the options for metal recovery and/or waste pre-treatment may be appropriate.

S9.3 Support for existing activities

The current regional initiatives for achieving reductions in particulate emissions to air are also relevant to dioxin reductions, especially for domestic coal and wood burning. The Ministry for the Environment is already working closely with regional councils to support these activities.

Landfill fires are prohibited under the Resource Management Act 1991 regulations, but the most recent New Zealand Fire Service statistics (2006/07) show that there are still around 50 landfill fires a year. This suggests a need for continuing support for regional councils in their enforcement of the Regulations.

S9.4 Regional regulation and enforcement

Many regional councils already have controls on open burning, including for the purposes of land clearance and the burning of domestic wastes, and these activities could be supported by central government, as and when appropriate.

S9.5 No useful action identified

The dioxin content of the sludge produced by wastewater treatment plants is primarily driven by the dioxin content of the wastewater inputs, usually from both domestic and industrial sources. There are no practical controls that can be applied within the waste treatment processes themselves to minimise dioxin outputs. In addition, the input sources for most plants are so many and so varied that it would be extremely difficult to identify specific sources that could be targeted for release reductions.

The dioxin content of the solid wastes disposed to landfills is also driven by waste inputs. In this case it may be possible to target some specific high-risk sources, such as the wastes from secondary metal production (see sections 19.2.2 and 20.2.2). However, there are unlikely to be any practical control options for the more diverse inputs from domestic, commercial and industrial wastes generally.

Part 1:
Introduction, Background and Methodology

1 Introduction

1.1 The Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention on Persistent Organic Pollutants commits governments to reduce or eliminate the production and environmental releases of persistent organic pollutants (POPs).[1] The Convention came into force on 17 May 2004. New Zealand ratified it on 24 September 2004 and became a party to the Convention on 23 December 2004.

Article 5 of the Convention requires parties to take measures to reduce or eliminate releases of specific POPs that are formed and released unintentionally from anthropogenic sources, "with the goal of their continuing minimisation and, where feasible, ultimate elimination". The unintentional POPs, as listed in Annex C of the Convention, are: polychlorinated dibenzo-*p*-dioxins and dibenzofurans, hexachlorobenzene, polychlorinated biphenyls and pentachlorobenzene (the latter added in May 2009 – see section 2.5). The main focus of this report is on the first two of these, which, for convenience, are generally referred to using the collective term 'dioxins', or the abbreviations PCDDs and PCDFs.

The measures required under Article 5 include the development of an action plan "designed to identify, characterise and address" the release of unintentional POPs. An Action Plan for Dioxins and Other Annex C Chemicals was included in New Zealand's National Implementation Plan (Ministry for the Environment, 2006), which was submitted to the Convention Secretariat in December 2006. The Action Plan included the following activities, which form the basis of the current report:

- a review and update of the dioxin release inventory for New Zealand
- an assessment of the extent to which best available techniques and best environmental practices (BAT/BEP) are currently applied in New Zealand to minimise dioxin releases
- a review of relevant laws and policies.

This report also establishes the framework for New Zealand's five-yearly reporting requirements under the Convention in relation to the measures taken to reduce releases of unintentional POPs. The first such report must be submitted to the Convention Secretariat by December 2010.

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[1] The full text of the Convention can be found on the Stockholm Convention website (http://chm.pops.int) or by using the following direct link: http://chm.pops.int/Convention/tabid/54/language/en-US/Default.aspx#convtext).

1.2 Review and update of the New Zealand inventory

The previous *New Zealand Inventory of Dioxin Releases to Air, Land, and Water, and Reservoir Sources* was published before the adoption of the Stockholm Convention (Ministry for the Environment, 2000b, herein referred to as the 2000 Inventory report). The reference year for the previous inventory was 1998, and the reference year for the update is 2008.

The methodology used for the update is similar to that used for the previous inventory, but with modifications to reflect current international practice (UNEP, 2005). Both inventories are based on an emission factor approach, in which the annual releases from each source are estimated by multiplying an activity statistic by an emission factor. Activity statistics are chosen on the basis of fuel consumption, production rates or some other similar measure, while the emission factors are based on data for the average releases to air, land or water, per unit of activity.

The sources covered in the current inventory are much the same as those reported previously, but with some minor additions. The release estimates for each source were given as ranges of values in the 2000 Inventory report, as a reflection of the inherent uncertainties in trying to derive release estimates from limited, and often highly variable, emission data. However, this creates difficulties in trying to assess inventory changes over time (eg, between the current and previous New Zealand inventories), or in comparing inventory results for different countries. Most of the results for the current inventory are reported as single-value release estimates based on emission factors taken from the *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases* (UNEP, 2005 – herein referred to as the UNEP Toolkit). Comparisons with the previous inventory results have been made by considering both the ranges, and the mid-point values of the ranges, given in the 2000 Inventory report.

The use of the UNEP Toolkit is discussed further in section 3 of this report, along with other aspects of the methodology.

1.3 Other reporting requirements

1.3.1 Best available techniques/best environmental practices

Article 5(d) of the Stockholm Convention requires parties to promote or require the use of best available techniques and best environmental practices (BAT/BEP) for reducing releases of the unintentionally produced POPs from new and existing sources. Some general guidance on BAT/BEP is given in Annex C, Part V, of the Stockholm Convention, while detailed guidelines for specific sources are given in a guidance document adopted by a decision of the Conference of the Parties (UNEP, 2007). Further information on the BAT/BEP requirements is given in section 2 of this report.

The extent to which New Zealand sources comply with the BAT/BEP recommendations is summarised at the end of each section. This assessment is also considered in section 34, with a discussion of possible actions to further reduce releases of dioxins.

1.3.2 Review of laws and policies

Article 5(a)(i) of the Stockholm Convention requires parties to undertake “an evaluation of the efficacy of the laws and policies of the Party relating to the management of [dioxin] releases”. Releases of unintentional POPs are primarily controlled in New Zealand through the various mechanisms available under the Resource Management Act 1991. These include national regulations, regional rules, and the issuing of resource consents for specific sources. A review of the effectiveness of the current laws and policies is given in section 33 of this report.

1.4 Content and layout of the report

The overall structure of this report is as follows.

- **Part 1: Introduction, Background and Methodology**
- **Section 1** Introduction
- **Section 2** provides some background information on the unintentional POPs, and the BAT/BEP requirements under the Stockholm Convention.
- **Section 3** provides details of the methodology used to compile the inventory.
- **Part 2: The Inventory**
- **Sections 4 to 30** give the release estimates for individual sources or groups of sources, including comparisons with the previous estimates and future projections for 2013 and 2018. An assessment of the extent to which sources currently comply with the BAT/BEP recommendations is given at the end of each of these sections.

  The order in which the sources are addressed in these sections is more or less the same as that used in the 2000 Inventory, but with some minor changes to allow for the inclusion of additional sources and the consolidation of text (ie, sections 28 to 31 of the 2000 Inventory, previously used for reservoir sources, have been consolidated in this report into a single section (section 28).
- **Section 31** provides a tabular summary of the PCDD and PCDF release estimates for 2008, and a summary of the activity statistics and emission factors used for each source.
- **Part 3: Discussion**
- **Section 32** summarises the uncertainties and data gaps in the release estimates.
- **Section 33** presents a review of current laws and policies.
- **Section 34** concludes the report with a discussion of possible actions to further reduce releases of dioxins.
- The **Consolidated List of References** gathers together all of the references cited throughout the report. (Note: the references specific to each source have also been given at the end of each of the Part II sections, to assist the reader).
- The **Appendix** contains a UNEP Toolkit version of the inventory results.

2 Background Information

The unintentional POPs listed in Annex C of the Stockholm Convention are: polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs) and pentachlorobenzene (the latter added in May 2009). These chemicals can be found throughout the world in air, soil, sediment and water. Once in the environment, they accumulate in the fatty tissues of animals such as birds, fish, shellfish, marine mammals and domestic animals, and in people. POPs break down very slowly and can remain in the environment and in people's bodies for a very long time.

Animal studies show that some dioxins and dioxin-like compounds are extremely toxic. Although less is known about their impact on human health, it is widely assumed that dioxins have the potential to cause neurobehavioural, developmental, reproductive and immunotoxic effects at low doses. Significantly, 2,3,7,8-TCDD was evaluated by the International Agency for Research on Cancer in 1997 and was classified as a "known human carcinogen" (class I).

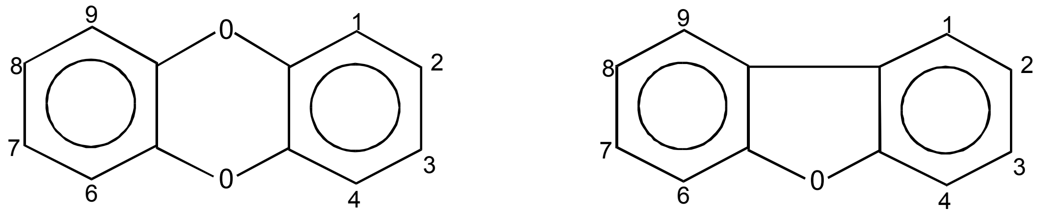
PCDDs and PCDFs have never been produced intentionally, other than for research, but are formed as unintentional by-products in various chemical production processes and in most thermal processes, including combustion. Both HCB and PCBs have been intentionally produced and used for a variety of purposes. However, they can also be formed as unintentional by-products in a manner analogous to the formation of PCDDs and PCDFs.

This inventory is limited to release estimates for PCDDs and PCDFs, mainly because the amount of data available on unintentional releases of HCB and PCBs is extremely limited. In general, it is expected that any actions taken to reduce dioxin releases would have similar effects on the unintentional releases of HCB and PCBs from those same sources (AEA Technology, 2006).

2.1 Dioxins: structure and composition

The basic structures of the PCDDs and PCDFs are shown in figure 2.1. Both groups of chemicals can have up to eight chlorine atoms attached at positions 1 to 4 and 6 to 9. Each individual compound resulting from this arrangement is referred to as a congener, and specific congeners are distinguished by the number and position of chlorine atoms around the core structure. In total there are 75 possible PCDD congeners and 135 possible PCDF congeners. Groups of congeners with the same number of chlorine atoms are known as homologues. The number of congeners in each homologue group is shown in table 2.1.

Figure 2.1: Structures of dibenzo-p-dioxin and dibenzofuran



dibenzo-p-dioxin

dibenzofuran

Table 2.1: Homologues and congeners of PCDDs and PCDFs

Abbreviation	Homologue name	No. of possible congeners	No. of possible 2,3,7,8-chlorinated congeners
MCDD	Monochlorodibenzo-p-dioxin	2	0
DiCDD	Dichlorodibenzo-p-dioxin	10	0
TrCDD	Trichlorodibenzo-p-dioxin	14	0
TCDD	Tetrachlorodibenzo-p-dioxin	22	1
PeCDD	Pentachlorodibenzo-p-dioxin	14	1
HxCDD	Hexachlorodibenzo-p-dioxin	10	3
HpCDD	Heptachlorodibenzo-p-dioxin	2	1
OCDD	Octachlorodibenzo-p-dioxin	1	1
MCDF	Monochlorodibenzofuran	4	0
DiCDF	Dichlorodibenzofuran	16	0
TrCDF	Trichlorodibenzofuran	28	0
TCDF	Tetrachlorodibenzofuran	38	1
PeCDF	Pentachlorodibenzofuran	28	2
HxCDF	Hexachlorodibenzofuran	16	4
HpCDF	Heptachlorodibenzofuran	4	2
OCDF	Octachlorodibenzofuran	1	1

2.2 Toxicity

Congeners containing one, two or three chlorine atoms are thought to be of no toxicological significance. However, the 17 congeners with chlorine atoms substituted in the 2,3,7,8 positions are thought to pose a risk to human and environmental health. Of these, the most toxic and widely studied congener is 2,3,7,8-TCDD. Increasing substitution from four to eight chlorine atoms generally results in a marked decrease in potency.

2.2.1 Toxic equivalents

In environmental media the PCDDs and PCDFs occur as complex mixtures of congeners, which results in complex, multivariate data sets. A system of toxic equivalents (TEQs) has been developed in response to this, so that the data can be reduced to single values. The toxic equivalents method is based on the available toxicological and *in vitro* biological data, and knowledge of structural similarities among the PCDDs and PCDFs. This information has been used to produce a set of weighting factors, each of which expresses the toxicity of each PCDD or PCDF congener in terms of an equivalent amount of 2,3,7,8-TCDD. Multiplication of the concentration of a PCDD or PCDF congener by the toxic equivalence factor (TEF) gives a corresponding 2,3,7,8-TCDD TEQ concentration. The toxicity of any mixture of PCDDs and PCDFs, expressed as 2,3,7,8-TCDD, is derived by summing the individual TEQ concentrations. This is reported as the ‘total TEQ’ for a mixture.

A number of toxic equivalents schemes have been developed, although the most widely adopted system is the International Toxic Equivalents Factor (I-TEF) scheme proposed by the North Atlantic Treaty Organization’s Committee on Challenges to Modern Society (Kutz et al, 1990). This approach assigns a TEF to each of the 17 toxic 2,3,7,8-chlorinated PCDDs and PCDFs (see table 2.2). The remaining non 2,3,7,8-chlorinated congeners are considered biologically inactive and are assigned a TEF of zero.

Table 2.2: Toxic equivalence factors for PCDDs and PCDFs

PCDD and PCDF congeners	I-TEF	WHO-TEF (humans/mammals)	
		1998	2005
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PeCDD	0.5	1	1
1,2,3,4,7,8-HxCDD	0.1	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01	0.01
OCDD	0.001	0.0001	0.0003
2,3,7,8-TCDF	0.1	0.1	0.1
1,2,3,7,8-PeCDF	0.05	0.05	0.03
2,3,4,7,8-PeCDF	0.5	0.5	0.3
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
OCDF	0.001	0.0001	0.0003

The I-TEF scheme was revised and expanded through the auspices of the World Health Organization (WHO) to provide TEF values for humans/mammals, and fish and birds (Van den Berg et al, 1998). A more recent review of the mammalian toxicity data resulted in some minor changes to some of the WHO-TEFs, as shown in table 2.2 (Van den Berg et al, 2006).

To maintain comparability with the 2000 Inventory, all of the PCDD and PCDF release estimates in this inventory are reported as I-TEQs. Generally, the differences between I-TEQs and WHO-TEQs are not significant when releases are being assessed on a national scale because of the much greater uncertainties in the activity data and emission factors.

2.3 Dioxin release reduction and prevention measures

Article 5(c) of the Stockholm Convention requires each party to “promote the development, and where it deems appropriate, require the use of substitute or modified materials, products and processes to prevent the formation and release of” dioxins and other Annex C chemicals. Part V of Annex C provides the following guidance on general prevention measures for reducing or eliminating unintentional releases:

a. the use of low-waste technology

b. the use of less hazardous substances

c. the promotion of the recovery and recycling of waste and of substances generated and used in a process

d. replacement of feed materials which are persistent organic pollutants or where there is a direct link between the materials and releases of persistent organic pollutants from the source

e. good housekeeping and preventive maintenance programmes

f. improvements in waste management with the aim of the cessation of open and other uncontrolled burning of wastes, including the burning of landfill sites. [In addition,] when considering proposals to construct new waste disposal facilities, consideration should be given to alternatives such as activities to minimize the generation of municipal and medical waste, including resource recovery, reuse, recycling, waste separation and promoting products that generate less waste. Under this approach, public health concerns should be carefully considered

g. minimisation of these chemicals [POPs] as contaminants in products

h. avoiding elemental chlorine or chemicals generating elemental chlorine for bleaching.

2.4 Best available techniques/best environmental practices

Articles 5(d) and (e) of the Stockholm Convention require parties to *promote* or *require* the application of best available techniques/best environmental practices (BAT/BEP) to both new and existing sources. The more stringent provision to *require* BAT/BEP only applies to new[2] sources in the following categories listed in Annex C, Part II, although parties may also target other sources in accordance with national priorities:

a. waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge

b. cement kilns firing hazardous waste

c. production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching

d. the following thermal processes in the metallurgical industry:
    i. secondary copper production;
    ii. sinter plants in the iron and steel industry
    iii. secondary aluminium production;
    iv. secondary zinc production.

Some general guidance on BAT/BEP is given in Annex C, part V, of the Stockholm Convention, including the following release reduction measures (taken from part V[B][b]):

i. use of improved methods for flue-gas cleaning such as thermal or catalytic oxidation, dust precipitation, or adsorption

ii. treatment of residuals, wastewater, wastes and sewage sludge by, for example, thermal treatment or rendering them inert or chemical processes that detoxify them

iii. process changes that lead to the reduction or elimination of releases, such as moving to closed systems

iv. modification of process designs to improve combustion and prevent formation of the chemicals listed in this Annex, through the control of parameters such as incineration temperature or residence time.

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[2] The term ‘new sources’ includes existing sources undergoing substantial modifications.

Detailed guidelines for specific sources are given in a BAT/BEP guidance document adopted by a decision of the Conference of the Parties (UNEP, 2007). The main requirements for each source category are summarised at the end of each of the source-specific sections of this report, along with an assessment of the extent to which New Zealand sources comply.

2.5 New POPs

Nine additional chemicals were added to the list of POPs covered under the Stockholm Convention in 2009 (see http://chm.pops.int/programmes/newPOPs/). All of these new POPs are (or were) intentionally produced and have been added to Annexes A (elimination) or B (restriction) of the Convention. However, one of the new POPs, pentachlorobenzene, was also added to Annex C because it can be formed as an unintentional by-product.

Pentachlorobenzene (PeCBz) was used in the past as a pesticide, flame retardant, and in combination with PCBs in dielectric fluids (UNEP, 2006). It is not clear whether it is still used as a pesticide or flame retardant on its own, but it can also appear as an impurity of pentachloronitro-benzene (quintozene) and other pesticides such as clopyralid, atrazine, chlorothalonil, dacthal, lindane, pentachlorophenol, picloram and simazine. It may be released to the environment indirectly through waste incineration, household waste burning, and in the waste streams from pulp and paper mills, iron and steel mills, petroleum refineries, and activated sludge wastewater treatment plants.

The implications of this new listing were discussed by the Toolkit Expert Group (see section 3.1.1) at its most recent meeting in December 2009 (Expert Group, 2010). After discussion, the Group recommended that:

> [emission factors] should be generated where possible, but Parties would not have to make efforts to compile a full inventory of unintentional PeCBz ([or] HCB, PCB) releases since the purpose of the Convention is to identify sources, prioritise them and undertake measures to reduce them [while] being aware that also other unintentional POPs are formed and released and could be controlled by the same measures.

On this basis, pentachlorobenzene releases will not be considered in the current inventory.

3 Assessment Methodology

PCDDs and PCDFs may be released directly to air, land or water from industrial and non-industrial activities, as well as from natural events such as forest fires. They may also be present in products or materials, including wastes, and enter the environment during the use or disposal of these materials.

This inventory attempts to quantify releases of PCDDs and PCDFs to all environmental media, and the extent of reservoir sources. However, it should be noted that the relative contribution of the different sources to the exposure of a population or ecosystem is not necessarily indicated by a simple ranking of relative source strength. The distribution and fate of PCDDs and PCDFs in the environment play an important role in mediating between releases and exposure.

In aiming to reduce general population exposures, most attention has focused historically on controlling levels of PCDDs and PCDFs released from the use of chlorinated chemicals such as PCP and 2,4,5-T, and on controlling releases to air and water. Direct releases to land and into landfills are generally thought to contribute much less to exposure.

3.1 Methodology

The methodology followed in this inventory is consistent with current international practice (UNEP, 2005), and is based on the emission factor approach. The annual releases from each source are estimated by multiplying an activity statistic by an emission factor:

$$\text{annual release (g TEQ yr}^{-1}) = \text{activity (tonnes yr}^{-1}) \times \text{emission factor (g TEQ tonne}^{-1})$$

Activity statistics are chosen on the basis of fuel consumption, production rates or some other similar measure, while the emission factors are based on data for the average emissions to air, land or water, per unit of activity. For any source category characterised by a large number of (often small) emitters, the activities of the individual sources are grouped, and an overall activity statistic is applied across the group.

It should be noted that there is considerable uncertainty in an inventory of this nature, in terms of the factors controlling the releases of PCDDs and PCDFs. The emissions from individual sources can vary significantly depending on changes in the process itself or in the materials being processed. Implicit in the activity statistic approach, and the grouping of source categories, is the assumption that facilities with similar design and operating conditions will have similar PCDD/PCDF release potential. However, this is not always the case.

The 2000 Inventory was based on the use of a range of emission factors for each source to indicate some of the variations in published emissions data. Uncertainty rankings were also reported for the activity statistics and for the emission factors used for each source. A similar approach has been taken in the current inventory – with one major difference. Emission factors are now based on the recommendations given in the *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases* (the Toolkit, UNEP, 2005), which is discussed below.

3.1.1 The UNEP Toolkit

The UNEP Toolkit was developed by UNEP Chemicals with the aim of achieving an effective and standardised approach to compiling PCDD/PCDF emission inventories (UNEP, 2005). This was intended to ensure a reasonable degree of consistency between the inventories reported by different countries, as part of their requirements under the Stockholm Convention, and should also help in comparing inventory results between countries or changes over time. As indicated in the introductory Toolkit text, “Only comparable sets of PCDD/PCDF source release data can provide a clear global picture on the scale of releases as a step in prioritising actions to control or reduce releases. International comparability is the goal of this process.”

Two of the main issues addressed by the Toolkit are consistency in source identification and the use of a standard set of default emission factors. The first of these issues is relevant to the current work, in that a number of potential, albeit quite minor, sources were not included in the 2000 Inventory. The second is also relevant, in that many of the recommended emission factors are based on a wider range of published data than was considered in the previous inventory.

Source categories

The UNEP Toolkit classifies all potential PCDD/PCDF sources into the following 10 categories:

- waste incineration
- ferrous and non-ferrous metal production
- heat and power generation
- production of mineral products
- transportation
- open burning processes
- production of chemicals and consumer goods
- miscellaneous sources
- disposal
- potential hot spots.

While the UNEP Toolkit classification has not been adopted for the 2011 Inventory (to help readers to compare the two New Zealand reports), a summary of the 2011 Inventory results consistent with the UNEP Toolkit categories is given in the Appendix to this report.

Emission factors

Each of the Toolkit categories is divided into subcategories on the basis of the different types of processes (eg, incineration of hazardous wastes, municipal wastes, medical wastes, etc), and each of the subcategories is divided into several classes, depending on the degree of process and/or emission control. Typically, class 1 processes are those with basic equipment and minimal levels of control. As the class number increases (from class 2 through classes 4 or 5), the performance of the process or activity improves, resulting in lower PCDD/PCDF releases. The highest class in each subcategory is usually representative of the emission levels that can be achieved through the application of best available techniques and best environmental practices (see section 2.4).

The emission factors given for each class represent the best-estimate average emission rates based on measured data at existing sources with similar technologies, process characteristics and operating practices. Most of the emission factors are based on published data found in peer-reviewed literature, or in government or institutional reports. To make the emission factors user-friendly, manageable and robust, this original data has been aggregated into order-of-magnitude estimates for the majority of the classes within each subcategory.

Emission factors have been recommended for the following release vectors: air, water, land, and in products or residues, although not all vectors are applicable to each subcategory. This differs from the 2000 Inventory, which did not include a separate residue vector. However, the difference is not significant. The Toolkit residues vector relates mainly to sources that result in a process by-product or waste (eg, the dusts collected in bag filters). These may be either processed (eg, for materials recovery) or disposed, usually to landfill. In New Zealand the latter option is the dominant route, and hence most of these residues are considered as releases to land.

The Toolkit category for hot spots is effectively the same as the various reservoir sources considered in the New Zealand inventory.

Limitations

The main limitation with the Toolkit is the use of a one-size-fits-all approach, although this limitation also applied to the 2000 Inventory. The only way to accurately determine the PCDD and PCDF emissions from each source or group of sources is through an extensive emission-testing programme. However, such an exercise would be prohibitively expensive, especially on a national scale. The main advantage of using the Toolkit is that the emission factors for most sources have been broken down into several different performance levels by drawing on a wider range of published data, as indicated previously.

Overall, the amount of data used in developing the Toolkit factors for each source subcategory is still quite limited. In addition, some of it is relatively dated. It should also be recognised that some source characteristics may vary significantly between countries; for example, the Toolkit factors for industrial coal combustion appear to be based on relatively large boilers, whereas a third of all New Zealand plants would be classified as small (< 10 MW). Local emission factors have been used whenever available to address this point.

The Toolkit emission factors will be amended, or the classifications expanded, as new data becomes available. An Expert Group has been established under the auspices of the Stockholm Convention for this purpose (see http://chm.pops.int/Programmes/ToolKit/Processes-Procedures/tabid/196-/language/en-US/Default.aspx).

3.2 PCDD/PCDF emissions and releases

3.2.1 Emissions to air

PCDDs and PCDFs may be emitted to air by a wide range of processes, including waste incineration, thermal processing of metals and the combustion of fuels. Releases due to evaporation are not generally assessed as part of an inventory study.

The formation of PCDDs and PCDFs in thermal processes is complex, and many factors are important. The material being burned, the combustion conditions, the temperature and composition of the discharges, and the design and operation of plant can all influence the formation of PCDDs and PCDFs. The final emissions can also be strongly dependent on the performance characteristics and efficiency of any ‘end-of-pipe’ pollution control systems. The control of emissions from waste incineration processes has been well studied, and good levels of control can be achieved. Releases from other processes have been less intensely studied, but effective controls are becoming available. The recommended controls are summarised in the notes on BAT/BEP given at the end of each of the inventory sections of this report.

Emissions to air can also occur when contaminated sites are subject to scouring by wind and material is carried off-site. Information is not available on the significance of this in New Zealand, and it has not been assessed in the inventory.

3.2.2 Releases to land and water

Many industrial and non-industrial processes are thought to release PCDDs and PCDFs to land and, to a lesser extent, to water. There is a concern when considering releases to these media that there will be double accounting of some PCDDs and PCDFs. For example, some PCDDs and PCDFs present in stormwater discharges, or in domestic refuse, are likely to have come originally from emissions to air, and the stormwater or refuse simply accumulates them and acts as a transport vector. At times there is no way of identifying the original source of the PCDDs and PCDFs. The potential for double accounting has been avoided in the current work by focusing on direct releases to the environment, without considering their subsequent distribution and fate.

3.2.3 Reservoirs

Reservoirs are materials or places that contain previously deposited PCDDs and PCDFs. The inventory considers reservoirs from certain industrial activities, and landfills. These generally represent sites of localised contamination in which the levels of PCDDs and PCDFs are higher than the typical ‘background’ levels in the general environment. For such reservoirs, there is the potential for the redistribution and circulation of the contaminants through the wider environment. Reservoirs sources therefore pose an ongoing risk to the environment and to human health, although the potential exposure pathways and the resulting environmental significance are often difficult to characterise and are poorly understood.

The presence of PCDDs and PCDFs bound to soils and sediments throughout the general environment may also be considered a diffuse reservoir. However, the magnitude of this has not been assessed because of the difficulties in obtaining accurate overall estimates.

3.3 Uncertainty

There is a reasonable amount of data available on PCDD and PCDF emissions to air for most of the larger industrial sources in New Zealand. However, much less data is available for these industries on the concentrations in solid or liquid waste streams. There is almost no PCDD and PCDF data available for the majority of the smaller industrial sources, for any of the process streams. This lack of specific industry or process data creates problems when trying to derive a national emission estimate for these sources. A further uncertainty is that, for some industrial processes, a wide range of different equipment is used, with varying inputs and operating conditions. As a consequence it is often not possible to reliably predict the emissions from different plant configurations and operational conditions. However, activity/production data is almost always available, and is generally of good quality.

For non-industrial sources there is considerable difficulty in estimating emissions, due to the lack of data, the widely varying conditions and the uncontrolled nature of these emissions. Activity statistics for such processes are also imperfect, and are often derived from secondary indicators.

3.3.1 Emission factors

The choice of emission factors for each source or group of sources is discussed within each of the inventory sections. The general approach taken has been to use New Zealand data, when available. In the absence of any local data, the factors given in the UNEP Toolkit have been used. In those cases where the amount of local data is limited, a judgement call has been made as to the most appropriate factor to use.

3.3.2 Emission factor ranges

The release estimates in the 2000 Inventory were reported as ranges of values, as a reflection of the inherent uncertainties in trying to derive release estimates from limited data. However, this is not consistent with the UNEP Toolkit, which uses single factors for each class of sources within each subcategory. It also creates difficulties when trying to compare results between inventories for different countries, or inventory changes over time (ie, between the current and previous New Zealand inventories).

In keeping with the Toolkit approach, the results for the 2011 Inventory are reported as single values. Comparisons with the previous inventory results have been made by considering both the ranges, and the mid-point values of the ranges, given in the 2000 Inventory report.

3.3.3 Certainty rankings

No source considered in this inventory has been studied comprehensively (ie, had its emissions measured under all conditions over an extended period of time), and therefore all estimates made are subject to uncertainty. This uncertainty applies to both the activity data and the emission factors used to estimate the emissions. A qualitative indication of the certainty of each estimate has been provided using three ranking levels: high, medium and low. The certainty ranking was assigned on the basis of the available data, including a consideration of data quality, knowledge of each source sector, and a broad knowledge of emission factors. In addition, the following general principles were adopted.

Activity statistics

- A high certainty ranking was assigned if the statistics were based on specific industry data, or were derived from comprehensive survey data.
- A medium certainty ranking was applied if limited industry or survey data was available, or if the data was modified to account for confounding factors.
- A low certainty ranking was assigned if there was no data available and the level of activity was based on subjective assessment and/or modelled data.

Emission factor

- A high certainty ranking was assigned if a reasonable amount of emissions data was available for the specific New Zealand sources.
- A medium certainty ranking was assigned if the New Zealand emissions data was limited, but the emission factors compared well with international data.
- A low certainty ranking was assigned if there was no New Zealand data available, and the estimate of PCDD/PCDF emissions was based solely on international (Toolkit) factors.

3.4 Units

Generally, the factors given in this report are in units of μg TEQ tonne^{-1}, for releases to air or land, and pg TEQ L^{-1} for releases to water. Annual releases are given in units of g TEQ yr^{-1}.

3.4.1 Toxic equivalents

All New Zealand PCDD and PCDF data presented in this inventory is reported as I-TEQ. The UNEP Toolkit is less specific about which form of toxicity equivalence factors have been used, and notes that, for the purposes of national inventories, the differences between I-TEQs and WHO-TEQs are relatively minor. As a general principle, all release estimates given in this report should be read as being I-TEQ unless otherwise stated.

3.5 Reference date

The reference date for this inventory is taken as the 2008 calendar year, and 2008 activity data has been used whenever possible in deriving the release estimates. The use of data from earlier years has been noted where relevant.

3.5.1 Back-calculations and future forecasts

The tables of release estimates given in each section show activity data and release estimates for 1998, 2008, 2013 and 2018. The release estimates shown for 1998 are based on 1998 activity data combined with the current emission factors. However, this is sometimes not possible and/or appropriate because of significant changes in methodology. In those cases, the 1998 release estimates are simply based on the actual value or the mid-point of the range reported in the 2000 Inventory. This is indicated by the use of brackets, and is also noted in the accompanying text.

The release forecasts for 2013 and 2018 are based on the 2008 emission factors coupled with estimates for future activity data. Where available, the future activity estimates were based on historical trend data. However, in many cases no such data was available, and the projections are based on there being no significant changes from current activity levels.

3.6 Consultation

A wide range of industry representatives and other stakeholders were consulted during the preparation of this inventory. This particularly related to the provision of activity data for specific industries or groups of industries, and also to the assessments at the end of each section on current levels of compliance with the BAT/BEP recommendations. Specific inputs from these people have been acknowledged through appropriate references in the text.

Particular efforts have been made to involve regional councils in this work, given that they are responsible for implementing and enforcing many of the controls available through the Resource Management Act. These efforts have included presentations to the National Air Quality Working Group, the inclusion of nominated personnel in the data gathering for specific source categories, and circulation of a discussion paper on possible control options before finalising the draft report.

The draft inventory report was distributed for comment to a wide range of people, including industry representatives, regional councils, government agencies, UNEP Chemicals, the Secretariat of the Stockholm Convention, and the members of the Expert Group established under the Convention to review and update the UNEP Toolkit.

Part 2: The Inventory

4 Clinical, Pathological and Quarantine Waste Incineration

Historically, incineration has been used throughout New Zealand for the treatment and disposal of clinical, pathological and quarantine wastes. Twenty-four incinerators were identified as operating in the 2000 Inventory but this number has now been reduced to only two: one burning hospital wastes and the other quarantine wastes. The drastic reduction in the number of incinerators used for the purposes of disposing of clinical and pathological wastes is due mainly to the introduction of the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004. There has also been a move towards alternative treatment technologies, such as steam sterilisation (Ryan, 2007).

The Regulations (see Updated Users Guide, Ministry for the Environment, 2005a) prohibit the operation of high-temperature hazardous waste incinerators, with the exception of crematoria. At the time of this regulation, three incineration facilities were specifically listed as being consented to operate. Of these, the one incinerator listed for operating as a hazardous waste incinerator is discussed separately in section 5.

In the Regulations, high-temperature hazardous waste incinerators are defined as facilities designed and operated principally for burning hazardous wastes at a temperature greater than 850°C. The Regulations define hazardous waste as waste belonging to one or more of the categories listed in Annex I of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, and having one or more of the characteristics listed in Annex III of that convention. Clinical and pathological wastes are classified as hazardous wastes under category Y1 (clinical wastes from medical care in hospitals, medical centres and clinics) and have waste characteristic H6.2 (infectious substances).

4.1 Emissions to air

The sole remaining incinerator used for clinical waste is a dual-chamber type with diesel used as auxiliary fuel. The unit is operated six to seven days per week throughout the year, with a total throughput of about 200 tonnes of waste per annum. In addition to clinical waste, some non-hazardous materials such as confidential documents are also incinerated. Attempts are being made to reduce the amount of waste incinerated, although alternative disposal options are costly.

The sole remaining incinerator burning quarantine waste is also a dual-chamber type but this one uses natural gas as the auxiliary fuel. Its primary function is the disposal of quarantine waste from overseas aircraft flights. However, other waste types are also burned, including confiscated drugs, bio-hazardous materials and classified documents. The facility operates on approximately 50 occasions per year, with a total throughput of about 19 tonnes per annum.

The 2000 Inventory used a range of plant-specific emission factors, which were based on emission test results. Plants for which no test data was available were assigned an emission factor range of 62.5–617 μg tonne^{-1}, which was based on the published data for plants without gas scrubbing. No specific test data is available for the two incinerators considered here.

The UNEP Toolkit provides emission factors for four classes of medical waste incineration. Class 2 corresponds to "controlled batch type combustion – no or minimal air pollution control systems". This classification applies to all medical waste incinerators with controlled combustion and an afterburner (ie, secondary combustion stage) operated in batch mode, but with no additional emissions controls such as bag filters. The emission factor is 3000 μg TEQ tonne^{-1} medical waste. This emission factor has been adopted for the current assessment.

The Toolkit does not provide emission factors for quarantine waste incineration. However, because quarantine waste is likely to exhibit the same problematic characteristics as medical waste (high moisture content and the presence of high-energy materials such as plastics), the medical waste emission factor is seen as appropriate.

National emission estimates

PCDD and PCDF emissions to air from clinical, pathological and quarantine waste incineration are summarised in table 4.1. As expected, the total emissions from these sources are towards the bottom end of the range reported in the 2000 Inventory (0.38–3.5 g I-TEQ yr^{-1}) because most of the incinerators have been shut down. The future projections assume no significant change from the current situation, while the figure shown for 1998 is the mid-point of the range reported in the 2000 Inventory.

Table 4.1: PCDD and PCDF emissions to air from clinical, pathological and quarantine waste incineration

Annual waste throughput (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
13,000	219	219	219	(1.94)	0.657	0.657	0.657

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a 'medium' certainty ranking because they are based on estimated waste throughput for each unit. The emission factor is assigned a 'low' certainty ranking because it is based on published values rather than site-specific data.

4.2 Residues (releases to land)

Neither of the two incinerators has air pollution control equipment installed. Consequently, the only residue produced is bottom (grate) ash, which is disposed to landfill. No specific data is available for PCDD/PCDF residues in the bottom ash produced by either of the two incinerators. The UNEP Toolkit assigns an emission factor of 20 μg TEQ tonne^{-1} of medical waste for class 2 incinerators, and this has been used for the current release estimate.

Table 4.2: PCDD and PCDF releases to land from clinical, pathological and quarantine waste incineration

Annual waste throughput (tonnes yr^{-1})				Annual residue release (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
13,000	219	219	219	(1.82)	0.0044	0.0044	0.0044

National release estimates

PCDD and PCDF releases in ash from clinical, pathological and quarantine waste incineration are summarised in table 4.2.

The release estimate for 1998 was proportionately much higher (0.43–3.2 g I-TEQ yr^{-1}) than the current estimate because some of the incinerators had gas-scrubbing equipment installed and produced residues containing fly ash, which has much higher PCDD/PCDF concentrations than bottom ash.

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a medium certainty ranking because they are based on estimated waste throughput for each unit. The emission factor is assigned a low certainty ranking because it is based on published values, rather than site-specific data.

4.3 Releases to water

No releases to water are expected from these sources.

4.4 Application of BAT/BEP

The BAT/BEP Guidance (UNEP, 2007) provides information on medical waste incineration but does not address quarantine wastes. However, most of the measures suggested for medical waste can be regarded as also appropriate for quarantine waste because of the similarity in properties of the two waste types.

The BAT/BEP for medical waste incineration cover a comprehensive listing of waste-handling practices and incinerator operation. The key requirements are:

- appropriate transport, storage and security of health-care waste, according to the needs of that type of waste
- incineration of health-care waste only in dedicated plants, or in larger incinerators for hazardous waste
- well-trained personnel

- management of time, temperature, turbulence (the 3 Ts) and air supply (oxygen), through proper incinerator design and operation – temperatures at or above 850°C are required for complete combustion in most technologies, and the recommended residence time in the secondary combustion chamber is at least 2 seconds at 6% oxygen
- proper management and control of system operation, including waste input, burn conditions and post-burn management, and avoidance of cold starts, sudden process upsets and shutdowns
- process monitoring, including continuous monitoring of process temperatures and pressures, gas flows, carbon monoxide and oxygen in the exhaust gases, and periodic testing for other emissions such as particulate matter, hydrogen chloride and PCDD and PCDFs
- operation and regulation of the incineration from a central console
- the use of appropriate emission control equipment, including particulate (fly ash) removal and scrubbing systems for acid gases
- proper handling and disposal of incinerator residues, including fly ash and bottom ash
- regular inspection and maintenance programmes.

With a suitable combination of primary and secondary measures, PCDD/PCDF concentrations in air emissions should be no higher than 0.1 ng I-TEQ Nm^{-3} (at 11% O_2). Alternative disposal methods should also be considered, particularly if incinerator performance targets cannot be met.

Discussions with staff at the two operational incinerators indicate that they do not fully comply with the BAT/BEP Guidance. In particular, the residence times at operating temperature are 0.75 and 0.27 seconds for the clinical and quarantine units, respectively, which is well short of the 2-second recommendation. Annual emission testing is carried out at both facilities, but this does not include PCDD/PCDF monitoring of the flue gases. Consequently, it is not possible to determine if they are meeting the BAT/BEP performance requirement of 0.1 ng I-TEQ Nm^{-3} (at 11% O_2). Neither facility monitors excess oxygen or carbon monoxide levels in the combustion gases, although temperature is monitored. Neither facility has the suggested emission control equipment.

4.5 References

Ministry for the Environment. 2005a. *Updated Users Guide to Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004 (Including Amendments 2005)*. Wellington: Ministry for the Environment.

Ryan D. 2007. *GHG from the Waste Incineration Sector*. Prepared for the Ministry for the Environment by Sinclair Knight Merz. Wellington: Ministry for the Environment. (See also: http://www.interwaste.co.nz).

UNEP. 2007. *Revised Draft Guidance on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants.* Geneva: Secretariat to the Stockholm Convention, United Nations Environment Programme.

5 Hazardous Waste Incineration

There is only one specialised hazardous waste incinerator in New Zealand, which is used for the disposal of wastes associated with an agrichemical plant.

5.1 Emissions to air

The hazardous waste incinerator is a batch-operated, double-chamber unit with a fixed hearth, and it is relatively small by international standards. Wastes are weighed and loaded into the primary chamber, where they are burned at temperatures of 600–900°C. The combustion off-gases are fully combusted in the secondary chamber under controlled oxygen and high temperature (> 1100°C) conditions. There is no scrubbing of the gas stream before discharge to air, through a stack.

The incinerator is used for the disposal of manufacturing wastes and for any leachate generated from a permitted secure containment facility. The incinerator is operated on an intermittent basis several times per year. In 2007, 75 tonnes of waste were incinerated, which is significantly lower than the 302 tonnes reported in the 2000 Inventory. Future waste throughput is likely to remain at similar levels over the next 5 and 10 years as the company embraces new waste-reduction and waste-handling initiatives to offset the anticipated increase in production volumes over that time.

PCDD/PCDF emission testing is carried out once per year on the air discharge from the incinerator. On each testing occasion three different waste types are investigated: crushed drums, general waste and liquid waste. The following emission factors have been calculated, based on the results from testing in 2007: 0.034 µg I-TEQ tonne^{-1} for crushed drums, 2.72 µg I-TEQ tonne^{-1} for general waste, and 0.28 µg I-TEQ tonne^{-1} for liquid waste.

National emission estimates

Past, current and projected emissions from the incinerator are summarised in table 5.1. The activity data and emission estimates for 2008 are based on the 2007 data, while the figures shown for 1998 emissions are based on the mid-point of the ranges given in the 2000 Inventory.

Table 5.1: PCDD and PCDF emissions to air from hazardous waste incineration

Waste	Amount incinerated (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
Crushed drums	173	30	30	30	(0.0008)	0.000001	0.000001	0.000001
General waste	6	7	10	10	(0.0006)	0.000018	0.000027	0.000027
Liquid waste	95	38	35	35	(0.00047)	0.000010	0.000010	0.000010
Total	**302***	**75**	**75**	**75**	**(0.0022)***	**0.000029**	**0.000038**	**0.000038**

* The 1998 totals include emissions from two other waste streams that are no longer generated.

Certainty

Activity statistics:	High
Emission factor:	High

The activity statistics are assigned a 'high' certainty ranking because they are based on specific throughput data. The emission factor is also assigned a 'high' certainty ranking because it is based on specific emission data for this incinerator.

5.2 Residues (releases to land)

The quantity of grate ash generated from the incinerator in the past three years has been as follows:

- 2005: 0.5 tonnes
- 2006: 1.25 tonnes
- 2007: 0.75 tonnes.

A 2002 analysis of an ash sample for PCDD/PCDF gave a result of 25 μg I-TEQ tonne^{-1}. The amount of ash produced in the future should remain relatively constant at 2006/07 quantities. Ash is stored on-site until a sufficient amount has been collected (usually over about four years), after which it is sent to an approved landfill.

National release estimates

PCDD and PCDF releases in ash from the incinerator are summarised in table 5.2. The activity data and release estimates for 2008 are based on the 2007 data, while the 1998 back-projection is based on the 1998 activity data coupled with the current release factor.

Table 5.2: PCDD and PCDF releases to land from hazardous waste incineration

Ash production (tonnes yr^{-1})				Annual residue production (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
2.5	0.75	1.0	1.0	0.000064	0.000019	0.000025	0.000025

Certainty

Activity statistics:	High
Emission factor:	High

The activity statistics are assigned a 'high' certainty ranking because they are based on specific ash production data for this incinerator. The emission factor is also assigned a 'high' certainty ranking because it is based on measured PCDD and PCDF concentrations in the ash.

5.3 Releases to water

There are no releases to water from the operation of this incinerator.

5.4 Application of BAT/BEP

The BAT/BEP Guidance for hazardous waste incineration covers a range of issues related to waste-handling practices and incinerator operation. The key requirements are:

- characterisation of the waste materials
- management of time, temperature, turbulence (the 3 Ts) and air supply (oxygen), through proper incinerator design and operation – temperatures at or above 850°C are required for complete combustion in most technologies, and the recommended residence time in the secondary combustion chamber is at least 2 seconds at 6% oxygen
- proper management and control of system operation, including waste input, burn conditions and post-burn management, and avoidance of cold starts, sudden process upsets and shutdowns
- process monitoring, including continuous monitoring of process temperatures and pressures, gas flows, carbon monoxide and oxygen in the exhaust gases, and periodic testing for other emissions such as particulate matter, hydrogen chloride and PCDD/PCDFs
- the use of appropriate emission control equipment, including particulate (fly ash) removal and scrubbing systems for acid gases
- proper handling and disposal of incinerator residues
- regular inspection and maintenance programmes
- operator training
- other relevant practices, such as promotion of waste minimisation programmes, careful siting of the incinerator, and ongoing programmes for liaison with the public.

Discussions were held with senior company staff to evaluate the operation of the incinerator with regard to the BAT/BEP recommendations (Bingham, 2008a). The operation of the incinerator complies with the recommendations, with the exception of using emission control equipment. The incinerator exceeds the BAT/BEP requirement with regard to residence time at working temperature (2 seconds at 850°C). The incinerator does not employ any emission control equipment, but the results of emission testing demonstrate that the operation of the incinerator can easily match the BAT/BEP air emission performance standard of 0.1 ng I-TEQ Nm^{-3} at 11 % O_2.

5.5 References

Bingham AG. 2008a. *Report to Ministry for the Environment on an Assessment of the Dow Agrosciences High Temperature Waste Incinerator*. Prepared for the Ministry for the Environment by JCL Air & Environment, Auckland.

6 Wastewater Solids Incineration

There is only one operational wastewater solids (sewage sludge) incinerator in New Zealand, and the releases from this source are considered below. The releases of PCDD and PCDFs in solid wastes and liquid effluents from wastewater treatment plants are discussed in section 27.

6.1 Emissions to air

The wastewater solids incinerator is a fluidised bed unit that typically operates in the temperature range of 820–860°C. The off-gases are treated in a high-efficiency venturi scrubber, followed by a packed tower caustic scrubber. The gases are then passed through a large bark biofilter, which acts as a final scrubber, primarily for odour control.

The incinerator currently processes about 1500 dry tonnes of wastewater solids per year, although this throughput is expected to approximately double in about five years' time, when the wastewater treatment plant is upgraded to include a secondary treatment stage. A final decision on the amount of sludge that will be incinerated after the upgrade has not yet been made, so the estimate of 3000 tonnes per annum should be regarded as a tentative figure.

PCDD and PCDF emissions have been tested annually since 2004 using a sampling point in the ducting before the bark filter. The results of the emissions tests are shown in table 6.1 and have been used to derive an emission factor for the plant of 0.085 μg I-TEQ tonne^{-1}. This factor is considerably lower than the 9 μg I-TEQ tonne^{-1} that was used in the 2000 Inventory, based on a review of UK incinerators. The difference in factors most likely reflects differences in the nature and composition of the materials being processed through the wastewater treatment plant, such as a low proportion of industrial wastes.

Table 6.1: Results of PCDD and PCDF emission testing from the wastewater solids incinerator

Year	PCDD/PCDF concentration (ng I-TEQ Nm^{-3} @ 11% O_2)	Emission rate (ng I-TEQ hr^{-1})	Emission factor (μg I-TEQ tonne^{-1})*
2002	0.018	71.3	0.183
2004	0.0024	9.6	0.021
2005	0.0034	10.4	0.021
2006	0.0029	11.5	0.029
2007	0.0040	12.2	0.031
Average	0.0061	23.0	0.057

* Calculated on the basis of 240 operating days per year and 16 hours per day.

National emission estimates

PCDD and PCDF emissions to air from the incinerator are summarised in table 6.2. Note that the back-projection for 1998 is considerably lower than the figure of 0.009 g I-TEQ yr^{-1} given in the 2000 Inventory report. This arises from the use of the much lower, but more relevant, emission factor.

Table 6.2: PCDD and PCDF emissions to air from wastewater solids incineration

Wastewater solids incinerated (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
1000	1500	3000	3000	0.000057	0.000086	0.00017	0.00017

Certainty

Activity statistics:	High
Emission factor:	High

Both the activity statistics and the emission factor are assigned a 'high' certainty ranking because they are based on actual data for the sewage sludge incinerator.

6.2 Residues (releases to land)

The ash captured by the flue gas scrubbers is returned to the wastewater treatment plant as a component of the liquid waste stream, and should therefore not be counted as a release from the process. There is no information available locally on the PCDD or PCDF content of this waste stream, although measurements on a UK fluidised bed incinerator indicated a concentration of less than 1 ng I-TEQ kg^{-1} (UNEP, 2005).

There is no bottom (grate) ash production in fluidised bed incinerators, although there may be some ash accumulation in the bed medium (sand). This material is replaced annually and disposed to landfill, which will result in a release of PCDD/PCDFs to land. Similarly, there will be some additional releases to land associated with the replacement of the bark filter medium, although this is currently only done about once every 8 to 10 years. The UNEP Toolkit provides a residue release factor of 0.5 μg I-TEQ $tonne^{-1}$ for wastewater solids incinerators fitted with this degree of emission control, and this has been used in calculating an overall estimate for both of the above releases.

National release estimates

PCDD and PCDF releases in ash from wastewater solids incineration are summarised in table 6.3. The estimated residue production rate given in the 2000 Inventory report was 0.024 g I-TEQ yr^{-1}, but this was based on emission factors for multiple hearth furnaces, taken from the UK review noted above. These appear to produce a lot more ash than the fluidised bed units, and hence the estimated residues are a lot higher.

Table 6.3: PCDD and PCDF releases to land from wastewater solids incineration

Wastewater solids incinerated (tonnes yr^{-1})				Annual residue production (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
1000	1500	3000	3000	0.00050	0.00075	0.0015	0.0015

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because, although they are based on actual throughput data for the sewage sludge incinerator, there are some uncertainties around the overall quantities of residues produced and the frequency of disposal. The emission factor is assigned a ‘low’ certainty ranking because no New Zealand test data is available for this facility. The factor used is taken from international sources.

6.3 Releases to water

The liquid discharges from the venturi and caustic scrubbers are recycled back to the wastewater treatment plant and so there are no direct releases to water from this source. No data is available on PCDD and PCDF concentrations in this waste stream.

6.4 Application of BAT/BEP

The BAT/BEP Guidance for sewage sludge incineration is extensive and covers many aspects relating to waste-handling practices and incinerator operation. The key requirements are:

- careful management of waste composition and properties (eg, removal of the fat component and control of the moisture content)
- management of time, temperature, turbulence (the 3 Ts) and air supply (oxygen), through proper incinerator design and operation – temperatures at or above 850°C are required for complete combustion in most technologies, and the recommended residence time in the secondary combustion chamber is at least 2 seconds at 6% oxygen
- proper management and control of system operation, including waste input, burn conditions and post-burn management, and avoidance of cold starts, sudden process upsets and shutdowns
- process monitoring, including continuous monitoring of process temperatures and pressures, gas flows, carbon monoxide and oxygen in the exhaust gases, and periodic testing for other emissions such as particulate matter, hydrogen chloride and PCDD/PCDFs
- the use of appropriate emission control equipment, including particulate (fly ash) removal and scrubbing systems for acid gases
- proper handling and disposal of incinerator residues
- regular inspection and maintenance programmes
- operator training
- other relevant practices, such as promotion of waste minimisation programmes, careful siting of the incinerator and ongoing programmes for liaison with the public.

An on-site assessment was carried out in November 2007, with the participation of senior staff, to evaluate the operation of the incinerator with regard to the BAT/BEP recommendations (Bingham, 2008b). In general the system complies with most of the recommendations. The results of emission testing demonstrate that the operation of the incinerator, combined with the installed emission control equipment, is well capable of matching the BAT/BEP air emission performance standard of 0.1 ng I-TEQ Nm^{-3} at 11% O_2. The incinerator does not meet the BAT/BEP requirement with regard to residence time at working temperature (2 seconds at 850°C) and the requirement for continuous monitoring of carbon monoxide, although this does not prevent it from achieving the performance standard. Consideration should be given to landfilling the fly ash collected in the air pollution control equipment, after assessing its suitability, rather than the current practice of recycling it with sludge for incineration. In addition, the liquid effluent from the wet scrubber should be analysed to establish that it conforms with the BAT/BEP standard of < 0.1 ng I-TEQ L^{-1}.

6.5 References

Bingham AG. 2008b. *Report to Ministry for the Environment on an Assessment of the Dunedin Wastewater Solids Incinerator*. Prepared for the Ministry for the Environment by JCL Air & Environment, Auckland.

UNEP. 2005. *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases.* Version 2.1, December 2005. Geneva: UNEP Chemicals.

7 Other Waste Incineration

This section considers three other sources of PCDD and PCDF releases from incineration: document destruction, school incinerators and animal carcass disposal (pet incinerators).

Another potential source is municipal solid waste incineration, which has been identified internationally as a significant contributor to PCDD and PCDF emissions in some countries. However, there are no municipal waste incinerators in New Zealand, and most residential and industrial solid waste is either disposed to landfills or recycled. The disposal of residential and industrial solid waste in landfills is discussed in section 26, while the small-scale burning of domestic waste is covered in section 13.

7.1 Emissions to air

7.1.1 Document destruction

Only one facility has been identified in New Zealand for the disposal of papers and other documents by incineration, although some of the pet incinerators discussed in section 7.1.3 are occasionally used for this purpose as well. The incinerator uses LPG as auxiliary fuel and operates two days per week. It burns about 25 tonnes of waste per year, and this quantity is not expected to change significantly over the next 5 to 10 years.

Document destruction involves a reasonably uniform fuel type, which can be expected to be generally free of 'undesirable' materials such as plastics. There is no New Zealand data available on the PCDD and PCDF emissions from this type of incinerator, and UNEP Toolkit does not give an emission factor. However, it is expected that the emissions will be reasonably similar to those for biomass incineration, for which the Toolkit recommends an emission factor of 100 μg TEQ tonne^{-1}. This factor will be used here.

National emission estimates

The estimated emissions from document incineration are shown in table 7.1. This source was not specifically addressed in the 2000 Inventory so no comparative estimates are available for 1998.

Table 7.1: PCDD and PCDF emissions from document incineration

Weight of documents incinerated (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	25	25	25	–	0.0025	0.0025	0.0025

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on actual waste throughput. The emission factor is assigned a low certainty ranking because it is based on a relatively general published value for biomass incineration.

7.1.2 School incinerators

There are approximately 2300 schools in New Zealand, and about 700 of these were identified as having operational incinerators in 2005/06 (Ministry of Education, 2006). The waste disposed in these incinerators generally consists of waste paper and food packaging (ie, classroom and playground wastes). The use of school incinerators was banned under the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004, unless the activity was authorised by a resource consent issued before 1 October 2006. In response to this restriction, the Ministry of Education was proactive in identifying best practices for waste management to enable schools to avoid incineration through the use of alternative approaches such as composting, recycling and disposal to landfill. About 90% of the school incinerators were subsequently shut down, and there are only 71 incinerators currently operating under resource consents (M Stallman, Ministry of Education, pers comm, 2007). Most of these incinerators are in small rural schools without easy access to waste collection services or a local waste transfer station.

The total quantity of wastes disposed in these incinerators has not been determined. However, most of the schools will have rolls of fewer than 50 pupils, which suggests a weekly waste generation rate of no more than about 25 kg per school (roughly equivalent to one 200-litre drum of rubbish). Thus the total waste disposed at all 71 schools during a 40-week school year would be no more than about 70 tonnes per year. This quantity is unlikely to change significantly over the next 5 or 10 years.

There is no New Zealand data available on the PCDD and PCDF emissions from school incinerators. As indicated above, the waste composition, and the burning conditions, will be quite similar to those for domestic waste burning. The UNEP Toolkit recommends a factor of 300 µg I-TEQ tonne^{-1} for this activity, and this will be used for the current release estimates.

National emission estimates

PCDD and PCDF emissions to air from school incinerators are summarised in table 7.2. The emissions from this source were not specifically estimated in the 2000 Inventory, but they are likely to have been 30 or more times greater than at present because of the much greater number of incinerators, many of which would have been burning much more than 25 kg per week.

Table 7.2: PCDD and PCDF emissions to air from school incinerators

Total waste burned, tonnes yr^{-1}				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	70	70	70	–	0.021	0.021	0.021

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because, although they are based on an exact figure for the number of incinerators, the figure for the waste quantities is only an estimate. The emission factor is assigned a ‘low’ certainty ranking because no New Zealand emission test data is available and the factor used is a very general one for waste burning.

7.1.3 Animal carcass disposal

Animal carcass disposal falls into two distinct categories in New Zealand: the on-farm disposal of dead livestock by open burning, and the disposal of domestic pets and other small animals by controlled incineration. The open burning of dead livestock is a permitted activity in most regions, although it is usually regarded as an option of last resort. Alternative methods include burial in offal pits or removal to a rendering facility. No data is available on the number of carcasses disposed by burning and so the PCDD and PCDF releases cannot be determined with any degree of confidence. A rough estimate of the possible releases is given at the end of this section.

Thirteen pet incinerators have been identified throughout the country. Several of these were previously operated by agricultural research facilities for quarantine purposes (Ryan, 2007) but are now privately owned and operated, with a focus on the domestic market. Most of the other units have been established in the main urban areas over the past 5 to 15 years in response to a growing demand for pet disposal services. These newer units are typically based on a double-chamber design, with minimum temperature requirements of 850 to 1000°C, especially in the secondary chamber, and gas residence times of 0.5 to 2 (or more) seconds. Most resource consents require continuous monitoring of operating temperatures and an adequate supply of combustion air, although there is no requirement for continuous monitoring of oxygen or carbon monoxide.

The throughput of each of the pet incinerators ranges from around 6 to 36 tonnes per year, with an average of about 20 tonnes per year. On this basis, the total quantity disposed throughout the country would be about 260 tonnes per year. There is no data available to show whether the number of pets disposed in this way is increasing or decreasing, so future increases of 5 and 10% will be assumed, for 2013 and 2018 respectively, roughly in line with the expected (human) population increases.

PCDD and PCDF emissions have been measured on one pet incinerator in New Zealand, but the results were only reported on a concentration basis. The UNEP Toolkit recommends emission factors of 500 μg I-TEQ tonne^{-1} for ‘older furnaces’ and 50 μg I-TEQ tonne^{-1} for ‘better-controlled, newer facilities’. Most of the current units in New Zealand would fall into the latter category, but a few of them would not. On this basis, it will be assumed that 20% of all animal carcasses are disposed in older incinerators, for which the higher emission factor applies. These units are expected to be shut down or replaced over the next 5 to 10 years.

National emission estimates

The estimated emissions from animal carcass disposal in pet incinerators are shown in table 7.3. This source was not specifically addressed in the 2000 Inventory, so no comparative estimates are available for 1998.

Table 7.3: PCDD and PCDF emissions to air from animal carcass incineration

Incinerator type	Weight of carcasses (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
Older incinerators	–	52	27	0	–	0.026	0.014	0
Newer incinerators	–	208	246	286	–	0.01	0.012	0.014
Totals	–	260	273	286	–	0.036	0.026	0.014

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a 'medium' certainty ranking because they are based on the throughputs across the range of New Zealand facilities. The emission factor is assigned a 'low' certainty ranking because no New Zealand test data is available and the UNEP Toolkit factor is based on a limited amount of published data from a range of other countries.

Animal carcass disposal by open burning

There are approximately 50,000 farms in New Zealand involved in some form of livestock production. Anecdotal evidence indicates that open burning of animal carcasses could take place at least once a year on about 50% of these properties (P Baynham, Northland Regional Council, pers comm, 2008). Also, it is mainly smaller animals (eg, calves, sheep, goats) that are disposed in this way. The UNEP Toolkit recommends an emission factor of 500 µg I-TEQ $tonne^{-1}$ for open burning of animal carcasses. If we assume a disposal rate of 50 kg per burn, the potential PCDD and PCDF releases to air would be 0.75 g I-TEQ yr^{-1}. Clearly, these releases are not insignificant. However, in the absence of any more exact figures for burn quantities, it would be inappropriate to include them in the inventory totals.

7.2 Residues (releases to land)

7.2.1 Document destruction

The UNEP Toolkit does not provide a factor for the PCDD/PCDF releases via bottom ash in biomass incinerators. However, the ash produced by the document incinerator is not expected to be of any great significance, in terms of both quantities and PCDD/PCDF contamination.

7.2.2 School incinerators

The UNEP Toolkit recommends a factor of 600 µg I-TEQ $tonne^{-1}$ for the PCDD/PCDF residues produced from the burning of domestic wastes. This was derived from a limited number of international studies, but will be used in the release calculations for school incinerators in the absence of any relevant data for New Zealand.

National release estimates

PCDD and PCDF releases in ash from the burning of wastes in school incinerators are summarised in table 7.4. It is expected that most of this ash will be disposed by dumping on land.

Table 7.4: PCDD and PCDF releases to land from school incinerators

Total waste burned, tonnes yr^{-1}				Annual releases (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
–	70	70	70	–	0.042	0.042	0.042

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a 'low' certainty ranking because they are based on an exact figure for the number of incinerators but an estimated figure for the waste quantity. The emission factor is assigned a 'low' certainty ranking because no New Zealand emission test data is available and the factor used is a very general one for waste burning.

7.2.3 Animal carcass disposal

The UNEP Toolkit does not provide a factor for the PCDD and PCDF releases via bottom ash in pet incinerators. However, by comparison with the releases from clinical and pathological waste incinerators (see section 4) and crematoria (section 8), the ash quantities should be relatively insignificant. These would generally be disposed to landfill or scattered on the ground.

7.3 Releases to water

There are no direct releases to water from document destruction, school incinerators or animal carcass disposal.

7.4 Application of BAT/BEP

There are no specific recommendations in the BAT/BEP Guidance for document destruction, but it would be expected that these would be similar to the recommendations given for incinerators generally and, to a lesser extent, to the more demanding requirements for clinical and pathological waste incinerators, as discussed in section 4.

The most appropriate BAT/BEP guidance for school incinerators would be that given for the burning of domestic wastes (see section 13). The initiatives taken by the Ministry of Education in promoting alternatives to incineration should also be acknowledged. These have been highly successful in reducing the number of operational incinerators by about 90%.

Pet incinerators are also not specifically covered in the BAT/BEP Guidance but should be expected to comply with the recommendations given for crematoria (see section 8). As indicated earlier in this section, most of the current incinerators have been designed to meet the relevant requirements for chamber design and temperatures, although oxygen monitoring is not normally included. The few older units still in operation are expected to be shut down over the next 5 to 10 years.

7.5 References

Ministry of Education. 2006. Letter to the Ministry for the Environment, dated 14 July 2006, regarding the draft National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants.

Ryan D. 2007. *GHG from the Waste Incinerations Sector: Report to the Ministry for the Environment*. Prepared for the Ministry for the Environment by Sinclair Knight Merz. Wellington: Ministry for the Environment.

8 Crematoria

There are 43 cremation facilities in New Zealand, of which 21 are privately owned and the remainder are operated by territorial local authorities (R Grooby, Funeral Directors Association of New Zealand, pers comm, 2007). These service a significant demand for cremation, which is used for the disposal of human remains in about 60% of all deaths.

8.1 Emissions to air

The Burial and Cremations Act 1964 and the Cremation Regulations 1973 require that all cremators must have approval in writing by the Minister of Health, before commissioning. This approval is generally based on compliance with New Zealand guidelines covering a range of matters, including the crematorium site, the layout and construction of the cremator building, and the design and operation of the equipment (Department of Health, 1992). The recommended design parameters include a double-chamber cremator, with the primary chamber being preheated to 800–900°C before committal of the casket, and a minimum afterburner chamber temperature of 800°C.

Most installations will also require resource consent for discharges to air, under the Resource Management Act 1991, and this may include more stringent requirements than the Department of Health guidelines. Some regulatory authorities refer to a British standard that requires a minimum flue gas residence time of 2 seconds in the secondary chamber, calculated at 850°C and 6% oxygen. Others refer to the US requirement for a residence time of 1 second at 1000°C. Most cremators installed in New Zealand in recent years have complied with the British standard (T Brady, Terry Brady Consulting Ltd, Auckland, pers comm, 2008). The actual secondary chamber temperatures range from 850 to 1000°C, with oxygen levels between 6 and 11%. Primary chamber charging is usually carried out at 450 to 700°C depending on the type of unit.

The total numbers of deaths recorded in New Zealand by the Births, Deaths and Marriages registry for the 2007 and 2008 calendar years was 28,639 and 29,332, respectively (V Millar, Births, Deaths and Marriages, Department of Internal Affairs, Wellington, pers comm, 2008 and 2009). The place of disposal was recorded as a crematorium, cremator or similar for 17,293 of the deaths in 2007 and for 18,289 in 2008. This data indicates cremation rates of 60.4 and 62.4%, which are quite comparable to the range of 59–63% quoted in the 2000 Inventory report.

Recent projections by Statistics NZ (2007b) indicate that the number of deaths in New Zealand is expected to rise to 30,200 in 2013 and to 32,200 in 2018. These estimates are based on the 2006 Census data, coupled with mid-range assumptions for changes in mortality rates and net migration. A cremation rate of 61.4% will be assumed to apply to the emission estimates for 2013 and 2018, on the basis of the average cremation rate over the last two years.

The emission factor range adopted for the 2000 Inventory was 0.5–28 μg I-TEQ per body, which is reasonably consistent with the UNEP Toolkit factor of 10 μg I-TEQ per cremation, for cremators with a 'medium' level of performance management and emission control. No new data has been identified that would indicate the need to revise these factors.

National emission estimates

PCDD and PCDF emissions from crematoria are summarised in table 8.1. These were calculated using the UNEP emission factor of 10 μg I-TEQ per cremation. The annual emissions shown for 1998 are a back-projection, based on the UNEP Toolkit emission factor. The emission range reported in the 2000 Inventory was 0.0080–0.45 g I-TEQ yr^{-1}.

Table 8.1: PCDD and PCDF emissions to air from crematoria

No. of cremations yr^{-1}				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
15,900	18,289	18,543	19,771	0.159	0.183	0.185	0.197

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on current registry data (Births, Deaths and Marriages) for the number of cremations, and national population projections. The emission factor is assigned a ‘low’ certainty ranking because no New Zealand test data is available. The factor used is taken from the UNEP Toolkit and is based on reviews of a range of studies on overseas crematoria, with varying design and operational parameters and varying levels of emission control.

8.2 Residues (releases to land)

There is no New Zealand data available on the dioxin content of crematoria ash, although the quantity of ash produced was estimated in the 2000 Inventory to be 4 kg per cremation, giving a total of 64 tonnes per year. The equivalent production for 2008 would be 73 tonnes. These ashes are usually disposed by scattering on the ground or interment in a memorial wall or garden.

The UNEP Toolkit includes the results of ash analyses for a cremator in Thailand, with a ‘medium’ level of performance management and emission control. The average dioxin concentration was 46 ng I-TEQ kg^{-1} of bottom ash. If this result were applicable to New Zealand, it would indicate a total residue production for 2008 of 0.0034 g I-TEQ, which is insignificant compared to other releases to land.

8.3 Releases to water

There are no direct releases to water from the use of crematoria. Any leaching of PCDDs and PCDFs from the scattering of ashes should be insignificant, because the quantities involved are limited and the potential for leaching should be very low.

8.4 Application of BAT/BEP

The key requirements from the BAT/BEP Guidance for crematoria are:

- avoidance of chlorinated materials such as PVC coffin handles
- minimum design criteria of 850°C, 2 seconds residence time, and ensuring the provision of sufficient combustion air (eg, through oxygen monitoring)
- effective equipment operation, maintenance and management
- additional emission control equipment, such as activated carbon absorption, which is recommended for large installations, although the term ‘large’ is not defined.

The New Zealand guidelines noted in section 8.1 are consistent with the design criteria listed above, although some recent resource consents have included more demanding temperature specifications of 1000°C or higher, especially in the secondary chamber. In addition, the use of continuous oxygen monitoring is increasingly being recognised as an important factor in ensuring effective combustion control. Most operators are now well aware of the need for plastic materials to be removed from the casket before cremation, along with other relevant practices designed to minimise contaminant emissions.

No New Zealand cremators are fitted with additional emission control equipment, and any such requirements in the future would be determined on a case-by-case basis through the resource consent process. As shown in table 8.1, crematoria are a relatively minor contributor of dioxin emissions to air. Under Article 5 of the Stockholm Convention, these emissions should be addressed through the *promotion* of BAT/BEP, for both new and existing sources. As such, this requirement should be adequately addressed by simply ensuring that regional councils are properly informed of the recommendations given in the BAT/BEP Guidance.

8.5 References

Department of Health. 1992. *Guidelines on the Siting and Construction of Crematoria.* Wellington: Department of Health.

Statistics NZ. 2007b. *National Population Projections: 2006 (base) – 2061.* Wellington: Statistics New Zealand.

9 Power Generation

The majority of PCDD and PCDF releases from electricity generation in New Zealand arise from the combustion of fossil fuels, principally natural gas and coal, and a relatively small amount of diesel. Some electricity is also generated from the combustion of renewable materials such as woody biomass, which is covered under section 12.

In 2008, fossil fuels were used to generate 34.2% of total electricity. The breakdown by fuel type for all electricity generated in New Zealand is shown in table 9.1 (Ministry of Economic Development, 2009).

Table 9.1: Electricity generation, by fuel type, 2008

Sector type	GW hours	% of total generation
Hydro	23,220	52.3
Natural gas	9,181	23.7
Geothermal	3,210	9.4
Coal	5,119	10.5
Oil	21	0.3
Wind	617	2.5
Others	687	1.3
Total	42,056	100

9.1 Emissions to air

9.1.1 Emissions from coal-fired electricity generation

There is only one coal-fired power station in New Zealand, located in the Waikato region. The Huntly Power Station was originally built with four separate generating units of 250 MW each, capable of being fired on either gas or coal. The generating capacity has since been augmented with two additional gas turbine units to give a total site capacity of 1448 MW. This one station currently accounts for about 15% of New Zealand's total installed generation capacity (Ministry of Economic Development, 2009).

The annual coal consumption for electricity generation is highly variable. This reflects the dynamic wholesale market in which the generators operate, with retail electricity suppliers and large users bidding for their requirements each half hour. Many factors can interact to affect the short- or long-term demands on any one sector or fuel type. These can include restrictions on hydro supply in drought years, plant outages for planned or unplanned maintenance, the commissioning of new plant, changes in climatic conditions leading to increased (or decreased) domestic use, malfunctions in the transmission system, and the availability of fossil fuel supplies.

The variability in coal consumption for electricity generation is well illustrated by the following annual data for the period 2004 to 2008: 43.2, 54.6, 52.5, 26.4 and 43.4 PJ (gross). This can create difficulties in determining a representative annual activity rate, although, fortuitously, the 2008 coal consumption (43.4 PJ) was very close to the average consumption over the past five years (44.0 PJ).

The 2008 coal consumption data will be used for the current emission estimates. However, the projections for future coal consumption are more problematic – partly because of the wide variations in annual consumption, but also because the long-term future of the coal/gas units is uncertain (Genesis Energy, 2009). Considerable capital and operating expenditure are required to keep these units available to the market, yet their projected output in an average hydrological year is declining as new generation with lower short-run marginal costs enters the wholesale electricity market. As indicated in Genesis Energy's *Annual Report*, "the crucial issue is how to derive a commercial return on plant that provides more value to the country [eg, in terms of supply security] than it does to the Company" (Genesis Energy, 2009, page 5).

The emission calculations for 2013 and 2018 will be based on there being no change from current consumption levels. However, the potential for significant reductions in coal consumption, and hence PCDD/PCDF emissions, should be acknowledged.

The 2000 Inventory used the results of two emission-testing exercises, combined with an estimate of annual coal consumption, to produce an emission factor range of 0.2–0.36 μg I-TEQ tonne^{-1}. Assuming a calorific value of 30 MJ kg^{-1} for the bituminous coal used during testing, the emission factor range can be expressed in energy terms as 6.7–12.0 μg I-TEQ TJ^{-1}. This is quite comparable to the factor of 10 μg I-TEQ TJ^{-1} given in the UNEP Toolkit, and this latter figure will be used for the current estimates.

National emission estimates

PCDD and PCDF emissions from coal-fired power generation are summarised in table 9.2. The annual emissions shown for 1998 are a back-projection, based on the UNEP Toolkit emission factor. The emission range reported in the 2000 Inventory was 0.059–0.11 g I-TEQ yr^{-1}. Current coal consumption, and hence emissions, are much higher than those recorded for the 2000 Inventory. This has arisen because the power station now fires all of its four generating units on coal, whereas previously three out of four units would have typically been fuelled with natural gas.

Table 9.2: PCDD and PCDF emissions to air from coal-fired power generation

Coal consumption (PJ yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
9.63	43.4	43.4	43.4	0.096	0.434	0.434	0.434

Certainty

Activity statistics:	High
Emission factor:	Medium

The activity statistics are assigned a 'high' certainty ranking because they are based on national energy data. The emission factor is assigned a 'medium' certainty ranking because it is based on international studies, which agree well with limited historical test data from the power station.

9.1.2 Emissions from gas- and oil-fired electricity generation

Emissions from power stations fired on natural gas were not assessed in the 2000 Inventory because it was considered that the releases would be minimal. There are now 10 such facilities operating in New Zealand with individual electricity-generating capacities of 10 MW or greater, and a combined capacity of 1556 MW (Ministry of Economic Development, 2009). Six of these are combined-cycle gas turbines, one is an open-cycle gas turbine, and the remaining three are co-generation plants. The total estimated gas-fired generation capacity in 2008 was 1805 MW, which includes a contribution from the Huntly Power Station gas/coal units.

In 2008, New Zealand produced 154.8 PJ of natural gas, of which 83.9 PJ were used for electricity generation, including that consumed in co-generation plants (Ministry of Economic Development, 2009). Gas consumption for electricity generation is subject to much the same variability factors as for coal, with the annual gas consumption figures for the last five years ranging from about 60 to 100 PJ per year. Once again, the 2008 figure gives a reasonable representation of the average consumption rate over this period, and will therefore be used for the emission estimates.

Total electricity consumption is currently increasing at a rate of about 1.5% per year (Ministry of Economic Development, 2009). A significant proportion of future demand is likely to be met from renewable resources, such as wind power and geothermal energy. However, the recent significant investments in gas-fired plant suggest that this fuel will continue to be a significant contributor in the years to come. The emission projections for 2013 and 2018 will be based on an assumed increase in gas consumption of 1% per year.

The only oil-fired power station in New Zealand is a 155 MW 'standby' unit at Whirinaki (Ministry of Economic Development, 2009). This facility is only intended for operation in extraordinary circumstances when generating capacity is critically low. In 2008, the net electricity generation from oil was 0.44 PJ, which is roughly equivalent to about 1.5 PJ (gross) – assuming a conversion efficiency of 30%. The latter figure will used for both the 2008 emission estimates and the future projections.

The UNEP Toolkit gives an emission factor of 0.5 μg I-TEQ TJ^{-1} for boilers fired on natural gas or light fuel oil, and this factor will be used for the emission estimates, in the absence of any specific local data.

National emission estimates

PCDD and PCDF emissions from gas- and oil-fired electricity generation are summarised in table 9.3. The emission estimate for 1998 is a back-projection based on the UNEP Toolkit emission factor and the 1998 gas and oil consumption data (Ministry of Economic Development, 2009).

Table 9.3: PCDD and PCDF emissions to air from electricity generation using natural gas and oil

Fuel consumption (PJ yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
70.6	85.4	89.6	94.8	0.035	0.043	0.045	0.047

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on national energy data. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international studies.

9.2 Residues (releases to land)

Power plants fired on natural gas or oil are not expected to produce any ash waste stream. For coal-fired plants, the UNEP Toolkit indicates that fly ash is the principal source of PCDD/PCDF releases, while the quantities of boiler bottom ash are usually negligible.

The UNEP Toolkit provides an emission factor of 14 µg TEQ TJ^{-1} of fuel burned. This was based on an average fly ash concentration of 4 ng TEQ kg^{-1} ash. The 2000 Inventory reported a range of 2.7–5.4 ng TEQ kg^{-1} for fly ash from a New Zealand coal-fired power station. However, this was estimated from total PCDD and PCDF concentration data rather than isomer-specific analysis. The UNEP Toolkit factor will be used for the current release estimates.

National release estimates

PCDD and PCDF releases in ash from coal-fired electricity generation are summarised in table 9.4. The annual releases shown for 1998 are a back-projection, based on the UNEP Toolkit factor. The range reported in the 2000 Inventory was 0.0016–0.12 g I-TEQ yr^{-1} for releases of both fly ash and bottom ash.

Table 9.4: PCDD and PCDF releases to land / residues from coal-fired power generation

Coal consumption (PJ yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
9.63	43.4	43.4	43.4	0.135	0.608	0.608	0.608

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on national energy data. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international data.

9.3 Releases to water

No releases to water are expected from these sources.

9.4 Application of BAT/BEP

The BAT/BEP Guidance for fossil fuel-fired utility and industrial boilers includes the following.

- Identify and control key process parameters.
- Conduct inspection and maintenance programmes at appropriate cycles.
- Ensure all staff are appropriately trained in the application of the best environmental practices relevant to their duties.
- Define a fuel specification for key fuel parameters and introduce a monitoring and reporting protocol. Conduct regular monitoring of fuel quality to prevent the use of contaminated fuels.
- Ensure environmentally sound management of waste materials (eg, fly ash and bottom ash).
- Attention should be paid to the four cornerstones of high destruction efficiency: temperature, time, turbulence and excess oxygen. Temperatures in excess of 900°C and a residence time of at least 1 second should be maintained to ensure that all persistent organic pollutants are oxidised.
- When solid fuel is used, low-moisture pulverised fuels are preferable to crushed or lumpy fuels.
- Continuous monitoring of carbon monoxide is useful for indicating combustion quality.
- Install air pollution control devices when environmental benefits can be demonstrated.

The performance level associated with BAT/BEP is a concentration well below 0.1 ng I-TEQ Nm^{-3} (at 6% oxygen for solid fuels and 3% for liquid fuels).

Facilities associated with fossil fuel electricity generation in New Zealand would be regarded as generally complying with the above BAT/BEP requirements. For instance, the boilers at the coal-fired power station are carefully maintained on a regular basis and operated continuously by trained staff, who should be aware of the requirements for maintaining good combustion conditions. The boilers have an operating temperature in excess of 900°C and a residence time of more than 2 seconds. Pulverised coal is produced on-site, and defined fuel quality parameters are monitored on a daily basis. Instruments continuously monitor not only carbon monoxide but also carbon dioxide, sulphur dioxide, nitrogen oxides, excess oxygen, particulate matter and moisture content in the stack gases discharged from each boiler, which assists in the maintenance of good combustion quality. Electrostatic precipitators are used to capture fly ash. Previous emission-testing results show the plant is capable of meeting the above performance standard.

9.5 References

Genesis Energy. 2009. *Open Conversations: Annual Report, 2009*. Auckland: Genesis Energy.

Ministry of Economic Development. 2009. *New Zealand Energy Data File 2009.* Wellington: Ministry of Economic Development.

10 Industrial and Commercial Coal, Oil and Gas Combustion

A wide range of fuel-burning appliances are used in the industrial and commercial sectors, where their primary function is the production of steam and hot water for process use. Natural gas, coal and oil (diesel and light fuel oil) are the principal fuels, along with minor uses of LPG. For appliances rated at 1 MW or greater, the total gas-fired capacity in New Zealand is about 1500 MW, with about 800 MW fired on coal and 100 MW on oil (BioEnergy Association, 2006).

The 2000 Inventory only reported PCDD/PCDF emission estimates for coal within this source category, because there was insufficient information available to assess the releases from natural gas and oil use. The latter fuels have been included in the current assessment because additional PCDD/PCDF emissions data is now available.

10.1 Emissions to air

10.1.1 Coal-fired industrial manufacturing and commercial appliances

The total New Zealand coal consumption for consumer energy uses in 2008 was 25.46 PJ (Ministry of Economic Development, 2009). Consumer energy uses include agricultural, industrial, commercial, residential and transport. Consumption over the past 10 years has varied between 20.04 and 28.87 PJ, and the 2008 consumption was close to the average rate over that period (25.47 PJ).

The figures for coal consumption include two sources that are covered under other sections of the inventory: cement manufacture (170,000 tonnes per year, or about 4.3 PJ) and domestic heating (0.36 PJ) (Ministry of Economic Development, 2009; Crown Minerals, 2009). Therefore, the total annual energy consumption associated with the remaining coal combustion sources is 20.8 PJ. (Note that the Ministry of Economic Development data for consumer energy does not include the coal used in steel production, which is accounted for separately as a form of energy transformation.)

The size of coal-fired boilers in New Zealand varies markedly across different industry types and even within each industry. For instance, the average capacity of the 18 coal-fired boilers used in the dairy industry is 25 MW, with a range from 5.1 to 53 MW. This can be compared with the meat industry, where 41 coal-fired boilers have an average capacity of 4.8 MW and range from 0.75 to 18 MW (BioEnergy Association, 2006).

The 2000 Inventory was based on an emission factor range of 0.04–4.8 μg I-TEQ tonne^{-1} of coal, but also noted that smaller sources were likely to have higher emissions than larger plants. The range was based on a UK review of published emission factors but was subsequently cross-checked against emission test results for two New Zealand plants. One of these, a 7.2 MW unit, gave results in the range of 1.16–1.95 μg I-TEQ tonne^{-1}, and the other, a 210 kW unit, gave a factor of 2.9 μg I-TEQ tonne^{-1}. If we assume an average calorific value of 25 MJ kg^{-1} for bituminous/sub-bituminous coal, the mid-point of the emission factor range used in the 2000 Inventory (2.4 μg I-TEQ tonne^{-1}) can be expressed as 96 μg I-TEQ TJ^{-1}.

The UNEP Toolkit provides an emission factor of 10 µg I-TEQ TJ^{-1} for coal-fired boilers based on a range of international studies, although the main emphasis appears to be on relatively large installations.

Given the wide discrepancy between the UNEP Toolkit factor and the range used in the 2000 Inventory, the current estimates will be based on two factors, according to plant size. For plant greater than 10 MW, the UNEP Toolkit emission factor of 10 µg I-TEQ TJ^{-1} will be applied, while a factor of 100 µg I-TEQ TJ^{-1} will be used for plants less than 10 MW. In addition, the 20.8 PJ of total coal consumption in this source category will be assigned to the two size ranges in accordance with the proportion of the total boiler capacity they comprise in the national heat plant database (Bioenergy Association, 2006). The total capacity of boilers of 10 MW or greater is 528 MW (66.6% of the total), while those less than 10 MW have a total capacity of 265 MW (33.4%).

National emission estimates

PCDD and PCDF emissions from coal-fired industrial and commercial appliances are summarised in table 10.1. The projections for 2013 and 2018 are based on the assumption that there will be no significant changes in coal consumption. No back-projection has been shown because the methodology used in the 2000 Inventory differs significantly from the current approach. However, it should be noted that the estimated releases for 2008 are towards the lower end of the range reported in the previous inventory (0.034–4.0 g I-TEQ yr^{-1}), which is mainly due to the use of lower emission factors.

Table 10.1: PCDD and PCDF emissions to air from industrial and commercial coal combustion

Source	Energy consumption (PJ yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
Boilers greater than 10 MW	–	13.9	13.9	13.9	–	0.139	0.139	0.139
Boilers less than 10 MW	–	6.9	6.9	6.9	–	0.690	0.690	0.690
Totals	–	20.8	20.8	20.8	–	0.829	0.829	0.829

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on national coal-use data. The emission factor is assigned a ‘low’ certainty ranking because, although it is based on a combination of both local and international data, the assumed distribution between large and small emitters is quite arbitrary.

10.1.2 Gas- and diesel-fired industrial manufacturing and commercial appliances

Industrial and commercial combustion of natural gas (excluding electricity generation) accounted for 34.3 PJ of energy in 2008 (Ministry of Economic Development, 2009). Industrial and commercial use of LPG comprised 4.0 PJ, half of which has been assumed to be used in heat-raising appliances.

Industrial and commercial combustion of diesel in boilers is not easily distinguished from that used in stationary combustion engines on the basis of the available statistical information. An estimate of the heat produced by boilers fired by diesel has been made using boiler capacities recorded in the heat plant database (Bioenergy Association, 2006), where the total capacity for diesel boilers is 96 MW. If it is assumed these boilers operate 24 hours per day for 320 days a year, at 75% efficiency, the total energy consumed would be about 2.0 PJ per annum.

The UNEP Toolkit provides an emission factor of 0.5 μg I-TEQ TJ^{-1} for plants fired with natural gas and light fuel oil, and this factor will be used for the current estimates in the absence of any specific local data. No significant changes in future consumption will be assumed, on the basis that industrial and commercial gas consumption has been relatively steady over the past 10 years.

National emission estimates

PCDD and PCDF emissions from natural gas, LPG and diesel combustion in industrial and commercial appliances are summarised in table 10.2. No back-projection has been shown for 1998 because no specific consumption data is available for this source.

Table 10.2: PCDD and PCDF emissions to air from industrial and commercial natural gas, LPG and diesel combustion

Natural gas and diesel consumption (PJ yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
–	38.3	38.3	38.3	–	0.019	0.019	0.019

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are primarily based on national fuel use data. The emission factor is assigned a ‘low’ certainty ranking because it is sourced from a limited range of international studies.

10.2 Residues (releases to land)

Gas- and diesel-fired boilers operated under optimal conditions should not produce any ash waste stream. For coal-fired appliances, the UNEP Toolkit indicates that releases of PCDD/PCDFs in boiler bottom ash should be negligible, and fly ash is the principal source.

The 2000 Inventory used an emission factor range of 0.02–13.5 ng I-TEQ kg^{-1} and applied this to estimates of bottom ash production, because there was insufficient information on the quantities of fly ash produced. The UNEP Toolkit provides an emission factor of 14 μg TEQ TJ^{-1}, based on the energy of the fuel consumed. This estimate was based on an average fly ash concentration of 4 ng TEQ kg^{-1} and is considered appropriate for boilers of all capacities operating in New Zealand.

National release estimates

PCDD and PCDF releases in residues from coal combustion in industrial and commercial appliances are summarised in table 10.3. The projections for 2013 and 2018 are based on the assumption that there will be no significant changes in coal consumption. No back-projection has been shown for 1998 because the methodology used in the 2000 Inventory differs significantly from the current approach. However, the estimated releases for 2008 are quite comparable with the top of the range reported in the previous inventory (0.00047–0.32 g I-TEQ yr^{-1}).

Table 10.3: PCDD and PCDF releases to land from industrial and commercial coal combustion

Coal consumption (PJ yr^{-1})				Annual releases to land (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	20.8	20.8	20.8	–	0.291	0.291	0.291

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on national data for the amount of coal used in New Zealand. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international studies and no New Zealand data is available.

10.3 Releases to water

No releases to water are expected from these sources.

10.4 Application of BAT/BEP

The BAT/BEP Guidance for fossil fuel-fired utility and industrial boilers includes the following.

- Identify and control key process parameters.
- Conduct inspection and maintenance programmes at appropriate cycles.
- Ensure all staff are appropriately trained in the application of the best environmental practices relevant to their duties.
- Define a fuel specification for key fuel parameters and introduce a monitoring and reporting protocol. Conduct regular monitoring of fuel quality to prevent use of contaminated fuels.

- Ensure environmentally sound management of waste materials (eg, fly ash and bottom ash).
- Attention should be paid to the four cornerstones of high destruction efficiency: temperature, time, turbulence and excess oxygen. Temperatures in excess of 900°C and a residence time of at least 1 second should be maintained to ensure that all persistent organic pollutants are oxidised.
- When solid fuel is used, low-moisture pulverised fuels are preferable to crushed or lumpy fuels.
- Continuous monitoring of carbon monoxide is useful for indicating combustion quality.
- Install air pollution control devices when environmental benefits can be demonstrated.

The achievable performance level for BAT/BEP is a concentration well below 0.1 ng I-TEQ Nm^{-3} (at 6% oxygen for solid fuels and 3% for liquid fuels).

Assessing the extent to which New Zealand facilities comply with the above BAT/BEP requirements is a complex task, and one that is beyond the scope of this study. There are several hundred fossil fuel-fired boilers in New Zealand, which will vary in capacity from a few kilowatts to the largest, currently 146 MW. Individual boilers will vary in age from those recently installed to a group 50–60 years old. Management practices might be expected to vary significantly. However, in general, economic factors such as fuel efficiency and the control exercised by regional councils through resource consents or rules in regional plans should result in a minimum acceptable operating standard.

10.5 References

BioEnergy Association. 2006. *Heat Plant in New Zealand: Heat Plant Sized Greater than One Megawatt Thermal Segmented by Industry Sector as at April 2006*. Database maintained by East Harbour Management Services on behalf of the Bioenergy Association of New Zealand in conjunction with Energy Efficiency and Conservation Authority.

Crown Minerals. 2009. *Coal Overview.* Wellington: New Zealand Crown Minerals, Ministry of Economic Development. Retrieved from http://www.crownminerals.govt.nz/cms/coal/overview.

Ministry of Economic Development. 2009. *New Zealand Energy Data File 2009.* Wellington: Ministry of Economic Development.

11 Domestic Coal, Oil and Gas Burning

The use of different types of energy for home heating is surveyed every five years in New Zealand through the national Census of Populations and Dwellings. The results for the last three surveys are shown in table 11.1 (Statistics NZ, 2007c), from which it can be seen that electricity is the dominant form of energy used, followed by wood burning. The use of mains gas and bottled gas (LPG) is less significant individually, although the combined contribution (40.9%) of these two fuels is on a par with wood burning. Coal use is relatively low at 7.0%, and has been steadily declining over the past 10 years. Oil is not specifically shown in the table, but presumably contributes to the 2.1% of 'other fuels'. (Note that the figures in the table add up to more than 100% because many homes use more than one type of heating.)

Table 11.1: Energy use for home heating in New Zealand

Fuel type	Percentage of dwellings using each fuel type		
	1996	2001	2006
Electricity	77.2	72.0	74.8
Mains gas	11.6	13.5	13.2
Bottled gas (LPG)	22.3	28.3	27.7
Wood	48.7	44.7	40.9
Coal	13.0	9.3	7.0
Solar energy	0.7	0.9	1.1
None	0.9	2.8	2.4
Other fuels	1.9	1.1	2.1

This section addresses the emissions from the domestic burning of oil, coal and gas, while those from wood burning are covered in section 13. The 2000 Inventory only assessed emissions from coal and wood burning because there was insufficient information available at the time to assess the emissions from gas and oil use. Emission factors are now available for these fuels and they have been included in the current assessment.

11.1 Emissions to air

11.1.1 Domestic coal burning

The total amount of coal burned in domestic appliances in 2008 was 0.36 PJ (Ministry of Economic Development, 2009), which is significantly less than the 1.31 PJ reported for 1998. Domestic coal consumption has been steadily declining over the past 10 years at a rate of about 10% per year. This rate of reduction will be assumed to continue over the next 10 years, for the purposes of the future emission projections.

The 2000 Inventory used an emission factor range of 5.7–9.3 μg I-TEQ tonne^{-1} for the emissions of PCDD and PCDF from domestic coal burning. Using an average calorific value of 25 MJ kg^{-1} for bituminous/sub-bituminous coal, the mid-point of this range (7.5 μg I-TEQ tonne^{-1}) can be expressed as 300 μg I-TEQ TJ^{-1}. This is significantly higher than the factor of 100 μg I-TEQ TJ^{-1} recommended in the UNEP Toolkit. However, the latter factor is based on a much wider range of emission data than was available at the time of the 2000 Inventory and will be used in the current estimates.

National emission estimates

PCDD and PCDF emissions from domestic coal burning are summarised in table 11.2. The back-projection for 1998 is significantly lower than the range reported in the 2000 Inventory (0.36–0.59 g I-TEQ yr^{-1}) as a result of the lower emission factor. The current estimated emissions are also much lower because of the significant reduction in coal usage.

Table 11.2: PCDD and PCDF emissions to air from domestic coal burning

Annual coal use, PJ yr^{-1}				Annual emissions, g I-TEQ yr^{-1}			
1998	2008	2013	2018	1998	2008	2013	2018
1.31	0.36	0.18	0.09	0.131	0.036	0.018	0.009

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on national data for domestic coal usage. The emission factor is assigned a ‘low’ certainty ranking because it is based on international studies rather than New Zealand emissions data.

11.1.2 Domestic gas burning

The domestic use of gas in New Zealand includes both natural gas and LPG. Natural gas is used mainly in fixed installations for heating, cooking and water heating, while LPG is more commonly used in portable equipment such as barbeques and patio heaters. The total residential usage of natural gas in 2008 was reported to be 4.27 PJ, while LPG usage was 2.56 PJ (Ministry of Economic Development, 2009). The corresponding figures for 1998 were 4.67 PJ of natural gas and 2.33 PJ of LPG.

PCDD/PCDF emission estimates from the domestic use of gas were not included in the 2000 Inventory due to the lack of any recognised emission factors. The UNEP Toolkit recommends a factor of 1.5 μg I-TEQ TJ^{-1} based on reported emission data from a range of different countries.

National emission estimates

PCDD and PCDF emissions from domestic gas burning are summarised in table 11.3. The back-projection for 1998 is based on the 1998 Ministry of Economic Development data, and the projections for 2013 and 2018 are based on no change in current consumption levels.

Table 11.3: PCDD and PCDF emissions to air from domestic gas burning

Annual gas usage, PJ yr^{-1}				Annual emissions, g I-TEQ yr^{-1}			
1998	2008	2013	2018	1998	2008	2013	2018
7.00	6.83	6.83	6.83	0.011	0.010	0.010	0.010

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on national fuel usage data. The emission factor is assigned a 'low' certainty ranking because it is based on international studies rather than New Zealand emissions data.

11.1.3 Domestic oil burning

The amount of oil used in residential applications is very low, as indicated in the national energy statistics, which report figures of 0.01 and 0.00 PJ for diesel and fuel oil, respectively, for 2008 (Ministry of Economic Development, 2009). Some earlier national data (Ministry of Commerce, 1999) indicated annual consumption figures for 1998 of 0.07 and 0.00 PJ year^{-1} for these two fuels. The use of oil for home heating was relatively common in the 1970s and 1980s, but it has now declined to the point of insignificance.

The UNEP Toolkit recommends an emission factor for domestic oil burning of 10 μg I-TEQ TJ^{-1}. If we assumed a total domestic oil consumption of 0.01 PJ year^{-1} (diesel plus fuel oil), this would equate to annual PCDD/PCDF emissions of about 0.0001 g I-TEQ yr^{-1}, which are insignificant.

11.2 Residues (releases to land)

11.2.1 Domestic coal burning

The ash residues produced from domestic coal combustion were estimated in the 2000 Inventory at approximately 1760 tonnes of grate ash per year. On a pro rata basis, the quantity of ash produced in 2008 would be about 480 tonnes per year. The release estimates for the 2000 Inventory were based on UK data, which indicated a PCDD/PCDF concentration factor of 0.41 ng I-TEQ kg^{-1}. The only factor given in the UNEP Toolkit is for PCDD/PCDF concentrations in soot, which is produced in far smaller quantities compared to ash. Therefore the factor used in the 2000 Inventory will be used here.

National release estimates

PCDD and PCDF releases in ash from domestic coal burning are summarised in table 11.4. The estimated releases for 1998 are lower than the 0.00072 g I-TEQ yr^{-1} reported in the 2000 Inventory because of the significant reduction in domestic coal consumption over the past 10 years. Ash from domestic coal burning is primarily disposed to landfills via domestic waste collections, or it may be scattered on home gardens.

Table 11.4: PCDD and PCDF releases to land from domestic coal burning

Annual ash production, tonnes yr^{-1}				Annual releases, g I-TEQ yr^{-1}			
1998	2008	2013	2018	1998	2008	2013	2018
1760	480	240	120	0.0007	0.0002	0.0001	0.00005

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a 'medium' certainty ranking because they are based on national data for domestic coal usage in New Zealand, but with some assumptions about the amount of grate ash produced during combustion. The emission factor is assigned a 'low' certainty ranking because it is based on limited overseas data for PCDD and PCDF concentrations in domestic coal ash.

11.2.2 Domestic oil and gas burning

Domestic heaters and other appliances fired on oil or natural gas should not produce any significant ash waste streams provided they are operated at close to optimum conditions.

11.3 Releases to water

There are no direct releases to water from the domestic burning of coal, oil or gas. Any leaching of PCDDs and PCDFs from the coal ash residues that are deposited in landfills will be accounted for in the estimate of releases to water from landfill leachate (see section 26).

11.4 Application of BAT/BEP

The key requirements from the BAT/BEP Guidance for domestic fuel burning are as follows.

- Appliances should be designed to ensure optimal combustion conditions, including good mixing of fuel and combustion air, and sufficient gas residence times in the combustion zone.
- Off-gas residence times in the temperature range of 180–500°C should be minimised to avoid *de novo* PCDD/PCDF formation.
- Where fitted, flues and stacks should be kept clean and free from soot, through the use of correct operating procedures and regular (at least annual) cleaning.
- Public education and awareness programmes should be developed on the correct use of appliances, the use of appropriate fuels, and the potential health impacts from excessive emissions.

As indicated earlier, the use of coal for domestic heating is steadily declining, and further reductions can be expected as regional councils attempt to reduce the emissions of fine particulate (PM_{10}) from these and other heating appliances (see section 14). Article 5 of the Stockholm Convention requires that these emissions be addressed through the *promotion* of BAT/BEP, for both new and existing sources. As such, this requirement should be adequately addressed by simply ensuring that regional councils are appropriately encouraged and supported in their current endeavours.

Gas and oil burning are very minor contributors of PCDD/PCDF releases, and no significant actions are required. However, it may be appropriate to encourage regional councils and other relevant agencies to include advice on good operating practices for these types of appliances in the informational materials produced for domestic heating using wood and coal.

11.5 References

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Ministry of Economic Development. 2009. *New Zealand Energy Data File 2009.* Wellington: Ministry of Economic Development.

Statistics NZ. 2007c. *Quick Stats about Housing: 2006 Census*. Wellington: Statistics New Zealand [as revised 27 July 2007].

12 Industrial Combustion of Wood and Other Woody Biomass

The combustion of wood and other woody biomass in New Zealand includes:

- the large-scale combustion of waste materials from the forestry, wood-processing and pulp and paper industries
- medium-scale combustion of waste from wood-manufacturing industries
- small-scale domestic burning of wood.

This section addresses the industrial processes, while domestic sources are covered in section 13. Combustion processes in the pulp and paper industry are split into two, with wood and biomass combustion included here and the combustion of black liquor solids covered in section 22.

The nature of wood processing has changed significantly since the 2000 Inventory was compiled, at which time the manufacturing of sawn timber was seen as the principal activity outside of pulp and paper production. However, the last decade has seen a marked rise in significance of the panel sector, with the commissioning of a number of large new plants combined with the upgrading of most existing operations. Panel production includes medium-density fibreboard (MDF), particle board, plywood and other laminated wood products.

Increased production from the panel sector has another bearing on the amount of woody biomass combusted because, like pulp and paper production, it is much more energy intensive than sawn timber preparation. In the latter case, the chief use of energy is for the drying of timber in kilns. However, with a process such as MDF production considerably more heat energy is needed, on a product volume basis, for the various stages of chip production, drying, gluing and pressing. This is reflected in the relative energy intensities, or energy expended per unit production volume, for the three sectors. Sawmilling has an average energy intensity of 1 GJ m^{-3}, panel production an average of 6 GJ m^{-3} and pulp and paper an average of 19 GJ m^{-3} (Gifford, 2003).

12.1 Emissions to air

Taking into account the energy produced from the combustion of black liquor, the pulp and paper sector is by far the largest producer of heat energy from woody biomass combustion. A total of 8400 TJ yr^{-1} is produced from the three black liquor recovery boilers located in Waikato and the Bay of Plenty.[3] This sector also includes boilers fuelled with wood waste at six locations in Auckland, Bay of Plenty, Waikato and Hawke's Bay, with a total installed capacity of 427 MW and an estimated energy production of 8260 TJ yr^{-1} (Bioenergy Association, 2006).

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[3] Estimates of energy production have been derived from gross power figures shown in the Bioenergy Association's Heat Plant database. Facilities were assumed to operate 24 hours a day at 70% capacity for 320 days per year.

The wood waste boilers associated with the major panel sector plants in Northland, Auckland, Waikato, Poverty Bay, Wairarapa, Nelson, Canterbury and Southland have a combined capacity of 380 MW, equating to a production rate of 7350 TJ yr^{-1} (Bioenergy Association 2006). A survey conducted by the Forest Research Institute in 2002 showed the following typical wood waste fuel composition for these sources: bark 31%; product trim 26%; dry sander dust 21%; green sander dust 6%; green chips 4%; dry sawdust 4%; with green and dry shavings and green off-cuts and peelings making up the final 4% (Gifford, 2003).

Finally, there are approximately 50 sawmill boilers rated at 1 MW or greater that are fuelled principally with wood waste. Together these generate about 5740 TJ yr^{-1} (Bioenergy Association, 2006). The Forest Research Institute survey indicated that the wood waste has the following composition: green sawdust 64%; green shavings 27%; dry shavings 6%; with minor amounts of bark 2%; and product trim 1%.

The energy production figures used in this inventory are summarised in table 12.1. The total energy production shown (38,250 TJ) is considerably higher than the figure of 31, 700 TJ that was used as a starting point for the 2000 Inventory. The difference is largely due to the increased energy use in the panel sector.

Table 12.1: National energy production from wood and woody biomass

Source/activity	Annual energy production	
	(TJ yr^{-1})	(%)
Black liquor recovery boilers	8,400	22.0
Pulp and paper power boilers	8,260	21.6
Panel sector boilers	7,350	19.2
Sawmill boilers	5,740	15.0
Wood waste incinerators	< 100	< 0.3
Domestic wood burning (see section 13)	8,400	22.0
Total wood consumption	38,250	

The figure for total consumption compares reasonably well with two other alternative estimates. The annual Energy Data File produced by the Ministry of Economic Development (2009) gives an estimate of 36,000 TJ for total energy production from wood in 2008. This covers both industrial and domestic use. Similarly, a recent survey of energy production and use in the manufacturing sector (Statistics NZ, 2007a) gave an estimate of 29,250 TJ for energy production from wood waste and black liquor combustion. A value of 37,650 TJ is obtained for total wood consumption if domestic wood burning is added to the total.

The level of agreement between the three different data sets provides a high degree of support for the approach adopted here of assigning individual energy production values to the various source categories, based on a quantitative assessment of installed capacity. The figures given in table 12.1 will thus be used in the release estimates that follow.

Future projections for wood consumption

Factors likely to lead to changes in wood waste fuel consumption include the installation of new wood waste boilers and the conversion of existing fossil-fuel-fired boilers to run on wood waste. The Energy Efficiency and Conservation Authority is actively promoting the latter option. However, boiler retrofitting will occur largely in the less energy-intensive sawmilling sector, where boilers are smaller and use less fuel. In addition, growth is currently occurring in the small to medium sawmilling operations rather than the larger facilities (Gifford, 2003). The introduction of major new plant that has taken place over the last decade to accommodate the increasing volumes of timber is not expected to be matched in the coming years.

In theory there is sufficient wood waste material produced by the wood industry as a whole to supply up to four times the existing fuel requirements. For instance, for 2005 it was estimated that on-site wood-processing wastes at production facilities amounted to 4 million tonnes per year, with a further 2.3 million tonnes of wastes left in the forest after felling (Nielsen, 2005). In the same year only 1.6 million tonnes was used for energy production. However, there are obstacles to the utilisation of some of this material. It may be produced at a site that either does not utilise the wood waste or generates more that it can consume. Alternatively, some of the waste may be unsuitable for use in the available facilities. An estimated 0.2 million tonnes were sent to landfill in 2005, presumably because of such factors. The costs of transporting green wood waste, which has a much lower calorific value than fossil fuels, is another impediment to its utilisation.

MDF plants are also now competing for sawdust waste from sawmilling that might originally have been used for energy generation.

Competition for wood waste fuel from domestic users may also inhibit future increased utilisation in the wood industry. For instance, domestic heating appliances utilising pellet fuel – uniform-sized pellets of compressed sawdust – may result in a significant loss of wood waste mass for industry if this technology is widely adopted in place of open fires or older-style wood burners, which have much higher particulate emission rates. The use of bark for landscaping is another area where domestic demand is in competition with industrial fuel supply.

Annual statistics for the energy raised from woody biomass combustion (Ministry of Economic Development, 2009) show a flattening for individual years in the period 2004–2008, which lends support to only modest increases being likely in the next 5 to 10 years. In addition, the trend is likely to have been further exacerbated by the current economic recession. Therefore, we have assumed that industrial wood waste consumption will increase by only 5% and 10% respectively over these two periods.

Emission factors

The 2000 Inventory included an adjustment to the emission calculations for a portion (10%) of ‘contaminated’ wood. This referred to sawdust, shavings and off-cuts that could contain antisapstain chemicals, preservatives, resins, hardeners, surface coatings and glues. Emission factor ranges of 9–19 μg I-TEQ tonne^{-1} and 1–2.2 μg I-TEQ tonne^{-1} were used for contaminated and uncontaminated wood, respectively, based on a review of UK and US emission data.

The UNEP Toolkit specifies an emission factor of 50 μg I-TEQ TJ^{-1} for the combustion of clean wood. In the case of dry wood produced from *Pinus radiata*, this factor is roughly equivalent to an emission rate of 2.6 μg I-TEQ $tonne^{-1}$. The Toolkit does not provide an emission factor for contaminated wood waste, as defined by the 2000 Inventory, although it does consider separately the incineration of wood waste from sources such as demolition.

In virtually all cases, the fuel used in New Zealand wood waste boilers will contain some minor proportion of man-made chemicals. Consequently, it is not possible to consider 'contaminated' and 'uncontaminated' fuels separately – all should be considered to be contaminated.

There is continuing debate in the literature as to which factors are important for PCDD and PCDF formation during combustion. For instance, no correlation was found between the levels of dioxin formation and fuel chlorine content during combustion of an artificial fuel mix with added PVC or calcium chloride (Wikstrom et al, 1996). On the other hand, salt-laden hog[4] fuel has been found to give elevated dioxin emissions. Low levels of sulphur in the fuel promoted the formation of dioxin, but when sulphur levels were higher the formation was suppressed (Duo and Leclerc, 2004).

It would appear that the quality of combustion conditions rather than the chlorine content of the fuel is the predominant influence in PCDD/PCDF production (UNEP, 2007). Recent emission testing in New Zealand supports this contention. For instance, tests at two large panel facilities in Northland and Gisborne gave average emissions of 0.017 and 0.0045 ng I-TEQ Nm^{-3} and maximum emissions of 0.031 and 0.012 ng I-TEQ Nm^{-3} respectively (Aer'aqua, 2003). Both facilities were utilising wastes containing resins and glues, with the Gisborne plant also burning wood treated with antisapstain chemicals containing chlorine. The concentrations reported would correspond to emission rates significantly less than 2.6 μg I-TEQ $tonne^{-1}$. Emission testing was also conducted at a wood-waste boiler located in a pulp and paper mill during the combustion of a number of different supplementary fuels, including plywood waste, recycled fibre plant wastes and clarifier sludge. During the trials, these wastes were added either singly or in combination at a rate of 10% by volume to the normal clean wood-waste fuel. Emissions were not significantly different from a control test based on clean wood waste alone (Bingham and Graham, 2006).

Poor combustion conditions, including low combustion temperature, was one of the causes attributed to some relatively high emission testing results of 0.80 and 2.51 ng I-TEQ Nm^{-3} obtained from recent testing on two wood-waste boilers in the pulp and paper sector (Beca AMEC, 2006).

On the basis of all the above, it was decided to adopt the UNEP emission factor of 50 μg I-TEQ TJ^{-1} for all industrial wood-waste consumption, with no distinction made between contaminated and uncontaminated wood waste.

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[4] Fuel made by grinding waste wood and bark.

National emission estimates

PCDD and PCDF emissions from the industrial combustion of wood and other woody biomass are summarised in table 12.2. These estimates are based on an energy production rate of 21,350 TJ, which is the sum of the figures given in table 12.1 for pulp and paper power boilers, panel sector boilers and sawmill boilers. The projections for 2013 and 2018 are based on the 5% and 10% increases discussed above, and the back-calculation for 1998 is based on the 2000 Inventory data converted to an energy basis using a net calorific value for wood of 19.2 MJ kg^{-1}.

Table 12.2: PCDD and PCDF emissions to air from industrial wood combustion

Energy production (TJ yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
10,900	21,350	22,418	23,485	0.545	1.068	1.121	1.174

Certainty

Activity statistics: High
Emission factor: Medium

The activity statistics are assigned a ‘high’ certainty ranking because, while some assumptions have been made with regard to boiler operating conditions and hours of operation, the overall estimates show good agreement with national fuel-use data. The emission factor is assigned a ‘medium’ certainty ranking because New Zealand emission test data is in reasonable agreement with the UNEP emission factor.

12.2 Residues (releases to land)

The PCDD and PCDF releases in ash from the industrial combustion of wood were estimated in the 2000 Inventory to be in the range of 0.33–1.9 g I-TEQ yr^{-1}. This estimate was based on an assumed rate of ash production and a range of emission factors taken from a UK a review.

The UNEP Toolkit gives an emission factor of 15 μg I-TEQ TJ^{-1} of wood waste burned, to account for releases due to fly ash and other residues.

National release estimates

The estimated PCDD and PCDF releases in residues from the industrial combustion of wood and other woody biomass are shown in table 12.3. These are based on the UNEP Toolkit factor, which, as indicated by the 1998 back-projection, gives a lower result than the range reported in the 2000 Inventory (0.33–1.9 g I-TEQ yr^{-1}). The fate of ash produced by these plants has not been determined, although it is likely that a major proportion will be disposed to landfills.

Table 12.3: PCDD and PCDF releases in residues from industrial wood combustion

Energy production (TJ yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
10,900	21,350	22,418	23,485	0.164	0.320	0.336	0.352

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because, while some assumptions have been made with regard to boiler operating conditions and hours of operation, the overall estimates show good agreement with national fuel-use data. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international data.

12.3 Releases to water

There is insufficient information to assess the nature or magnitude of any direct releases to water from industrial wood combustion. Any leaching of PCDDs and PCDFs from ash residues deposited directly to land is not considered a direct release to water. The leaching from ash in landfills will be accounted for in the estimate of releases from landfill leachate (see section 26).

12.4 Application of BAT/BEP

The BAT/BEP Guidance contains the following key recommendations for installations fired with wood and other biomass fuels.

- Strictly limit the combustion of contaminated wood, such as urban wood waste and demolition wood, to installations with efficient emission control; it is preferable that this material not be used in boilers and instead be treated as waste.
- Control the fuel quality (eg, calorific value, water content, contaminants).
- Give attention to good combustion practices: temperature, residence time in the hot zone, and gas stream turbulence resulting in improved burn-out of gases and fly ash. Optimise excess air ratio to less than 1.5:2. Ensure minimal disturbance of the glow bed and homogeneous distribution of the primary air.
- Prevent rapid changes in energy demand.
- Clean the hot zone of flue gases at regular intervals.
- Minimise off-gas residence time in the temperature range 180–500°C, and minimise flow changes that encourage fly ash deposition.
- Rapidly quench flue gases to below 200°C before air pollution control equipment to avoid *de novo* dioxin formation.
- Incorporate continuous carbon monoxide monitors to ensure complete combustion.
- Incorporate continuous particulate monitors to ensure the performance of emission control equipment.

Emission levels associated with BAT/BEP are generally below 0.1 ng I-TEQ Nm^{-3}.

One of the difficulties in assessing current New Zealand practice against the recommendations is the sheer number and diversity of units that would need to be assessed. There are more than 100 boilers or other heat-raising plants fired principally on wood waste in this country. Individually they range in gross capacity from less than 1 MW up to 160 MW and will have fuel-firing rates in roughly the same proportion. The individual fuel type varies from dry sawdust with 10% moisture content, to hog fuel with moisture contents of 60% or greater, on a wet basis. Air pollution control equipment varies from simple multicyclones to electrostatic precipitators and fabric filters.

Each sector of the wood-processing industry contains plant of varying ages, with some dating back to the 1950s. However, about 90% of the total wood-waste energy is produced in 15 facilities in the pulp and paper and panel sectors and the 10 largest facilities in the sawmilling sector. In general, these plants are characterised by having been installed or refurbished relatively recently and are overseen continuously by staff in purpose-built energy management centres, where energy demands are closely monitored. Typically such plants will exercise close control over fuel quality, such as its composition and moisture content, where required. Maintenance of good combustion conditions will be achieved by monitoring temperatures and excess oxygen concentrations. The requirement for continuous particulate emission monitoring is an almost standard condition in the resource consents for these facilities. Monitoring of carbon monoxide is less common and generally occurs only in the largest facilities. The process of heat transfer, typically to boiler tubes, helps to quench the temperature of the flue gases, but in general there are no special precautions taken to reduce them to below 200°C before entering air pollution equipment.

Emission testing of such plants shows that discharges can be expected to be below the target limit of 0.1 ng I-TEQ Nm^{-3}, but individual plants may exceed this limit from time to time. The quality of combustion conditions rather than the chlorine content of the fuel appears to be the predominant influence in PCDD/PCDF production.

The burning of contaminated wood such as urban wood waste and demolition timbers is not common practice, although it may occur in isolated cases (Beca Amec, 2006). Control over the nature and quality of fuel is best exercised through the resource consent process.

12.5 References

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13 Domestic Wood Burning

The Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004 specify acceptable limits for a range of contaminants in ambient air, including particulate matter less than 10 microns in size (PM_{10}). The limit for PM_{10} is currently exceeded in about 25 urban areas throughout New Zealand (Ministry for the Environment, 2008a). Domestic heating, especially wood and coal burning, has been identified as the dominant source of winter-time PM_{10} emissions in many of the non-complying areas and significant efforts are now being made to find ways of reducing the emissions. This includes the promotion of good operational practices, energy efficiency measures such as improved insulation for houses, and the replacement of wood burners with cleaner alternatives such as heat pumps.

Currently, the Regulations require compliance with the PM_{10} standard by 2013. However, at the time of writing, the target date and the PM_{10} standard itself are under review.

The 2004 Regulations also set two design standards for new wood burners installed in properties of less than 2 hectares, and have applied nationally since 1 September 2005. The design standards specify a maximum discharge of 1.5 grams of particulate matter for each kilogram of dry wood burnt, and a minimum thermal efficiency of 65%. Compliance with these standards should also help reduce the emissions of other harmful pollutants such as carbon monoxide, volatile organic compounds, polycyclic aromatic hydrocarbons and dioxins.

The 2006 Census of Populations and Dwellings found that wood was used for heating in 40.9% of all occupied dwellings in New Zealand (Statistics NZ, 2007c), which is significantly down on the 44.7% found in 2001 and 48.7% in 1996. The total number of dwellings using wood for heating dropped by 4%, while the total number of occupied dwellings increased by 15%. This suggests there was a significant move away from installing wood burners in new dwellings. However, more recent anecdotal evidence indicates a significant swing in the opposite direction (L Wickham, Ministry for the Environment, pers comm, 2010).

13.1 Emissions to air

The 2000 Inventory used an estimated annual domestic wood consumption rate of 713,000 tonnes. This was based on extrapolation from fuel use surveys in Auckland and Christchurch. It was also assumed that 35% of this wood was burnt on open fires and 65% in enclosed appliances.

A considerable amount of work has been done over the past 10 years or so on estimating domestic fuel use at both a national and regional level. This has been driven by initiatives such as the National Energy Efficiency and Conservation Strategy (Energy Efficiency and Conservation Authority, 2001) and the Warm Homes Project (Ministry for the Environment, 2005b), and also by the requirements for a more rigorous approach to air quality management arising out of the national regulations noted above.

The most direct assessment of domestic fuel use has been produced by the Household Energy End-use Project (HEEP), a multi-year, multidisciplinary programme involving energy and temperature monitoring, occupant surveys, and energy audits of about 400 houses throughout New Zealand (Isaacs et al, 2006). The average energy consumption of houses that use an enclosed solid-fuel burner was found to be 4480 kWh, and those with an open fire used 995 kWh (Camilleri et al, 2008). Air-dry wood has a net calorific value of about 4 kWh kg^{-1}, although Isaacs et al (2005) suggest that a more realistic figure would be 3.5 kWh kg^{-1}, to allow for a proportion of freshly cut wood. On this basis, the average wood consumption per household would be 1280 kg per year for enclosed wood burners and 284 kg per year for open fires.

Most other assessments of domestic fuel use have been based on telephone surveys, in which people were asked to estimate their daily fuel use on a 'typical' winter's day, and the number of days per week the appliances were used in each month. The results from these surveys have been very effective in identifying the relatively high contributions made by domestic heating to winter-time emissions of PM_{10}. However, they are less useful as a method of estimating annual fuel consumption. The results (eg, Ministry for the Environment, 2005b; Wilton, 2005, 2006, 2007) generally indicate annual fuel consumption rates of 1.5 to 4 times that found in the HEEP study; ie, a national average household wood usage of between two and five truckloads per year, which is unrealistically high. This discrepancy possibly comes about because of the lack of information on the day-to-day variations in wood use. In addition, there is considerable uncertainty around the factors used in converting from numbers of logs or pieces of wood to an overall wood weight.

The 2006 Census found that wood was used for heating in 574,485 dwellings nationwide. A 2004 survey published by the Ministry for the Environment (2004) indicates that about 12% of these dwellings may still be using open fires. Applying the HEEP factors noted above gives a total national energy consumption of 2265 GWh yr^{-1} from the burning of wood in enclosed appliances and a further 69 GWh yr^{-1} from the use of open fires. This is equivalent to a total energy consumption of 8.4 PJ yr^{-1}, and approximately 667,000 tonnes of wood. The figure is in reasonable agreement with the 713,000 tonnes estimated for the 2000 Inventory.

The emission reductions required in some areas to achieve compliance with the PM_{10} air quality standard are in the range of 60 to 80% (eg, Wilton, 2002; Scott, 2005; Environment Bay of Plenty, 2007). However, these are relatively extreme examples, and in other areas the required reductions are much lower. Also, the reductions only apply to the non-complying urban areas, so will be less significant when considered on a national basis. Overall, it is likely that wood usage for home heating will drop by at least 25% over the next five years. A further 10% reduction could possibly be expected in the following five years as a carry-on effect of the emission reduction initiatives.

The UNEP Toolkit recommends the use of emission factors of 100 μg I-TEQ TJ^{-1} for emissions to air from the burning of virgin wood or biomass in domestic heating and cooking appliances, and 1500 μg I-TEQ TJ^{-1} for contaminated wood. The emission factors adopted for the 2000 Inventory were 1–3 μg I-TEQ $tonne^{-1}$ for enclosed appliances, and 1–29 μg I-TEQ $tonne^{-1}$ for open fireplaces. Assuming a wood energy content of 3.5 kWh kg^{-1}, these are equivalent to 80–240 and 80–2300 μg I-TEQ TJ^{-1}. The bottom end of these ranges is reasonably comparable to the Toolkit factor for clean wood, which will be used here.

No allowance was made in the 2000 Inventory for a proportion of contaminated wood because it was not possible to obtain an accurate estimate of the possible wood quantities. However, it was expected that these would be relatively small. The practice of burning off-cuts of treated timber is actively discouraged by most wood suppliers, regional councils and other agencies, and it will be important that these activities continue to ensure that the potential emissions from this source are kept to a practical minimum.

National emission estimates

PCDD and PCDF emissions from domestic wood-fired appliances are summarised in table 13.1. These have been calculated using the UNEP Toolkit emission factor for clean wood. The back-calculation for 1998 is based on conversion of the wood quantities (713,000 tonnes) to an energy basis, using the factor of 3.5 kWh kg^{-1}. As expected, the indicated emissions (0.84 g I-TEQ yr^{-1}) are towards the lower end of the range reported in the 2000 Inventory (0.7–8.7 g I-TEQ yr^{-1}).

Table 13.1: PCDD and PCDF emissions to air from domestic wood burning

Wood use, PJ yr^{-1}				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
9.0	8.4	6.3	5.5	0.9	0.84	0.63	0.55

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on a national survey of household energy use. The emission factor is assigned a ‘low’ certainty ranking because the Toolkit factor is based on a limited number of international studies.

13.2 Residues (releases to land)

The UNEP Toolkit recommends factors of 20 μg I-TEQ TJ^{-1} (1st edition, 2003) and 10 μg I-TEQ tonne^{-1} of ash (2nd edition, 2005) for the PCDD and PCDF residues produced from the domestic burning of clean wood. These were derived from a limited number of measurements of the dioxin content of wood ash and an assumed ash content of 3%. The older energy-based factor will be used in the release calculations, for consistency with the air emission estimates.

National release estimates

PCDD and PCDF releases in ash from domestic wood burning are summarised in table 13.2. The estimates are significantly lower than those given in the 2000 Inventory (0.48–9.7 g I-TEQ yr^{-1}) because the UNEP Toolkit release factor is much lower than that used previously. Ash from domestic fires is primarily disposed to landfills via domestic waste collections or scattered on gardens. No information is available on the quantities disposed by each route.

Table 13.2: PCDD and PCDF releases to land from domestic wood burning

Wood use, PJ yr^{-1}				Annual releases (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
9.0	8.4	6.3	5.5	0.18	0.17	0.13	0.11

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a 'medium' certainty ranking because they are based on a national survey of household energy use. The emission factor is assigned a 'low' certainty ranking because it is based on a limited number of international studies.

13.3 Releases to water

There are no direct releases to water from the domestic burning of wood. Any leaching of PCDDs and PCDFs from the ash deposited in landfills will be accounted for in the estimate of releases to water from landfill leachate (see section 26).

13.4 Application of BAT/BEP

The key requirements from the BAT/BEP Guidance for domestic wood burning are:

- public education and awareness programmes on the correct use of appliances, the use of appropriate fuels, and the potential health impacts from excessive emissions
- the use of enclosed low-emission burners and appliances
- the use of dry, well-seasoned wood
- avoid burning treated timber, salt-laden wood, plastics and other household waste.

The initiatives currently underway in New Zealand are all consistent with these guidelines, although the main driving force here is the reduction of PM_{10} emissions rather than PCDDs and PCDFs. Article 5 of the Stockholm Convention requires that these emissions should be addressed through the *promotion* of BAT/BEP, for both new and existing sources. As such, this requirement should be adequately addressed by simply ensuring that regional councils are appropriately encouraged and supported in their current endeavours.

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14 Domestic Waste Burning

This section covers the emissions from the burning of domestic wastes in open fires or crude incinerators, where combustion conditions are poor and no controls are applied. Most of the waste disposed of in this way comprises wood, paper, leaves and vegetation, together with a range of other possible materials, including kitchen wastes and plastics.

14.1 Emissions to air

The available information on the extent of domestic waste burning in New Zealand is very limited. The 2000 Inventory used data from an earlier survey for the Auckland region, and adjusted the results on a per capita basis to give an estimated burn rate of 58,000 tonnes year per year for the whole country. The equivalent figure for the 2008 national population would be 65,400 tonnes per year.

Some of the home-heating surveys mentioned in section 13 have also collected information on domestic waste burning. In Whangarei it was found that 6% of households burned household or garden wastes (Wilton, 2007), while in Taupo the proportion was 4% (Wilton, 2004), and in Rotorua it was 11% (Iremonger and Graham, 2006). In the Wellington region waste burning was reported by 5% of households surveyed in Wainuiomata and 7% of those in Upper Hutt (Wilton, 2006). Domestic waste burning is now either restricted or banned in some of our major urban areas, including Auckland and Christchurch, but is still permitted in most rural locations. It appears that the proportion of rural households burning waste is generally higher than in urban areas (eg, see Wilton, 2005), although the exact percentages have not been reported. On a national basis, it should be reasonable to assume that domestic waste burning is practised by 5% of all households (ie, 72,000 households, based on the 2006 Census). This assumes that the higher burning rates in rural areas are offset by lower rates in those areas where it is prohibited.

The results from the above surveys indicate annual waste-burning rates of between 200 and 1000 kg per household. To put this in perspective, the total quantity of waste disposed annually to landfills in New Zealand is just over 3 million tonnes (Ministry for the Environment, 2008b), and slightly less than half of this is domestic waste. This is equivalent to a waste disposal rate of about 1000 kg per household. Most households that burn waste do so only about 5 to 10 times per year. This suggests that the waste quantities burned should be much lower than those disposed through the weekly rubbish collections. In the absence of any more definitive data, a burn rate of 250 kg per household will be used for the emission estimates, thereby giving a total national waste burning rate of 18,000 tonnes per year. This is much lower than the 58,000 tonnes per year used in the 2000 Inventory, but would be consistent with the restrictions now in place in major urban areas.

The 2000 Inventory assumed that the composition of domestic waste was approximately 70% green waste and 30% household waste, including paper and plastics. However, this distinction is no longer required for calculations using the UNEP Toolkit emission factor (see below).

Some additional reductions in domestic waste burning can be expected over the next few years because bans on this activity are currently being considered by several other regional councils as part of their programmes to address regional particulate emissions (see section 13). However, these restrictions will be limited to specific urban areas, and the overall effect nationally could be quite small. Taking a conservative approach, it will be assumed here that the total quantities of waste burned will be reduced by 15% by 2013, and by a further 5% by 2018.

The 2000 Inventory used emission factor ranges of 1–29 μg I-TEQ tonne^{-1} for the burning of organic waste and 29–300 μg I-TEQ tonne^{-1} for household waste. The UNEP Toolkit recommends a factor of 300 μg I-TEQ tonne^{-1} for all domestic waste burning, regardless of waste composition, and this factor will be used for the current release estimates.

National emission estimates

PCDD and PCDF emissions to air from domestic waste burning are summarised in table 14.1. A back-calculation for 1998 is not appropriate because the method used for estimating waste quantities has changed significantly. The figure shown in the table for 1998 is simply the mid-point of the range reported in the 2000 Inventory (0.54–6.4 g I-TEQ yr^{-1}).

Table 14.1: PCDD and PCDF emissions to air from domestic waste burning

Total waste burned, ktonnes yr^{-1}				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
58	18	15.3	14.4	(3.5)	5.4	4.6	4.3

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a ‘low’ certainty ranking because the waste quantities have been estimated indirectly from a very limited range of national and regional information. The emission factor is assigned a ‘low’ certainty ranking because it is based solely on overseas emission factors that were derived from a limited number of studies.

14.2 Residues (releases to land)

The UNEP Toolkit recommends a factor of 600 μg I-TEQ tonne^{-1} for the PCDD and PCDF residues produced from the burning of domestic wastes. This was derived from a limited number of international studies, but will be used in the release calculations in the absence of any relevant data for New Zealand.

National release estimates

PCDD and PCDF releases in ash from the domestic burning of wastes are summarised in table 14.2. It is expected that most of this ash will be disposed by dumping on land. The estimated releases are much higher than those reported in the 2000 Inventory (5.7 g I-TEQ yr^{-1}), because the latter only considered ash production from household wastes (ie, excluding green wastes). The estimation methodology was also quite different.

Table 14.2: PCDD and PCDF releases to land from domestic waste burning

Total waste burned, ktonnes yr^{-1}				Annual releases (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
58	18	15.3	14.4	(5.7)	10.8	9.2	8.6

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a 'low' certainty ranking because the waste quantities have been estimated indirectly from a very limited range of national and regional information. The emission factor is assigned a 'low' certainty ranking because it is based solely on overseas factors that were derived from a limited number of studies.

14.3 Releases to water

There are no direct releases to water from domestic waste burning.

14.4 Application of BAT/BEP

The key requirements from the BAT/BEP Guidance for domestic waste burning are as follows.

- The amount of waste material disposed by burning should be minimised, and wherever possible eliminated.
- Avoid burning non-combustible materials, such as concrete, metal and glass.
- Avoid burning wet wastes, or wastes containing high levels of chlorine (eg, PVC plastics) or catalytic metals such as copper, iron, chromium and aluminium.
- Materials to be burned should be dry, homogeneous or well blended, and of low density (ie, non-compacted).
- Wastes should be burned in such a way as to maintain a sufficient supply of combustion air and a steady burning rate. Smouldering should be minimised, possibly by direct extinguishment as soon as most of the waste has been burned.
- Limit burning to small, actively turned, well-ventilated fires.

The existing and proposed bans or restrictions on waste burning in urban areas are consistent with the first of the points noted above. In addition, several regional councils have produced guidance leaflets on best practice waste burning, especially for rural areas (eg, see Hawke's Bay Regional Council, 2006). The advice given is consistent with that noted above. Continuing support for these measures would be consistent with the requirements for promotion of BAT/BEP under Article 5 of the Stockholm Convention.

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15 Transport

This section covers emissions to air from the combustion of petroleum-based fuels in transportation. The primary focus is on fuel use in motor vehicles, but the methodology will also capture domestic fuel consumption by other forms of transport, such as trains, boats and off-road vehicles. Aircraft are not included because the combustion of aviation fuel is believed to not result in any significant releases of PCDDs or PCDFs (UNEP, 2005).

15.1 Emissions to air

Some of the first evidence for PCDD and PCDF releases from motor vehicles was reported by Ballschmiter et al (1986), who detected the chemicals in used motor oil. It was subsequently shown that the use of leaded petrol was the major cause of PCDD and PCDF emissions from motor vehicles, due to the presence of chemicals such as dichloroethane that were used as scavengers for the lead. PCDD and PCDF emissions have also been detected in the emissions from vehicles burning unleaded petrol and diesel, but in much lower amounts. The use of modern emission control technologies, especially catalytic converters, has been shown to reduce the emissions to negligible levels. No PCDD or PCDF emissions have been associated with the use of LPG or CNG as vehicle fuels (UNEP, 2005).

The use of leaded petrol in New Zealand was phased out during the 1980s and 1990s. Refinery production of unleaded regular (91 octane) petrol began on 1 January 1987, and unleaded premium (96 octane) petrol was introduced to the market on 1 January 1996 (Ministry of Economic Development, 2001, 2009). Leaded petrol is no longer available through the retail distribution system. However, small quantities may still be imported for use as high-performance racing fuel and in piston-engine aircraft. The owners of older (pre-1980) vehicles that were designed to run on leaded fuel must now use after-sales additives.

All New Zealand motor vehicles are now manufactured overseas, and as a result the engine performance and emission control technologies are determined by standards applied in the manufacturing countries. About 50% of current imports are second-hand vehicles, typically six or more years old, which would have been manufactured to less-demanding performance standards. However, a more significant technology ‘lag’ occurred in the past with vehicles assembled in New Zealand. Local manufacturers only started fitting exhaust catalysts in the late 1990s, and the Ministry of Transport has identified some non-catalyst vehicles assembled as recently as 2004. The local manufacturers were also relatively slow in adopting electronic engine management systems (I McGlinchy, Ministry of Transport, pers comm, 2009). In 2008 the average age of the New Zealand vehicle fleet was 12.19 years (Ministry for the Environment, 2009b). The emission problems associated with this ageing vehicle fleet have been recognised over the past few years and addressed through several regulatory measures, including a Vehicle Exhaust Emissions Rule, which requires newly imported vehicles to have been manufactured to progressively more stringent performance standards (Ministry of Transport, 2007).

The current proportion of vehicles fitted with catalysts is unknown, but a survey carried out in 2004 found that about 60% of petrol vehicles inspected (~2400 vehicles) were fitted with catalytic converters (Campbell et al, 2006). The condition of the catalytic converters was not established, but 60% of the catalyst-equipped vehicles (ie, 36% of the total) were found to exhibit near-zero exhaust emissions (carbon monoxide and hydrocarbons) under idle. A more recent, unpublished survey by the Ministry of Transport suggests that the proportion of vehicles fitted with catalysts is now close to 70%, although not all of these may be working effectively (I McGlinchy, Ministry of Transport, pers comm, 2009).

Methodology for estimating emissions

The methodology used in the 2000 Inventory for estimating PCDD and PCDF emissions from vehicles was based on the total number of vehicle-kilometres travelled (VKT). This differs from the approach recommended in the UNEP Toolkit, which is based on fuel consumption. The Toolkit approach has the advantage of also capturing non-road uses of fuel, such as off-road vehicles, boats and trains, lawn mowers and chainsaws, generators and other stationary engines.

The UNEP Toolkit recommends the following consumption-based emission factors for vehicles using unleaded fuels:

- 0.1 μg I-TEQ tonne^{-1} of fuel for four-stroke petrol engines without exhaust catalysts
- 0 μg I-TEQ tonne^{-1} of fuel for four-stroke petrol engines fitted with exhaust catalysts
- 2.5 μg I-TEQ tonne^{-1} of fuel for two-stroke petrol engines without exhaust catalysts
- 0.1 μg I-TEQ tonne^{-1} of fuel for all diesel engines.

The total amount of petrol consumed in New Zealand in 2008 was 111.0 PJ (gross), or about 2,360,000 tonnes, and the total amount of diesel consumed was 109.8 PJ (gross), or about 2,390,000 tonnes (Ministry of Economic Development, 2009). The average rate of increase in total fuel consumption since 1998 has been about 100,000 tonnes per year. It is not known how much of the petrol is used in two-stroke engines, which have higher dioxin emissions, but it is likely to be very minor, say no more than 1%. For example, motor cycles account for less than 1% of the total estimated VKT for New Zealand (Ministry for the Environment, 2009b), and many of these have four-stroke engines. The emission estimates below will be based on 60% of all petrol being used in catalyst-equipped vehicles (ie, with zero PCDD/PCDF emissions) and 1% of petrol being used in two-stroke engines.

National emission estimates

PCDD and PCDF emissions from unleaded petrol and diesel use in transport are summarised in table 15.1. The figure shown for 1998 is the mid-point of the range reported in the 2000 Inventory (0.11–1.16 g I-TEQ yr^{-1}). The agreement between 1998 and 2008 is quite reasonable, given the differences in methodology and the significant allowance in the current estimates for zero emissions from petrol vehicles fitted with catalytic converters. The future projections are based on fuel consumption continuing to increase at a rate of 100,000 tonnes per year, but no net change in emissions due to continuing improvements in the New Zealand vehicle fleet. For example, most new petrol consumption should be in catalyst-equipped vehicles.

Table 15.1: PCDD and PCDF emissions to air from land transport

Annual fuel consumption (ktonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
3850	4750	5250	5750	(0.64)	0.39	0.39	0.39

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a 'medium' certainty ranking because, although the data for national fuel consumption is well based, assumptions have been made about the proportion of fuels used in catalyst-equipped vehicles and in two-stroke engines. The emission factor is assigned a 'low' certainty ranking because it is based on factors derived from overseas studies, some of which are now relatively dated.

15.2 Releases to land

No direct releases of PCDDs and PCDFs to land are expected from this source category. PCDD and PCDF residues in used oil may be applied to land when the oil is used for dust suppression. This source has been addressed separately in section 24.

15.3 Releases to water

No direct releases of PCDDs and PCDFs to water are expected from this source category. The potential for releases to water from used oil disposal is discussed separately in section 24.

15.4 Application of BAT/BEP

The BAT/BEP Guidance for transport is mainly directed at motor vehicles operating on leaded petrol, for which the preferred approach is to switch to unleaded petrol or alternative fuels, such as LPG, CNG or biofuels. Best available techniques for vehicles generally are the use of exhaust catalysts, for both petrol and diesel engines, and particulate filters on diesel engines. Best environmental practices include regular vehicle maintenance, and educating the public on driving techniques that will assist greater fuel economy. The promotion of alternative forms of transport, such as electric and hybrid vehicles, cycling and the use of public transport, should also be considered.

There are several national programmes in New Zealand of relevance to the reduction of PCDD and PCDF emissions from transport, including the New Zealand Transport Strategy, the Vehicle Fleet Emissions Control Strategy (Ministry of Transport, 2007) and the progressive improvements required under fuel quality regulations (eg, Ministry of Economic Development, 2008). In addition, other national bodies such as the Automobile Association and the Energy Efficiency and Conservation Authority, along with many regional and local councils, are actively promoting relevant aspects such as fuel economy measures and the use of alternative forms of transport. A recent pilot programme on the scrapping of old vehicles is also of note (Ministry of Transport, 2008).

15.5 References

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16 Uncontrolled Fires

Uncontrolled fires are potentially a major contributor of PCDD and PCDF emissions to the environment, particularly as a result of the poor combustion conditions that usually prevail and the range of materials that may be burnt. This section presents estimates of the PCDD and PCDF emissions from biomass burning, and from structure and vehicle fires, and discusses two other potential sources: the burning of construction and demolition timbers and the flaring of gas and oil condensates. Domestic waste burning has been addressed previously in section 14, and the releases from landfill fires are covered in section 26.

16.1 Emissions to air

16.1.1 Forest, scrub and grass fires

The emission calculations in the 2000 Inventory for this source category were based on data obtained from the New Zealand Fire Service for the areas of forest, scrub and grassland burnt annually in fires attended by the emergency services. It was noted that the data did not account for any authorised burning that might take place with the Fire Service not in attendance. This deficiency can now be addressed through the use of data collated by the Ministry for the Environment for New Zealand's annual reports of greenhouse gas emissions (Ministry for the Environment, 2009a). The relevant data for 2005, 2006 and 2007 is shown in table 16.1.

Table 16.1: Estimates of annual biomass burning

Source category	Annual biomass burning (tonnes dry matter yr^{-1})		
	2005	2006	2007
Prescribed burning of savannah (tussock)	19,110	20,270	20,270
Field burning of agricultural residues	161,850	159,970	199,490
Forest wildfires	135,966	183,456	430,976
Controlled burning of forest land	175,485	23,956	11,200
Grassland wildfires	252,581	263,148	263,432
Total biomass burning	744,992	650,800	925,368

The average biomass burned over the three-year period is about 775,000 tonnes per year (± 20%). These figures are significantly greater than the 39,780 tonnes per year given in the 2000 Inventory report. This difference is mainly due to the use of significantly different factors for biomass density. The factors used in the 2000 Inventory were 10 tonnes per hectare for forests, 20 tonnes per hectare for scrub and 2.5 tonnes per hectare for grass. However, the factors used in the greenhouse gas inventories are 364 tonnes per hectare for forests, 136 tonnes per hectare for grassland with woody vegetation (scrub) and 28 tonnes per hectare for savannah (tussock). These latter factors are considered to be more reliable than those used in the 2000 Inventory report because they are based on specific national research.

No New Zealand test data is available on the emission of PCDDs and PCDFs from forest, scrub and grass fires. The emission estimates for the 2000 Inventory were based on an emission factor range of 2–29 μg I-TEQ tonne^{-1}, which was developed from reports of studies in the US and UK. The UNEP Toolkit recommends a factor of 5 μg I-TEQ tonne^{-1} for forest, scrub (moorland) and grass fires, and 0.5 μg I-TEQ tonne^{-1} for agricultural residue burning. These factors are based on emission data from a range of countries and will therefore be used in the estimates given below.

National emission estimates

PCDD and PCDF emissions from uncontrolled burning of forest, scrub and grass are summarised in table 16.2. The total release for this source category is estimated to be just under 3 g I-TEQ yr^{-1}. As expected, this is significantly higher than the range of 0.08–1.1 g I-TEQ yr^{-1} given in the 2000 Inventory, although at the time it was also noted that a more realistic estimate could be in the range of 0.16–2.2 g I-TEQ yr^{-1}.

The estimates for 2008 are based on the three-year average of the data given in table 16.1, which allows for a degree of smoothing of the variations that occur from year to year in the land area burned. The projections for 2013 and 2018 are the same as for 2008, on the basis of no significant changes in current land use and land management practices. However, this situation could change if, for example, greater emphasis were given in government policies to the importance of forests as a sink for greenhouse gases. No back-calculation has been attempted for 1998 because of the significant changes that have been made in both the land area data and the biomass density factors.

Table 16.2: PCDD and PCDF emissions to air from forest, scrub and grass fires

Material burned	Quantity of biomass burned (ktonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
Forest, scrub and grass	–	600	600	600	–	3.000	3.000	3.000
Agricultural residues	–	174	174	174	–	0.087	0.087	0.087
Total	–	774	774	774	–	3.087	3.087	3.087

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because of the assumptions involved in estimating the land areas cleared by burning. The emission factor is assigned a ‘low’ certainty ranking because it is based on a limited range of international data, which may not be representative of the emissions from forest, scrub and grass fires in New Zealand.

16.1.2 Structure fires

Fires in structures, such as factories, offices and houses, can vary enormously in size, intensity, and the types of materials involved. The poor combustion conditions and the multitude of materials present in most fires will lead to the formation and release of PCDDs and PCDFs. Because of this complexity, it is difficult to develop estimates for either the mass of material involved in the fires or the likely emission factors.

The release estimates for the 2000 Inventory were based on New Zealand Fire Service statistics for the number of structure fires in New Zealand for the period July 1997 to June 1998. No information was available on the quantity of material consumed in these fires, but an estimate was produced by assuming the following distribution of fire size:

- 90% of the fires are small, consuming 100–250 kg of material per fire
- 9% of the fires are moderate, consuming 1–2.5 tonnes of material per fire
- 0.9% of the fires are large, consuming 10–25 tonnes of material per fire
- the remaining 0.1% of fires are very large,[5] consuming 100–250 tonnes of material per fire.

The more recent Fire Service reports (eg. New Zealand Fire Service, 2008) give a different breakdown of the statistics for structure fires, which indicates that this size distribution should be revised. The fire statistics are now broken down into those involving structural damage and those with no damage. The latter relate to minor fires inside buildings, such as kitchen fires, fires in electrical appliances, rubbish bins, etc, which account for about 50% of the total fire numbers. The amount of material consumed in these fires would be minimal at, say, no more than 10–25 kg per fire. It is therefore proposed to modify the size distribution by assuming 50% of the fires involve 10–25 kg material per fire, and the remaining 50% have the distribution noted above.

The total number of fires recorded in 1998/99 was 7310, and the total quantity of material burned was estimated to be between 2680 and 6690 tonnes (mid-range 4685 tonnes per year). The revised size distribution would give a range of 1325–3311 tonnes (mid-range 2318 tonnes per year).

The more recent data from the New Zealand Fire Service reports is shown in table 16.3 (New Zealand Fire Service, 2008). The number of fires is significantly lower than that recorded in 1997/98. However, it appears that the latter figure was unusually high (eg, see New Zealand Fire Service 2000, 2008). The annual average number of fires for the five-year period is 6467 and the year-to-year variation around this mean is about ± 6%. Applying the revised size distribution discussed above gives an estimate of 1204–3046 tonnes (mid-range 2125 tonnes per year) for the total quantity of material burned.

Table 16.3: Annual numbers of structure fires

Total number of structure fires in each year					
Year	2002/03	2003/04	2004/05	2005/06	2006/07
No. of structure fires	6880	6590	6486	6111	6270

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[5] This range was incorrectly stated in the 2000 Inventory as 250–1000 tonnes per fire.

No PCDD and PCDF emission data is available for structure fires in New Zealand. In the 2000 Inventory an emission factor range of 100–400 μg I-TEQ tonne^{-1} of material consumed was applied, and the upper value of this range is consistent with the UNEP Toolkit recommendation of 400 μg I-TEQ tonne^{-1}. The latter factor will be used in the current emission estimates, coupled with the mid-range value for the quantity of material consumed in the fires.

National emission estimates

PCDD and PCDF emissions from uncontrolled structure fires are summarised in table 16.4 and can be compared with the previous estimate of 0.27–2.7 g I-TEQ yr^{-1}. The future projections are based on the assumption that there will be no significant change in the annual numbers of fires.

Table 16.4: PCDD and PCDF emissions to air from structure fires

Material consumed (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
2318	2125	2125	2125	0.93	0.85	0.85	0.85

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a ‘low’ certainty ranking because they are based on a very rough estimate of the quantity of material consumed in structure fires in New Zealand rather than actual measured data. The emission factor is assigned a ‘low’ certainty ranking because it has been developed by UNEP on the basis of only a limited amount of highly variable data.

16.1.3 Vehicle fires

There is no information on the quantity of material burned in vehicle fires. In addition, there is only a limited amount of information relating to the emissions of PCDDs and PCDFs from this source. However, PCDD and PCDF emissions should be expected, given the potential for poor combustion conditions and the variety of different materials involved.

The release estimates in the 2000 Inventory were based on New Zealand Fire Service statistics for the numbers of fires attended over the periods July 1996 to June 1997, and July 1997 to June 1998. These included fires involving cars, buses, caravans, motor homes, trucks, vans and passenger trains. An annual average of 3200 fires was assumed for the 2000 Inventory. More recent data from the Fire Service is shown in table 16.5 (New Zealand Fire Service, 2008), and it can be seen that the annual numbers of fires is relatively steady (± 5%), with an overall mean for the five-year period of 3329 fires.

Table 16.5: Annual numbers of vehicle fires

Total number of vehicle fires in each year					
Year	**2002/03**	**2003/04**	**2004/05**	**2005/06**	**2006/07**
No. of vehicle fires	3218	3154	3295	3491	3486

No PCDD and PCDF emission data is available for vehicle fires in New Zealand. An emission factor range of 32–44 µg I-TEQ per fire was used in the 2000 Inventory. However, a factor of 94 µg I-TEQ per fire is recommended in the UNEP Toolkit, and this has been derived from a wider, though still very limited, range of studies. The Toolkit factor will be used in the current emission estimates.

National emission estimates

PCDD and PCDF emissions from vehicle fires are summarised in table 16.6. The total annual emissions of about 0.3 g I-TEQ yr^{-1} can be compared with the previous estimated range 0.10–0.14 g I-TEQ yr^{-1}.

Table 16.6: PCDD and PCDF emissions to air from vehicle fires

Annual numbers of fires				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
3200	3329	3329	3329	0.30	0.31	0.31	0.31

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a ‘low’ certainty ranking because the quantity and type of material consumed in vehicle fires is not known with any certainty. The emission factor is assigned a ‘low’ certainty ranking because it is based on a limited range of international data.

16.1.4 Burning of construction and demolition timbers

In the past, on-site burning was commonly used for the disposal of the waste timber produced during construction or demolition works. As with waste burning, this practice is now either prohibited or restricted in many urban areas (see section 14). However, it is still likely to occur on rural properties and in those urban areas where restrictions have not been applied. There may also be some illegal burning in the controlled areas.

Nationally, it has been estimated that construction and demolition timbers make up about 14% of the waste disposed in landfills; ie, about 440,000 tonnes per year (Ministry for the Environment, 2007b). An additional 300,000 tonnes per year is disposed at cleanfill sites. No information has been found on the quantities of construction and demolition timbers disposed by burning, but this is not surprising given that the locations would be constantly changing and the quantities burned would be highly variable. For the purposes of developing a rough indication of potential releases, it might be reasonable to assume that the amount disposed by burning is equivalent to 5% of the total disposed of to landfill, given that the practice is restricted or banned in many areas.

The UNEP Toolkit recommends an emission factor of 60 μg I-TEQ tonne^{-1} for PCDD and PCDF releases to air from the open burning of wood. Using the 5% quantity suggested above indicates possible annual releases to air of about 2.2 g I-TEQ yr^{-1}, which is much the same order as the estimated releases from forest, scrub and grass burning. The estimated releases for this source will not be listed in the overall inventory because the actual activity data is unknown. However, these initial estimates provide an indication that this source should not be overlooked in any future programmes to further reduce PCDD and PCDF releases in New Zealand.

16.1.5 Flaring of gas and oil condensates

The 2000 Inventory report included a brief consideration of the potential for PCDD and PCDF emissions from the flaring of gas and oil condensates. This was known to have been practised at a number of well sites in the Taranaki region during exploration and production testing for oil and gas. Information provided by the Taranaki Regional Council (G Bedford, Taranaki Regional Council, pers comm, 2008 and 2010) indicates that well discharge flows are now required to be passed through phase separation systems, with the effect that only the gaseous component is flared. In addition, consent conditions require immediate remedial action to be taken in the event of visible smoke in the flare. As a result, this need be no longer listed as a potential source of PCDD and PCDF emissions.

Flaring is also practised at the various gas production and treatment plants in the Taranaki region, but only on an intermittent basis, when required for safety reasons. Most of the flares maintain pilot flames and burn the gas very cleanly. In addition, the volumes of gas being flared are believed to be no more than about 10% of those of 10 to 20 years ago. These flares are not expected to be a significant source of PCDD/PCDF releases.

16.2 Residues (releases to land)

16.2.1 Forest, scrub and grass fires

In the case of forest, scrub and grass fires, ash will be left *in situ* on the land. The UNEP Toolkit provides emission factors of 4 μg I-TEQ tonne^{-1} for releases to land from forest, scrub (moorland) and grass fires, and 10 μg I-TEQ tonne^{-1} for releases from agricultural residue burning. These factors are based on emission data from a range of countries.

National release estimates

PCDD and PCDF releases to land from the burning of forest, scrub and grass are summarised in table 16.7. The basis for the projections for 2013 and 2018 is as explained previously in section 16.1.1. No release estimates are shown for 1998 because they were not included in the 2000 Inventory estimates.

Table 16.7: PCDD and PCDF releases to land from forest, scrub and grass fires

Material burned	Quantity of biomass burned (ktonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
Forest, scrub and grass	–	600	600	600	–	2.400	2. 400	2. 400
Agricultural residues	–	174	174	174	–	1.740	1.740	1.740
Total	–	774	774	774	–	4.140	4. 140	4. 140

Certainty

Activity statistics: Medium
Emission factor: Low

The activity statistics are assigned a ‘medium’ certainty ranking because of the assumptions involved in estimating the proportions of land areas cleared by burning. The emission factor is assigned a ‘low’ certainty ranking because it is based on a limited range of international data.

16.2.2 Structure fires

Ash from structure fires will usually be removed as part of the clean-up operations and should normally be disposed to landfill. The UNEP Toolkit provides an emission factor of 400 μg I-TEQ tonne^{-1} for releases to land from structure fires.

National release estimates

PCDD and PCDF releases to land from structure fires are summarised in table 16.8. The releases from this source were not assessed in the 2000 Inventory.

Table 16.8: PCDD and PCDF releases to land from structure fires

Material consumed (tonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
2318	2125	2125	2125	0.93	0.85	0.85	0.85

Certainty

Activity statistics: Low
Emission factor: Low

The activity statistics are assigned a ‘low’ certainty ranking because they are based on a very rough estimate of the quantity of material consumed in structure fires in New Zealand rather than actual measured data. The emission factor is assigned a ‘low’ certainty ranking because it has been developed by UNEP on the basis of only a limited amount of highly variable data.

16.2.3 Vehicle fires

Ash from vehicle fires will usually be removed as part of the clean-up operations, and should normally be disposed to landfill. The UNEP Toolkit provides an emission factor of 18 µg I-TEQ per fire for the releases from vehicle fires.

National release estimates

PCDD and PCDF releases to land from vehicle fires are summarised in table 16.9. The releases from this source were not assessed in the 2000 Inventory.

Table 16.9: PCDD and PCDF releases to land from vehicle fires

Annual numbers of fires				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
3200	3329	3329	3329	0.058	0.060	0.060	0.060

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a ‘low’ certainty ranking because the quantity and type of material consumed in vehicle fires is not known with any certainty. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international data.

16.3 Releases to water

Releases to water will occur during fire-fighting operations, particularly in the case of structure and vehicle fires. However, insufficient data is available to make an estimate of PCDDs and PCDFs released to water from these activities.

16.4 Application of BAT/BEP

The open burning of biomass is only covered very briefly in the BAT/BEP Guidance. Some of the general ‘process’ recommendations in the guidance are relevant to biomass burning, including restricting burning to clean, dry material; avoiding specific contaminants such as chlorinated plastics, metals and agricultural chemicals; and the application of environmentally sound waste management practices, including waste reuse or recycling, and waste minimisation. Other specific recommendations include careful planning of prescribed burns, operating within specific weather conditions, and the promotion of alternatives such as composting.

Land clearance by burning is allowed in many parts of New Zealand, but only in accordance with specific provisions set out in regulatory documents, such as the regional air plans produced by regional councils. Significant burn-offs will also require a permit from the Rural Fire Authority, and burn-offs may be prohibited during particular high-risk times of the year. Many councils and rural fire authorities provide specific guidance on best-practice procedures for these activities, and the recommendations are generally consistent with those given in the BAT/BEP Guidance.

There is no specific coverage given to accidental structure fires or vehicle fires in the BAT/BEP Guidance, and by their very nature there is little or nothing that can be done in advance to 'manage' these events. One possible option would be controls aimed at reducing the amount of materials such as chlorinated plastics in buildings or motor vehicles, although it is not at all certain that this would lead to reduced emissions of PCDDs and PCDFs during fires. A recent review of the Building Code (Department of Building and Housing, 2007) included proposals for a building rating scheme in which buildings would be assessed on the basis of a range of factors such as energy efficiency, potential environmental impacts and health-related aspects. If adopted, these changes could provide a mechanism for the promotion of 'preferred' building materials, although this would be based on an assessment across the full range of factors rather than just the potential for PCDD and PCDF formation in fires.

The BAT/BEP recommendations for construction and demolition timbers would be essentially the same as those summarised in section 14 for domestic waste burning.

16.5 References

Department of Building and Housing. 2007. *Building for the 21st Century: Review of the Building Code: Performance Requirements*. Wellington: Department of Building and Housing.

Ministry for the Environment. 2007b. *Targets in the New Zealand Waste Strategy: 2006 Review of Progress.* Wellington: Ministry for the Environment.

Ministry for the Environment. 2009a. *New Zealand's Greenhouse Gas Inventory 1990–2007*. Wellington: Ministry for the Environment.

New Zealand Fire Service. 2000. *Emergency Incident Statistics, 1995–1999*. Wellington: New Zealand Fire Service.

New Zealand Fire Service. 2008. *Emergency Incident Statistics, 1 July 2006–30 June 2007*. Wellington: New Zealand Fire Service.

17 Mineral Products

This section addresses PCDD and PCDF releases from the manufacture of cement, lime, bricks, tiles, pottery and ceramics, and from asphalt plants. Releases from glass manufacturing are covered in section 21.

17.1 Emissions to air

17.1.1 Cement manufacture

There are two plants currently operating in New Zealand, located in Northland and near Westport. The Northland plant had a major upgrade in 2006 and now has a capacity of about 900,000 tonnes of clinker per year, approximately double that reported in the 2000 Inventory (Concrete[3], 2008). The Westport plant produces about 450,000 tonnes of clinker per year (Holcim, 2008). The final cement product consists of a mixture of clinker and 5 to 10% other materials, and the total annual cement production is currently about 1,300,000 tonnes per year.

Both plants use coal as the primary fuel, but in Northland this is supplemented with about 15 to 20% wood waste, while the South Island plant is co-fired with about 5% waste oil. The Northland plant uses a 'dry' process in which the raw materials are fed into the system in a dry state, while at Westport the raw materials are fed in as a slurry (the 'wet' process). The significant difference between the two, from an emissions perspective, is that the dust collected from plant discharges (cement kiln dust, ie CKD) can be recycled with raw material inputs in the dry process, but must be disposed of by some other means in the wet process. The Northland plant is fitted with bag filters for the control of dust emissions, and the Westport plant uses electrostatic precipitators. The CKD from the Westport plant is sold to a fertiliser company.

A range of emission factors have been reported for cement kilns, and these have shown that PCDD and PCDF emissions are generally low. The gas flow in the kilns is counter-current to the flow of the highly alkaline cement clinker, and this acts as an effective gas-cleaning system. In addition, good combustion control, high kiln temperatures and long residence times help minimise the formation of PCDDs and PCDFs.

Cement kilns firing hazardous wastes are specifically listed in the Stockholm Convention as having a relatively high potential for releases of PCDDs and PCDFs, and other unintentional POPs. However, this observation was based on emission studies from the 1980s and 1990s and the kilns were often tested under worst-case conditions. A recent industry survey involving about 2000 test results from plants around the world indicated that this is no longer the case (Karstensen, 2006, 2008). It is believed that the main factors contributing to increased PCDD/PCDF releases are the levels of organic matter in the raw materials and elevated temperatures in the air pollution control equipment.

PCDD and PCDF emissions are tested annually at the Westport plant. The stack concentrations in recent years have been generally within the range of 0.005–0.015 ng I-TEQ Nm^{-3}, with little difference between the emissions for coal alone and when co-firing with used oil (Halliday et al, 2007, Holcim, 2008). These emissions correspond to an average release rate of about 0.02 μg I-TEQ $tonne^{-1}$ of cement. There is no PCDD/PCDF emission data for the Northland plant.

The UNEP Toolkit recommends an emission factor of 0.05 μg I-TEQ tonne^{-1} of cement for releases to air from modern plants using either the wet or dry process and fitted with electrostatic precipitators or fabric filters, with the dust-collector temperature held below 200°C. This factor is towards the lower end of the range of 0.02–1.08 μg I-TEQ tonne^{-1} noted in the 2000 Inventory and applied to the previous estimates for the Northland plant. The emission estimates for the Westport plant were based on the test results. A similar approach will be adopted for the current estimates, but using the Toolkit factor for the Northland plant and an emission factor based on the more recent testing for the Westport plant.

National emission estimates

PCDD and PCDF emissions from cement manufacture are summarised in table 17.1. A back-calculation for 1998 is not appropriate because there have been significant changes in the processes and/or emissions for both plants. Thus, the figure shown for 1998 is simply the mid-point of the range given in the previous inventory. The significant reduction in emissions from 1998 to 2008 is due to the changes in emission factors.

The future projections are based on the potential for increased production from a proposed new plant in the South Island, which is likely to replace the existing one at Westport and will have a similar production capacity to the Northland plant.

Table 17.1: PCDD and PCDF emissions to air from cement manufacture

Annual cement production (million tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
1.02	1.30	1.60	1.60	(0.38)	0.050	0.056	0.056

Certainty

Activity statistics:	High
Emission factors:	High/Medium

The activity statistics are assigned a ‘high’ certainty ranking because they are based on industry data for the amount of cement produced. The emission factor for the Westport plant is assigned a ‘high’ certainty ranking because it is based on actual emission data, while the emission factor for the Northland plant is assigned a ‘medium’ certainty ranking because it is based on international recommendations.

17.1.2 Lime manufacture

New Zealand produces around 5 million tonnes of limestone each year for use in cement manufacturing, agriculture, industry and roading (Crown Minerals, 2008a). A small fraction of this material is used for the production of burnt lime using high-temperature calcination. There are eight lime kilns in New Zealand, four of which form integral parts of the two North Island pulp and paper mills. Three of the other plants are located in the central North Island, although one of these is currently not operating. The eighth plant is in Otago. The burnt lime produced by the non-pulp-mill plants is used in agriculture, soil stabilisation for roading, steel manufacture, gold processing, sugar refining, leather tanning, wastewater treatment, and a wide range of other industrial applications (Christie et al, 2001). The kilns are generally fired by coal or gas, and most are fitted with dust control equipment, such as wet scrubbers, electrostatic precipitators and fabric filters.

In 2008 the total burnt lime production at the two pulp and paper mills was about 180,000 tonnes, and the total production at the other three plants was also around 180,000 tonnes.

The PCDD/PCDF emissions from the lime kilns at one of the pulp and paper plants were tested in 2000 and gave results of 14 and 23 pg I-TEQ Nm^{-3} (Beca AMEC, 2006). This is consistent with the data given in the UNEP Toolkit for a range of European plants, which were all less than 100 I-TEQ Nm^{-3}. Much higher results were noted for several plants in Sweden, but these were attributed to specific raw material and/or fuel quality issues, and less than optimal burning conditions. The UNEP Toolkit recommends two emission factors for releases to air from lime kilns: 10 µg I-TEQ $tonne^{-1}$ for plants with poor combustion control and simple, or no, gas cleaning systems; and 0.07 µg I-TEQ $tonne^{-1}$ for modern plants with high energy efficiencies and fitted with fabric filters. The latter factor will be adopted here.

National emission estimates

PCDD and PCDF emissions from the manufacture of burnt lime are summarised in table 17.2. The estimated emissions for 2008 are towards the bottom end of the range of 0.0030–0.16 g I-TEQ yr^{-1} given in the 2000 Inventory, although the latter appears to be based on incorrect production figures. The projections for 2013 and 2018 are based on 'business as usual'.

Table 17.2: PCDD and PCDF emissions to air from lime manufacture

Annual burnt lime production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
151,000*	360,000	360,000	360,000	–	0.025	0.025	0.025

* It is believed that the figure of 151,000 tonnes per annum given in the 2000 Inventory did not include the production at the pulp and paper mills.

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on industry data for the amount of lime produced. The emission factor is assigned a 'low' certainty ranking because it is based on limited international data.

17.1.3 Bricks, tiles, pottery and ceramics

PCDD and PCDF emissions from the manufacture of bricks, tiles, pottery and ceramics were not included in the 2000 Inventory, most likely because the amount of information available on releases from these sources is very limited. The emission factors given in the UNEP Toolkit are based on a limited number of tests on brick kilns in Germany, and no specific data was reported for pottery and ceramics. However, more recent reports from the US EPA indicates the presence of PCDDs and PCDFs in specific types of raw and processed pottery clays, some of which may be released during the manufacturing processes (Ferrario et al, 2006).

In the past, bricks and tiles were manufactured in many small plants, and several larger ones, throughout New Zealand (Christie et al, 2000). However, most of these have closed and there is now only one major manufacturer, based in Auckland, and about six smaller plants scattered throughout the country. Bricks are manufactured from clay blended with sand, pumice, scoria, and other minerals, which are added to produce a range of colours. The mixture is extruded through a die, then sliced into brick-sized pieces. These are dried, then loaded onto kiln cars and fired at temperatures of 1000°C or more. Similar processes are used for tiles. The kilns at the Auckland plant are fired on natural gas, while most of the smaller plants use coal, oil or waste oil.

The New Zealand pottery and ceramics industry has undergone a similar decline to that of brick and tile manufacturers (Christie, 2000), although there are a significant number of plants still operating, mainly in niche markets. This includes one manufacturer of specialty industrial ceramics, a manufacturer of electrical insulators, several manufacturers of tableware, numerous studio potters and an unknown number of hobby potters. The manufacturing processes for pottery and ceramics are similar to those for bricks, with the wet clay being mixed with other materials, such as silica, feldspar and talc, formed or moulded into the desired shapes and then fired in a kiln. The kilns may be heated by gas, oil or wood, although electric kilns are also used for small-scale work. Kiln temperatures vary depending on the specific materials being processed and/or the desired products, but most would be operated above 1000°C.

The total annual production in New Zealand is around 30 million bricks, which is equivalent to a product weight of about 54,000 tonnes per year (Bingham, Graham, 2006). The latter figure is in reasonable agreement with the annual production of 45,000 to 55,000 tonnes per year of ‘clay for bricks, tiles, etc’ reported in the national commodity production statistics (Crown Minerals, 2008b), after allowing for the additional raw materials used in brick making, such as sand and other minerals, coupled with a weight loss on heating of about 20%.

The Ministry of Economic Development data also indicates an annual production of about 14,000 to 15,000 tonnes per year of ‘clay for pottery and ceramics’. A significant proportion (~90%) of this clay is exported, but this is offset by annual imports of a similar quantity of other pottery clays.[6] The proportions of clay used for pottery and ceramics are usually between about 50 and 100% of the mixture, which suggests that the total annual production of pottery and ceramic articles would be between about 15,000 and 30,000 tonnes per year, on a raw materials basis, or about 12,000 to 24,000 tonnes per year for the finished articles (after 20% moisture loss). The mid-point of this range (18,000 tonnes per year) will be used in the release estimates given below.

The UNEP Toolkit recommends the following factors for PCDD and PCDF emissions to air from brick manufacture: 0.02 μg I-TEQ tonne^{-1} for “modern facilities with high standards of combustion control and energy efficiency”; and 0.2 μg I-TEQ tonne^{-1} for “smaller less well-controlled kilns with no gas cleaning”. It also recommends that these factors be used for pottery and ceramics production, in the absence of any specific data for those processes. Most of the larger New Zealand plants (both brick and ceramics) are expected to fit into the well-controlled category, but the smaller ones will not. For the purposes of the release estimate, it will be assumed that 75% of the total New Zealand production will fall into the former category.

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[6] Annual import/export data provided by Statistics New Zealand, Wellington, 2009.

National emission estimates

PCDD and PCDF emissions from the manufacture of bricks, tiles, pottery and ceramics are summarised in table 17.3. The projections for 2013 and 2018 assume no significant future changes. No data has been shown for 1998 because these sources were not considered in the 2000 Inventory.

Table 17.3: PCDD and PCDF emissions to air from brick, tile, pottery and ceramics

Total annual production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	72,000	72,000	72,000	–	0.005	0.005	0.005

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because they are based on industry estimates for brick production, clay production data and import/export statistics. The emission factor is assigned a ‘low’ certainty ranking because it is based on very limited international data.

17.1.4 Asphalt plants

PCDD and PCDF emissions from asphalt plants were not included in the 2000 Inventory, most likely because the amount of information available on releases from these sources is very limited. The emission factors given in the UNEP Toolkit are based on a limited number of tests on plants in Germany and the Netherlands, and some additional data has been reported for plants in North America (US EPA, 2004). Hot-mix asphalt is a mixture of size-graded aggregate and a liquid asphalt (bitumen) binder. A portion of reclaimed asphalt pavement may also be used. The materials are mixed in a heated rotating drum, usually fired on oil or gas, and the PCDD/PCDF emissions are believed to be due partly to incomplete fuel combustion and partly to decomposition of some of the volatiles released from the bitumen during heating.

There are 39 stationary asphalt plants in New Zealand and several mobile units (A Stevens, Roading New Zealand Inc, pers comm, 2009), and the annual asphalt production is about 850,000 tonnes per year. The UNEP Toolkit recommends two factors for PCDD/PCDF emissions to air from asphalt production: 0.007 μg I-TEQ $tonne^{-1}$ of asphalt for “modern asphalt mixing installations fitted with fabric filters or wet scrubbers” and 0.07 μg I-TEQ $tonne^{-1}$ for “installations without gas cleaning systems or when poor or contaminated fuels are used”. Most New Zealand asphalt plants are fitted with either wet scrubbers or bag filters and would fit into the former category.

National emission estimates

PCDD and PCDF emissions to air from asphalt plants are summarised in table 17.4. The projections for 2013 and 2018 assume no significant future changes. No data has been shown for 1998 because this source was not considered in the 2000 Inventory.

Table 17.4: PCDD and PCDF emissions to air from asphalt plants

Total annual production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	850,000	850,000	850,000	–	0.006	0.006	0.006

Certainty

Activity statistics: High
Emission factor: Low

The activity statistics are assigned a 'high' certainty ranking because they are based on industry data for annual asphalt production. The emission factor is assigned a 'low' certainty ranking because it is based on very limited international data.

17.2 Releases to land (residues)

17.2.1 Cement manufacture

Dust is generated by numerous sources within a cement plant, including the kilns, the clinker cooler, grinding mills and bypass streams. Most of this dust is collected using bag filters and/or electrostatic precipitators, and is referred to collectively as cement kiln dust (CKD). As noted in section 17.1, most of this material is recycled through the plant in the dry process but requires separate disposal in the wet process. The Westport cement plant produces approximately 20,000 tonnes per year of CKD (Bingham, Graham, 2006), and this is sold for use as a soil conditioner.

The UNEP Toolkit does not give a specific factor for releases to land from CKD disposal but notes that PCDD/PCDFs have been previously reported in the range of 0.001–40 μg I-TEQ $tonne^{-1}$. More recent data reported by Karstensen (2006) gives a range of 0–96 μg I-TEQ $tonne^{-1}$ and a mean of 6.7 μg I-TEQ $tonne^{-1}$. This latter figure will be used in the estimates given below.

The 2000 Inventory included an estimate of 0.97 g I-TEQ yr^{-1} for the releases to land as a result of PCDD/PCDF contamination of clinker (and therefore also present in the cement). This was based on an assumed concentration in clinker of < 1 μg I-TEQ $tonne^{-1}$, which is reasonably consistent with an industry average level of 0.91 μg I-TEQ $tonne^{-1}$ recently reported by Karstensen (2006). However, the amount actually deposited to land as cement dust is likely to be minimal, as most of the PCDD/PCDFs would be 'locked up' inside concrete. This potential source of PCDD/PCDF releases is therefore considered to be negligible and has not been included below.

National release estimates

PCDD and PCDF releases to land from cement manufacture are presented in table 17.5. As indicated, these are relatively minor, at 134 mg per year. The back-projection for 1998 can be compared to the estimated range of releases of 0.000013–1.4 g I-TEQ yr^{-1} given in the 2000 Inventory. The projections for 2013 and 2018 assume that the Westport plant has been replaced by the new plant proposed for the South Island, which will use the 'dry' cement process.

Table 17.5: PCDD and PCDF releases to land from cement kiln dust

Annual CKD production (tonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
13,200	20,000	20,000	20,000	0.088	0.134	0	0

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on specific industry data. The emission factor is assigned a 'low' certainty ranking because it is based solely on overseas data for PCDD and PCDF concentrations in cement kiln dusts.

17.2.2 Lime manufacture

The 2000 Inventory identified two potential sources for PCDD/PCDF releases to land from lime manufacture: the application of burnt lime to land for uses such as road stabilisation and in agriculture, and the disposal of waste materials collected by the air pollution control equipment on the lime kilns. The proportion of total lime production applied to land is uncertain, but is believed to be no more than about 20% of the total production from the three plants not associated with the pulp and paper mills – the production from the latter being used directly in the mill processes. The dust captured by the air pollution control equipment was estimated at around 5000 tonnes per year, and a corresponding estimate for 2008 would be 6000 tonnes per year. The bulk of this material is simply a relatively fine fraction of the burnt lime product, and it is quite suitable for applications such as road stabilisation. The total material applied to land from both sources is estimated to be no more than 42,000 tonnes per year.

No New Zealand data is available for PCDD/PCDF concentrations in lime dust. In the 2000 Inventory it was assumed that the PCDD and PCDF concentrations in the dust collected by the air pollution control equipment would be similar to those found in cement kiln dust. As indicated in section 17.2.1, the average PCDD/PCDF concentration from recent industry data for this material is 6.7 μg I-TEQ $tonne^{-1}$. However, a more appropriate comparison for the burnt lime produced in the kilns would be the concentration found in cement clinker: 1.24 μg I-TEQ $tonne^{-1}$ (Karstensen, 2006). The estimates given below are based on an annual production of 6000 tonnes of lime kiln dust with a PCDD/PCDF concentration of 6.7 μg I-TEQ $tonne^{-1}$, and 36,000 tonnes of product with a PCDD/PCDF concentration of 1.24 μg I-TEQ $tonne^{-1}$.

National release estimates

The estimated PCDD and PCDF releases to land from lime manufacture are shown in table 17.6. No back-calculation has been given for 1998 because the previous estimate was based on only one of the two possible sources. The projections for 2013 and 2018 are based on 'business as usual'.

Table 17.6: PCDD and PCDF releases to land from burnt lime manufacture

Annual burnt lime application to land (tonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	42,000	42,000	42,000	–	0.084	0.084	0.084

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because they are based on relatively broad estimates of the total quantities applied to land. The emission factor is assigned a ‘low’ certainty ranking because it is based solely on overseas data for PCDD and PCDF concentrations in related materials.

17.2.3 Bricks, tiles, pottery and ceramics

No information is available on the possible releases to land from these processes. The only likely sources would be manufacturing wastes. However, the quantities of these are expected to be relatively low, and PCDD/PCDF contamination levels should also be minimal.

17.2.4 Asphalt plants

The PCDD and PCDF emissions from asphalt plants are adsorbed on particulate matter, and a significant proportion will therefore be found in the residues captured by the gas cleaning systems. About 50% of New Zealand plants are fitted with bag filters, and the residues from these are periodically removed and recycled through the manufacturing process. The remaining plants use wet scrubbers, in which the residues collect as a sludge in the bottom of the system. This would be periodically removed and disposed to landfill. The UNEP Toolkit recommends a release factor of 0.06 μg I-TEQ $tonne^{-1}$ of asphalt for this residue.

National release estimates

The estimated PCDD and PCDF releases to land from asphalt plants are shown in table 17.7 and are based on the assumption that residues are only associated with 50% of the total national production. The projections for 2013 and 2018 are based on no significant change in production.

Table 17.7: PCDD and PCDF releases to land from asphalt plants

Annual asphalt production (tonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	425,000	425,000	425,000	–	0.024	0.024	0.024

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because, although they are based on industry production data, there is significant uncertainty in the actual quantities of sludge produced by each plant. The emission factor is assigned a ‘low’ certainty ranking because it is based on very limited international data.

17.3 Releases to water

No direct releases to water are expected from any of the sources covered in this chapter.

17.4 Application of BAT/BEP

17.4.1 Cement manufacture

The BAT/BEP Guidance for cement manufacture has a specific focus on those plants co-fired with hazardous wastes. However, many of the more generic aspects will be relevant to other cement plants as well, including the following.

- Ensure rapid cooling of exhaust gases to below 200°C, before the emission control equipment.
- Maintain stable operating conditions by optimising process control and raw material input rates.
- Minimise fuel use by optimising raw material preheating and pre-calcination, and the use of modern clinker coolers for heat recovery from the exhaust gases.
- Use measures to ensure consistent and continuous supplies of alternative fuels to maintain stable operating conditions.
- Develop quality specifications for alternative fuels, including limits on heavy metal content, chlorine and sulphur, and avoidance of potential precursor materials such as PCBs.
- Undertake process monitoring to ensure adequate levels of oxygen in the combustion process and effective control of carbon monoxide production.
- Use electrostatic precipitators or fabric filters to control particulate emissions.
- If necessary, activated carbon injection can also be considered, coupled with fabric filters for additional PCDD/PCDF capture and control.
- For new plants or major upgrades, best available techniques are considered to be the use of a dry process kiln, with multi-stage heating and pre-calcination.

The two New Zealand cement plants are believed to comply with all of the above specifications. The performance requirement recommended in the BAT/BEP Guidance is 0.1 ng I-TEQ Nm^{-3} (at 10% oxygen), and this has been consistently achieved in the annual tests on the Westport plant.

17.4.2 Lime manufacture, bricks, tiles, pottery and ceramics, and asphalt plants

There is currently no BAT/BEP Guidance for any of these processes.

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18 Iron and Steel Production

There are two iron and steel plants in New Zealand, both in the Auckland region. One plant manufactures steel from ironsand and coal (referred to as primary steel production) and the other uses steel scrap (secondary steel production). Significantly, New Zealand has no steel sinter plants, which can have relatively high emissions of PCDDs and PCDFs (UNEP, 2007).

There are two other processes covered in this section which were not included in the 2000 Inventory: hot-dip galvanising and metal shredding. These are both relatively minor sources of PCDD and PCDF releases.

18.1 Emissions to air

18.1.1 Primary steel production

This plant is one of only a few of its kind in the world, and produces steel using the direct reduction (Lurgi–Stelco) process from ironsand and coal. The coal is used as both a fuel in the multi-hearth furnaces and a source of the carbon required for steel making.

The PCDD and PCDF emission estimates for the 2000 Inventory were based on emission test results for each part of the plant. These were converted into an average emission factor across the whole plant of 0.16 μg I-TEQ tonne^{-1} of steel produced. The total annual emissions were estimated to be 0.10 g I-TEQ yr^{-1} for an average annual steel output of 650,000 tonnes per year.

There is no new PCDD/PCDF emission data available for the plant. However, one of the sources identified in the 2000 Inventory – the electric arc furnace – was decommissioned in 1997. This has the effect of reducing overall emissions to a rate of 0.134 μg I-TEQ tonne^{-1} of steel produced. The production rate is relatively constant at 620,000 tonnes per year, and no significant changes are expected over the next 5 to 10 years (C Jewell, Bluescope Steel Ltd, Auckland, pers comm, 2008).

The UNEP Toolkit recommends an emission factor of 0.1 μg I-TEQ tonne^{-1} of steel for iron and steel plants using virgin iron or clean scrap, although it is not clear whether the factor applies to the direct reduction process used in New Zealand. Nonetheless, there is a reasonable level of agreement between this factor and the site-specific factor indicated above.

National emission estimates

PCDD and PCDF emissions from primary steel production are summarised in table 18.1. The estimates are based on the site-specific emission factors.

Table 18.1: PCDD and PCDF emissions to air from primary steel production

Annual steel production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
650,000	620,000	620,000	620,000	0.10	0.08	0.08	0.08

Certainty

Activity statistics:	High
Emission factor:	Medium

The activity statistics are assigned a 'high' certainty ranking because they are based on actual production data. The emission factor is assigned a 'medium' certainty ranking because, although it is based on site-specific test data, the information is now relatively dated.

18.1.2 Secondary steel production

The secondary steel manufacturing plant in South Auckland uses a single 48-tonne electric arc furnace, and has a current production rate of about 260,000 tonnes of steel per year. This is a significant increase on the 170,000 tonnes per year reported in the 2000 Inventory and is the result of a number of process improvements, energy and operational efficiencies, and increased international demand for steel. The plant uses scrap steel from a variety of sources, including industrial scrap and old motor vehicles. The melting of scrap metal contaminated with metal working fluids and materials containing chlorine provides conditions that are conducive to the formation of PCDDs and PCDFs. However, the process does not involve any scrap preheating, which has been linked to higher emissions of PCDDs and PCDFs at other plants.

Historically the fume from the electric arc furnace was collected in a 'dog box' and cleaned using fabric filtration. In 1999 a new fume extraction plant was installed on the arc furnace, the 'dog box' was replaced with a canopy hood in the roof of the building, and the whole system was ducted to a new bag filter with a greatly increased capacity (Beca, 2008a). The new system has also resulted in significant reductions in fugitive emissions, although there are still some residual releases, which are difficult to quantify with any real accuracy.

The emissions of PCDDs and PCDFs are tested annually on the discharge from the bag house stack. The average of the three most recent test results (2004–2007) is 0.058 ng I-TEQ Nm^{-3}, which corresponds to an emission rate of 0.92 μg I-TEQ $tonne^{-1}$ of steel (Beca, 2008b). This is significantly higher than the range of 0.098–0.37 μg I-TEQ $tonne^{-1}$ used in the 2000 Inventory. The increased emissions are believed to be due to a combination of factors, including the increased production rate and greater capture of the fugitive emissions.

- The UNEP Toolkit recommends the following factors for secondary steel mills: 0.1 μg I-TEQ $tonne^{-1}$ for a state-of the-art plant using clean scrap and/or virgin iron.
- 3 μg I-TEQ $tonne^{-1}$ for plants processing clean scrap and fitted with afterburners and bag filters.
- 10 μg I-TEQ $tonne^{-1}$ for the processing of dirty scrap, with limited emission controls.

The 'local' emission factor based on recent testing fits comfortably within this range and will be the most appropriate figure to use for the current emission estimates.

National emission estimates

PCDD and PCDF emissions from secondary steel production are summarised in table 18.2. The figure shown for 1998 is the mid-point of the range reported in the 2000 Inventory.

Table 18.2: PCDD and PCDF emissions to air from secondary steel production

Annual steel production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
170,000	260,000	260,000	260,000	(0.04)	0.24	0.24	0.24

Certainty

Activity statistics:	High
Emission factor:	High

The activity statistics are assigned a ‘high’ certainty ranking because they are based on industry production data. The emission factor is assigned a ‘high’ certainty ranking because it is based on site-specific emission data.

18.1.3 Hot-dip galvanising

Galvanising refers to the process of coating iron or steel with a thin layer of zinc to provide long-term protection against corrosion. The hot-dip process involves pre-cleaning of the metal by immersion in acidic and/or alkaline cleaning baths, treatment with a fluxing agent (such as zinc ammonium chloride), and then immersion in a bath of molten zinc at a temperature of around 450°C. Hot-dip galvanising was first identified as a potential source of PCDDs and PCDFs in the 1997 Inventory for the European Union (UNEP, 2005) and was subsequently investigated in more detail in Spain (Martinez et al, 2008). The ‘organic’ component necessary for formation of PCDDs and PCDFs is believed to come from insufficient degreasing of the metal, or from inhibitors or additives such as quinoline, 8-methylquinoline or polyether phosphoric acid, which are used in the cleaning steps.

The New Zealand galvanising industry is made up of two large coating plants for continuous steel sheet and a wire-galvanising operation (production rates of 5000 to 10,000 tonnes per year each), several mid-sized batch-processing plants (1000–2000 tonnes per year), and about 20 small batch operators (< 500 tonnes per year). The total production of galvanised iron and steel is estimated to be no more than about 37,000 tonnes per year (J White, CSP Coating Systems, Auckland, pers comm, 2008). No significant changes in production are expected over the next 5 to 10 years.

No test data is available for PCDD and PCDF emissions from hot-dip galvanising processes in New Zealand. The UNEP Toolkit recommends the following emission factors for PCDD and PCDF releases to air:

- 0.02 µg I-TEQ $tonne^{-1}$ of galvanised iron/steel, for facilities with a metal degreasing step and good air pollution control systems (eg, bag filters)
- 0.05 µg I-TEQ $tonne^{-1}$ of galvanised iron/steel, for facilities with good air pollution control systems but no degreasing step
- 0.06 µg I-TEQ $tonne^{-1}$ of galvanised iron/steel, for facilities with no air pollution control systems.

Degreasing steps are likely to be used in all hot-dip galvanising plants in New Zealand because this is essential for achieving good adherence of the zinc coating. Most of the large and mid-sized plants are fitted with fume extraction systems and bag filters, but most of the small batch plants are not. The production split between controlled and uncontrolled operations is estimated to be approximately 2:1 (ie, 24,500 and 12,500 tonnes per year).

National emission estimates

PCDD and PCDF emissions from hot-dip galvanising are summarised in table 18.3. The estimated total annual emission from this sector is a relatively minor 0.0012 g I-TEQ yr^{-1}.

Table 18.3: PCDD and PCDF emissions to air from hot-dip galvanising

Total metal production, tonnes yr^{-1}				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	37,000	37,000	37,000	–	0.0012	0.0012	0.0012

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a ‘low’ certainty ranking because they are based on rough estimates of total production and an approximate split between controlled and uncontrolled processes. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international data.

18.1.4 Metal shredding

Metal shredders are used for processing a range of scrap metal, including car bodies, whiteware and roofing iron. There are two outputs: a relatively clean ferrous metal stream, made up of small (around 50 mm) pieces of steel, and a ‘fluff’ or ‘flock’, which contains fragments of other non-ferrous metals and any other waste materials in the input stream. PCDDs and PCDFs have been detected in the stack emissions from shredder plants, but there is no evidence to show that these are formed as a result of the shredding process. Instead, it is believed that the emissions arise from contaminants already present in the scrap metal (UNEP, 2005; UNEP, 2007). As an extreme example, PCBs (and possibly PCDD/DFs) may be released from old capacitors, if present.

The amount of data available on PCDD and PCDF releases to air is very limited, and the UNEP Toolkit recommends a single release factor of 0.2 µg I-TEQ $tonne^{-1}$ of steel.

There are two steel shredder plants in New Zealand, located in Auckland and Christchurch. Most of the shredded metal is used as feedstock in the secondary steel plant in Auckland, with any surplus production sold for export. The total annual throughput for the two plants is around 120,000 tonnes of steel per year (M Ripley, Sims Pacific Metals Limited, Auckland, pers comm, 2010).

National emission estimates

PCDD and PCDF emissions from metal shredding are summarised in table 18.4. The projections for 2013 and 2018 assume no significant changes in production.

Table 18.4: PCDD and PCDF emissions to air from metal shredding

Total metal production, tonnes yr^{-1}				Annual emissions (g I-TEQ yr^{-1})			
1998	**2007**	**2012**	**2017**	**1998**	**2007**	**2012**	**2017**
–	120,000	120,000	120,000	–	0.024	0.022	0.024

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on industry production data. The emission factor is assigned a ‘low’ certainty ranking because it is based on very limited overseas data.

18.2 Releases to land (residues)

18.2.1 Primary steel production

The main solid waste streams from primary steel production are slag, sludges, waste lime and bag-house dust. The levels of PCDDs and PCDFs in the slag are expected to be very low, because any PCDD/PCDFs generated in the arc furnace will be either destroyed or volatilised from the molten material. As a result, no analyses have been carried out on these waste streams. Most of the slag is sold for a variety of uses, including road surfacing, abrasive blasting, water filtration, and as a soil conditioner.

Approximately 46,140 tonnes per year (dry weight) of sludges and dusts are generated during the primary steel-making process, and PCDD and PCDF analyses have been conducted on each of these waste streams. The quantities of waste produced, and PCDD and PCDF concentrations measured, are the same as those reported in the 2000 Inventory, with the exception of the arc furnace bag-house dust. The closure of the arc furnace has had a major effect on the estimated PCDD/PCDF releases to land, because the bag-house dust was the major contributor (~70%) to the total PCDD and PCDF residues.

National release estimates

PCDD and PCDF releases in sludges and dusts from primary steel production are summarised in table 18.5. The individual source contributions to the releases are as reported in the previous Inventory. All of the waste materials are disposed at the company’s on-site landfill.

Table 18.5: PCDD and PCDF releases to land from primary steel production

Annual waste production (tonnes yr^{-1})				Annual releases in residues (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
47,440	46,140	46,140	46,140	0.67	0.21	0.21	0.21

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on actual production data. The emission factor is assigned a 'low' certainty ranking because it is based on a limited amount of site-specific test data and the information is now relatively dated.

18.2.2 Secondary steel production

There are three main solid waste streams from the secondary steel-manufacturing plant: waste lime (7000 tonnes per year), slag (26,000 tonnes per year) and bag-house dust (3600 tonnes per year). As with primary steel production, PCDD and PCDF concentrations in the slag are expected to be very low, and no analyses have been carried out. Waste lime has not been tested for PCDDs and PCDFs for the same reason.

The slag produced at this mill is taken to the primary steel mill site for processing and reuse in the variety of applications noted in section 18.2.1. The waste lime is either used for site construction activities (eg, in noise bunds) or disposed to landfill.

The bag-house dust is the most likely solid waste stream in which to find elevated levels of PCDDs and PCDFs. The 2000 Inventory reported 'recent' test data which gave a PCDD/PCDF concentration of 700 ng I-TEQ kg^{-1}, and this compared well with data reported from the UK. The same factor will be used for the current estimates, in the absence of any more recent data.

National release estimates

PCDD and PCDF releases in bag-house dust from secondary steel production are summarised in table 18.6. The bag-house dusts are treated (stabilised) and disposed to landfill.

Table 18.6: PCDD and PCDF releases to land from secondary steel production

Annual waste production (tonnes yr^{-1})				Annual releases in residues (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
2000	3600	3600	3600	1.4	2.5	2.5	2.5

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on site-specific data for waste production. The emission factor is assigned a 'low' certainty ranking because it is based on limited site-specific, but now relatively historical, concentration data.

18.2.3 Hot-dip galvanising

The residues produced from hot-dip galvanising are primarily dust and fumes collected in the bag filters. The estimated rate of production for New Zealand operations is about 1 kg per tonne of galvanised steel, which is within the range of 0.2 to 1.65 kg per tonne quoted by Martinez et al (2008) for plants in Denmark. The total residue production for New Zealand is estimated at about 24.5 tonnes per year, on the basis that the residues are only produced by those plants fitted with bag filters. At most of these plants the residues are removed by contractors and stabilised before disposal in a landfill.

The UNEP Toolkit recommends a PCDD/PCDF release factor of 1000 μg I-TEQ tonne^{-1} of residue for hot-dip galvanising plants with effective degreasing steps.

National release estimates

PCDD and PCDF releases in residues from hot-dip galvanising plants are summarised in table 18.7. As shown, the total annual releases from this source are relatively minor at 0.025 g I-TEQ yr^{-1}.

Table 18.7: PCDD and PCDF releases to land from hot-dip galvanising

Total residue production, tonnes yr^{-1}				Annual releases in residues (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	25	25	25	–	0.025	0.025	0.025

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a 'low' certainty ranking because they are based on industry estimates of total residue production. The emission factor is assigned a 'low' certainty ranking because it is based on limited international test data.

18.2.4 Metal shredding

The primary waste produced from metal shredding is the so-called fluff, which is stabilised before disposal to landfill. There is no data available on the likely PCDD and PCDF concentrations in this waste, although it is likely to be relatively minor.

18.3 Releases to water

18.3.1 Primary steel production

Both treated wastewater and stormwater from the primary steel manufacturing plant are discharged to water. The total discharge from the site is approximately 8500 m^3 per day. As reported in the 2000 Inventory, past analyses of the combined wastewater and stormwater discharge have found no PCDDs or PCDFs above the limits of quantification. A concentration of 4.7 pg I-TEQ L^{-1} was calculated solely by assuming that all congeners were present at half the limit of detection.

National release estimates

PCDD and PCDF releases to water at the primary steel manufacturing site are summarised in table 18.8.

Table 18.8: PCDD and PCDF releases to water from primary steel production

Annual wastewater volumes (10^6 m^3 yr^{-1})				Annual releases to water (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
3.1	3.1	3.1	3.1	0.015	0.015	0.015	0.015

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on site-specific data. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited, and now historical, site-specific data.

18.3.2 Secondary steel production

There is no information available on the release of PCDDs and PCDFs to water from secondary steel production in New Zealand. However, all plant wastewater and site stormwater is treated by passing through an artificial wetland before discharge to the Manukau Harbour. This treatment system should be highly effective in minimising any distribution of PCDDs and PCDFs into the wider environment.

18.3.3 Hot-dip galvanising

There are no direct releases to water from hot-dip galvanising. Any leaching of PCDDs and PCDFs from the waste streams deposited in landfills will be accounted for in the estimate of releases to water from landfill leachate (see section 26).

18.3.4 Metal shredding

There are no direct releases to water from metal shredding. Any leaching of PCDDs and PCDFs from the waste streams deposited in landfills will be accounted for in the estimate of releases to water from landfill leachate (see section 26).

18.4 Application of BAT/BEP

18.4.1 Primary steel production

The BAT/BEP Guidance for primary steel production is mainly concerned with steel sinter plants, which can be a major source of PCDDs and PCDFs. The direct reduction process, as used in the New Zealand mill, is only referred to as an example of a much cleaner alternative process. Nonetheless, the following generic guidance will be relevant. There should be:

- process monitoring and control to ensure stable and consistent plant operation
- quality control of input raw materials to avoid or minimise potential contamination by dioxin precursors, such as oils and chlorine/chloride compounds
- the use of bag filters for particulate removal, and operating/management practices to ensure consistent performance at high collection efficiencies.

Most processes at the steel mill are under computer control, with alarms and interlocks for major pollution control systems to ensure correct operation. The primary raw materials (ironsand, coal and limestone) are unlikely to be a source of contamination, and the only scrap used in steel making is clean metal sourced from within the plant. All bag houses are maintained and operated to a high standard and consistently achieve their particulate emission limits. The BAT/BEP performance guideline is 0.2 ng I-TEQ Nm^{-3} (at operating oxygen concentrations) and the PCDD and PCDF emissions reported in the 2000 Inventory were comfortably below this level.

The company also has an ongoing programme for investigating options for reducing water consumption, wastewater discharges and the quantities of solid waste disposed to landfill.

18.4.2 Secondary steel production

The BAT/BEP recommendations for secondary steel plants can be summarised as follows.

- Control scrap quality by minimising contaminants such as oils, plastics and other hydrocarbons.
- Minimise furnace roof opening times for scrap charging, reduce air infiltration to the furnace, and avoid or minimise operational delays.
- Use an off-gas conditioning system design (appropriate system sizing, maximised off-gas mixing, rapid cooling to < 200°C, good operating and maintenance practices).
- Use continuous process parameter monitoring for the off-gas conditioning system.
- Maximise off-gas fume/dust capture efficiencies through a combination of targeted collection systems and general building air extraction systems.
- Use high-efficiency fabric filter dust collectors or bag houses (< 5 mg dust m^{-3}).

- Where feasible, consider additional absorbent injection systems if unable to consistently achieve dioxin emission levels of < 0.1 ng m^{-3}.
- Process bag-house dust to recover valuable metals, where possible, and dispose of other residues in an environmentally sound manner.
- Use closed-loop water-cooling systems.

Most of these systems and practices are applied at the New Zealand plant, apart from rapid off-gas cooling, the use of absorbent injection, and metal recovery from bag-house dust. The BAT/BEP performance criterion is 0.1 ng m^{-3} (at operating oxygen conditions), and the results from annual stack testing (Beca, 2008b) indicate that the emissions are consistently below this level. However, the results are influenced to some extent by the inclusion of general building ventilation air.

18.4.3 Hot-dip galvanising

Hot-dip galvanising is not covered in the BAT/BEP Guidance. However, Martinez et al (2008) suggest that effective metal degreasing, fume collection and treatment through a bag filter should be appropriate for minimising PCDD and PCDF production and release.

18.4.4 Metal shredding

The BAT/BEP recommendations for metal shredding plants are as follows.

- Keep scrap metal free of material likely to be contaminated with PCBs, PCDDs or PCDFs, including old capacitors and transformers, and waste oil.
- Fit shredders with dust suppression or collection systems.
- Store ‘fluff’ wastes in closed containers before disposal.
- Put in place stringent site fire protection measures to minimise the risk of ‘fluff’ fires, which are a potential source of additional PCDD/PCDF formation.

All these systems and practices are applied at the two New Zealand plants (M Ripley, Sims Pacific Metals Limited, Auckland, pers comm, 2010).

18.5 References

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19 Aluminium Production

19.1 Emissions to air

There is one primary aluminium smelter in New Zealand, one large secondary aluminium processor, and about 45 small- to medium-sized foundries and scrap recovery plants. PCDD and PCDF emissions and releases from these different operations are considered below.

19.1.1 Primary aluminium production

The primary aluminium smelter is located at Tiwai Point in Southland. It produces approximately 350,000 tonnes of aluminium per year by the pre-bake Hall-Heroult process, with most production in the form of high-purity ingots. Over the past 10 years the company has successfully positioned itself as a preferred supplier of premium high-purity aluminium to the international markets.

Primary aluminium production is generally thought not to be a source of any significant PCDD or PCDF releases to air (UNEP, 2005; UNEP, 2007).

19.1.2 Secondary aluminium processing

The industries included in this subcategory are metal recyclers, who recover aluminium from mixed scrap, and manufacturers of cast aluminium products, such as alloy wheels and lawnmower bodies. Much of the manufacturing uses aluminium ingots and clean aluminium scrap, but may also include aluminium recovery from in-house metal wastes. Scrap metal and mixed metal wastes may contain organic impurities such as plastics, paints and solvents, and their presence during the reclamation processes can result in the formation and emission of PCDDs and PCDFs. In addition, the use of chlorine and hexachloroethane as de-gassing agents has been associated with elevated PCDD and PCDF emissions (UNEP, 2005).

Secondary aluminium was included in a 2002 survey of dioxin and furan emissions from secondary metallurgical processes in New Zealand (Ministry for the Environment, 2004). The survey covered 82 sites,[7] of which 48 were engaged in aluminium processing. Four of the aluminium processors were classified as large facilities (> 5000 tonnes per year), four as medium (1000–5000 tonnes per year), five as small–medium (250–1000 tonnes per year), and 36 as small (< 250 tonnes per year). The total annual aluminium production was estimated at 47,000 tonnes per year, of which 94% was attributed to the four large sites. One of these plants has since been shut down, and another has reduced its production by about 90%. Many of the small and medium plants are operating at significantly lower production rates (I Paine, Glucina Alloys Ltd, Auckland, pers comm, 2009; A Vernon, MCK Metals Pacific Ltd, New Plymouth, pers comm, 2009). The current annual production is now estimated to be no more than about 20,000 tonnes per year.

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[7] A further 40 sites were estimated from survey non-returns, but were assumed to be small or very small facilities and therefore of little significance at a national level. It should also be noted that the total number of plants is likely to have dropped significantly since 2002.

Tests for PCDD and PCDF emissions were carried out at the four large secondary aluminium plants during 2002 and 2003 (Ministry for the Environment, 2004). The estimated emission rates, from a total of eight tests, ranged from 0.0027 μg I-TEQ tonne^{-1} of metal to 17 μg I-TEQ tonne^{-1} of metal, although the plant recording the highest results has since replaced its molten salt rotary furnace with an induction system and is only processing clean scrap. The average emission rate across all four plants was 2.9 μg I-TEQ tonne^{-1} of metal. This is towards the lower end of the range of emission factors (0.3–150 μg I-TEQ tonne^{-1} of metal) given in the UNEP Toolkit and will be used in the national estimates given below.

National emission estimates

PCDD and PCDF emissions from secondary aluminium production are summarised in table 19.1. The back-projection to 1998 is based on the current emission factor. In the 2000 Inventory the total emissions for secondary aluminium were estimated at 0.009–1.8 g I-TEQ yr^{-1}, but this was based on emission factors reported for a variety of different plants in other countries. The projections for 2013 and 2018 assume no change in annual production rates.

Table 19.1: PCDD and PCDF emissions to air from secondary aluminium production

Annual metal production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
35,000	20,000	20,000	20,000	0.102	0.058	0.058	0.058

Certainty

Activity statistics:	Medium
Emission factor:	Medium

The activity statistics are assigned a 'medium' certainty ranking because they are based on industry survey data, but with some approximate adjustments to account for changes since 2002. The emission factor is assigned a 'medium' certainty ranking because it is based on a limited range of New Zealand test data.

19.2 Releases to land (residues)

19.2.1 Primary aluminium production

As indicated in the 2000 Inventory, the only primary aluminium waste stream with the potential for PCDD and PCDF contamination is the 'metal reclaim fines'. This potential arises from the use of chlorine- and/or chloride-based products to de-gas the aluminium before pouring into extrusion billets. The only data available on the contamination levels was from 1992, and this was used in the 2000 Inventory to estimate a PCDD/PCDF release to land of 0.0017 g I-TEQ yr^{-1}. However, since that time the billet casting process has been changed, with significantly less chlorine now being used and, presumably, lower contamination levels. In addition, since 2001 all metal reclaim wastes (dross) have been exported to Australia for metal recovery and recycling (C Scarlett, New Zealand Aluminium Smelters Ltd, Southland, pers comm, 2009).

19.2.2 Secondary aluminium production

Solid waste streams from secondary aluminium production include filter fines and dusts from gas-cleaning equipment, and slag and waste sand from casting. This 2011 Inventory addresses only filter fines and other dusts collected in gas-cleaning systems, because these are likely to have the highest levels of PCDDs and PCDFs.

The release estimates for the 2000 Inventory were based on a waste production rate of 1400 to 1700 tonnes per year of filter fines and dust from the only two sites known to be fitted with bag filters. However, both of the large plants have bag filters, and the 2002 industry survey also identified six small- or medium-sized plants fitted with bag filters. This suggests that bag filter dusts will now be associated with about 90% of all secondary aluminium production.

The UNEP Toolkit recommends release factors of 400 μg I-TEQ tonne^{-1} of metal for secondary aluminium plants with a high degree of emission control, and 200 μg I-TEQ tonne^{-1} of metal for those plants with simple or no dust removal. The average release rate for New Zealand plants is most likely intermediate between these two values, and a factor of 300 μg I-TEQ tonne^{-1} of aluminium will be used for the release estimates.

National release estimates

PCDD and PCDF releases in filter fines and dust from secondary aluminium production are summarised in table 19.2. The back-projection for 1998 is based on the waste production estimates used in the 2000 Inventory, coupled with the current release factor. The result is close to the top of the range of 0.67–6.8 g I-TEQ yr^{-1} reported previously. Most of the dusts produced from gas cleaning are disposed by controlled burial at landfills, although some are exported overseas for metal recovery and recycling (A Vernon, MCK Metals Pacific Ltd, New Plymouth, pers comm, 2009).

Table 19.2: PCDD and PCDF releases to land from secondary aluminium production

Annual metal production (tonnes yr^{-1})				Annual releases in residues (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
35,000	18,000	18,000	18,000	6.3	5.4	5.4	5.4

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because they are based on industry survey data, but with some approximate adjustments to account for changes since 2002. The emission factor is assigned a ‘low’ certainty ranking because it is based on published data from a limited number of overseas studies.

19.3 Releases to water

No direct PCDD and PCDF releases to water are expected from primary or secondary aluminium production in New Zealand. Any leaching of PCDDs and PCDFs from the waste streams deposited in landfills will be accounted for in the estimates given in section 26.

19.4 Application of BAT/BEP

Recommended measures for primary aluminium production are included in the BAT/BEP Guidance, even though this process has not been shown to be a significant source of PCDD and PCDFs (UNEP, 2007). Most of the recommendations are directed at the general principles of pollution prevention and minimising the releases of other pollutants, such as particulates, fluorides, sulphur dioxide and greenhouse gases. These releases are adequately controlled at the Tiwai Point smelter through existing resource consents, an accredited ISO 14001 environmental management system, and a strong commitment to the principle of continuous improvement (New Zealand Aluminium Smelters Ltd, 2006).

The BAT/BEP recommendations for secondary aluminium production are as follows.

- Pre-sort feed materials to minimise contaminants such as oils and plastics.
- Use effective process monitoring and control, including maintaining furnace temperatures above 850°C and minimising off-gas residence times at elevated temperatures.
- Avoid the use of hexachloroethane for demagging (magnesium removal).
- Employ high-efficiency dust removal using bag filters or wet scrubbers.
- Use afterburners at > 950°C, followed by rapid quenching to below 250°C.
- Treat with activated carbon before gas filtration.
- Use heat treatment and metal recovery for process residues, then dispose of wastes in an environmentally sound manner.

Ten of the 48 secondary aluminium plants covered by the 2002 survey were fitted with bag filters, two had afterburners, but none used carbon adsorption. Most plants practised scrap pre-sorting and there is no indication of any current use of hexachloroethane. Some wastes are exported overseas for metal recovery, but most are disposed to landfill.

It should also be noted that the larger secondary aluminium plants have made significant improvements to their processes since 2002. As noted previously, one plant has replaced its molten salt rotary furnace with an induction system and is only processing clean scrap. Another has upgraded its gas-fired furnace to include a magnetic stirrer, which helps to maintain even bath temperatures and reduces dross formation. It is also investigating ways of improving its process monitoring and management to reduce variability in operating conditions, improved scrap feeding systems, and testing of fluxes to reduce dross formation (I Paine, Glucina Alloys Ltd, Auckland, pers comm, 2009; A Vernon, MCK Metals Pacific Ltd, New Plymouth, pers comm, 2009).

A performance level of 0.5 ng I-TEQ Nm^{-3} (at operating oxygen concentrations) is believed to be achievable using the practices and controls recommended in the BAT/BEP Guidance. All but one of the New Zealand emission test results were below this level, although some of these results would have been affected by the inclusion of building ventilation air.

PCDD and PCDF releases to air from secondary aluminium production are a relatively minor contributor to the total national emissions, but the process residues make a moderately significant contribution to overall releases to land. Potentially the most productive areas for improvement would appear to be extending the number of plants fitted with bag filters, and the development of metal recovery systems (with appropriate PCDD/PCDF controls) for bag-filter residues and process wastes.

19.5 References

Ministry for the Environment. 2004. *Dioxin and Furan Emissions to Air from Secondary Metallurgical Processes in New Zealand.* Prepared by Sinclair Knight Merz Ltd for the Ministry for the Environment. Wellington: Ministry for the Environment.

New Zealand Aluminium Smelters Ltd. 2006. *Sustainable Development Report 2006*. Invercargill: New Zealand Aluminium Smelters Ltd.

UNEP. 2005. *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases.* Version 2.1, December 2005. Geneva: UNEP Chemicals.

UNEP. 2007. *Revised Draft Guidance on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants.* Geneva: Secretariat to the Stockholm Convention, United Nations Environment Programme.

20 Other Metallurgical Processes

This section addresses PCDD and PCDF releases from iron foundries, and from non-ferrous metal production other than secondary aluminium. These processes were the subject of a specific industry survey in 2002 (Ministry for the Environment, 2004) and the information presented here is based primarily on a review and update of the results from that study.

20.1 Emissions to air

20.1.1 Iron foundries

Iron foundries manufacture cast-iron products from scrap iron, pig iron and internal plant returns (manufacturing rejects and wastes). Alloying materials such as silicon, magnesium, copper, nickel and carbon may also be added to the charge, along with fluxing materials, which often include chlorides or fluorides. The basic foundry operations are: raw material handling and preparation, mould and core production, metal melting and alloying, casting, and mould breakout, followed by finishing processes such as trimming, cleaning and polishing (National Pollutant Inventory, 2004). A variety of furnaces can be used for metal melting, including electric arc and induction furnaces, cupolas and oil- or gas-fired crucibles. The melting operations have the greatest potential for PCDD and PCDF releases to air, especially when processing contaminated scrap. The presence of catalytic elements (such as copper) can also promote PCDD and PCDF formation.

Secondary iron (ferrous) processes were included in the 2002 survey of New Zealand secondary metallurgical processes (Ministry for the Environment, 2004). The survey covered 82 sites,[8] of which 27 were engaged in the processing of ferrous metals. One of the ferrous metal plants was classified as a large facility (> 5000 tonnes per year), 5 as medium (1000–5000 tonnes per year), 10 as small–medium (250–1000 tonnes per year) and 11 as small (< 250 tonnes per year). The total annual ferrous metal production was estimated at 21,000 tonnes per year, of which 70% was attributed to the large and medium sites. Some of the production at the largest plant has since been reduced, as the result of a partial relocation to China, and the current annual production for all sites is now estimated to be about 18,000 tonnes per year.

Tests for PCDD and PCDF emissions were carried out at seven iron- and steel-processing plants during 2002 and 2003 (Ministry for the Environment, 2004). The plants ranged in size from small to large, and the estimated emission rates, from a total of 11 tests, ranged from 0.0058 μg I-TEQ tonne^{-1} of metal to 89 μg I-TEQ tonne^{-1} of metal, with an average of 8.2 μg I-TEQ tonne^{-1} of metal. The latter figure is towards the top end of the range of emission factors (0.03–10 μg I-TEQ tonne^{-1} of metal) given in the UNEP Toolkit and will be used in the estimates below.

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[8] A further 40 sites were estimated from survey non-returns, but were assumed to be small or very small facilities and therefore of little significance at a national level.

National emission estimates

PCDD and PCDF emissions to air from ferrous metal production are summarised in table 20.1. Iron foundries were not considered as a distinct source category in the 2000 Inventory, but the annual emissions from all foundries (ferrous and non-ferrous) were estimated to be in the range of 0.10–1.3 g I-TEQ yr^{-1}. The current estimates are towards the bottom end of this range, even when combined with the estimates for non-ferrous metal production in section 20.1.2. The projections for 2013 and 2018 assume no significant changes in metal production.

Table 20.1: PCDD and PCDF emissions to air from iron foundries

Annual metal production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
–	18,000	18,000	18,000	–	0.15	0.15	0.15

Certainty

Activity statistics: Medium
Emission factor: Medium

The activity statistics are assigned a ‘medium’ certainty ranking because they are based on industry survey data, but with some approximate adjustments to account for changes since 2002. The emission factor is assigned a ‘medium’ certainty ranking because it is based on a limited range of New Zealand test data.

20.1.2 Secondary non-ferrous metal production

Secondary non-ferrous metal production can involve the recovery of metals such as copper, tin and lead from scrap metal; the manufacture of metal alloys such as brass and bronze; and the processing of metal ingots, scrap metal and internal plant returns to make cast metal products. Most non-ferrous plants in New Zealand use heated crucibles (pit furnaces) or induction furnaces (Ministry for the Environment, 2004). As with the iron foundries, the potential for PCDD and PCDF formation mainly arises during the heating stages and is greatest when processing contaminated scrap. However, most non-ferrous foundries in New Zealand are believed to process clean ingots rather than scrap (S Welburn, Skellern’s Metal Castings Ltd, Auckland, pers comm, 2008 and 2010).

Secondary copper processing and other secondary non-ferrous metals (tin, lead and zinc) were included in the 2002 industry survey. Of the 82 sites covered by the survey, 45 were engaged in copper processing and 20 were engaged in other non-ferrous metal production. The size range distribution of the plants was as follows (size classifications as given in section 20.1.1):

- copper production: 3 large, 3 medium, 7 small–medium, and 32 small
- other non-ferrous metals: 3 medium, 3 small–medium, and 14 small.

The total annual copper production was estimated at 15,000 tonnes per year, of which 73% was attributed to the three large sites. The total production for other non-ferrous metals was 8200 tonnes per year, with 85% attributed to the three medium-sized plants. One other lead smelter was not included in the survey because it had been specifically covered in the 2000 Inventory report. The additional output from this plant is 13,000 tonnes per year (N Manson, Exide Technologies, Adelaide, pers comm, 2009),[9] which increases the total other non-ferrous metal production to about 21,000 tonnes per year.

There have been a significant number of changes in this source subcategory since the 2002 industry survey, with some plants being upgraded, others relocated and others shut down. However, given the large number of plants, it is not possible to accurately estimate the effect of these changes on overall production rates. This could only be done through a repeat of the full industry survey. The annual production figures used in the release estimates will therefore be based on those given above, and the future projections for 2013 and 2018 will also assume no significant changes.

Tests for PCDD and PCDF emissions were carried out during 2002 and 2003 at two small copper/bronze foundries, one medium-sized plant using manganese, and one large plant processing mixed aluminium and copper scrap (Ministry for the Environment, 2004). The estimated emission rates, from a total of five tests, ranged from 0.0053 μg I-TEQ tonne^{-1} of metal to 17 μg I-TEQ tonne^{-1} of metal, with an average of 3.5 μg I-TEQ tonne^{-1} of metal. The UNEP Toolkit recommends factors of 0.03 to 50 μg I-TEQ tonne^{-1} of metal for copper processing with varying degrees of emission control, 0.1 to 10 μg I-TEQ tonne^{-1} of metal for brass and bronze production, 0.03 to 100 μg I-TEQ tonne^{-1} of metal for zinc, and 2 to 100 μg I-TEQ tonne^{-1} of metal for other non-ferrous metals. The 2000 Inventory estimates used a range of 0.03 to 50 μg I-TEQ tonne^{-1} of metal.

National emission estimates

PCDD and PCDF emissions to air from non-ferrous metal production are summarised in table 20.2. These have been calculated using an emission factor of 3.5 μg I-TEQ tonne^{-1} of metal.

Table 20.2: PCDD and PCDF emissions to air from non-ferrous metal production

Annual metal production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	36,000	36,000	36,000	–	0.13	0.13	0.13

Certainty

Activity statistics:	Medium
Emission factor:	Medium

The activity statistics are assigned a 'medium' certainty ranking because they are based on industry survey data but with some uncertainties due to changes since 2002. The emission factor is assigned a 'medium' certainty ranking because it is based on a limited range of local test data.

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[9] The production rate for the lead smelter was incorrectly stated in the 2000 Inventory as 5000 tonnes per year.

As noted in section 20.1.1, the current estimates for both ferrous and non-ferrous metal production are towards the bottom end of the range reported in the 2000 Inventory. This could be taken as an indication that the emissions from New Zealand plants are generally quite low when compared with overseas data. However, it should also be noted that the emission rate recorded at one of the local iron foundries was more than 10 times the average figure used for the release estimates. Similarly, the emissions at a plant processing a mixture of copper and aluminium gave an emission rate of almost five times the sector average. These extreme results indicate a clear need for compliance with the BAT/BEP guidelines summarised in section 20.4.

It should also be noted that the estimates do not include the potential emissions from the burning of copper wire for copper reclamation. This practice is prohibited under the Resource Management National Environmental Standards (Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004 but may still occur from time to time, especially in isolated locations. The potential for releases from this source was discussed in the 2000 Inventory.

20.2 Releases to land (residues)

20.2.1 Iron foundries

Solid waste streams from secondary iron and steel production include filter fines and dusts from gas-cleaning equipment, slag, and waste sand from casting. This inventory addresses only filter fines and other dusts collected in gas-cleaning systems, as these are likely to have the highest levels of PCDDs and PCDFs. There is insufficient information to make any estimate of PCDD and PCDF releases in slag or other wastes.

The release estimates for the 2000 Inventory, for both ferrous and non-ferrous metal processing, were based on a waste production rate of 1000 to 2000 tonnes per year of filter fines and dust, from all of the sites known to be fitted with bag filters. The 2002 industry survey identified one large, three medium, three small–medium and one small plant fitted with bag filters. This suggests that bag filter dusts will be associated with about 65% of all secondary ferrous metal production.

The UNEP Toolkit recommends a range of release factors from 0.2 to 8 µg I-TEQ tonne^{-1} metal, for iron foundries fitted with bag filters and using a variety of different furnaces. The upper value of this range will be used for the release estimates given below because it appears to be the most relevant to New Zealand plants.

National release estimates

PCDD and PCDF releases in residues from iron foundries are summarised in table 20.3. The annual production figure is based on 65% of the estimated total iron production. Filter fines, dusts and sludges from gas cleaning are most likely to be disposed to landfill. Some plants reuse their slag and much of the casting sand. However, most residual wastes would be disposed to landfill.

Table 20.3: PCDD and PCDF releases to land from iron foundries

Annual production associated with bag-house residues (tonnes yr^{-1})				Annual releases in residues (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	11,700	11,700	11,700	–	0.094	0.094	0.094

Certainty

Activity statistics:	Medium
Emission factor:	Low

The activity statistics are assigned a ‘medium’ certainty ranking because they are based on industry survey data, but with some uncertainties as to actual waste quantities. The emission factor is assigned a ‘low’ certainty ranking because it is based on very limited international data.

20.2.2 Secondary non-ferrous metal production

Solid waste streams from secondary copper production are expected to be much the same as for iron foundries. The 2002 industry survey identified three large, two medium, three small–medium and four small secondary copper plants fitted with bag filters. This suggests that bag-filter dusts will be associated with about 85% (ie, 12,750 tonnes per year) of all secondary copper production. Bag filters are also fitted to most of the medium and small–medium other non-ferrous metal plants, although in the case of lead smelters the bag-filter dusts are usually recycled through the furnace. It is not clear how much of the total non-ferrous metal production in the 2002 survey was based on lead, but it was most likely 80% or more. Bag filter residues from the other non-ferrous source category will be estimated at 20% of total metal production (ie, 2600 tonnes per year).

The UNEP Toolkit recommends release factors of 300 or 630 μg I-TEQ $tonne^{-1}$ of metal for residues from secondary copper production, depending on the level of controls, but notes that there is a very high level of uncertainty with these factors. It also recommends a factor of 125 μg I-TEQ $tonne^{-1}$ of metal for brass and bronze production, which was based on more recent and detailed investigations of a foundry in Thailand. No release factors were recommended for any other non-ferrous metals. In the absence of any more relevant data, the brass/bronze factor of 125 μg I-TEQ $tonne^{-1}$ of metal will be used for the current release estimates.

National release estimates

PCDD and PCDF releases in residues from non-ferrous metal production are summarised in table 20.4. The estimated releases are quite comparable to the upper end of the range given in the 2000 Inventory (0.19–2.2 g I-TEQ yr^{-1}) for all ferrous and non-ferrous secondary metal production.

Table 20.4: PCDD and PCDF releases to land from non-ferrous metal production

Annual production associated with bag-house residues (tonnes yr^{-1})				Annual releases in residues (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
–	15,350	15,350	15,350	–	1.92	1.92	1.92

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a ‘low’ certainty ranking because they are based on industry estimates of residue production. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited overseas test data.

20.3 Releases to water

There are no direct releases to water from any of the metallurgical processes covered in this section Any leaching of PCDDs and PCDFs from the waste streams deposited in landfills will be accounted for in the estimate of releases to water from landfill leachate (see section 26).

20.4 Application of BAT/BEP

The BAT/BEP recommendations for iron foundries are much the same as those for secondary steel production (see section 18.4). The BAT/BEP recommendations for secondary copper production are as follows.

- Pre-sort feed materials to minimise contaminants such as oils and plastics.
- Use effective process monitoring and control, including maintaining furnace temperatures above 850°C and minimising off-gas residence times at elevated temperatures.
- Ensure high-efficiency dust removal using bag filters or wet scrubbers.
- Use afterburners at > 950°C followed by rapid quenching to < 250°C.
- Treat with activated carbon before gas filtration.
- Use heat treatment and metal recovery for process residues, then dispose of wastes in an environmentally sound manner.

The BAT/BEP recommendations for lead and zinc are much the same as those for copper, although it is noted that bag-filter residues should be recycled through the furnaces. A performance level of 0.5 ng I-TEQ Nm^{-3} is believed to be achievable for secondary copper production using the above practices and controls, and 0.1 ng I-TEQ Nm^{-3} for secondary lead and zinc production (both at operating oxygen concentrations, UNEP, 2007).

Most of the large and medium-sized iron foundries and secondary non-ferrous metal plants covered by the 2002 survey were fitted with bag filters, along with about 10 to 20% of the small and small–medium plants. A few plants were found to use afterburners or wet scrubbers, but no plants used carbon adsorption. The wastes from some plants are known to be exported for metal recovery and recycling, while others are disposed to landfill (with the exception of lead smelters).

PCDD and PCDF releases to air from iron foundries and secondary non-ferrous metal production are a relatively minor contributor to the total national emissions. However, the process residues from secondary copper and other non-ferrous metal production make a moderately significant contribution to overall releases to land. Potentially the most useful areas for improvement would appear to be extending the number of plants fitted with bag filters, and the development of metal recovery systems (with appropriate PCDD/PCDF controls) for bag filter residues and process wastes.

20.5 References

Ministry for the Environment. 2004. *Dioxin and Furan Emissions to Air from Secondary Metallurgical Processes in New Zealand.* Prepared by Sinclair Knight Merz Ltd for the Ministry for the Environment. Wellington: Ministry for the Environment.

National Pollutant Inventory. 2004. *National Pollutant Inventory: Emission Estimation Technique Manual for Ferrous Foundries*, *Version 1.2*. Canberra: Department of Environment and Heritage.

UNEP. 2007. *Revised Draft Guidance on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants.* Geneva: Secretariat to the Stockholm Convention, United Nations Environment Programme.

21 Glass Production

21.1 Emissions to air

There are three industrial glass manufacturers in New Zealand. The largest of these is based in Auckland and produces glass bottles and jars, while the other two, located in Auckland and Christchurch, produce fibreglass insulation. There are also numerous small studio glassworks and an unknown number of glass hobbyists. The annual production figures for industrial glass are about 140,000 tonnes per year of glass containers (B Slingsby, O-I Limited, Auckland, pers comm, 2009) and 9200 tonnes per year of fibreglass (M Burgess, Tasman Insulation New Zealand Ltd, Auckland, pers comm, 2009). The quantities of glass produced by studio glassworks and hobbyists are unknown, but are unlikely to be of any significance when compared to the industrial production figures.

The emission factor range used in the 2000 Inventory was 0.002–0.032 μg I-TEQ tonne^{-1} and was based on a review of published data from the USA, Germany and the UK. The UNEP Toolkit recommends a factor of 0.015 μg I-TEQ tonne^{-1} for "plants with pollution control systems and careful control over combustion conditions and material inputs", and is based on release data from Germany. A factor of 0.2 μg I-TEQ tonne^{-1} is also recommended for plants where "no gas cleaning is used and controls on plants may be less stringent". The lower Toolkit factor will be adopted for the current estimates, since the three industrial plants are known to be well controlled.

National emission estimates

PCDD and PCDF emissions from glass production are summarised in table 21.1. The current estimated emissions from this source are within the range reported in the previous inventory: 0.00024–0.0038 g I-TEQ yr^{-1}. The future projections are based on an assumed increase of 65% in production at the Auckland glassworks, which is currently installing a third glass-making furnace, and a planned 30% increase in fibreglass production in mid-2009 (M Burgess, Tasman Insulation New Zealand Ltd, Auckland, pers comm, 2009).

Table 21.1: PCDD and PCDF emissions to air from glass production

Annual glass production (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
120,000	149,200	243,000	243,000	0.0018	0.0022	0.0036	0.0036

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on local industry production data. The emission factor is assigned a 'low' certainty ranking because it is based on limited international data.

21.2 Releases to land (residues)

The only likely sources of releases to land from these processes would be manufacturing wastes and residues from the emission control equipment. Any PCDD/PCDF contamination of these materials is likely to be very low, given the very low level of PCDD/PCDF production in the glass-making processes.

21.3 Releases to water

No direct releases to water are expected from any of the glass-making sources.

21.4 Application of BAT/BEP

There is currently no BAT/BEP Guidance for glass production.

22 Pulp and Paper Production

The total wood pulp production in New Zealand for 2008 was about 1.55 million tonnes (air dry basis), of which 48% was produced by thermo-mechanical or chemi-thermo-mechanical pulping, and 52% by chemical pulping (Ministry of Agriculture and Forestry, 2009b). Mechanical pulp is produced at four plants in the Bay of Plenty, Hawke's Bay and Manawatu–Wanganui regions. Chemical (kraft) pulp is produced at the Bay of Plenty mill and another mill in the Waikato region, and it is these that are of most interest for PCDD and PCDF releases. There are also two other mills in Auckland and the Bay of Plenty that produce paper and paperboard products from mixtures of wood pulp and waste paper.

The "production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching" is listed in Annex C of the Stockholm Convention as one of the sources with "the potential for comparatively high formation and release" of unintentional POPs. However, this entry is based on a relatively historical situation. As noted in the 2000 Inventory, PCDD and PCDF contamination from pulp bleaching was first identified in the mid- to late 1980s, and the pulp and paper industry moved quickly to address the issue. The use of elemental chlorine for bleaching was identified as the most important factor, and this was replaced with other options, including oxygen delignification and chlorine dioxide bleaching, which is the process adopted at the two New Zealand mills. The PCDD and PCDF releases to water in the 2000 Inventory were stated to be about 90% down on previous release rates for chlorine bleaching.

The current situation regarding PCDD and PCDF releases from the bleaching process is reflected in several international publications. For example, the European Commission (IPPC, 2001b) notes that "mills [have] virtually stopped the use of molecular chlorine for bleaching of pulp. This means that the formation of chlorinated dioxins and dibenzofurans has virtually ceased and the degree of chlorination of the remaining chlorinated substances has declined". Similarly an industry survey by the National Council for Air and Steam Improvement (2006) found that:

> "Efforts to reduce or eliminate TCDD and TCDF at mills have been remarkably successful. Data generated in 2004 from bleached paper grade kraft mills show no instances of TCDD or TCDF above analytical minimum levels in treated final effluents and no TCDD in bleach plant effluents. TCDF was observed only rarely and at just four mills at very low levels."

The estimates given below are for releases to air from some of the kraft mill combustion processes and releases in sludges from wastewater treatment systems. The potential for releases in products will also be discussed.

22.1 Emissions to air

22.1.1 Bleached kraft mills

There are two primary sources of PCDD and PCDF releases to air from bleached kraft mills: the combustion of wood and other biomass in the power boilers, and the combustion of black liquor in the chemical recovery boilers. The contributions from the power boilers have already been addressed under section 12, so only the recovery boilers will be covered below.

Black liquor is the liquid residue that is left after the cellulose fibre has been extracted from wood chips with pulping liquor in the kraft process. Once concentrated, black liquor is a fuel of high calorific value and is the chief source of heat energy in kraft pulp and paper mills. An estimated total of 12,000 terajoules (TJ) per annum is produced from the black liquor recovery boilers at the two kraft mills (Bioenergy Association, 2006). Combustion of black liquor occurs in specially designed furnaces. The fuel consistency is carefully controlled, which in general allows for better combustion conditions to be attained than with other biomass fuel types.

Releases from black liquor combustion are directly related to pulp production figures, and these are expected to remain relatively constant over the next 5–10 years as the available plant is operating at optimal production. The total annual production of kraft pulp at the two mills in 2008 was about 720,000 tonnes, on an air-dry basis (J Newfield, Carter Holt Harvey Pulp and Paper Ltd, Tokoroa, pers comm, 2009 and 2010). According to the 2000 Inventory, approximately 1.8 tonnes of black liquor solids are produced per tonne of pulp. This indicates a current annual production rate of about 1,300,000 tonnes of black liquor solids.

The release estimates for the 2000 Inventory were based on the results of emission testing on the two recovery boilers at the Waikato mill. Emission factors of 0.026 and 0.036 μg I-TEQ tonne^{-1} of black liquor solids were calculated from the results, and these compared well with data for plants in the USA. A more recent (2008) test at this mill gave a result equivalent to an emission rate of about 0.014 μg I-TEQ tonne^{-1} of black liquor solids. The average of all three results (0.025 μg I-TEQ tonne^{-1} of black liquor solids) will be used in the estimates given below. The UNEP Toolkit recommends an emission factor of 0.07 μg I-TEQ per air-dry tonne of pulp, but the lower factor is preferable because it is based on local emissions data.

National emission estimates

The estimated PCDD and PCDF releases to air from black liquor combustion are shown in table 22.1. The result shown for 1998 is the mid-point of the range of 0.033–0.045 g I-TEQ yr^{-1} given in the 2000 Inventory. The projections for future years are based on no significant change in production rates.

Table 22.1: PCDD and PCDF emissions to air from black liquor combustion

Annual kraft pulp production (ADT yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
700,000	720,000	720,000	720,000	(0.039)	0.0325	0.0325	0.0325

Certainty

Activity statistics:	High
Emission factor:	High

The activity statistics are assigned a 'high' certainty ranking because they are based on industry data for total pulp production and the amount of black liquor burned at the two kraft mills. The emission factor is assigned a 'high' certainty ranking because it is based on emission test results from the two New Zealand mills.

22.2 Releases to land (residues)

22.2.1 Bleached kraft mills

The main purpose of black liquor combustion is the recovery of the inorganic chemicals used in the digestion of the wood chips. These collect in the boiler ‘ash’, which is actually a molten smelt. As a result there is no bottom ash waste stream from the recovery boiler. The fly ash collected by the electrostatic precipitators is also recycled in the production process.

The wastewater treatment systems used at both mills result in the production of both primary and secondary sludges, and these are the only solid waste streams expected to contain PCDD and PCDF residues. The release estimates given in the 2000 Inventory were based on estimated sludge production rates coupled with analytical results for PCDD and PCDF concentrations in a primary sludge sample collected in 1992, and a secondary sludge sample collected in 1997, both from the Bay of Plenty mill. However, these results reflect historical mill operations using elemental chlorine, and the current levels will be much lower. The UNEP Toolkit recommends a release factor of 0.2 µg I-TEQ tonne^{-1} of air-dry pulp, and this will be used in the release estimates given below. In addition, the calculations will be based on an annual production rate of 415,000 tonnes of bleached pulp (J Newfield, Carter Holt Harvey Pulp and Paper Ltd, Tokoroa, pers comm, 2009), because only the bleached portion of the total pulp production is expected to contribute to the PCDD/PCDF releases.

National release estimates

PCDD and PCDF releases from sludge disposal are summarised in table 22.2. A back-calculation for 1998 is not appropriate because there have been significant changes in the processes and/or releases for both mills. Thus, the figure shown for 1998 is that given in the previous inventory. As expected, the current releases are considerably lower. The projections for future years are based on no significant change in production rates.

Table 22.2: PCDD and PCDF releases to land from pulp and paper production

Annual bleached pulp production (ADT yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
320,000	415,000	415,000	415,000	(0.56)	0.083	0.083	0.083

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on industry data for bleached pulp production. The emission factor is assigned a ‘low’ certainty ranking because it is based on limited international data.

22.2.2 Other pulp and paper mills

The three thermo-mechanical or chemi-thermo-mechanical mills do not use a chlorine bleach process, and no PCDDs or PCDFs are expected in the process wastes. However, the two other paper/board mills could represent a potential source as a result of the use of waste paper containing residual amounts of PCDDs and PCDFs (see 22.2.3). The annual releases to land from the processing of recycled paper were estimated in the 2000 Inventory at 0.005 g I-TEQ yr^{-1}. However, this figure is likely to have dropped considerably due to the much lower levels of PCDDs and PCDFs in paper produced over the past 10 years. For the current estimates, the potential releases to land from the processing of waste paper will be regarded as negligible.

22.2.3 Releases in products

The following factors are recommended in the UNEP Toolkit for PCDD/PCDF releases in pulp and paper products:

- 0.5 μg I-TEQ $tonne^{-1}$ for bleached kraft papers produced using chlorine dioxide
- 3 μg I-TEQ $tonne^{-1}$ for recycled products produced from 'modern paper' (ie, paper originally produced using modern bleaching technology).

The total paper and paperboard consumption in New Zealand is estimated at around 750,000 tonnes per year (2006 data, Ministry of Agriculture and Forestry, 2009a). This is made up of a mixture of locally produced materials and imports. The proportion of recycled paper is unknown, but it will be assumed to be 30%. On that basis, the total PCDD and PCDF releases in paper and paperboard products in New Zealand would be about 1 g I-TEQ yr^{-1}.

Any releases to the environment from this material will depend on the way in which the products are used. Some of it will remain in use for many years (eg, in publications and other documents). A significant proportion will be collected for recycling, and the remainder will be disposed of, mainly to landfill. This last distribution path is accounted for in the overall estimates of releases to land from industrial and domestic solid wastes (see section 26).

22.3 Releases to water

22.3.1 Bleached kraft mills

The wastewater discharges from both the Waikato and Bay of Plenty kraft mills are tested periodically for PCDD and PCDF concentrations as part of the requirements under their resource consents. The most recent data available indicates results generally in the range of < 0.1 to 2 pg I-TEQ L^{-1} (six-monthly data, 2007 to 2009, for the Waikato mill, and quarterly data, 2009, for the Bay of Plenty mill – J Newfield, Carter Holt Harvey Pulp and Paper Ltd, Tokoroa, pers comm, 2010).

The UNEP Toolkit indicates a release rate of 2 pg I-TEQ L^{-1} for kraft pulp mills using modern bleaching technology, but notes that:

> "The emission factor will only be applied if there is a direct discharge into the environment. If sludge is generated, the dioxin freight will be collected in the sludge and the effluents leaving from the effluent treatment plant will have non-accountable concentrations of PCDD/PCDF."

In other words, the PCDDs and PCDFs in the wastewater discharges have already been accounted for in the estimates given above for releases to land, and the releases to water are to be taken as zero. By comparison, the estimate given in the 2000 Inventory for releases to water was 0.20–0.35 g I-TEQ yr^{-1}.

22.3.2 Other pulp and paper mills

No significant PCDD or PCDF releases to water are expected from the thermo-mechanical or chemi-thermo-mechanical pulp mills. There is the potential for PCDD/PCDF releases from the two mills processing recycled paper, but these are unlikely to be of any significance given the current low levels of PCDDs and PCDFs in the incoming waste paper.

22.4 Reservoirs

22.4.1 Bleached kraft mills

Primary and secondary sludge produced during the production of bleached kraft pulp is also a reservoir for PCDDs and PCDFs. The overall size of the reservoir was estimated in the 2000 Inventory at 24 g I-TEQ on the basis of historical sludge production. This figure can now be updated for an additional 10 years' input. As shown in table 22.2, the annual rate of PCDD/PCDF release in sludge is currently estimated to be 0.083 g I-TEQ yr^{-1}. If this rate is assumed to apply for all of the past 10 years, the additional inputs to the reservoir would be 0.83 g I-TEQ, and the total current reservoir would be 24.8 g I-TEQ.

Certainty

Activity statistic:	Medium
Emission factor:	Low

The activity statistic is assigned a 'medium' certainty ranking because, while it is based partly on industry data for bleached pulp production, there are significant uncertainties in the estimates for historical sludge production. The emission factor is assigned a 'low' certainty ranking because it is based on a combination of historical local data and more recent international information.

22.4.2 Other pulp and paper mills

Any PCDD/PCDF reservoirs arising from waste disposal from the other pulp and paper mills are likely to be insignificant given the very low annual releases noted in section 22.2.2.

22.5 Application of BAT/BEP

The BAT/BEP Guidance for pulp and paper mills is focused mainly on eliminating elemental chlorine. The recommended measures are summarised below.

- Eliminate elemental chlorine by replacing it with ClO_2 (elemental chlorine-free bleaching) or with chlorine-free chemicals.
- Utilise de-foamers free from dibenzodioxins and dibenzofurans.
- Use effective brownstock washing to enable the reduction of chlorine multiple.[10]
- Maximise knot and dirt removal to enable the reduction of chlorine multiple.
- Eliminate the pulping of furnish[11] contaminated with polychlorinated phenols.
- Use secondary measures such as identification and substitution of potentially harmful substances; optimisation of investment/planning cycles; staff training, education and motivation; process control monitoring and optimisation; plant maintenance; the use of environmental management systems; and the development of environmental monitoring protocols and programmes.

As indicated previously, both of the New Zealand mills have adopted elemental chlorine-free bleaching systems. In addition, they have implemented all of the other primary measures listed above, and have made significant investments in relation to the secondary measures. Both mills are believed to comply with the performance specification given in the BAT/BEP Guidance; ie, that the releases of 2,3,7,8-TCDD and 2,3,7,8-TCDF should be less than the limit of quantification using US EPA method 1613.

22.6 References

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[10] An industry measure of the total amount of bleaching chemicals applied.

[11] Industry term for the materials used as inputs for pulp making.

23 Tobacco Smoking

Tobacco smoke has been shown to contain a wide range of potentially toxic chemicals, including PCDDs and PCDFs (International Agency for Research on Cancer, 2004). The sources of PCDDs and PCDFs in tobacco smoke are not fully understood, but it appears that a portion may simply be due to releases of PCDDs and PCDFs already present in the tobacco, while the remainder are formed as products of incomplete combustion (Aoyama et al, 2003). Estimates of potential intakes for tobacco smokers indicate maximum daily exposures can approach the lower end of the WHO recommended tolerable daily intake of 1–4 pg/kg-bw/day, depending on daily tobacco consumption and the brand (Wilson et al, 2008). This would be additional to the intakes from other PCDD /PCDF sources, such as food.

23.1 Emissions to air

In the 2000 Inventory, New Zealand tobacco consumption for 1998 was reported to be 3300 million cigarettes and 758 tonnes of loose tobacco, pipe tobacco and cigars. This was converted to a total of 4200 million cigarette equivalents per year, on the basis of a standard cigarette weight of 0.767 grams, plus additional minor adjustments for differing moisture contents between cigarettes (13.5%) and the other forms of tobacco (12 to 20%). More recent reports on tobacco consumption have used a conversion factor of 1 million cigarettes per tonne of loose tobacco, without adjustment for moisture content (Ministry of Health, 2005), and this latter approach will be adopted here. On that basis, the 1998 consumption would have been 4048 million cigarette equivalents.[12]

The total tobacco available for consumption in New Zealand in 2007 was 2445 million cigarettes and 904 tonnes of tobacco (Statistics NZ, 2008; A Bloomfield, M Doyle, J Stribling, Ministry of Health, pers comm, 2008), or 3349 million cigarette equivalents, which indicates an overall drop in consumption of about 17% over the past 10 years. This reduction is part of a longer-term trend reported by Laugesen (2005), who found that the total dry weight of tobacco used in New Zealand had fallen by 44% in the 15 years since the introduction of the Smoke-free Environments Act 1990. Additional reductions of 5% each will be assumed for the projections to 2013 and 2018 on the basis that the reductions in recent years appear to be less dramatic than those achieved during the 1990s.

A variety of published emission factors for cigarette smoking were noted in the 2000 Inventory, and the release estimates were based on a range of 0.07–2 pg I-TEQ per cigarette to cover both mainstream and side-stream smoke. The UNEP Toolkit recommends a release factor of 0.1 pg I-TEQ per cigarette, and this will be used for the current estimates.

National emission estimates

PCDD and PCDF emissions from tobacco smoking are summarised in table 23.1. The estimates for 2008 are based on the previous year's tobacco consumption. The back-calculation for 1998 gives a result just marginally above the bottom end of the range reported in the 2000 Inventory (0.00029–0.0084 g I-TEQ yr^{-1}).

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[12] Other data held by the Ministry of Health shows the figure as 4020 million cigarette equivalents (A Bloomfield, M Doyle, J Stribling, Ministry of Health, pers comm, 2008).

Table 23.1: PCDD and PCDF emissions to air from tobacco smoking

Annual cigarette equivalents (10^6 yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
4048	3349	3181	3014	0.00041	0.00033	0.00032	0.00030

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on industry data for the total quantities of tobacco sold in New Zealand. The emission factor is assigned a 'low' certainty ranking because there is no PCDD/PCDF release data for cigarette smoking in New Zealand, and the UNEP Toolkit factor is based on a limited range of studies.

23.2 Residues (releases to land)

No emission factors are available for PCDD and PCDF releases in residues, although Aoyama et al (2003) indicate that significant proportions of the dioxins originally present in the cigarette can be found in the filter and in the ash. These residues would represent a diffuse solid waste stream, with most being disposed of either directly to land or in municipal wastes. The quantities disposed of directly to land (eg, through littering) are not insignificant. For example, cigarette butts made up 5% of all the individual items of trash collected on Australia Clean Up Day 1993 (Novotny and Zhao, 1999).

Insufficient data is available to make an estimate of the PCDD and PCDF releases in residues, although the overall quantities are probably quite similar to the estimated releases to air.

23.3 Releases to water

The potential for releases to water from tobacco smoking is similar to that for releases to land. Novotny and Zhao (1999) report that cigarette butts were the leading individual waste item collected during the annual clean-up days sponsored by the International Coastal Cleanup Project at about 5000 sites worldwide. In 1997 cigarette butts made up 19.1% of all debris items collected, and have represented at least 12% of all items collected in each of the years from 1990 to 1997.

23.4 Application of BAT/BEP

Tobacco smoking is not covered in the BAT/BEP Guidance as this is a very minor contributor to overall dioxin releases. Nonetheless, there is significant potential for reducing releases from this source, mainly through the use of legislative and other measures to discourage smoking. The New Zealand data quoted above for reductions in tobacco consumption over the past 15 to 20 years gives a good indication of what can be achieved. These reductions can be attributed to the introduction of the Smoke-free Environments Act 1990, the Smoke-free Environments Amendment Act 2003, and related activities, including requirements for smoke-free workplaces and hospitality venues, restrictions on tobacco advertising and displays, restrictions on tobacco sales to minors, and extensive anti-smoking campaigns (Ministry of Health, 2005). Other initiatives currently being pursued by the Ministry of Health include the introduction of pictorial warnings on cigarette packets, increased access to nicotine replacement therapy, and a review of tobacco displays.

23.5 References

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24 Used Oil Use and Disposal

The average annual imports of lubricating and hydraulic oils into New Zealand for 2006 and 2007 were 61.6 million litres,[13] which is not significantly different from the 60 million litres (approximate) noted in the previous inventory. A report published in 1999 indicated that about 80% of the imports were for use as lubricants and transmission fluids in motor vehicles, tractors, boats and stationary engines (Worley, 1999). The remaining 20% were for cutting oils, hydraulic fluids, two-stroke oils, compressor oils and industrial lubricants. The oil is completely consumed in some of these applications (eg, as two-stroke oil), but in many others the losses should be relatively minor. Overall it has been estimated that 62% (ie, 38 million litres per year) of the total imports are potentially recoverable (PA Consulting, 2001). However, the Ministry for the Environment has previously worked to a target of about 30 million litres per year. For the purposes of this inventory, a 'middle ground' figure of 34 million litres per year will be applied.

It was noted in the 2000 Inventory that the amount of used oil collected in New Zealand annually was slightly less than about 50% of the estimated recoverable quantities. However, this situation appears to have improved considerably in recent years, with significant volumes of used oil being collected nationally, both through the Used Oil Recovery Programme and by several other regional oil-recycling operators (Ministry for the Environment, 2008b). Information obtained from a variety of sources indicates the following current collection rates.

- The Used Oil Recovery Programme collected approximately 13 million litres of used oil in 2006 for use as a supplementary fuel in the Westport Cement Plant.
- Approximately 7 million litres of used oil is collected by other oil-recycling companies for use as a supplementary fuel by several large industrial users, including asphalt plants and in industrial boilers.
- Approximately 7 million litres is collected and sold for use in small combustion units, including industrial heaters and boilers, and glasshouse heating systems.
- There are numerous other small-scale collectors of used oil, mainly for use in dust control on roads and in small-scale burners. The total quantity of oil collected by this group is unknown, but is unlikely to be more than about 2 million litres.
- An additional 2 million litres of ships' bunker oil is also collected from New Zealand ports and used as a supplementary fuel in the Westport Cement Plant and a pulp and paper mill.

On the basis of the above information, the total quantity of used oil currently being collected is about 29 million litres, or just over 75% of the amount estimated to be available for collection (Note: these figures do not include the ships' bunker oils). The remaining 5 million litres are either disposed of directly by the users (eg, by burning or dumping) or may simply not have arisen, as a result of higher loss rates during use.

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[13] Annual import/export data provided by Statistics New Zealand, Wellington, 2008.

24.1 Emissions to air

The emissions from used oil burned as a supplementary fuel in large industrial plants are included in the emission estimates given in sections 10 (industrial oil and coal), 17 (cement and asphalt) and 22 (pulp and paper).

The 2000 Inventory estimated that the amount of used oil burned in low-temperature agricultural, commercial and industrial appliances was between 340 and 4000 tonnes per year (420,000 to 5,000,000 litres per year). These appliances range from small 50 kW space heaters and commercial greenhouse heaters, to small to medium-sized (0.5 to 5 kW) industrial boilers. On the basis of the information given above, it appears that the actual usage is at least 5600 tonnes per year (7,000,000 litres per yr), and possibly higher. This figure will be used to provide an estimate of the current PCDD and PCDF emissions to air from this source.

There are no initiatives underway, either nationally or regionally, with the potential to have any significant effect on current oil-burning practices. It has therefore been assumed that future used oil burning will be much the same as at present.

There is no New Zealand data available on the PCDD and PCDF emissions from used oil burning. The 2000 Inventory used an emission factor range of 2–6 μg I-TEQ tonne^{-1} on the basis of a limited amount of published data from overseas. The UNEP Toolkit recommends a factor of 4 μg I-TEQ tonne^{-1} on the basis of some slightly more extensive data from Austria and the Netherlands, and this factor will be adopted here.

National emission estimates

PCDD and PCDF emissions to air from the low-temperature burning of used oil are summarised in table 24.1. The back-calculation for 1998 is based on the upper limit of the estimated range of oil quantities burned for that year. As expected, the estimated emissions for 2008 and beyond are still within the range reported for the 2000 Inventory (0.00068–0.024 g I-TEQ yr^{-1}) because the greater oil quantities have been offset by the use of a mid-range emission factor.

Table 24.1: PCDD and PCDF emissions to air from low-temperature oil burning

Used oil burned (tonnes yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
4000	5600	5600	5600	0.016	0.022	0.022	0.022

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a 'low' certainty ranking because they are based on very broad estimates of the quantities of used oil burned in low-temperature appliances. The emission factor is assigned a 'low' certainty ranking because it is based on limited international data.

24.2 Residues (releases to land)

The combustion of used oil will result in ash residues that are disposed in landfills or by dumping to land. However, the quantities of ash produced are unknown, and the UNEP Toolkit did not determine a release factor for this source. As a result, the releases cannot be estimated, although they are likely to be quite minor by comparison with the releases discussed below and those from other source categories.

One of the primary causes of releases to land from used oil is believed to be its use as a dust suppressant on unsealed roads. This use has been prohibited in some regions (eg, Northland Regional Council, 2007), is a controlled or restricted activity in others (eg, Greater Wellington Regional Council, 1999), but is still permitted elsewhere, especially in Otago and Southland (Halliday et al, 2007). A 1997 assessment of this practice produced an estimate of about 4 million litres per year (equivalent to 3200 tonnes per year) for the quantity of used oil applied to roads (Ministry for the Environment, 1997). However, it was also noted that the practice was gradually reducing. In the absence of any recent ‘hard’ data, it is proposed to use a figure of 2400 tonnes per year (3 million litres) for the quantity of used oil currently applied to roads, and future projections of 2200 and 2000 tonnes per year for 2013 and 2018, respectively.

The 2000 Inventory included an estimate of 7 million litres per year (5600 tonnes per year) for the disposal of used oil, and the residues from the processing of used oil, by dumping within landfills or indiscriminate discharges to land. However, the quantities disposed to landfills are likely to have decreased considerably since that time, due to the significant reductions in the number of poorly managed landfills in New Zealand (see section 26). A figure of 4 million litres (3200 tonnes) per year will be used in the current inventory for the releases to land by landfill disposal or dumping, which effectively accounts for all the remaining used oil not already allocated above.

It is also relevant to note here that just over 3 million oil filters are imported into New Zealand every year.[14] Information from the European Union (2006) indicates that, when disposed of, these can contain an average of about 0.3 litres of oil per filter. If it is assumed that all used oil filters are disposed to landfill, this source alone would account for a total of nearly 1 million litres per year.

The 2000 Inventory used an emission factor range of 14–60 ng TEQ kg^{-1} for PCDD and PCDF releases to land, on the basis of a limited amount of international data. There is no relevant factor in the UNEP Toolkit, nor has any more recent published information been found. The mid-point of the above range (37 ng TEQ kg^{-1}) will be used for the current release estimates, although it should be noted that PCDD and PCDF concentrations in used engine oil may have dropped significantly due to the removal of lead additives in petrol.

National release estimate

PCDD and PCDF releases to land from used oil use and disposal are summarised in table 24.2. The back-calculation for 1998 shows a reasonable level of agreement with the estimated range of 0.012–0.53 g I-TEQ yr^{-1} (mid-point 0.27 g I-TEQ yr^{-1} given in the 2000 Inventory.

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[14] Annual import/export data provided by Statistics New Zealand, Wellington, 2008.

Table 24.2: PCDD and PCDF releases to land from used oil use and disposal

Used oil used or disposed to land (tonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
8800	5600	5400	5200	0.325	0.207	0.200	0.192

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics are assigned a 'low' certainty ranking because they are based on very broad estimates of the oil quantities used or disposed to land. The emission factor is assigned a 'low' certainty ranking because it is based on limited international data.

24.3 Releases to water

It is possible that some used oil is disposed by discharges to sewers and drains. Insufficient information is available on the likely significance of PCDD and PCDF releases via this pathway. There does not appear to be widespread concern from local authorities and regulatory agencies in New Zealand regarding the dumping of used oil into sewers and stormwater systems, so it can be assumed that such practices represent a minor disposal route for used oil compared with burning, land disposal and road oiling.

24.4 Application of BAT/BEP

There are no recommendations given in the BAT/BEP Guidance for the use and disposal of used oil. However, the recommendations discussed in sections 10 (industrial oil and coal burning) and 26 (landfills) will be directly relevant to the potential releases to air and land, respectively. In addition, the promotion of alternative materials for dust suppression on unsealed roads (Northland Regional Council , 2007) and the development of recycling programmes for used oil filters (European Commission, 2006) would be consistent with the general BAT/BEP principles.

24.5 References

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25 Use of Halogenated Pesticides

This section presents an estimate of the release of PCDDs and PCDFs to land from the use of halogenated pesticides, including the current use of chlorinated phenoxy herbicides in agriculture. The historical use of 2,4,5-T is addressed separately in section 28.

25.1 Releases to land

25.1.1 Chlorinated phenoxy herbicides

Phenoxy herbicides may be applied either directly to land or via aerial application. The releases to air from aerial application are not considered a direct emission to air, but rather a transport pathway that ultimately leads to deposition onto land. Hence, for the purposes of this inventory, all phenoxy herbicide use is treated as a release to land.

The phenoxy herbicide of most interest is 2,4-dichlorophenoxyacetic acid (2,4-D), which is used in New Zealand, mainly on hill country pastoral land, to control thistles and other broadleaf weeds. This agrichemical has been shown in the past to contain PCDD and PCDF residues as production by-products. The annual usage in New Zealand was estimated in the 2000 Inventory at 180 to 220 tonnes of 2,4-D acid equivalents. Manktelow et al (2005) estimated an annual usage of 280 tonnes, and the current industry estimate is about 335 tonnes per year (A Cliffe, Nufarm NZ, Auckland, pers comm, 2009).

The release estimates for the 2000 Inventory used a PCDD/PCDF concentration factor of 0.7 μg TEQ kg^{-1}, which was based on analytical data for eight technical products manufactured in the USA in the early to mid-1990s. By comparison, Schecter et al (1997) reported average levels of 0.02 μg TEQ kg^{-1} in five US products, and 0.29 μg TEQ kg^{-1} in four products manufactured in Europe (three) and Russia (one); while Masunaga et al (2001) reported levels of < 0.01 μg TEQ kg^{-1} in two Japanese products. More recent data for products available in Canada showed average PCDD/PCDF concentrations of < 0.03 μg TEQ kg^{-1} (Pest Management Regulatory Authority, 2006). The major distributor of 2,4-D in New Zealand indicates that their product has been tested on a regular basis since the early 1990s and the PCDD/PDCF concentrations are consistently < 0.01 μg TEQ kg^{-1} (V Maier, Nufarm Ltd, Victoria, Australia, pers comm, 2009). This was confirmed by viewing the analytical reports held in the company files.

The UNEP Toolkit recommends a release factor of 0.7 μg TEQ kg^{-1}. This is based on the US EPA data, which, clearly, is of little or no relevance to the products currently used in New Zealand. A factor of < 0.01 μg TEQ kg^{-1} will be used for the current release estimates.

National release estimates

The estimated PCDD and PCDF releases from phenoxy herbicides are summarised in table 25.1. The figures shown for 1998 are the mid-points of the ranges given in the 2000 Inventory, while the projections for 2013 and 2018 are based on no significant change in current usage rates.

Table 25.1: PCDD and PCDF releases to land from the use of 2,4-D

Annual 2,4-D use (tonnes yr^{-1})				Annual releases to land (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
(200)	335	335	335	(0.14)	< 0.003	< 0.003	< 0.003

Certainty

Activity statistics:	High
Emission factor:	High

The activity statistics are assigned a 'high' certainty ranking because they are based on industry estimates for the total amount of 2,4-D sold in New Zealand. The emission factor is assigned a 'high' certainty ranking because it is based on regular testing of products sold in New Zealand.

25.1.2 Other New Zealand-registered pesticides

The 2000 Inventory report included a discussion of the potential for PCDD/PCDF contamination of a range of other pesticides registered for use in New Zealand. This information was based on an early draft version of the US dioxin inventory, which indicated that the US EPA had called for the analysis of production samples of 19 pesticides identified as having the potential for dioxin contamination. The final version of the US inventory report (US EPA, 2006a) indicates that 13 of these products were subsequently shown to contain no PCDDs and PCDFs at the limits of quantification, PCDDs and PCDFs were reported in two forms of 2,4-D, and data was still awaited for the following four pesticides: chlorothalonil, 2,6-dichloro-4-nitroaniline (DCNA, or Dicloran), dimethyl tetrachloroterephthalate (DCPA, or chlorthal dimethyl), and oxadiazon. All four of these are registered for use in New Zealand as agrichemicals.

Chlorothalonil is applied to a variety of fruit, vegetables and ornamentals for the control of fungal diseases. It is also used in anti-fouling paints and timber antisapstains. The annual horticultural usage in New Zealand in 2004 was estimated at 25.2 tonnes of active ingredient (Manktelow et al, 2005). The amount used in antisapstain products is believed to be between about 30 and 35 tonnes of active ingredient per year, although about 75% of the treated timber is intended for export (A Bergervoet, Arch Chemicals, Auckland, pers comm, 2009). Also, the potential for releases from this application are low because the chemical is applied under containment conditions. The amount used in anti-fouling paints is less than 100 kg per year (A Beale, Protective Paints Ltd, Auckland, pers comm, 2009).

No New Zealand data is available on the presence or otherwise of PCDD/PCDF contaminants in the commercial products. Masunaga et al (2001) reported levels of 0.24 and 0.25 μg TEQ kg^{-1} in two Japanese products manufactured in about 1970 and 1990, respectively. It was noted in the US re-registration eligibility decision document for chlorothalonil (US EPA, 1999) that PCDFs were present in one technical product, none had been found at the limits of quantification in a second product, and the data requested from other manufacturers was still outstanding. No other specific data has been identified. Two other significant contaminants in chlorothalonil (Food and Agriculture Organization, 2005; US EPA, 1999) are hexachlorobenzene and decachorobiphenyl (PCB-209), both of which fall under Annex C of the Stockholm Convention for control as unintentional by-products. The current Food and Agriculture Organization specification for chlorothalonil requires that these contaminants be limited to concentrations of 0.04 mg kg^{-1} and 0.03 mg kg^{-1}, respectively.

DCNA is sold in New Zealand as a protectant fungicide for the control of rhizopus rots in stonefruit, berryfruit, grapes and kumara. Annual usage quantities are not available for New Zealand, although it was not listed as a 'high use active' by Manktelow et al (2005). The most recent report on DCNA from the US EPA is the *Re-registration Eligibility Decision* document (US EPA, 2006b); however, unlike DCPA (see below), there is no mention of any responses to the earlier requests for manufacturers' data on PCDD/PCDF contamination.

DCPA is a selective herbicide for the control of annual grasses and many broadleaf weeds in onions, forest nurseries and ornamentals. Annual usage quantities are not available for New Zealand, although it was not listed as a 'high use active' by Manktelow et al (2005). The US *Re-registration Eligibility Decision* document (US EPA, 1998) reported that one of the dioxin/furan congeners was detected in a single sample of DCPA. However, after changes to the manufacturing process, all of the congeners were below the limits of quantification in six subsequent manufacturing batches. The PCDD/PCDF levels in these latter batches were assessed as being approximately 0.1 μg TEQ kg^{-1}. DCPA has also been reported to contain hexachlorobenzene (AEA Technology, 2006).

Oxadiazon is a pre-emergence herbicide for the control of grass and broadleaf weeds, and the current usage in New Zealand is about 200 kg of active ingredient per year (M Moore, Bayer CropScience New Zealand, Christchurch, pers comm, 2009). The US *Re-registration Eligibility Decision* document (US EPA, 2003) contains no information regarding any responses to the earlier requests for manufacturers' data on PCDD/PCDF contamination.

National release estimates

The above information can only be used to produce some indicative estimates of the potential PCDD and PCDF releases to the environment from the use of these pesticides in New Zealand. In the case of chlorothalonil, it appears that the total annual release to land from horticultural uses would be no more than about 0.006 g I-TEQ yr^{-1}, although it should be noted that it is by no means certain whether or not the currently available products are contaminated with PCDDs and PCDFs. There could also be some additional minor contributions from its use as an antisapstain and in anti-fouling paints. The releases from the three other pesticides are likely to be even less, assuming similar or lower PCDD/PCDF contaminant levels, and significantly lower annual usage. Overall, these are very minor releases compared to some of the other source categories covered in this inventory.

25.2 Application of BAT/BEP

Releases from the use of halogenated pesticides are not covered in the BAT/BEP Guidance document. However, the most obvious option for minimising releases from this source will be to ensure that PCDD/PCDF contamination levels in the commercial products are kept to a practical minimum. It is also relevant to note that two of the pesticides, 2,4-D and chlorothalonil, are currently on a priority list of chemicals for reassessment under the Hazardous Substances and New Organisms Act 1996 (ERMA NZ, 2008a).

25.3 References

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26 Landfills

There are a number of potential sources of PCDDs and PCDFs in the waste streams entering landfills. These include wastes such as ash from incinerators and boilers, ash and slag from industrial manufacturing processes, and wastewater solids. In addition, residential solid waste has been shown to contain PCDDs and PCDFs. Their origin in residential waste is not fully understood, but they may be introduced through the disposal of contaminated products and from combustion residues (ie, ash) from processes such as domestic heating.

Periodic reviews of landfills over the past 12 years show that the number of operational landfill sites in the country has steadily reduced, with just over 50 sites in 2010 compared to 327 in 1995 (Ministry for the Environment, 1997, 2000a, 2003, 2007a, and Lewis N, Ministry for the Environment, pers comm, 2010). This reflects a general trend for the numerous small sub-standard landfills to be replaced with much larger sites designed and operated more in accordance with current best practice. All current sites now have resource consents that aim to ensure effective monitoring and management of potential adverse effects.

26.1 Emissions to air

26.1.1 Landfill gas

Landfill gas is produced by the microbial degradation of organic waste materials present in the landfill. Initially the process is aerobic, with the production of carbon dioxide, but over time it becomes anaerobic and produces a mixture of methane gas and carbon dioxide. The methane generated in landfills may be collected for use in engines or may be flared without energy recovery. Currently landfills with a design capacity over one million tonnes are required to collect and flare or reuse landfill gas (Ministry for the Environment, 2005a). In 2007, it was reported that 14 sites in New Zealand had gas collection systems, of which 11 flared the gas and six used it to generate electricity (with some doing both) (Ministry for the Environment, 2007a).

The total landfill methane production in New Zealand in 2008 was estimated to be about 133,000 tonnes (Ministry for the Environment, 2010). Of this, 66,000 tonnes is recovered and flared or utilised, and 61,000 tonnes are released as fugitive emissions, with the remainder (<5%) being lost by oxidation at the landfill surface. On an energy basis, the amount of methane being flared or utilised is equivalent to 3300 PetaJoules and the fugitive losses are equivalent to 3056 PetaJoules (based on a net calorific value for methane of 50.1 MJ kg^{-1}).

The 2000 Inventory distinguished between flared landfill gas and gas combusted in engines. Emission factors of 0.22 ng I-TEQ Nm^{-3} and 0.06–12 ng I-TEQ Nm^{-3} were used, respectively. The UNEP Toolkit gives a single emission factor of 8 μg TEQ TJ^{-1} for both flared gas and use in engines, which is equivalent to 0.14 ng I-TEQ Nm^{-3}, assuming a heating value of 17 MJ Nm^{-3} for landfill gas (ie, for a gas mixture containing 50% methane). The Toolkit value will be used in the current estimates for releases from gas flaring and utilisation.

There is no New Zealand data on PCDD and PCDF concentrations in raw landfill gas, or in the emissions from combusted landfill gas. An emission factor range of 0.32–0.36 ng I-TEQ Nm^{-3} was used in the 2000 Inventory for fugitive gas emissions, based on international data, although the UNEP Toolkit indicates that no measurable emissions to air are expected from this source. The mid-point of the 2000 Inventory range (0.34 ng I-TEQ Nm^{-3}) has been used here for the releases associated with fugitive emissions. This is equivalent to an emission rate of 20 μg TEQ TJ^{-1}, assuming an energy content of 17 MJ Nm^{-3} for landfill gas.

For future projections, it has been assumed that landfill gas production is proportional to the total mass of waste present and that incremental additions to this mass, as occurs with ongoing waste disposal, will result in proportionately higher gas emissions. On the basis of past trends, waste in landfills can be expected to increase by about 5% and 10% over the next 5 and 10 years, respectively. No change has been made to the distribution between flared/utilised gas and fugitive gas in these projections, although it is possible that gas collection rates will increase in the forthcoming years.

National emission estimate

Releases associated with landfill gas production are summarised in table 26.1. The figures shown for 1998 gas production have been converted from the volumetric basis given in the 2000 Inventory, assuming an energy content of 17 MJ Nm^{-3} for landfill gas, and the estimated emissions are reasonably comparable with the range of 0.078 to 0.16 g I-TEQ yr^{-1} reported previously.

Table 26.1: PCDD and PCDF emissions to air from landfill gas

Landfill gas source	Gas quantities (10^3 PJ yr^{-1})				Annual emissions (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
Fugitive emissions	4.08	3.06	3.21	3.37	0.082	0.061	0.064	0.067
Flared/utilised gas	0.17	3.30	3.47	3.63	0.018	0.026	0.028	0.029
Totals	4.25	6.36	176	185	0.100	0.087	0.092	0.096

Certainty

Activity statistics:	Low (fugitive emissions, flared gas and gas combusted in engines)
Emission factor:	Low (fugitive emissions)

The activity statistics for landfill gas fugitive emissions and for gas flaring or utilization are both assigned a ‘low’ certainty ranking because they are estimated gas production rates based on the quantities of wastes present in New Zealand landfills. In addition, the distribution between fugitive releases and the gas captured in collection systems is based on incomplete industry data. The emission factors for all forms of releases are assigned a ‘low’ certainty ranking because no New Zealand test data is available. The factors used are taken from international data, which was derived from a limited number of studies.

26.1.2 Landfill fires

Landfill fires were identified in the 2000 Inventory as New Zealand's most significant source of dioxin releases to air. In response to this, the deliberate lighting of fires and burning of wastes at landfills was banned in October 2004, under the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations.

The Landfill Census for 1995 reported that there were at least 142 fires at landfills during the year (Ministry for the Environment, 1997). These were distributed across 52% of the 327 operational landfills, and about two-thirds were reported as accidental while the remainder were intentionally lit. By 2002 only 17% of the 115 operational landfills reported fires (Ministry for the Environment, 2003). There was no question on landfill fires in the 2007 questionnaire, although the survey report indicated, somewhat optimistically, a fire rate of 0% (Ministry for the Environment, 2007a). The annual report by the New Zealand Fire Service (2006) indicated that a total of 50 landfill fires were attended during 2005/06 (37 public and 13 private facilities). This is well down on the numbers reported for previous years, which is consistent with the overall trend indicated in the Landfill Census reports. However, they do confirm that fires are still occurring at landfill sites throughout the country, albeit at a significantly reduced rate.

No New Zealand emission factors are available for the release of PCDDs and PCDFs from landfill fires. In the 2000 Inventory the emissions were estimated on a *pro rata* basis from some Swedish work. The total emissions from landfill fires in Sweden were adjusted on a population basis to give an upper estimate for New Zealand of 15 g I-TEQ yr^{-1}. Adjusting the data on the basis of relative waste quantities gave a lower limit for the estimate of 10 g I-TEQ yr^{-1}. The Swedish work was based on an emission factor of 1000 μg TEQ $tonne^{-1}$ of waste burned, and this factor was also adopted in the UNEP Toolkit.

In the absence of any more relevant emission factors, the mid-point of the range reported in the 2000 Inventory (10–15 g I-TEQ yr^{-1}) will be used in estimating the current releases of PCDDs and PCDFs from landfill fires. However, this figure will be adjusted to reflect the significant reduction in the number of landfill fires that has been achieved over the intervening period.

National emission estimates

The number of landfill fires recorded by the New Zealand Fire Service between 1995/96 and 1997/98 varied between 260 and 290 per year, with an average for the three years of 274 (New Zealand Fire Service, 2000). The number of fires recorded in 2005/06 was only 50, or 18.2% of the earlier numbers. The release estimates for 2008 will be based on the 2005/06 fire numbers and calculated on a *pro rata* basis from the 1998 estimates (ie, 18.2% of 12.5 g I-TEQ yr^{-1}).

The reduction in fire numbers since 1997/98 is equivalent to an annual rate of about 8% per year. Further reductions can be anticipated in the future as landfill operators continue to upgrade their operations and old (closed) landfill sites are remediated. However, it is unlikely that the current rate of reduction will be maintained because many of the smaller, more troublesome landfills have been closed down. Thus, the future projected emissions shown in the table are based on an assumed continuing reduction rate of 1% per year.

Table 26.2: PCDD and PCDF emissions to air from landfill fires

Annual numbers of fires				Annual emissions (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
274	50	48	45	12.5	2.3	2.2	2.1

Certainty

Activity statistics:	Low
Emission factor:	Low

The activity statistics and the emission factor are both assigned a 'low' certainty ranking because the estimates are based on *pro rata* population and waste quantity data. This approach assumes that the composition of the wastes going to New Zealand landfills is similar to that in Sweden, and that the quantities of waste burned in landfill fires in the two countries are also comparable.

26.2 Releases to land

Approximately 3.16 million tonnes of solid waste was disposed to landfill in New Zealand in 2006. This value is only marginally lower than the 1995 figure of 3.18 million tonnes used in the 2000 Inventory. More detailed yearly data reported by the Ministry for the Environment (2008b) indicates that annual waste quantities dropped to a low of about 2.8 million tonnes in 1998 and then increased steadily to a high of about 3.25 million tonnes in 2004, followed by some minor reduction during 2005 and 2006. The 2006 figure will be used for both the 2008 estimates and the projections to 2013 and 2018, although it is expected that the recent introduction of a national waste levy, through the Waste Minimisation Act 2008, will lead to significant reductions in future waste quantities disposed to landfills (see: http://www.mfe.govt.nz/issues/waste/waste-minimisation.html).

No New Zealand data is available on the concentration of PCDDs and PCDFs in residential waste deposited in landfills. The 2000 Inventory assigned a release factor of 6.3 µg I-TEQ $tonne^{-1}$ for both residential and industrial wastes, which it considered separately. The UNEP Toolkit recommends the use of 6 µg I-TEQ $tonne^{-1}$ for countries with "lesser potential for dioxin contamination of their wastes", and this factor will be used here.

National release estimates

PCDD and PCDF releases from waste disposed of to landfills are summarised in table 26.3. This estimate represents the quantity of PCDDs and PCDFs added each year to the already existing PCDD and PCDF reservoir within landfills. Estimates for the latter are given in section 28.

Table 26.3: PCDD and PCDF releases to land in landfills

Quantity of waste (10^6 tonnes yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
3.18	3.16	3.16	3.16	19.1	19.0	19.0	19.0

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a ‘high’ certainty ranking because they are based on industry census data. The emission factor is assigned a ‘low’ certainty ranking because no New Zealand data is available and the factor used is based on international waste concentration data.

26.3 Releases to water

The 2000 Inventory used an empirical calculation to estimate the total amount of leachate produced by all landfills in New Zealand, including closed landfills. The calculation took into account waste volumes, site area rainfall and the likely extent of rain infiltration. A range of 1.1–4.3 million m^3 yr^{-1} was estimated based on a total waste volume of 159 million m^3. The mid-point of this range is 2.7 million m^3. It is relevant to compare this result with more recent data for a landfill site in Germany, which began operations in 2002 and produces 400 m^3 of leachate daily from a total of 10.7 million m^3 of waste (Sieksmeyer and Packhaeuser, 2003). Applying this rate to the 1998 volume of waste in New Zealand landfills gives an annual leachate production of 2.2 million m^3, which is reasonably similar to the 2.7 million m^3 mid-point value noted above.

Increases in leachate production to the present, and looking forward 5 and 10 years, will be proportional to the incremental growth in total waste volumes over these periods. The 2000 Inventory used an estimate of 79.5 million tonnes for the total mass of waste disposed in New Zealand landfills in 1998. The amount of additional waste placed annually between 1995 and 2006 has varied between about 2.8 and 3.25 million tonnes per year, with an average rate of about 3.1 million tonnes per year (Ministry for the Environment, 2008b). Consequently by 2008, the total waste present can be estimated at 110 million tonnes, an increase of 138%. Similar annual rates of waste deposition over the next 5- and 10-year periods will result in totals of about 126 million tonnes and 141 million tonnes of waste by 2013 and 2018, respectively. These quantities have been used to estimate the volumes of leachate indicated in table 26.4.

The 2000 Inventory reported leachate concentration data from five New Zealand landfills in the range of 7.5–221 ng I-TEQ m^{-3}. Two release factor ranges were developed: for small–medium landfills (14–48.3 ng I-TEQ m^{-3}) and large landfills (7.5–221 ng I-TEQ m^{-3}). The UNEP Toolkit has also used the New Zealand data in the development of leachate release factors for two different landfill classifications. Class 1 landfills are those that may contain hazardous wastes and were given a release factor of 200 ng I-TEQ m^{-3}. Class 2 landfills are those containing non-hazardous municipal wastes and have a release factor of 30 ng I-TEQ m^{-3}. The class 1 landfill factor has been adopted here, given that nearly all New Zealand landfills will have received hazardous wastes at some time in their history.

National release estimates

PCDD and PCDF releases from the production of landfill leachate are summarised in table 26.4. As at 2006, 77% of landfill sites in New Zealand operated a leachate collection system and 80% of these sites treat their leachate, with the majority sending it off-site to local wastewater treatment plants or settling ponds. All other landfills use on-site treatment systems, including the use of settling ponds, land irrigation, leachate recirculation through the landfill, and leachate disposal to artificial wetlands (Ministry for the Environment, 2007a).

Table 26.4: PCDD and PCDF releases from landfill leachate

Volume of leachate (10^6 m^3 yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
1998	2008	2013	2018	1998	2008	2013	2018
2.7	3.7	4.3	4.8	0.54	0.74	0.86	0.96

Certainty

Activity statistics:	Low
Emission factor:	Medium

The activity statistics are assigned a ‘low’ certainty ranking because the amount of landfill leachate produced has been modelled on the basis of estimated volumes of refuse, landfill areas and rates of leachate generation for various landfill sizes. The emission factor is assigned a ‘medium’ certainty ranking because it is based on test data for PCDDs and PCDFs in leachate from a number of New Zealand landfills.

26.4 Application of BAT/BEP

Landfill fires are the only aspect of PCDD and PCDF releases from landfills specifically addressed in the BAT/BEP Guidance. The information given in the Guidance is very clear: the deliberate burning of landfill contents should be prohibited, and accidental fires can be minimised through appropriate landfill design and operational practices. In New Zealand, landfill fires have been prohibited through the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations. In addition, the significant reduction in landfill fires noted in section 26.1.3 provides clear evidence that these Regulations and other significant improvements in landfill management practices have been highly effective in reducing the releases from this source. Continuing reductions are expected to occur over the next 5 to 10 years.

Other releases from landfills, such as landfill gas and leachate, are not specifically covered under the BAT/BEP Guidance. However, if such guidance were to be provided, the measures most likely to be recommended would be much the same as those already given in New Zealand through the various good practice guidance documents published by the Ministry for the Environment and others. This includes the development of reticulation systems to capture and treat leachate, and to capture landfill gas for flaring or for other beneficial uses.

26.5 References

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27 Wastewater Treatment

There are about 320 wastewater treatment plants in New Zealand, which are used for the treatment of most domestic and commercial wastewater (Ministry for the Environment, 2008b), although about 15–20% of the population still rely on septic tanks for the disposal of domestic wastewater. The wastewater treatment plants use a variety of different systems, including primary and secondary treatment stages, anaerobic digesters and oxidation ponds. The generation of wastewater solids and other possible discharges from each of these processes was described in some detail in the 2000 Inventory and will not be repeated here.

PCDDs and PCDFs are present in wastewater, and consequently in treated effluent, wastewater solids and biosolids, as a result of:

- point source discharges by industry
- diffuse discharges from industrial, commercial and domestic sources
- atmospheric deposition and surface run-off.

The UNEP Toolkit indicates that wastewater from household activities such as laundering and bathing could be the major contributor of PCDDs and PCDFs at many of the treatment plants serving mainly residential populations. Biogenic formation of PCDDs and PCDFs in sewage sludge, which was highlighted in the 2000 Inventory, is regarded as making only a very small contribution.

Sludge-drying technologies involving significant heating of the sludge (to temperatures of 200°C or above) may also lead to additional PCDD and PCDF formation. There is one sludge-drying plant currently operating in New Zealand, where bio-solid pellets are produced at a rate of 1260 tonnes per year for use as fertiliser (Ministry for the Environment, 2007b).

There is one wastewater solids incinerator in New Zealand. The releases of PCDDs and PCDFs from this process were discussed in section 6.

27.1 Releases to land

The 2000 Inventory estimated wastewater solids production using a combination of available production data and assumptions based on the expected suspended solids removal efficiency for the different treatment processes. However, more detailed wastewater solids production data is now readily available from the WINFO database (http://www.winfo.org.nz) and can be used directly for the release estimates. WINFO was developed as a joint exercise between the Ministry for the Environment and the New Zealand Water and Wastes Association.

Production rates and disposal practices for 2006 were summarised in a recent report (Ministry for the Environment, 2007b). The total estimated sludge production was 234,112 tonnes. Of this total, 79,440 tonnes was sent to landfill, 116,380 tonnes was used for land reclamation, and 600 tonnes was disposed in forests. A further 36,817 tonnes was put to a variety of beneficial uses, including as a compost supplement or fertiliser products. The remaining 875 tonnes was identified as residual sludge in pond-based treatment plants, which would eventually be disposed of when the ponds are de-sludged.

The UNEP Toolkit specifies three different release factors depending on the sources of the wastewater: mixed domestic/industrial inputs, urban environments and remote environments. The urban environments classification would seem to be the most appropriate for New Zealand sludge production, given that the majority of the sludge is produced by about 25 high-rate urban wastewater treatment plants. The Toolkit factor for this category is 100 µg $tonne^{-1}$ of dry sludge (ie, 100 ng kg^{-1}). By comparison, the 2000 Inventory reported a range of results for New Zealand sewage sludge samples corresponding to 5.64–108 ng I-TEQ kg^{-1} of dry sludge, and applied emission factors in the following three ranges: 3.64–18.7, 6.84–108 and 11.5–35.6 ng I-TEQ kg^{-1} of dry sludge, depending on the different treatment processes. The use of the single Toolkit release factor is a much more straightforward approach and will be adopted for the current estimates.

Increases in sludge production over the next 5- and 10-year periods have been based on the current population growth of about 1% per annum (Statistics NZ, 2007b). Increased sludge production is also related to improvements in wastewater treatment practices. For instance, the recent upgrade to New Zealand's largest wastewater treatment plant resulted in sludge production increasing from 40,000 tonnes in the mid-1990s to 116,000 tonnes in 2005/06 (Ministry for the Environment, 2007b). Future technology-related increases are unlikely to be on such a large scale but may result in higher growth rates than the proposed 1% annual rate.

National release estimates

Releases of PCDDs and PCDFs from wastewater solids are summarised in table 27.1. The estimates shown for 2008 are based on the 2006 data noted above, while the back-projection for 1998 is based on the activity data reported in the 2000 Inventory and the Toolkit release factor.

Table 27.1: PCDD and PCDF releases to land from wastewater treatment

Annual sludge production (dry tonnes $year^{-1}$)				Annual releases (g I-TEQ yr^{-1})			
1998	**2008**	**2013**	**2018**	**1998**	**2008**	**2013**	**2018**
87,800	234,112	245,820	257,520	8.78	23.4	24.6	25.7

Certainty

Activity statistics:	High
Emission factor:	Medium

The activity statistics are assigned a 'high' certainty ranking because they are based on data from the WINFO database. The emission factor is assigned a 'medium' certainty ranking because it is based on overseas data, which is similar to the available New Zealand data.

27.2 Releases to water

The quantity and quality of effluent discharges from wastewater treatment will depend on the nature and composition of the influent streams and the treatment processes applied. Studies have shown that almost all of the PCDDs and PCDFs measured at the entry point to a wastewater treatment plant are associated with the wastewater solids rather than the liquid component. It is therefore reasonable to assume that the release of PCDDs and PCDFs to water will depend to a large degree on the proportion of solids in the effluent discharge.

New Zealand wastewater treatment plants discharge approximately 1.8 billion litres of wastewater daily into the sea and other waterways, and onto land (New Zealand Water and Wastes Association, 2008; Ministry for the Environment, 2008b). This equates to 657 billion litres, on an annual basis. The UNEP Toolkit provides two possible factors for wastewater plants servicing 'urban environments'; 2 pg I-TEQ L^{-1}, where no sludge is removed in the treatment process, and 0.5 pg I-TEQ L^{-1}, where sludge removal occurs. It has been assumed that half of the wastewater treated in New Zealand would fall into the sludge removal category, with the remainder corresponding to 'no sludge removed'.

The 2000 Inventory estimated PCDD and PCDF releases based on a combination of the likely suspended solids concentrations for the various treatment processes and their discharge volumes, coupled with an estimate of the PCDD/PCDF concentration in the solids discharged. The PCDD/PCDF release estimate (0.34–2.6 g I-TEQ yr^{-1}) was similar to that for sewage sludge production, and was regarded as possibly too high. This approach will not be used for the current estimates, which will be based on the Toolkit factors noted above.

As with sewage sludge production, projected increases in wastewater effluent discharges have been assumed to occur at about 1% per annum, in line with the rate of population growth.

National release estimates

Releases of PCDDs and PCDFs in wastewater effluent are summarised in table 27.2. It is not appropriate to do a back-projection for 1998 because of the differences in methodology, and the release shown is simply the mid-point of the range reported in the 2000 Inventory (0.34–2.6 g I-TEQ yr^{-1}).

Table 27.2: PCDD and PCDF releases to water from wastewater treatment

Plant classification	Wastewater discharged (10^9 litres yr^{-1})				Annual releases (g I-TEQ yr^{-1})			
	1998	2008	2013	2018	1998	2008	2013	2018
No sludge removed	–	329	346	362	–	0.658	0.691	0.724
Sludge removed	–	329	346	362	–	0.165	0.173	0.182
Totals	454	658	692	724	(1.47)	0.823	0.864	0.906

Certainty

Activity statistics:	High
Emission factor:	Low

The activity statistics are assigned a 'high' certainty ranking because they are based on data recorded in the WINFO database. The emission factor is assigned a 'low' certainty ranking because it is based on international data.

27.3 Application of BAT/BEP

Wastewater treatment is not covered in the BAT/BEP Guidance. The Ministry for the Environment provides a number of documents outlining good industry practice, which can be regarded as indicative of BAT/BEP. These include guidelines for the safe application of biosolids to land, guidelines on the operation of oxidation ponds, and a model trade wastes bylaw.

27.4 References

Ministry for the Environment. 2007b. *Targets in the New Zealand Waste Strategy: 2006 Review of Progress.* Wellington: Ministry for the Environment.

Ministry for the Environment. 2008b. Waste (Chapter 6). In: *Environment New Zealand 2007*. Wellington: Ministry for the Environment.

New Zealand Water and Wastes Association. 2008. *WINFO Database.* Wellington: Water New Zealand. Retrieved from http://www.winfo.org.nz.

Statistics NZ. 2007b. *National Population Projections: 2006 (base) – 2061*. Wellington: Statistics New Zealand.

28 PCDD and PCDF Reservoirs

Reservoirs are places or materials that contain significant amounts of PCDDs and PCDFs as a result of past contamination. The reservoir sources considered are:

- the manufacture of phenoxy herbicides
- the use of the herbicide 2,4,5-T
- timber treatment using pentachlorophenol
- coal gasification plants
- landfills.

Reservoirs associated with the pulp and paper industry are discussed separately in section 22.4. This section consolidates material on PCDD and PCDF reservoirs reported in sections 28 to 31 of the 2000 Inventory.

There are significant uncertainties in identifying potential PCDD and PCDF reservoirs. The reservoirs considered here are those associated with known sources of PCDDs and PCDFs and/or known disposal routes. However, it is quite likely that there will be other reservoirs not yet identified, especially in association with some of the thousands of contaminated sites that are known to exist throughout New Zealand (Ministry for the Environment, 2008c). Over 4000 of these sites have been assessed using a national screening system, and 56% of those identified as high-risk (559 sites) have been either cleaned up or placed under appropriate management. However, no specific investigations have been undertaken at the majority of sites, which means that we cannot say with absolute certainty that there are no residual risks. This was demonstrated by a recent incident at the site of an old landfill – now used as a public park – where two crushed drums containing chemical residues, including TCCD, were discovered during the laying of stormwater drainage pipes (Pattle Delamore Partners Ltd, 2009).

On a more positive note, it should be noted that the past practices that led to these contaminated sites are now much less likely to occur. Hazardous substances are subject to more rigorous controls under the Hazardous Substances and New Organisms Act 1996, while potential adverse effects from any discharges to the environment are regulated under the Resource Management Act 1991 (Ministry for the Environment, 2008b).

28.1 Pesticide manufacture

This section is concerned with the PCDDs and PCDFs present in a reservoir associated with the historical manufacture of phenoxy herbicides. The Waireka Secure Containment Facility, in the Taranaki region, was constructed in 1985 and contains waste from earlier manufacturing of phenoxy herbicides, including 2,4-D and 2,4,5-T. The accumulated wastes were deposited in 1985 and the landfill was closed. The facility is a secure landfill, fully lined and capped, with leak detection wells that are routinely monitored. Any leachate collected from within the landfill is disposed of in the incinerator described in section 5 of this report.

Although PCDDs and PCDFs are known to be present in the Waireka facility, insufficient data is available to enable an accurate estimate of the quantity present in this reservoir.

28.2 Historical use of 2,4,5-T

The herbicide 2,4,5-T was manufactured in New Zealand from 1948 to 1987 and was widely used for the control of gorse, blackberry and other woody weeds. The manufacturing process involved the initial formation of 2,4,5-trichlorophenol from 1,2,4,5-tetrachlorobenzene, and PCDDs and PCDFs, primarily 2,3,7,8-TCDD (TCDD), were formed as a by-product of this reaction.

The total quantity of 2,4,5-T manufactured was estimated in the 2000 Inventory at 11,640 tonnes, with about 15% of this being exported. The levels of TCDD in the final product varied greatly, depending on the manufacturing conditions and purification efficiency. From 1973 the level of TCDD was restricted by requirements imposed by the Agricultural Chemicals Board.

The variations in TCDD concentrations were described in detail in the 2000 Inventory report. On the basis of the total production figures and the known residue concentrations, it was estimated that the total quantity of TCDD distributed over the land surface of New Zealand, throughout the entire period of manufacture and use, was between 2.71 and 3.38 kg I-TEQ.

The size of the reservoir from 2,4,5-T usage was estimated in the 2000 Inventory by making an allowance for TCDD degradation over time using a TCDD half-life of 15 years. If the same factor is used here, the residual concentrations of TCDD will have dropped by a further 37% by 2008 (calculated using a factor of $1/2^n$, where n = number of half-lives). Therefore, the current quantities of residual TCDD distributed over land through the past use of 2,4,5-T can be estimated at 390 to 540 g I-TEQ, compared to the 1998 estimate of 620 to 860 g I-TEQ.

It is known that 2,4,5-T was sprayed over several hundred thousand hectares of pastoral land, annually, as well as forestry and other land blocks. Therefore, the estimated quantities of TCDD will generally represent a diffuse reservoir source, although there might also be localised areas of higher soil contamination as a result of spillages.

28.3 Historical use of pentachlorophenol for timber treatment

The primary use of pentachlorophenol (PCP) in New Zealand was in the timber industry, either as the sodium salt (NaPCP), for use as an antisapstain treatment, or as a preservative in diesel oil. PCP was also used to a relatively minor extent as a slimicide in the pulp and paper industry, as a soil and timber steriliser in mushroom production, and in a variety of other applications for the control of moss and algae. The use of PCP in the timber industry began in the mid- to late 1950s and voluntarily stopped in 1988. PCP was deregistered for all uses by the Pesticides Board in 1991. Health and environmental guidelines have been published for PCP and other timber treatment chemicals to help assess and manage contaminants on sawmill and timber treatment sites in New Zealand (Ministry for the Environment and Ministry of Health, 1997).

The total amount of PCP imported into New Zealand for use in the timber industry was estimated in the 2000 Inventory at about 5500 tonnes, although a more recent estimate puts the figure at 6000 tonnes (Ministry for the Environment, 2008d). The concentrations of PCDDs and PCDFs in the antisapstain formulations marketed in New Zealand were believed to be in the range 0.2–1.85 mg I-TEQ kg^{-1}, with a mean of 0.9 mg I-TEQ kg^{-1}. On the basis of this data, the total input of PCDDs and PCDFs into the New Zealand environment from PCP use in the timber industry was estimated in the 2000 Inventory at 1.2–10.2 kg I-TEQ. A more recent estimate by Bingham (2009) puts the figure at 9.9 kg I-TEQ.

The chemical handling and treatment processes involving PCP were described in some detail in the 2000 Inventory and will not be repeated here. The resulting environmental distribution and fate of PCDDs and PCDFs were also described, including the soil contamination that occurred at most of the sites. These contaminated sites are of most interest as long-term reservoirs of PCDDs and PCDFs.

28.3.1 Reservoirs from the use of NaPCP

The quantities of PCDDs and PCDFs in soils at timber treatment sites were estimated in the 2000 Inventory by calculating the soil burdens for each area of the sites where contaminant concentration data was available. These burdens were then summed to give a total PCDD/PCDF burden per site, and this result was multiplied by the number of sites where NaPCP was used. The estimates were made on the basis of four different site categories: small, moderate, large and very large users of NaPCP. Using this approach, the total PCDD/PCDF reservoir in soils at timber treatment sites, from the use of NaPCP, was estimated to be about 0.080 kg I-TEQ, although it was recognised that the estimates had a very high level of uncertainty.

More recent work reported by the Ministry for the Environment (2008d) has attempted to improve the quality of these estimates. Additional tests for PCP and dioxin concentrations were carried out on soil samples from 15 sawmill sites. In addition, more detailed information was obtained on the activities carried out at the 255 sites identified as having used NaPCP or PCP. The resulting reservoir estimates were reviewed by Bingham (2009), who recommended that some of the values be recalculated to allow for variations in sample numbers across sites of different sizes, and the use of a screening method for dioxin analyses. On the basis of these adjustments, the current reservoirs from past uses of NaPCP are estimated at 0.81 kg I-TEQ.

The above estimate is based on site assessments completed in 2002 (Ministry for the Environment, 2008d), and some of the sites have since been remediated. However, there have been no specific treatments aimed at removing the dioxin contaminants (KR Laing, Tonkin & Taylor Ltd, Auckland, pers comm, 2008). In addition, much of the remediation work is based simply on soil removal and replacement. Hence, the quantities of PCDDs and PCDFs in the reservoirs are unlikely to have changed, but they may have been moved to other locations.

28.3.2 Reservoirs from the use of PCP in diesel

The use of PCP as a preservative in diesel oil was only undertaken at four sites in New Zealand, although only two of these are believed to be of any significance: the Waipa Mill near Rotorua and a plant at Hanmer Springs in Canterbury. The usage of PCP was estimated in the 2000 Inventory to be approximately 2000 tonnes at the Waipa Mill and 420 tonnes at Hanmer.

The estimated dioxin reservoirs at these two sites were updated in the work noted previously for NaPCP. Bingham (2009) estimates that the total PCP used in the past was 2700 tonnes, and at an average contamination level of 1.65 g I-TEQ tonne^{-1} this would have resulted in a total PCDD/PCDF input of 4.5 kg I-TEQ. Of this total, 0.23 kg I-TEQ would have contributed to soil contamination at the sawmill sites, and the remaining 4.27 kg I-TEQ was absorbed in the treated products and distributed more widely. It is not expected that these reservoirs will substantially change over time, unless specific action is taken to destroy the dioxin contamination before the disposal of waste materials.

28.3.3 Releases to air and water from timber treatment reservoirs

PCDDs and PCDFs may be emitted to air from reservoir sources via direct volatilisation from the soil surface and by wind entrainment of contaminated soil. The latter is likely to be the more significant of the two processes, particularly from exposed soil surfaces at sites that are still in active use (such as where the soil may be disturbed by vehicle movement). Earth movement at contaminated timber sites (eg, during site remediation) may also lead to the generation of windblown dust. No data is available from which to estimate the quantities of PCDDs or PCDFs that may be carried off site from any of these processes.

PCDDs and PCDFs may be released to water either through the direct contamination of groundwater or, as a result of rain events, via site run-off and the migration of contaminated soil and other materials to surface water. The contamination of surface waters is likely to be the more significant of the two processes. Historical off-site contamination of the aquatic environment is confirmed by the presence of PCDDs and PCDFs in the biota and sediments associated with three major sawmills (Campin et al, 1991; Gifford et al, 1993; Park, 2005). Insufficient information is available to estimate the quantities of PCDDs and PCDFs that may be released to water from these reservoirs over time. Nevertheless, it can be assumed that these transportation processes, unless adequately managed, will result in the ongoing release of contaminants to the wider aquatic environment.

28.4 Gasworks sites

Before the introduction of natural gas in New Zealand, ‘town gas’ was produced by coal gasification plants at gasworks sites throughout the country. According to the 2000 Inventory, there were approximately 54 gasworks sites in New Zealand, which operated for varying periods from the mid-1800s through to 1988. Internationally, PCDDs and PCDFs have not been recognised as a priority contaminant of gasworks waste. However, New Zealand studies have found that PCDDs and PCDFs may be present in the wastes produced from coal gasification and can be found at some of the sites where gasworks were previously located.

The amount of coal tar and contaminated soil at gasworks sites varies considerably, depending on the size of the works and the length of time over which they operated. Based on environmental assessment data for a number of sites within New Zealand, it was estimated in the 2000 Inventory that the quantities of contaminated soil and other materials were generally between 500 and 10,000 tonnes per gasworks site. Studies undertaken at four of these sites indicated PCDDs and PCDFs in the range of 1.13–13.1 μg I-TEQ tonne^{-1}. These figures were used to estimate the total quantities of the PCDD/PCDF reservoirs associated with these sites.

In 1997, when the 2000 Inventory was being prepared, it was known that at least five of the 54 gasworks sites had been remediated, and the reservoir estimates were based on the remaining 49 sites. It is believed that a further 10 sites have been remediated over the past 10 years. Therefore the current (2008) PCDD/PCDF reservoir is estimated to be between 0.022 and 5.2 g I-TEQ, compared to the previous inventory estimate of 0.028–6.4 g I-TEQ.

It should also be noted that most site remediation work in New Zealand does not involve destruction of the contaminants. In most cases they would simply be transferred to a landfill, and hence become part of the annual releases to land associated with these facilities (see section 26).

There is some potential for PCDD and PCDF releases to water from gasworks sites, especially from movement of the coal tar/water emulsions that are sometimes known to be present. There is no information available to enable any estimate of the potential releases from these sites, although it is expected that any releases would be very minor given the relatively small quantities of PCDDs and PCDFs present as a reservoir source. Similar conclusions would apply to the potential for releases to air.

28.5 Landfills

Solid waste landfills also represent a reservoir of PCDD and PCDF. The 2000 Inventory estimated the total mass of waste present in all New Zealand landfills at 79.5 million tonnes in 1998. A factor of 6.3 μg I-TEQ tonne^{-1} was used to determine the total amount of PCDD and PCDF stored in this reservoir. The UNEP Toolkit suggests that countries with few dioxin-generating activities should apply an emission factor of 6 μg I-TEQ^{-1} tonne, and this factor has been used for the current estimate.

The mass of waste currently (2008) stored in landfills has been estimated by assuming an annual deposition rate of 3.1 million tonnes per annum since 1998 (see section 26.3). This gives a total waste quantity of 110 million tonnes, and a PCDD/PCDF reservoir of 0.66 kg I-TEQ.

28.6 Application of BAT/BEP

PCDD and PCDF reservoirs are not covered in the BAT/BEP Guidance document.

28.7 References

Bingham AG. 2009. *The Significance of Pentachlorophenol (PCP) as a Dioxin Reservoir Source for New Zealand*. Auckland: JCL Air & Environment Ltd.

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29 Other Chemical Products and Processes

This section addresses a number of other miscellaneous chemical products and/or manufacturing processes listed in the UNEP Toolkit as potential sources of PCDDs and PCDFs. There are no detailed release estimates in this section, mainly because of the absence of any relevant usage and/or release data. In addition, most of the sources are either historical and/or believed to be relatively minor.

29.1 Chloranil

Chloranil (2,3,5,6-tetrachloro-2,5-cyclohexadiene-1,4-dione) was used in the past as a fungicide and seed dressing, although these uses were discontinued in most countries by the early 1980s. It is still used in the manufacture of dioxazine dyes and as a laboratory reagent (eg, for the detection of primary and secondary amines). Chloranil can be made by the chlorination of phenol or the hydro-chlorination of hydroquinone. The first of these processes has been found to result in PCDD/PCDF concentrations of several hundred μg TEQ kg^{-1}, while the latter gives levels about 50 to 100 times lower (UNEP, 2005).

Chloranil is listed in the database of existing chemical substances maintained by ERMA NZ (2009). This indicates that the substance was notified as being present in New Zealand on or before 2 July 2001, the date the hazardous substance provisions of the Hazardous Substances and New Organisms Act 1996 came into force. The Transfer Notice for chloranil lists it as a pesticide, veterinary medicine or pharmaceutical active ingredient (ERMA NZ, 2006). However, the substance is not currently registered for use in New Zealand under the Agricultural Chemicals and Veterinary Medicines Act 1997 (ACVM, 2009).

No current uses of chloranil have been specifically identified for New Zealand, although some minor uses as a laboratory reagent are likely.

29.2 Dioxazine pigments and dyes

Dioxazine pigments and dyes are obtained by the reaction of chloranil with aromatic amines in the presence of a base. Tests on some of these pigments in the early 1990s showed PCDD/PCDF concentrations in the range of about 1 to 60 μg TEQ kg^{-1}, which was attributed to the use of chloranil produced by chlorination of phenol. Subsequent developments in the US and Europe have led to the use of low-dioxin chloranil produced by the alternative hydro-chlorination route, with a resulting reduction in PCDD/PCDF concentrations (UNEP, 2005; US EPA, 2006a; Krizanec and Le Marechal, 2006).

The dioxazine pigments with the potential for PCDD/PCDF contamination are CI[15] Pigment Violet 23 (also known as Carbazole Violet), CI Pigment Violet 37, and CI Direct Blue 106. These pigments can be used in a wide range of materials, including plastics, paints and printing inks, and are also used in the production of dyes for use on textiles and leather. Only the first of these pigments is listed in the New Zealand database of existing chemical substances (ERMA NZ, 2006, 2009). It is also listed in Schedule 7 to the ACVM Act (ACVM, 2004) as being

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[15] CI = colour index.

acceptable for use as a seed treatment (coating), provided the total levels of PCDDs and PCDFs are no more than 20 ppb (μg kg^{-1}; note: this refers to total dioxins rather than TEQ).

No information has been found on the quantities of Pigment Violet 23 being used in New Zealand, although, as a pigment, the amounts used in most formulations are likely to be very low – typically less than 1%. When coupled with the relatively low contamination levels resulting from the use of low-dioxin chloranil, the resulting PCDD/PCDF concentrations in the finished products are likely to be in the parts per trillion range (ie, ng kg^{-1}).

29.3 Textiles and leather production

The UNEP Toolkit indicates that PCDDs and PCDFs may be found in textile and leather products and production wastes as a result of a number of factors, including the:

- use of agrichemicals, especially pentachlorophenol, on the raw materials
- use of dioxin-contaminated dyestuffs (eg, dioxazine dyes)
- formation of PCDDs and PCDFs as unintentional by-products in the production processes.

Pentachlorophenol and the sodium salt of pentachlorophenol were mainly used in New Zealand for timber treatment (see section 28), but they may have also been used in the textiles and leather industries, mainly as a fungicide or preservative. All uses were deregistered by the Pesticides Board in 1989. In 2006 the substances were transferred into the control system under the Hazardous Substances and New Organisms Act 1996 (ERMA NZ, 2006), even though there were no known uses at the time. The resulting (inferred) approvals have since been withdrawn (ERMA NZ, 2008b). Testing of New Zealand pelts and hides intended for export has not shown any detectable levels of pentachlorophenol (G Holmes, Leather and Shoe Research Association, Palmerston North, pers comm, 2009).

The uses of pentachlorophenol have been either banned or severely restricted in many other countries. For example, the register maintained by the Secretariat of the Rotterdam Convention indicates that the substance has been banned in at least 11 countries and is prohibited from import in a further 49 (Secretariat of the Rotterdam Convention, 2008). Imports and/or uses may still be permitted in other countries, including Australia, Canada, the European Union and China, but with conditions; for example, the EU and China specify a maximum PCP residue limit of 5 ppm in finished products.

The potential for PCDD/PCDF contamination from dioxazine dyes was discussed in the previous section. Some of these dyes have been used in the past in the New Zealand leather and textiles industries, but there are no current known uses (G Holmes, Leather and Shoe Research Association, Palmerston North, pers comm, 2009).

PCDDs and PCDFs are expected to occur in the wastes from textile and leather-processing plants, especially wastewater discharges, but mainly as a result of contaminated inputs from the chemicals discussed above (UNEP, 2005). There is also the potential for PCDD/PCDF production as unintentional by-products when incineration processes are used as part of the waste-processing operations (eg, incineration of the sludges produced from closed-loop water and grease recovery systems, UNEP, 2007). However, this type of system is not used in New Zealand.

On the basis of the above information, there is no reason to expect any significant PCDD/PCDF releases from the processing and manufacture of textiles and leather products within New Zealand. However, there is some potential for them to be present in imported products, especially those sourced from countries where pentachlorophenol or dioxazine dyes are still in use.

The annual imports of leather goods to New Zealand are about 500 tonnes per year, with an additional 500 to 1100 tonnes of imported footwear (G Holmes, Leather and Shoe Research Association, Palmerston North, pers comm, 2009). The total annual New Zealand imports of textiles and textile articles have a value of about $2,000 million (Statistics NZ, 2009b). There is no accurate way of converting this figure to a mass basis, because the value of individual items will vary significantly. However, a reasonable upper estimate would be about 200,000 tonnes, based on the current average value (~$10 per kilogram) of New Zealand yarn exports. The UNEP Toolkit indicates PCDD/PCDF contamination levels ranging from 10 to 1000 μg TEQ tonne^{-1} in leather and 0.1 to 100 μg TEQ tonne^{-1} in textile products. However, these factors are relatively dated, and it would be reasonable to expect that the PCDD/PCDF concentrations in most current imports are either non-detectable or at the bottom end of these ranges.

Applying the lowest factors to the import estimates given above suggests total annual PCDD/PCDF imports of about 10 to 16 mg I-TEQ in leather goods and footwear, and 20 mg I-TEQ in textiles. This can be taken as a reasonable first-order indication of the likely PCDD/PCDF imports on the basis that any materials with significantly higher contamination levels should be offset by those with no contamination at all. In particular, a significant proportion of the textile imports will be synthetic materials with no potential for PCDD/PCDF contamination.

29.4 Chlorine production

The industrial production of chlorine gas is based almost exclusively on the electrolysis of solutions of sodium chloride (brine). Before the 1980s most plants used either a mercury cell process or a diaphragm process, both involving the use of graphite electrodes. These processes have been shown to be a source of PCDDs and PCDFs, which have been detected in the graphite sludge formed in the cells (UNEP, 2005; US EPA, 2006a). Nowadays, most plants use an alternative membrane cell process, which has not been shown to produce any PCDDs or PCDFs.

The older technologies were used for chlorine manufacture at the two pulp and paper mills in New Zealand until the early 1980s, with one mill using the mercury cell process and the other using the diaphragm process. No information is available on the quantities and composition of any sludge produced by these plants or its method of disposal, although this was most likely by burial in the company landfills. A limited amount of data published by the European Commission indicates carbon sludge production rates of about 2 to 3.5 tonnes per year from two mercury cell plants with chlorine capacities of 100,000 and 120,000 tonnes per year (IPPC, 2001a). The total production capacity at the two New Zealand plants is believed to have been no more than about 20,000 tonnes of chlorine per year (J Newfield, Carter Holt Harvey Pulp and Paper Ltd, pers comm, 2010), which suggests a sludge production rate of about 0.5 tonnes per year. According to the UNEP Toolkit, the PCDD/PCDF concentrations in the sludge are between 13.5 and 30 mg TEQ tonne^{-1}. Thus, an indicative figure for the potential releases from this source would be in the range of about 7–15 mg TEQ yr^{-1}, with a total reservoir contribution over the lifetime of the two plants (~25 years) of between 0.2 and 0.4 g TEQ.

It must be stressed that the above estimate is highly speculative. It mainly serves to illustrate that while the use of mercury cells for chlorine production may have been a source of PCDD and PCDF releases in the past, the resulting discharges to land would have been a very minor contributor to the overall total for reservoir sources in New Zealand.

29.5 Oil refinery catalyst regeneration

Generally, oil refineries are not considered to be a significant source of PCDD and PCDF releases. However, a limited amount of testing in the USA, Canada and Europe has shown that PCDDs and PCDFs can be produced during the regeneration of spent catalysts used in catalytic reforming (US EPA, 2006a; IPPC, 2003). The reforming process operates at high temperature and pressure and involves the use of a platinum or platinum/rhenium catalyst. A complex mixture of aromatic compounds, known as coke, is formed and deposited on the catalyst during the process, and this causes a gradual decrease in catalytic activity. Catalyst regeneration is achieved by burning the coke deposits at temperatures of 399 to 454°C and then reactivating the catalyst at elevated temperatures (454 to 538°C) using chlorine gas or chlorinated organics such as perchloroethylene. Two basic catalyst regeneration processes are used: semi-regenerative and continuous. In the semi-regenerative process, the entire catalytic reformer is taken off line and regenerated. In the continuous process, aged catalyst is continuously removed from the system for treatment and recycling so that the reformer never shuts down.

The US EPA based its estimates of emissions from this process on test results from only two oil refineries in the USA (equivalent to < 1% of total US capacity). The emission factor for one of the plants, using a semi-regenerative process, was estimated at 0.001 ng I-TEQ per barrel of oil, although, as a separate batch process, the relationship to total plant throughput is highly questionable. The emission factor for the second plant, using a continuous process, was found to be much higher, at 3.04 ng I-TEQ per barrel. The emission data for European plants has only been reported in terms of stack gas concentrations, and no information is available on the regeneration processes associated with each set of results. No emission factors are given in the UNEP Toolkit, and it is noted that “measured data are urgently needed”.

The Marsden Point oil refinery in Northland uses the semi-regenerative process for catalyst regeneration approximately every 18 months. Tests have been carried out on the PCCD and PCDF emissions to both air and water during regeneration. The testing indicated that the concentration of PCDD/PCDF in the discharge to air was negligible, and that trace quantities of these substances were partitioned in the process wash water. The refinery has adopted a precautionary approach by removing traces of PCDD/PCDF from the wash water using carbon filtration before the wastewater treatment processes, and eventual controlled disposal. The effectiveness of this removal has been confirmed by further testing of the effluent discharge (G Taylor, NZ Refining Company Ltd, Whangarei, pers comm, 2009).

The total throughput for the Marsden Point refinery is approximately 40 million barrels of oil per year. Applying the US emission factor for the semi-regenerative process to this figure suggests an annual release rate of 0.04 mg I-TEQ, which is insignificant when compared to the total New Zealand PCDD/PCDF emissions to air.

29.6 Application of BAT/BEP

Textile and leather dyeing and finishing are specifically covered under the BAT/BEP Guidance, in which it is noted that:

> "the most efficient primary measure to prevent contamination of textiles and leather goods with PCDD/PCDF would be not to use dioxin-contaminated biocides and dyestuffs in the production chains. Also, if any of the above-mentioned chemicals are being used, preference should be given to batches containing low concentration[s] (eg, distilled or otherwise purified chemicals)."

As noted previously, there is no indication that any of the potentially contaminated chemicals are being used in New Zealand, but materials contaminated with PCDDs and PCDFs may be entering the country in some imported goods.

None of the other sources addressed in this section are specifically covered under the BAT/BEP Guidance. However, the advice regarding the use of contaminated dyestuffs on leather and textiles would also apply to other uses of the dioxazine pigments and dyes.

29.7 References

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30 Other Miscellaneous Sources

This section addresses two other processes that are listed in the UNEP Toolkit as potential sources of PCDDs and PCDFs. However, no detailed release estimates will be given, mainly because the data available on release rates is extremely limited. In addition, both sources are believed to be very minor contributors to overall PCDD/PCDF releases.

30.1 Smokehouses

Smoking is used to add flavour, colour and aroma to various meats, including pork, beef, poultry and fish. Several methods are used to produce the smoke, but the most common approach is based on the pyrolysis of wood chips or sawdust. In a typical smoke generator, the wood is placed on a heated metal surface at 350° to 400°C. Another method involves use of the heat generated by constantly rubbing blocks of wood against a blunt metal blade, or vice versa. Liquid smoke, which is a washed and concentrated natural smoke, is also used. This type of smoke can be introduced into the smokehouse through the air recirculation system, can be mixed or injected into the meat, or can be applied by drenching, spraying or dipping (US EPA, 1996).

It is quite reasonable to expect PCDDs and PCDFs to be produced in the smoke generation processes, although the information available on PCDD/PCDF releases is extremely limited. The data given in the UNEP Toolkit appears to be based on a single 1993 report on emissions from smokehouses in Germany. The BAT/BEP Guidance includes reference to another publication by Pohlandt and Marutzky (1994), who found PCDDs and PCDFs in the ash collected from a single smokehouse. The following three emissions factors are recommended in the UNEP Toolkit: 50 μg TEQ tonne^{-1} of product for smokehouses using treated (eg, with pentachlorophenol) wood; 6 μg TEQ tonne^{-1} of product for smokehouses burning clean fuel; and 0.6 μg TEQ tonne^{-1} of product for smokehouses burning clean fuel and fitted with an afterburner. PCDD and PCDF residues are also likely to be present in any process residues (ash), at concentrations similar to those found in wood ash (see sections 12 and 13).

The largest source of smoked meat in New Zealand is bacon and ham. The total annual production of bacon and ham in New Zealand is about 25,000 tonnes per year (Statistics NZ, 2009a; J Kippenberger, Poultry Industry Association of New Zealand, Auckland, pers comm, 2009), although not all of this is smoked. Total poultry production in New Zealand is about 150,000 tonnes per year,[16] but only a small fraction (1.3%) is smoked (J Fick, Poultry Industry Association of New Zealand, Auckland, pers comm, 2009). The total annual seafood harvest, including aquaculture, is over 600,000 tonnes per year, but about 90% of this (by value) is exported.[17] The exports of smoked seafood in 2008 were about 300 tonnes, or 0.1% of total seafood exports. The proportion of smoked seafood produced for local consumption is likely to be slightly higher, and would also include a contribution from non-commercial production (ie, recreational fishers). On this basis, total smoked seafood production is estimated to be no more than about 500 tonnes per year.

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[16] Industry production data published by the Poultry Industry Association of New Zealand, Auckland, http://www.pianz.org.nz.

[17] Seafood production and export data provided by the New Zealand Seafood Industry Council, Wellington, 2009.

From the above data, it appears that a reasonable first estimate for total smoked meat and fish production in New Zealand would be no more than 25,000 tonnes per year. Applying the UNEP Toolkit factor for smoke production using clean fuel indicates a potential PCDD/PCDF release rate to air of no more than 0.150 g TEQ yr^{-1}.

It must be stressed that this estimate relates to the potential for PCDD and PCDF releases from the smokehouses, as opposed to PCDD and PCDF concentrations in the smoked products. The results from routine food surveys indicate that the PCDD and PCDF concentrations in foodstuffs are primarily determined by the type of food and its origin (UNEP, 2005).

30.2 Drycleaning

PCDDs and PCDFs have been detected in the distillation residues from drycleaning, but this is believed to originate from contaminants already present on the textiles from the use of chemicals such as pentachlorophenol and dioxazine dyes (see section 29). The drycleaning process itself does not generate any PCDDs or PCDFs (UNEP, 2005). The PCDDs and PCDFs are found in the residues produced by distillation of the cleaning solvent for recovery and reuse. The UNEP Toolkit indicates release factors of 3000 μg TEQ $tonne^{-1}$ of residue for cleaning of textiles with high levels of PCDD/PCDF contamination, and 50 μg TEQ $tonne^{-1}$ of residue for 'normal' textiles. The source of these factors is not indicated, and it is likely that the current contamination levels in New Zealand will be much lower than at the time the factor was developed. For instance, as discussed in section 29, the incidence of contamination resulting from the use of pentachlorophenol in textiles is now expected to be very low.

There is no accurate data available on the quantities of drycleaning distillation residues produced in New Zealand. However, one estimate obtained from a national waste disposal company put the figure at about 140 tonnes per year (Bingham and Graham, 2006). Applying the low-contamination release factor to this total gives an indicative estimate of 0.007 g TEQ yr^{-1} for PCDD/PCDF releases from this source. The residues are normally disposed to landfill.

30.3 Application of BAT/BEP

Neither of these sources is specifically covered under the BAT/BEP Guidance. However, the emission factors given in the UNEP Toolkit indicate that PCDD and PCDF releases from smokehouses could be reduced through the use of afterburners.

30.4 References

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31 Data Summaries: 2008

A summary of the 2008 estimates of PCDD and PCDF releases to air, land and water is presented in table 31.1 for the 2008 reference year. Estimates for reservoirs are presented in table 31.2.

Summaries of the activity statistics and emission factors used to derive these estimates are provided in tables 31.3 to 31.5, for emissions to air and releases to land and water, respectively. The source of the emission factors used to derive each estimate is also noted in these summary tables. In most cases this is New Zealand data or the UNEP Toolkit.

Table 31.1: Summary of PCDD and PCDF releases for 2008

Source	Annual release estimate (g I-TEQ yr^{-1})					
	Air	Cert[a]	Land[b]	Cert[a]	Water	Cert[a]
Clinical, pathological and quarantine waste incineration	0.657	M, L	0.004	M, L	–	
Hazardous waste incineration	0.000029	H, H	0.000019	H, H	–	
Wastewater solids incineration	0.000086	H, H	0.008	M, L	–	
Document destruction	0.003	H, L	nd		–	
School incinerators	0.021	M, L	0.042	L, L	–	
Animal carcass disposal	0.036	M, L	nd		–	
Crematoria	0.183	H, L	nd		–	
Power generation – coal	0.434	H, M	0.608	H, L	–	
Power generation – oil and gas	0.043	H, L			–	
Industrial, commercial coal combustion	0.829	H, L	0.291	H, L	–	
Industrial, commercial oil and gas combustion	0.019	H, L	–		–	
Domestic coal burning	0.036	H, L	0.00020	M, L	–	
Domestic oil and gas burning	0.01	H, L			–	
Industrial wood and biomass combustion	1.068	H, M	0.320	H, L	–	
Domestic wood burning	0.84	H, L	0.17	M, L	–	
Domestic waste burning	5.40	L, L	10.80	L, L	–	
Land transport	0.39	M, L	–		–	
Forest, scrub and grass fires	3.087	M, L	4.14	M, L	–	
Structure fires	0.85	L, L	0.85	L, L	–	
Vehicle fires	0.31	L, L	0.060	L, L	–	
Cement manufacture	0.050	H, H/M	0.134	H, L	–	
Lime manufacture	0.025	H, L	0.084	M, L	–	
Bricks, tiles, pottery and ceramics	0.005	M, L	nd		–	
Asphalt plants	0.006	H, L	0.026	M, L	–	
Primary steel production	0.08	H, M	0.21	H, L	0.015	H, L
Secondary steel production	0.24	H, H	2.50	H, L	–	
Metal shredding	0.012	H, L	–		–	
Hot-dip galvanising	0.001	L, L	0.025	L, L	–	
Iron foundries	0.15	M, M	0.094	M, L	–	
Non-ferrous metal production	0.13	M, M	1.92	L, L	–	
Primary aluminium production	–		–		–	
Secondary aluminium processing	0.058	M, M	5.4	M, L	–	
Glass production	0.0022	H, L	–		–	
Pulp and paper (recovery boilers)	0.0325	H, H	–		–	
Bleached kraft pulp production			0.083	H, L	–	
Tobacco smoking	0.00033	H, L	nd		–	
Used oil use and disposal	0.022	L, L	0.207	L, L	–	
Use of halogenated pesticides	–	–	< 0.003	H, H	–	
Landfill gas (fugitive emissions)	0.061	L, L	–		–	
Landfill gas combustion	0.026	L, L	–		–	
Landfill fires	2.3	L, L	–		–	
Landfills (solid waste disposal)	–		19.0	H, L	0.74	L, M
Wastewater treatment	–		23.4	H, M	0.823	H, L
Total estimated releases for 2008	17.4		70.38		1.6	

a. The certainty rankings are presented in the order *activity statistic, emission factor ranking.* The rankings are H = high; M = medium; L = low. See section 3.3.

b. The entry 'nd' indicates *not determined*, and a dash (–) indicates that no significant releases are expected.

Table 31.2: Summary of PCDD and PCDF reservoirs for 2008

Source	Reservoir (g I-TEQ)	Certainty[a]
Pulp and paper production (bleached kraft mills)	24.8	M, L
Landfills	660	M, L
Historic use of 2,4,5-T[b]	390–540	M, M
Use of NaPCP as antisapstain – sawmill sites	810	L, L
Use of PCP in diesel sawmill sites	230	M, M
Use of PCP in diesel – treated timber	4270	
Gasworks sites	0.022–5.2	L, M
Total reservoir estimate for 2008	6385–6540	

a. The certainty rankings are unchanged from those reported for 1998, except for pulp and paper production. They are presented in the order *activity statistic, emission factor ranking.* The rankings are H = high; M = medium; L = low. See section 3.3.

b. Reservoir estimate for 2,3,7,8-TCDD.

Table 31.3: Summary of activity statistics and emission factors for emissions to air

Source	Measure	Activity statistic[a] (tonnes yr^{-1})	Emission factor[a] (µg I-TEQ $tonne^{-1}$)	Data source
Clinical, pathological and quarantine waste	Waste	219	3000	UNEP Toolkit
Hazardous waste incineration	Waste	75	0.000029	New Zealand
Wastewater solids incineration	Dry solids	1,500	0.085	New Zealand
Document incineration	Waste	25	100	UNEP Toolkit
School incinerators	Waste	70	300	UNEP Toolkit
Animal carcass disposal – newer units	Weight	208	500	UNEP Toolkit
Animal carcass disposal – older units	Weight	52	50	UNEP Toolkit
Crematoria	Cremations	18,289 yr^{-1}	10 µg $cremation^{-1}$	UNEP Toolkit
Power generation – coal	Fuel	43.3 PJ yr^{-1}	10 µg TJ^{-1}	UNEP Toolkit
Power generation – oil and gas	Fuel	85.4 PJ yr^{-1}	0.5 µg TJ^{-1}	UNEP Toolkit
Industrial, commercial coal – > 10MW	Fuel	13.9 PJ yr^{-1}	10 µg TJ^{-1}	UNEP Toolkit
Industrial, commercial coal – < 10MW	Fuel	6.9 PJ yr^{-1}	100 µg TJ^{-1}	UNEP Toolkit
Domestic coal burning	Fuel	0.36 PJ yr^{-1}	100 µg TJ^{-1}	UNEP Toolkit
Domestic gas burning	Fuel	6.83 PJ yr^{-1}	1.5 µg TJ^{-1}	UNEP Toolkit
Industrial wood combustion	Fuel	21.35 PJ yr^{-1}	50 µg TJ^{-1}	UNEP Toolkit
Domestic wood burning	Fuel	6.9 PJ yr^{-1}	100 µg TJ^{-1}	UNEP Toolkit
Domestic waste burning	Waste	18,000	300	UNEP Toolkit
Transport – petrol, no catalysts	Fuel	1.4×10^{6}	0.1	UNEP Toolkit
Transport – petrol, 2-stroke	Fuel	0.02×10^{6}	2.5	UNEP Toolkit
Transport – diesel	Fuel	2.4×10^{6}	0.1	UNEP Toolkit
Forest, scrub and grass fires	Biomass	600	5	UNEP Toolkit
Agricultural residues	Biomass	174	0.5	UNEP Toolkit
Structure fires	Material	2,125	400	UNEP Toolkit
Vehicle fires	Number	3,329 yr^{-1}	94 µg $fire^{-1}$	UNEP Toolkit
Cement manufacture – Northland	Production	450,000	0.05	UNEP Toolkit
Cement manufacture – Westport	Production	850,000	0.02	New Zealand
Lime manufacture	Production	360,000	0.07	UNEP Toolkit
Bricks, tiles, etc – good control	Production	54,000	0.02	UNEP Toolkit
Bricks, tiles, etc – less control	Production	18,000	0.2	UNEP Toolkit
Asphalt plants	Production	850,000	0.007	UNEP Toolkit
Primary steel production	Production	620,000	0.134	New Zealand
Secondary steel production	Production	260,000	0.92	New Zealand
Hot-dip galvanising – controlled	Production	24,500	0.02	UNEP Toolkit
Hot-dip galvanising – uncontrolled	Production	12,500	0.06	UNEP Toolkit
Metal shredding	Production	120,000	0.2	UNEP Toolkit
Iron foundries	Production	18,000	8.2	New Zealand
Non-ferrous metal production	Production	36,000	3.5	New Zealand
Secondary aluminium processing	Production	20,000	2.9	New Zealand
Glass production	Production	149,200	0.015	UNEP Toolkit
Pulp and paper (recovery boilers)	BLS[b]	1.3×10^{6}	0.025	New Zealand
Tobacco smoking	Cigarettes	$3,349 \times 10^{6}$	0.1 µg $cigarette^{-1}$	UNEP Toolkit
Used oil combustion	Used oil	5,600	4	UNEP Toolkit
Landfill gas, fugitive emissions	Gas	3.06 x TJ yr^{-1}	20 µg TJ^{-3}	2000 Inventory[c]
Landfill gas, flared/utilised gas	Gas	3.30 x TJ yr^{-1}	8 µg TJ^{-1}	UNEP Toolkit
Landfill fires	Number	50 yr^{-1}	1,000	2000 Inventory[c]

a. Activity statistics and emission factors are in the units shown at the top of the table, unless otherwise indicated.

b. BLS = black liquor solids.

c. Refer to the previous inventory report (Ministry for the Environment, 2000b).

Table 31.4: Summary of activity statistics and release factors for releases to land

Source	Measure	Activity statistic[a] (tonnes yr^{-1})	Release factor[a] (µg I-TEQ $tonne^{-1}$)	Data source
Clinical, pathological – quarantine waste	Waste	219	20	UNEP Toolkit
Hazardous waste incineration	Grate ash	0.75	25	New Zealand
Wastewater solids incineration	Dry solids	1500	0.5	UNEP Toolkit
School incinerators	Waste	70	600	UNEP Toolkit
Power generation – coal	Fuel	43.4 PJ yr^{-1}	14 µg TJ^{-1}	UNEP Toolkit
Industrial, commercial coal combustion	Fuel	38.3 PJ yr^{-1}	14 µg TJ^{-1}	UNEP Toolkit
Domestic coal burning	Grate ash	480	0.41	2000 Inventory[b]
Industrial wood combustion	Fuel	21.35 PJ yr^{-1}	15 µg TJ^{-1}	UNEP Toolkit
Domestic wood burning	Fuel	8.4 PJ yr^{-1}	20 µg TJ^{-1}	UNEP Toolkit
Domestic waste burning	Waste	18,000	600	UNEP Toolkit
Forest, scrub and grass fires	Biomass	600	4	UNEP Toolkit
Agricultural residues	Biomass	174	10	UNEP Toolkit
Structure fires	Material	2,125	400	UNEP Toolkit
Vehicle fires	Number	3,329 yr^{-1}	18 µg $fire^{-1}$	UNEP Toolkit
Cement manufacture	Kiln dust	20,000	6.7	Karstensen, 2006
Lime manufacture	Kiln dust	6,000	6.7	Karstensen, 2006
Lime application to land	Quantity	36,000	1.24	Karstensen, 2006
Asphalt plants	Production	0.425×10^6	0.06	UNEP Toolkit
Primary steel production	Plant wastes	46,140	Variable[b]	New Zealand
Secondary steel production	Filter dust	3,600	700	New Zealand
Hot-dip galvanising	Plant wastes	24,500	1000	UNEP Toolkit
Iron foundries	Production	11,700	8	UNEP Toolkit
Non-ferrous metal production	Production	15,350	125	UNEP Toolkit
Secondary aluminium production	Production	18,000	300	UNEP Toolkit
Pulp and paper – sludge	Bleached pulp	415,000	0.2	UNEP Toolkit
Used oil use and disposal	Oil quantities	5,600	37	2000 Inventory[b]
Use of halogenated pesticides	2,4-D production	335	< 0.01 µg kg^{-1}	New Zealand
Landfills (solid waste disposal)	Waste quantity	3.16×10^6	6	UNEP Toolkit
Wastewater treatment	Sludge	234,112	100	UNEP Toolkit

a. Activity statistics and emission factors are in the units shown at the top of the table, unless otherwise indicated.

b. Refer to the previous inventory report (Ministry for the Environment, 2000b).

Table 31.5: Summary of activity statistics and release factors for discharges to water

Source	Measure	Activity statistic[1] (10^6 m^3 yr^{-1})	Release factor[1] (pg I-TEQ L^{-1})	Data source
Primary steel production	Wastewater	3.1	4.7	New Zealand
Landfill leachate	Leachate	3.7	200	New Zealand/ UNEP Toolkit
Wastewater – sludge removal	Wastewater	329	0.5	UNEP Toolkit
Wastewater – no sludge removal	Wastewater	329	2	UNEP Toolkit

1. Activity statistics and emission factors are in the units shown at the top of the table, unless otherwise indicated.

Part 3: Discussion

32 Uncertainties and Data Gaps

The results of most emission inventories have a significant degree of uncertainty, and this is especially so for dioxin inventories. The relatively high cost of dioxin measurements means that the amount of available emissions data is quite limited. In addition, where sources have been studied intensively, the data shows that emissions can be highly variable (eg, Lavric et al, 2004). There are also large uncertainties in the activity data, especially for some of the more significant sources such as domestic rubbish burning and forest, scrub and grass fires.

An assessment of the uncertainties in the dioxin inventories for 13 countries in central and eastern Europe was reported by Pulles and Kok (2005). The emission factors used in the inventories were taken mainly from the UNEP Toolkit, although a limited amount of local source testing was used to check on the relevance of the factors. Activity data was derived from international energy statistics. Using a Monte Carlo analysis, Pulles and Kok estimated that the 90% confidence interval for the total releases to air from all countries was between 1.2 and 7.4 g I-TEQ yr^{-1}, which indicates that the central value of 3.3 g I-TEQ yr^{-1} may only be accurate to within a factor of ± 2.5. Despite these uncertainties, the authors concluded that the results were still quite acceptable for use in decision-making, especially when considered in conjunction with other related EU policy initiatives such as those relating to waste management and ambient air quality.

The uncertainties in the UK dioxin inventory have also been examined using a Monte Carlo technique (AEA Technology, 2006). This showed that most of the uncertainty in the total emission estimates was dominated by three sources: small-scale waste combustion, accidental fires and agricultural waste combustion, which accounted for 45.7% of the total estimated emissions but almost 90% of the uncertainty estimate. These are diffuse sources, and the certainty estimates in both the activity data and emission factors were all ranked as low. By comparison, the fourth largest emitter – iron sinter production – accounted for 8.0% of the total emissions but only 0.9% of the uncertainty, because the available activity and emissions data was of much better quality.

The analysis of the UK inventory results was used to identify those sources for which better-quality activity and/or emissions data would be most useful, and it was noted that the UK Environment Agency was planning to undertake additional monitoring of some of these sources. The results of the previous New Zealand inventory were also used in this way; for example, the additional work on secondary metallurgical sources noted in sections 19 and 20 (Ministry for the Environment, 2004).

32.1 Certainty estimates

The use of certainty estimates in both this and the previous New Zealand inventory is similar to the approach taken with dioxin inventories in other countries, and is recognised internationally as ‘good practice’ (AEA Technology, 2006). The same approach was used in the US inventory (US EPA, 2006a), but with two additional categories of ‘preliminary estimate’ and ‘not quantified’. These were applied, respectively, to sources where the data was either extremely limited or non-existent. The US approach has effectively been applied in the current inventory to some of the sources discussed in section 32.2 (‘Data gaps’).

The reasons for each of the certainty estimates given in this report have been noted within each section and need not be repeated here. However, the following broad observations are relevant.

- The certainty estimates for activity factors were assessed as high for 57%, medium for 26% and low for 18% of the 37 sources of dioxin emissions to air, whereas the emission factors were estimated as 12% high, 20% medium and 68% low. The corresponding distributions for the 2000 Inventory were 57% high, 15% medium and 28% low for the activity data, and 10% high, 20% medium and 70% low for the emission factors, across 30 sources.
- For the 27 sources of releases to land, the certainty distribution for the activity factors was 41% high, 33% medium and 26% low, while the release factors were assessed as 7% high, 4% medium and 89% low. The corresponding distributions for the 2000 Inventory were 38% high, 46% medium and 16% low for activity data, and 0% high, 16% medium and 83% low for the release factors, across 24 sources.
- The certainties in the estimates for releases to water (four sources) and reservoirs (six sources) were all assessed as either medium or low, apart from the activity data for two of the sources of discharges to water.
- The certainties in the estimates for the three largest contributors of emissions to air – domestic waste burning, forest, scrub and grass fires, and landfill fires, which account for 62.2% of the total emissions – were all assessed as low/low (activity/release).
- The certainty estimates for the three largest contributors of releases to land were more variable, with wastewater treatment ranked as high/medium, landfills as high/low, and domestic waste burning as low/low. Together these three sources account for 76% of the total releases to land.

The above analysis indicates that there has been little change overall in the certainty estimates for the inventory results when compared to the previous inventory. There have been some improvements at an individual source level (eg, the additional emissions data for secondary metallurgical sources), but these gains have been offset by the inclusion of additional poorly characterised sources.

32.2 Data gaps

The most significant data gap in both this and the previous inventory is the lack of specific New Zealand dioxin emissions data for most of the sources. This situation is unlikely to change markedly over time, nor is it unique to New Zealand, because of the relatively high costs of dioxin testing and analysis. The use of the UNEP Toolkit has been helpful in ensuring that the emission factors are drawn from a reasonably representative international database. However, the non-specific nature of many of the inventory results should be kept in mind when considering individual New Zealand sources.

Dioxin releases from animal carcass disposal by open burning (section 7.1.3) and the burning of construction and demolition timbers (section 16.1.4) were noted in the inventory as being potentially significant. However, neither of these was included in the release estimates because of the lack of reliable activity data.

The following potential sources of releases to land were also not quantified, although they were all assessed as likely to be very minor contributors to the overall total: document destruction (section 7.2.1), crematoria (8.2), metal shredding (18.2.4), tobacco smoking (23.2), drycleaning residues (30.2), the use of halogenated pesticides (chlorothalonil, DCNA, DCPA and oxadiazon – section 25.1.2), and the use of chloranil (29.1).

33 Review of Laws and Policies

33.1 Current laws and policies

The Resource Management Act 1991 (RMA) is the primary piece of legislation for environmental management in New Zealand and has the purpose of promoting the sustainable management of natural and physical resources. Regional councils have the primary functions under the Act for controlling discharges to air, land and water. The RMA framework allows councils and central government to develop a mix of regulation, promotion, education and enforcement for addressing environmental issues, including the control of dioxin emissions.

The tools available to regional councils for managing discharges from specific sources or groups of sources are regional policy statements, regional plans and resource consents. All regional councils have proposed or operative plans to address discharges to air, land and water. Many of these contain rules that relate to activities that produce unintended releases of dioxins and other POPs (eg, prohibitions on the open burning of certain substances, and consent requirements for specific industrial processes).

The Minister for the Environment can issue national policy statements and make national environmental standards that are promulgated as regulations. The Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004, October 2004, now includes amendments made in December 2004, July 2005, and November 2008. These Regulations prohibit seven activities that would otherwise discharge significant quantities of dioxins and other air toxics:

i. lighting fires and burning of waste at landfills
ii. burning of tyres in the open
iii. burning of coated wire in the open
iv. bitumen burning for road maintenance
v. burning of oil in the open (with some exceptions)
vi. operating an incinerator at a school or a health-care institution, unless a resource consent was obtained by September 2006
vii. operating new high-temperature hazardous waste incinerators.

The Regulations also included a requirement for large landfill sites to collect and destroy greenhouses gases (by September 2007). Although the purpose of this Regulation is to control greenhouse gas emissions at landfills, its effect will also be to reduce the likelihood of a spontaneous or accidental fire, and in that sense this Regulation can also be seen as a POPs release reduction measure.

Two other national environmental standards included in the Regulations were directed at improving air quality but will also have significant effects on minimising the release of dioxins from combustion.

- The ambient air quality standards place limits on allowable levels of PM_{10} and require air quality improvements in airsheds where the standard is exceeded. Reducing particulate emissions in order to comply with the standard will also reduce releases of dioxins associated with the particulate matter.

- In addition, new wood burners sold for installation in domestic dwellings are required to meet specific flue gas particulate and thermal efficiency design standards.

Also of note is the government response to the issue of leaded fuels. Unleaded petrol was introduced to New Zealand in 1986 and the use of halogenated lead scavengers ceased in 1995. The Government has now introduced tighter controls on vehicle design standards for emission control in line with internationally accepted standards. Although the main objective is to reduce air pollution generally, such measures may also have the beneficial effect of reducing releases of dioxins from land transport sources.

Finally, mention should also be made here of the Hazardous Substances and New Organisms Act 1996 (HSNO Act). The main focus of this legislation is on controlling the import, manufacture and use of hazardous substances (and new organisms) and it generally does not cover manufactured articles. However, the HSNO substance approvals and controls can be relevant to preventing the import or use of substances potentially contaminated with dioxins (ie, those discussed in sections 25 and 29). These controls have already been applied to the import and use of PCBs and the organochlorine pesticides covered under the Stockholm Convention.

The HSNO Act also provides for controls to be placed on the disposal of approved substances (eg, a requirement that they be disposed in an appropriate manner, such as at a controlled landfill). This could be relevant to prohibiting the disposal of particular substances by burning, if that were considered to be a significant potential source of PCDD and PCDF releases.

33.2 Effectiveness of current laws and policies

Landfill fires were identified in the 2000 Inventory as the most significant source of dioxin emissions to air. However, the release estimates have dropped significantly: from 10–15 g I-TEQ yr^{-1} in 1998 (nearly 40% of the total emissions) to 2.3 g I-TEQ yr^{-1} in 2008 (13% of the total). This can be attributed to a combination of the above Regulations and other significant improvements in landfill management practices. The latter was a key component of the New Zealand Waste Strategy 2002, and has been promoted by the Ministry for the Environment through a programme of periodic landfill audits and the publication of a series of good practice guidance documents for landfill management.

Another significant source targeted by the 2004 Regulations was the incineration of clinical, pathological and quarantine wastes. Twenty-four incinerators were identified in the 2000 Inventory, but there are now only two: one used for hospital wastes and the other for quarantine wastes. The emission estimates have reduced from 0.38–3.5 g I-TEQ yr^{-1} in 1998 to 0.66 g I-TEQ yr^{-1} in 2008.

The dioxin emission estimates for domestic wood burning have dropped significantly (from 0.7–8.7 g I-TEQ yr^{-1} in 1998 to 0.84 g I-TEQ yr^{-1} in 2008), but this is almost entirely due to the use of a much lower emission factor rather than to any major changes in wood consumption. The activity estimates for domestic wood burning show a relatively minor reduction: from 713,000 tonnes per year in 1998 to 667,000 tonnes per year in 2008. However, more significant reductions in dioxin releases from wood burning are expected in the future as a result of the actions currently being taken by many regional councils to improve air quality by reducing emissions of fine particulates.

The activity estimates for domestic waste burning have shown a significant reduction in total waste quantities, which were estimated at 58,000 tonnes/year in 1998 and 18,000 tonnes/year in 2008. However, this is not reflected in the dioxin emission estimates (0.54–6.4 g I-TEQ yr^{-1} in 1998 compared to 5.4 g I-TEQ yr^{-1} in 2008) because of changes in the emission factors. Some additional reductions in domestic waste burning can be expected over the next few years because bans on this activity are currently being considered by several regional councils as part of their programmes to address regional particulate emissions (this is in addition to those regions where domestic waste burning is already banned).

The estimates for dioxin emissions to air from land transport have shown a significant reduction over the 10-year period (from 0.11–1.2 g I-TEQ yr^{-1} in 1998 to 0.39 g I-TEQ yr^{-1} in 2008). Both of these estimates post-date the restrictions on the use of leaded petrol, and the reduction in the emission estimates is due to an increase in the proportion of vehicles fitted with exhaust catalysts. This trend is expected to continue as a result of the current vehicle exhaust emission requirements on vehicle imports.

33.3 Conclusions

It is clear from the above that significant reductions in dioxin releases have been achieved through a combination of national and regional activities directed at specific sources. Some reductions have also occurred as an indirect result of other initiatives (eg, the programmes for reducing particulate emissions to air, and upgrading the operation and management of landfills). Some possible options to further reduce releases of dioxins are discussed in the next section. These could all be implemented under existing laws and policies.

34 Possible Actions to Further Reduce Releases of Dioxins

34.1 Discussion

The work presented in this report provides a starting point for identifying possible actions to achieve further reductions in the releases of PCDDs and PCDFs, in accordance with New Zealand's obligations under the Stockholm Convention. The release estimates for each source give an indication of the relative potential for achieving reductions. Similarly, the BAT/BEP assessment given in each section is helpful in identifying those sources with the greatest potential for achieving improvements through the upgrading of process technologies, emission controls or other relevant aspects.

A brief summary of the key information for the more significant New Zealand sources is given in table 34.1. This shows all of the source categories that contribute 1% or more of the releases to air, land or water, and the current compliance with the BAT/BEP recommendations. The most relevant option to achieve a further reduction for each source is listed in the fourth column of the table. These options are discussed in more detail below.

34.2 Possible actions

As discussed in section 33, significant reductions in dioxin releases have already been achieved in New Zealand through a combination of national and regional activities directed at specific sources. Some reductions have also occurred as an indirect result of other initiatives (eg, the programmes for reducing particulate emissions to air, and upgrading landfill operation and management).

Further and incremental reductions in dioxin releases are considered possible and could be achieved by ongoing support for current initiatives, coupled with additional national and regional activities that target selected sources. All options could be implemented under existing laws and policies by using, for example, national regulation and guidance, and regional plans and consents.

National regulation

No new national regulations would appear to be warranted, on the basis that most of the significant industrial sources can be managed effectively and more appropriately through other existing control mechanisms, such as resource consents. Non-industrial sources, such as uncontrolled fires and domestic heating, are also more appropriately controlled by other means.

National regulation was considered in relation to the need to *require* BAT/BEP for the new sources listed in Annex C, Part II, of the Stockholm Convention (see section 2.4). However, the only sources likely to be of any relevance in New Zealand are secondary metal production processes, and even here the number of new sources is expected to be few. The more appropriate approach, therefore, would be the provision of national guidance, as discussed below.

National guidance

Most industrial sources of PCDDs and PCDFs are controlled in New Zealand under the Resource Management Act 1991, through the issuing of resource consents by regional councils.

Table 34.1: Source analysis and proposed actions

Source category	Significance	BAT/BEP status	Possible actions
Clinical, pathological and quarantine waste incineration (2 units only)	3.8% of air, 0.7% of total	Do not comply	Review existing RMA consents for consistency with BAT/BEP
Crematoria	1.1% of air, 0.2% of total	Variable compliance	National guidance (eg, good practice guide)
Power generation – coal	2.5% of air, 0.9% of land, 1.2% of total	Complies	None
Industrial, commercial coal combustion	4.8% of air, 0.4% of land, 1.3% of total	Variable compliance	National guidance (eg, good practice guide)
Industrial wood and biomass combustion	6.1% of air, 0.5% of land, 1.2% of total	Variable compliance	National guidance (eg, good practice guide)
Domestic wood burning	4.8% of air, 0.2% of land, 1.1% of total	Variable compliance	Support for current moves to reduce PM_{10} emissions
Domestic waste burning	31.1% of air, 15.3% of land, 18.1% of total	Variable compliance	Encourage local restrictions and alternative disposal practices
Transport	2.2% of air, 0.4% of total	Variable compliance	Addressed through current national programmes
Forest, scrub and grass fires	17.8% of air, 5.9% of land, 8.1% of total	Variable compliance	Encourage local restrictions and alternative practices
Structure fires	4.9% of air, 1.2% of land, 1.9% of total	No guidance	Addressed through existing fire prevention programmes
Vehicle fires	1.8% of air, 0.1% of land, 0.4% of total	No guidance	Addressed through existing fire prevention programmes
Construction and demolition timber	No data but probably significant (see 16.1.4)	Variable compliance	Encourage local restrictions and alternative disposal practices
Secondary steel production	1.4% of air, 3.6% of land, 3.1% of total	Complies	National guidance (eg, good practice guide)
Iron foundries, non-ferrous metals and secondary aluminium	1.9% of air, 10.5% of land, 8.7% of total	Variable compliance	National guidance (eg, good practice guide)
Landfill fires	13.2% of air, 2.6% of total	Variable compliance	Support regional councils in enforcing RMA regulations
Solid waste disposal (landfills)	27.0% of land, 21.3% of total	No guidance	None
Landfill leachate	46.2% of water, 0.8% of total	No guidance	None
Wastewater treatment liquids	51.4% of water, 0.9% of total	No guidance	None
Wastewater treatment sludge disposal	33.3% of land, 26.2% of total	No guidance	None

The Ministry for the Environment has published a series of good practice guides on various aspects of air quality management, including dust, odour, ambient air monitoring, and the assessment of industrial discharges. This approach could also be effective for those groups of sources where specific national guidance on the BAT/BEP recommendations would be appropriate, to ensure a reasonable degree of consistency in the controls applied throughout the country. In addition, it should result in a gradual reduction in releases over time as existing resource consents come up for renewal.

The candidate sources for good practice guides could include the industrial and commercial combustion of coal, oil, wood and other biomass, crematoria and secondary metal production, and other minor sources (not listed in table 34.1) such as pet cremators. The good practice guides could either be specific to dioxin release reductions, or they could cover a wider range of pollutants and/or discharges.

A national guidance document could also be considered for the treatment and disposal of bag-filter residues and other process wastes from iron foundries and secondary metal production. Currently some of these wastes are exported for processing and metals recovery, but most are simply disposed to landfill. Dioxins are not specifically covered in the New Zealand waste acceptance criteria for landfills, and the application of any such limit would be cost-prohibitive (in terms of testing/monitoring requirements). However, some guidance on the options for metal recovery and/or waste pre-treatment may be appropriate.

Support for existing activities

The current regional initiatives for achieving reductions in particulate emissions to air are also relevant to dioxin reductions, especially for domestic coal and wood burning. The Ministry for the Environment is already working closely with regional councils in support of these activities.

Landfill fires are prohibited under the RMA Regulations, but the most recent New Zealand Fire Service statistics (2006/07) show that there are still around 50 fires a year. This suggests a need for continuing support for regional councils in their enforcement of the Regulations.

Regional regulation and enforcement

Many regional councils already have controls on open burning, including for the purposes of land clearance and the burning of domestic wastes, and these activities could be supported by central government, as and when appropriate.

No useful action identified

The dioxin content of the sludge produced by wastewater treatment plants is primarily driven by the dioxin content of the wastewater inputs, usually from both domestic and industrial sources. There are no practical controls that can be applied within the waste treatment processes themselves to minimise dioxin outputs. In addition, the input sources for most plants are so many and so varied that it would be extremely difficult to identify specific sources that could be targeted for release reductions.

The dioxin content of the solid wastes disposed to landfills is also driven by waste inputs. In this case it may be possible to target some specific ‘high risk’ sources, such as wastes from secondary metal production (see sections 19 and 20). However, there are unlikely to be any practical options for the more diverse inputs from domestic, commercial and industrial wastes generally.

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Appendix: UNEP Toolkit Spreadsheets

The UNEP Toolkit was developed by UNEP Chemicals with the aim of achieving an effective and standardised approach to the compilation of PCDD/PCDF emission inventories (UNEP, 2005). This was intended to ensure a reasonable degree of consistency between the inventories reported by different countries as part of their requirements under the Stockholm Convention, and should also help in comparing inventory results between countries, or changes over time.

Overall, the amount of data used in developing the Toolkit factors for each source subcategory is still quite limited. In addition, some of it is relatively dated. It should also be recognised that some source characteristics may vary significantly between countries; for example, the Toolkit factors for industrial coal combustion appear to be based on relatively large boilers, whereas a third of all New Zealand plants would be classified as small (< 10 MW). Local emission factors have been used, whenever available, to address this point.

Results in the Toolkit format

The UNEP Toolkit includes a spreadsheet for determining the release estimates. The New Zealand activity data has been entered into the spreadsheet and the resulting release calculations are shown on the following pages. The one notable difference between these estimates and those given in the main body of this report is that the Toolkit distinguishes between releases to land and process residues, whereas these are all treated as releases to land in the 2011 Inventory report. There may also be some minor discrepancies due to differences in rounding.

The following points may assist in understanding the Toolkit tables A1 to A10

- Shading has been used in Columns D (Subcategories) and C (Potential release route) to indicate the source categories relevant to New Zealand. Additional rows have also been inserted where the treatment of New Zealand sources differs from the Toolkit (usually through the use of local emission factors).
- The worksheets are used by inserting New Zealand activity data in the **Production** columns.
- The totals for each subcategory are shown in the **top row** of each sub-group block, rather than in the bottom row.

(Note: all annual releases given in the tables are in grams TEQ per annum (ie, g TEQ/a).

Summary table from spreadsheet

Cat.	Source categories	Annual releases (g TEQ/a)				
		Air	Water	Land	Product	Residue
1	Waste incineration	0.717	0.000	0.000	0.000	0.047
2	Ferrous and non-ferrous metal production	0.679	0.015	0.210	0.000	9.938
3	Heat and power generation	3.366	0.000	0.000	0.000	1.387
4	Production of mineral products	0.090	0.000	0.218	0.000	0.026
5	Transportation	0.415	0.000	0.207	0.000	0.000
6	Open burning processes	11.950	0.000	15.850	0.000	0.000
7	Production of chemicals and consumer goods	0.033	0.000	0.000	0.000	0.083
8	Miscellaneous	0.183	0.000	0.000	0.000	0.000
9	Disposal	0.000	1.563	18.960	0.000	23.411
1–9	**Total**	**17.420**	**1.578**	**35.445**	**0.000**	**34.892**
	Grand total	**89.34**				

Table A1: Category 1 – Incineration

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)						Production	Annual release, g TEQ/a					
				Air	Water	Land	Product	Fly ash	Bottom ash	tonnes/a	Air	Water	Land	Product	Fly ash	Bottom ash
1			**Waste incineration**													
	a		**Municipal solid waste incineration**							**0**	**0.000**	**0**	**0**	**0**	**0.000**	**0.000**
		1	Low-tech combustion, no APCS	3,500		NA	NA	0	75		0.000				0.000	0.000
		2	Controlled combustion, minimal APCS	350		NA	NA	500	15		0.000				0.000	0.000
		3	Controlled combustion, good APCS	30		NA	NA	200	7		0.000				0.000	0.000
		4	High-tech combustion, sophisticated APCS	0.5		NA	NA	15	1.5		0.000				0.000	0.000
	b		**Hazardous waste incineration**							**75**	**0.000030**	**0**	**0**	**0**	**0.000000**	**0.000019**
		1	Low-tech combustion, no APCS	35,000		NA	NA	9,000			0.000000				0.000000	0.000000
		2	Controlled combustion, minimal APCS	350		NA	NA	900			0.000000				0.000000	0.000000
		3	Controlled combustion, good APCS	10		NA	NA	450			0.000000				0.000000	0.000000
			New Zealand plant, using site-specific factors	0.40		NA	NA	NA	0.25	75	0.000030					0.000019
		4	High-tech combustion, sophisticated APCS	0.75		NA	NA	30			0.000000				0.000000	0.000000
	c		**Medical waste incineration**							**219**	**0.657**	**0**	**0**	**0**	**0.000**	**0.004**
		1	Uncontrolled batch combustion, no APCS	40,000		NA	NA		200		0.000				0.000	0.000
		2	Controlled batch combustion, no or minimal APCS (New Zealand medical and quarantine)	3,000		NA	NA		20	219	0.657				0.000	0.004
		3	Controlled batch combustion, good APCS	525		NA	NA	920	ND		0.000				0.000	
		4	High-tech, continuous, sophisticated APCS	1		NA	NA	150			0.000				0.000	0.000
	d		**Light fraction shredder waste incineration**							**0**	**0.000**	**0**	**0**	**0**	**0.000**	**0.000**
		1	Uncontrolled batch combustion, no APCS	1,000		NA	NA	ND	ND		0.000					
		2	Controlled, batch, no or minimal APCS	50		NA	NA	ND	ND		0.000					
		3	High-tech, continuous, sophisticated APCS	1		NA	NA	150			0.000				0.000	0.000

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)						Production	Annual release, g TEQ/a					
				Air	Water	Land	Product	Fly ash	Bottom ash	tonnes/a	Air	Water	Land	Product	Fly ash	Bottom ash
	e		**Sewage sludge incineration**							**0**	**0.000086**	**0**	**0**	**0**	**0.000750**	**0.000000**
		1	Old furnaces, batch, no/little APCS	50		NA	NA	23			0.000000				0.000000	0.000000
		2	Updated furnaces, continuous, some APCS	4		NA	NA	0.5			0.000000				0.000000	0.000000
			New Zealand plant, site-specific factors	0.057		NA	NA	0.5		1,500	0.000086				0.000750	0.000000
		3	State-of-the-art, full APCS	0.4		NA	NA	0.5			0.000000				0.000000	0.000000
	f		**Waste wood and waste biomass incineration**							**95**	**0.0235**	**0**	**0**	**0**	**0.0420**	**0.0000**
		1	Old furnaces, batch, no/little APCS	100		NA	NA	1,000			0.0000				0.0000	0.0000
			New Zealand document incinerators	100		NA	NA	NA		25	0.0025					0.0000
			New Zealand school incinerators	300		NA	NA	600		70	0.0210				0.0420	0.0000
		2	Updated furnaces, continuous, some APCS	10		NA	NA	10			0.0000				0.0000	0.0000
		3	State-of-the-art, full APCS	1		NA	NA	0.2			0.0000				0.0000	0.0000
	g		**Animal carcasses burning**							**260**	**0.0364**	**0**	**0**	**0**	**0.0000**	**0.0000**
		1	Old furnaces, batch, no/little APCS	500		NA	NA		ND	52	0.0260				0.0000	
		2	Updated furnaces, continuous, some APCS	50		NA	NA		ND	208	0.0104				0.0000	
		3	State-of-the-art, full APCS	5		NA	NA		ND		0.0000				0.0000	
1			**Waste incineration**								**0.717016**	**0**	**0**	**0**	**0.042750**	**0.004399**
											Fly ash + Bottom ash = 0.047149					

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors), APCS = air pollution control systems.

Table A2: Category 2 – Ferrous and non-ferrous metal production

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
2			**Ferrous and non-ferrous metal production**											
	a		**Iron ore sintering**						**0**	**0.000**	**0**	**0**	**0**	**0.0**
		1	High-waste recycling, including oil-contaminated materials	20	ND	ND	ND	0.003		0.000				0.000
		2	Low-waste use, well-controlled plant	5	ND	ND	ND	0.003		0.000				0.000
		3	High-tech, emission reduction	0.3	ND	ND	ND	0.003		0.000				0.000
	b		**Coke production**						**0**	**0.000**	**0.000**	**0**	**0**	**0**
		1	No gas cleaning	3	0.06	ND	ND	ND		0.000	0.000			
		2	Afterburner / dust removal	0.3	0.06	ND	ND	ND		0.000	0.000			
	c		**Iron and steel production plants plus foundries**						**898,000**	**0.470**	**0.015**	**0.210**	**0**	**2.594**
			Iron and steel plants						880,000	0.322	0.015	0.210	0	2.500
		1	Dirty scrap, scrap preheating, limited controls	10	ND	ND	NA	15		0.000				0.000
		2	Clean scrap / virgin iron, afterburner, fabric filter	3	ND	ND	NA	15		0.000				0.000
			Clean scrap etc – Pacific Steel	0.92	ND	ND	NA	15	260,000	0.239				2.500
		3	Clean scrap / virgin iron, Blast furnaces	0.1	ND	ND	NA	1.5		0.000				0.000
		4	Hot air cupola or induction furnace, fabric filter	0.03	ND	ND	NA	0.5		0.000				0.000
			Primary – NZ Steel	0.134					620,000	0.083	0.015	0.210		
			Foundries						18,000	0.148	0	0	0	0.094
		1	Cold air cupola or rotary drum, no APCS	10	ND	ND	NA	ND		0.000				
		2	Rotary drum – fabric filter	4.3	ND	ND	NA	0.2		0.000				0.000
		3	Cold air cupola, fabric filter	10	ND	ND	NA	8		0.000				0.000
			New Zealand plants and factors	8.2	ND	ND	NA	8	18,000	0.148				0.094
		4	Hot air cupola or induction furnace, fabric filter	0.03	ND	ND	NA	0.5		0.000				0.000
			Hot-dip galvanising plants						**37,000**	**0.00124**	**0**	**0**	**0**	**0.025**
		1	Facilities without APCS	0.06	NA	NA	NA	ND	12,500	0.00075				
		2	Facilities without degreasing step, good APCS	0.05	NA	NA	NA	2,000		0.00000				0.000
		3	Facilities with degreasing step, good APCS	0.02	NA	NA	NA	1	24,500	0.00049				0.025

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
	d		**Copper production**						**36,000**	**0.126**	**0**	**0**	**0**	**1.920**
		1	Secondary Cu – basic technology	800	ND	NA	NA	630		0.000				0.000
		2	Secondary Cu – well controlled	50	ND	NA	NA	630		0.000				0.000
		3	Secondary Cu – optimised for PCDD/PCDF control	5	ND	NA	NA	300		0.000				0.000
			New Zealand plants/factors – all non-ferrous metals	3.5	ND	NA	NA	300	36,000	0.126				1.920
		4	Smelting and casting of Cu and Cu alloys	0.03	ND	NA	NA	ND		0.000				
		5	Primary Cu, well controlled, with some secondary feed materials	0.01	ND	NA	NA	ND		0.000				
		6	Pure primary Cu smelters with no secondary feed	ND	ND	NA	NA	NA						
	e		**Aluminium production**						**20,000**	**0.058**	**0.000**	**0.000**	**0.000**	**5.400**
		1	Processing scrap Al, minimal treatment of inputs, simple dust removal	150	ND	NA	NA	200		0.000				0.000
		2	Scrap treatment, well controlled, good APCS	35	ND	NA	NA	400		0.000				0.000
		3	Scrap treatment, well controlled, fabric filter, lime injection	5	ND	NA	NA	100		0.000				0.000
			New Zealand plants and factors	2.9	ND	NA	NA	300	20,000	0.058				5.400
		4	Optimised process for PCDD/PPCDF abatement	0.5	ND	NA	NA	100		0.000				0.000
		5	Shavings/turnings drying (simple plants)	5.0	NA	NA	NA	NA		0.000				
		6	Thermal de-oiling, rotary furnaces, afterburners, fabric filters	0.3	NA	NA	NA	NA		0.000				
		7	Pure primary Al plants	ND	NA	NA	NA	ND						
	f		**Lead production**						**0**	**0.000**	**0**	**0**	**0**	**0.000**
		1	Secondary lead from scrap, PVC battery separators	80	ND	NA	NA	ND		0.000				
		2	Secondary from PVC/Cl_2 free scrap, some APCS	8	ND	NA	NA	5		0.000				0.000
		3	Secondary lead, PVC/Cl_2 free scrap in modern furnaces, with scrubber	0.5	ND	NA	NA	ND		0.000				
		4	Pure primary lead production	0.5	ND	NA	NA	ND		0.000				
	g		**Zinc production**						**0**	**0.000**	**0**	**0**	**0**	**0.000**
		1	Kiln with no dust control	1,000	ND	NA	NA	ND		0.000				
		2	Hot briquetting / rotary furnaces, basic control	100	ND	NA	NA	ND		0.000				
		3	Comprehensive control	5	ND	NA	NA	ND		0.000				
		4	Melting (only)	0.3	ND	NA	NA	ND		0.000				
		5	Pure primary zinc production	ND	ND	NA	NA	ND						

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
	h		**Brass and bronze production**						**0**	**0.000**	**0**	**0**	**0**	**0.000**
		1	Thermal de-oiling of turnings	2.5	NA	NA	NA	NA		0.000				
		2	Simple melting furnaces	10	NA	NA	NA	ND		0.000				
		3	Mixed scrap, induction furnace, bag filter	3.5	ND	NA	NA	125		0.000				0.000
		4	Sophisticated equipment, clean inputs, good APCS	0.1	ND	NA	NA	ND		0.000				
	i		**Magnesium production**						**0**	**0.000**	**0.0**	**0.0**	**0.0**	**0.0**
		1	Using MgO/C thermal treatment in Cl_2, no effluent treatment, poor APCS	250	9,000	NA	ND	0		0.000	0.000			
		2	Using MgO/C thermal treatment in Cl_2, comprehensive pollution control	50	24	NA	ND	9,000		0.000	0.000			0.000
		3	Thermal reduction process	3	ND	NA	NA	ND		0.000				
	j		**Thermal non-ferrous metal production (eg, Ni)**						**0**	**0.000**	**0**	**0**	**0**	**0**
		1	Contaminated scrap, simple or no APCS	100	ND	ND	ND	ND		0.000				
		2	Clean scrap, good APCS	2	ND	ND	ND	ND		0.000				
	l		**Shredders**						**120,000**	**0.024**	**0**	**0**	**0**	**0**
		1	Metal-shredding plants	0.2	NA	NA	ND	ND	120,000	0.024				
	m		**Thermal wire reclamation**						**0**	**0.000**	**0**	**0**	**0**	**0**
		1	Open burning of cable	5,000	ND	ND	ND	ND		0.000				
		2	Basic furnace with afterburner, wet scrubber	40	ND	NA	ND	ND		0.000				
		3	Burning electric motors, brake shoes, etc, afterburner	3.3	ND	NA	ND	ND		0.000				
2			**Ferrous and non-ferrous metal production**							**0.679**	**0.015**	**0.210**	**0.000**	**9.938**

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors), APCS = air pollution control systems.

Table A3: Category 3 – Heat and power generation

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/TJ)					Production	Annual release, g TEQ/a					Ash generation
				Air	Water	Land	Product	Residue	TJ/a	Air	Water	Land	Product	Residue	tonnes/a
3			**Heat and power generation**												
	a		**Fossil fuel power plants**						**149,600**	**1.325**	**0**	**0**	**0**	**0.899**	
		1	Fossil fuel/waste co-fired power boilers	35	ND	NA	NA	ND		0.000					
		2	Coal-fired power boilers (New Zealand electricity)	10	ND	NA	NA	14	43,400	0.434				0.608	
			New Zealand industrial coal, > 10MW	10	ND	NA	NA	14	13,900	0.139				0.195	
			New Zealand industrial coal, < 10MW	100	ND	NA	NA	14	6,900	0.690				0.097	
		3	Heavy-fuel-fired power boilers	2.5	ND	NA	NA	ND		0.000					
		4	Shale-oil-fired power plants	1.5	ND	NA	NA	ND		0.000					
		5	Light-fuel-oil / natural-gas-fired power boilers	0.5	ND	NA	NA	ND	38,300	0.019					
			New Zealand-oil / natural-gas-fired power boilers (electricity)	0.5	ND	NA	NA	ND	85,400	0.043					
	b		**Biomass power plants**						**21,350**	**1.068**	**0**	**0**	**0**	**0.320**	
		1	1. Mixed-biomass-fired power boilers	500	ND	NA	NA	ND		0.000					
		2	2. Clean-wood-fired power boilers	50	ND	NA	NA	15	21,350	1.068				0.320	
	c		**Landfill and biogas combustion**	**µg TEQ/TJ**					**6.4**	**0.087**	**0**	**0**	**0**	**0**	
		1	Biogas- / landfill-gas-fired boilers, motors/turbines and flaring	8	ND	NA	NA	NA	3.3	0.026					
			New Zealand fugitive emissions	20	ND	NA	NA	NA	3.1	0.061					
	d		**Household heating and cooking – biomass**					**µg TEQ/t ash**	**8,400**	**0.840**	**0**	**0**	**0**	**0.168**	
		1	Contaminated-wood/biomass-fired stoves	1,500	ND	NA	NA	1,000		0.000				0.000	
		2	Virgin-wood/biomass-fired stoves	100	ND	NA	NA	10							
			New Zealand estimates	100	ND	NA	NA	20	8,400	0.840				0.168	
	e		**Domestic heating – fossil fuels**					**µg TEQ/t ash**	**7,200**	**0.046**	**0**	**0**	**0**	**0.0002**	
		1	High-chlorine coal-fired stoves	12,000	ND	NA	NA	30,000		0.000				0.0000	
		2	Coal-fired stoves	100	ND	NA	NA	5,000		0.000				0.0000	
			New Zealand estimates	100	ND	NA	NA	0.41	360	0.036				0.0002	480
		3	Oil-fired stoves	10	ND	NA	NA	NA	10	0.0001					
		4	Natural-gas-fired stoves	1.5	ND	NA	NA	NA	6,830	0.010					
3			**Heat and power generation**							**3.366**	**0**	**0**	**0**	**1.387**	

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors), TJ = terrajoules

Table A4: Category 4 – Production of mineral products

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
4			**Production of mineral products**											
	a		**Cement kilns**						**1,300,000**	**0.052**	**0**	**0.134**	**0**	**0**
		1	Shaft kilns	5	NA	NA	ND	ND		0.000				
		2	Old wet kilns, ESP temperature > 300°C	5	NA	ND	ND	NA		0.000				
		3	Wet kilns, ESP/FF temperature 200–300°C	0.6	NA	ND	ND	NA		0.000				
		4	Wet kilns, ESP/FF temperature < 200°C and all types of dry kilns with preheater/precalciner, T < 200°C	0.05	NA	ND	ND	NA	850,000	0.043				
			New Zealand – Westport plant	0.02	NA		ND	NA	450,000	0.009		0.134		
	b		**Lime**						**360,000**	**0.025**	**0**	**0.084**	**0**	**0**
		1	Cyclone / no dust control, contaminated or poor fuels	10	ND	ND	ND	ND		0.000				
		2	Good dust abatement	0.07	ND	ND	ND	ND	360,000	0.025		0.084		
	c		**Brick (+ New Zealand tiles, pottery, ceramics)**						**18,000**	**0.005**	**0**	**0**	**0**	**0**
		1	Cyclone / no dust control, contaminated or poor fuels	0.2	NA	ND	ND	ND	18,000	0.004				
		2	Good dust abatement	0.02	NA	ND	ND	ND	54,000	0.001				
	d		**Glass**						**149,200**	**0.0022**	**0**	**0**	**0**	**0**
		1	Cyclone / no dust control, contaminated or poor fuels	0.2	NA	ND	ND	ND		0.0000				
		2	Good dust abatement	0.015	NA	ND	ND	ND	149,200	0.0022				
	e		**Ceramics**						**0**	**0.000**	**0**	**0**	**0**	**0**
		1	Cyclone / no dust control, contaminated or poor fuels	0.2	NA	ND	ND	ND		0.000				
		2	Good dust abatement	0.02	NA	ND	ND	ND		0.000				
	f		**Asphalt mixing**						**850,000**	**0.006**	**0**	**0**	**0**	**0.026**
		1	Mixing plant with no gas cleaning	0.07	NA	ND	ND	ND		0.000				
		2	Mixing plant with fabric filter, wet scrubber	0.007	NA	ND	ND	0.06	850,000	0.006				0.026
	g		**Oil shale processing**						**0**	**0.000**	**0**	**0**	**0**	**0.000**
		1	Thermal fractionation	ND	ND	ND	ND	ND						
		2	Oil shale pyrolysis	0.003	NA	ND	0.07	2		0.000			0.000	0.000
4			**Production of mineral products**							**0.090**	**0**	**0.218**	**0**	**0.026**

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors), ESP = electrostatic precipitator, FF = fabric filter.

Table A5: Category 5 – Transportation

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Consumption	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
5			**Transport**											
	a		**4-stroke engines**						**2,360,000**	**0.094**	**0**	**0**	**0**	**0**
		1	Leaded fuel	2.2	NA	NA	NA	NA		0.000				
		2	Unleaded fuel without catalyst	0.1	NA	NA	NA	NA	944,000	0.094				
		3	Unleaded fuel with catalyst	0.00	NA	NA	NA	NA	1,416,000	0.000				
	b		**2-stroke engines**						**23,600**	**0.059**		**0**	**0**	**0**
		1	Leaded fuel	3.5	NA	NA	NA	NA		0.000				
		2	Unleaded fuel without catalyst	2.5	NA	NA	NA	NA	23,600	0.059				
	c		**Diesel engines**						**2,390,000**	**0.239**	**0**	**0**	**0**	**0**
		1	Diesel engines	0.1	NA	NA	NA	ND	2,390,000	0.239				
	d		**Heavy oil-fired engines**						**5,600**	**0.022**	**0**	**0.207**	**0**	**0**
		1	All types	4	NA	NA	NA	ND						
		1	New Zealand – waste oil burning	4	NA	NA	NA	ND	5,600	0.022		0.207		
5			**Transport**							**0.415**	**0**	**0.207**	**0**	**0**

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors).

Table A6: Category 6 – Open burning processes

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
6			**Open burning processes**											
	a		**Fires/burnings – biomass**						**774,000**	**3.087**	**0**	**4.140**	**0**	**0**
		1	Forest fires	5	ND	4	NA	ND	600,000	3.000		2.400		
		2	Grassland and moor fires	5	ND	4	NA	ND		0.000		0.000		
		3	Agricultural residue burning (in field), impacted, poor combustion conditions	30	ND	10	NA	ND		0.000		0.000		
		4	Agricultural residue burning (in field), not impacted	0.5	ND	10	NA	ND	174,000	0.087		1.740		
	b		**Fires, waste burning, landfill fires, industrial fires, accidental fires**						**23,454**	**8.863**	**0**	**11.710**	**0**	**0**
		1	Landfill fires – New Zealand calculation method	1,000	ND	600	NA	600		0.000		0.000		
			New Zealand calculation – see sections 26.1.2 and 26.2.2							2.300		0.000		
		2	Accidental fires in houses, factories	400	ND	400	NA	400	2,125	0.850		0.850		
		3	Uncontrolled domestic waste burning	300	ND	600	NA	600	18,000	5.400		10.800		
		4	Accidental fires in vehicles (per vehicle)	94	ND	18	NA	18	3,329	0.313		0.060		
		5	Open burning of wood (construction/demolition)	60	ND	10	NA	10		0.000		0.000		
6			**Open burning processes**							**11.950**	**0**	**15.850**	**0**	**0**

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors).

Table A7: Category 7 – Production of chemicals and consumer goods

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
7			**Production and use of chemicals and consumer goods**											
	a		**Pulp and paper mills***							**0.0325**	**0.0**	**0.0**	**0.0**	**0.083**
			Boilers (per tonne of pulp)						0	0.0000	0	0	0	0.000
		1	Black liquor boilers, burning of sludges, wood	0.07				NA						
			New Zealand plants and factors						720,000	0.0325				
		2	Bark boilers only	0.2				50		0.000				0.000
			Aqueous discharges and products						415,000		0.000		0.000	0.083
		1	Kraft process, Cl_2 gas, non-wood fibres, impacted		ND		30	ND					0.000	
		2	Kraft process, old technology (Cl_2)		4.5		8	4.5			0.000		0.000	0.000
		3	Kraft process, mixed technology		1.0		3	1.5			0.000		0.000	0.000
		4	Sulphite pulp/papers, old technology		ND		1	ND					0.000	
		5	Kraft process, modern technology (ClO_2)		0.06		0.5	0.2	415,000		0.000		0.000	0.083
		6	Sulphite papers, new technology (ClO_2, TCF)		ND		0.1	ND					0.000	
		7	TMP pulp		ND		1.0	ND					0.000	
		8	Recycling papers from contaminated waste papers		ND		10						0.000	
		9	Recycling pulp/paper from modern papers		ND		3	ND					0.000	
	b		**Chemical industry**							**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
			PCP						0	0	0	0	0.000	0
		1	European, American production (chlorination of phenol with Cl_2)				2,000,000						0.000	
		2	Chinese production (thermolysis of HCH)				800,000						0.000	
		3	PCP-Na				500						0.000	
			PCB						0	**0**	**0**	**0**	**0.0**	**0**
		1	Low chlorinated, eg, Clophen A30, Aroclor 1242				15,000							
		2	Medium chlorinated, eg, Clophen A40, Aroclor 1248				70,000						0.000	
		3	Medium chlorinated, eg, Clophen A50, Aroclor 1254				300,000						0.000	
		4	High chlorinated, eg, Clophen A60, Aroclor 1260				1,500,000						0.000	
			Chlorinated pesticides						0	**0**	**0**	**0**	**0.000**	**0**
		1	Pure 2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)				7,000						0.000	
		2	2,4,6-Trichlorophenol (2,4,6-PCPh)				700						0.000	
		3	Dichlorprop				1,000						0.000	
		4	2,4-Dichlorophenoxy acetic acid (2,4-D)				700						0.000	
		5	2,4,6-Trichlorophenyl-4'-nitrophenyl ether (CNP = chloronitrofen)						0	0	0	0	0.000	0

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
			Old technology				300,000						0.000	
			New technology				400						0.000	
			Chloranil						0	**0**	**0.0**	**0.0**	**0.000**	**0**
		1	*p*-chloranil *via* chlorination of phenol				400,000						0.000	
		2	*p*-chloranil *via* hydrochinone				100						0.000	
		3	Dyestuffs on chloranil basis (old process, class 1)				1,200						0.000	
		4	*o*-chloranil *via* chlorination of phenol				60,000						0.000	
			Chlorobenzenes						0	**0**	**0**	**0**	**0**	**0**
		1	*p*-Dichlorobenzene	ND	NA	NA	39	ND					0.000	
		2	*o*-Dichlorobenzene	ND	NA	NA	0	ND					0.000	
		3	1,2,4-Trichlorobenzene	ND	NA	MA	0	3,000					0.000	0
			Chlorine/chloralkali production						0	0	0	0	0	0
			Chloralkali production using graphite anodes	NA	NA	NA	NA	1,000						0
			EDC/VCM/PVC						0	**0.0**	**0.0**		**0.000**	**0**
		1	Old technology, EDC/VCM, PVC		1	NA		ND			0			
		2	Modern plants, EDC/VCM or EDC/VCM/PVC	0.4	0.5	NA	0.03	10		0	0.000		0.000	0
		3	PVC only	0.0003	0.03	NA	0.1	0.2		0	0		0.000	0.0
	c		**Petroleum refineries**						**0**	**0.0**	**0**	**0**	**0**	**0**
		1	All types (flares) (µg TEQ/TJ)	8	NA	NA	NA	ND		0				
	d		**Textile plants**						**0**	**0**	**0**	**0**	**0**	**0**
		1	Upper limit	NA	ND	NA	100	ND					0	
		2	Lower limit	NA	ND	NA	0.1	ND					0	
	e		**Leather plants**						**0**	**0**	**0**	**0**	**0**	**0**
		1	Upper limit	NA	ND	NA	1,000	ND					0	
		2	Lower limit	NA	ND	NA	10	ND					0	
7			**Production and use of chemicals and consumer goods**							**0.033**	**0.000**	**0.000**	**0.000**	**0.083**

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors), TCF = totally chlorine free, TMP = thermo-mechanical pulp, PCP = pentachlorophenol, PCB = polychlorinated biphenyl, EDC/VCM/PVC = ethylene dichloride/vinyl chloride monomer/polyvinyl chloride.

Table A8: Category 8 – Miscellaneous

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a				
				Air	Water	Land	Product	Residue	tonnes/a	Air	Water	Land	Product	Residue
8			**Miscellaneous**											
	a		**Drying of biomass**						**0**	**0.000**	**0**	**0**	**0.000**	**0**
		1	Clean wood	0.007	NA	ND	0.1	ND		0.000			0.000	
		2	Green fodder	0.1	NA	ND	0.1	ND		0.000			0.000	
		3	PCP – or otherwise treated biomass	10	NA	ND	0.5	ND		0.000			0.000	
	b		**Crematoria**						**18,289**	**0.183**	**0**	**0**	**0**	**0.000**
		1	No control (per cremation)	90	NA	NA	NA	ND		0.000				
		2	Medium control (per cremation)	10	NA	NA	NA	ND	18,289	0.183				
		3	Optimal control (per cremation)	0.4	NA	NA	NA	ND		0.000				
	c		**Smokehouses**						**0**	**0.000**	**0**	**0**	**0**	**0.000**
		1	Treated wood, waste fuels used as fuel	50	NA	ND	ND	2,000		0.000				0.000
		2	Clean fuel, no afterburner	6	NA	ND	ND	20		0.000				0.000
		3	Clean fuel, afterburner	0.6	NA	ND	ND	20		0.000				0.000
	d		**Drycleaning residues**						**0**	**0**	**0**	**0**	**0**	**0.000**
		1	Heavy textiles, PCP-treated, etc	NA	NA	NA	NA	3,000						0.000
		2	Normal textiles	NA	NA	NA	NA	50						0.000
	e		**Tobacco smoking**						**3.349E+09**	**0.00033**	**0**	**0**	**0**	**0**
		1	Cigar (per item)	0.3	NA	NA	NA	NA		0.00000				
		2	Cigarette (per item)	0.1	Na	NA	NA	NA	3,349,000,000	0.00033				
8			**Miscellaneous**							**0.183**	**0**	**0**	**0.000**	**0.000**

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors), PCP = pentachlorophenol.

Table A9: Category 9 – Disposal

Cat.	Subcat.	Class	Subcategories	Potential release route (µg TEQ/tonne)					Production	Annual release, g TEQ/a					
				Air	Water	Land	Product	Residue	tonnes/a or m^3/a	Air	Water	Land	Product	Residue	
9			**Disposal**		**µg TEQ/m^3**			**µg TEQ/m^3**							
	a		**Landfill leachate**							**0**	**0.740**	**19.0**	**0**	**0.000**	
		1	Hazardous waste	NA	0.2	NA	NA	50			0.000			0.000	
			New Zealand landfill leachate (m^3)	NA	0.2	NA	NA	50	3,700,000		0.740				
		2	Non-hazardous waste	NA	0.03	NA	NA	6			0.000			0.000	
			New Zealand landfill – solid waste disposal (tonnes)	NA		6			3,160,000			19.0			
	b		**Sewage/sewage treatment**						**658,000,000**		**0.823**	**0**	**0**	**23.411**	**Sludge (t/a)**
		1	Industrial, mixed domestic with chlorine relevance	NA					0		0.000	0	0	0.000	
			No sludge removal	NA	0.005	NA	NA	1,000			0.000			0.000	
			With sludge removal	NA	0.0005	NA	NA	1,000			0.000			0.000	
		2	Urban environments	NA					658,000,000		0.823	0	0	23.411	
			(No sludge removal)	NA	0.002	NA	NA	100	(329,000,000)		0.658			23.411	234,112
			(With sludge removal)	NA	0.0005	NA	NA	100	(329,000,000)		0.165			0.000	
		3	Remote and residential or modern treatment plant	NA	0.0001	NA	NA	10			0.000			0.000	
	c		**Open water dumping**						**0**	**0**	**0.000**	**0**	**0**	**0**	
		1	Mixed domestic and industrial inputs	NA	0.005	NA	NA	NA			0.000				
		2	Urban environments	NA	0.0002	NA	NA	NA			0.000				
		3	Remote environments or input control	NA	0.0001	NA	NA	NA			0.000				
	d		**Composting**						**0**	**0**	**0**	**0**	**0.000**	**0**	
		1	All organic fraction	NA	ND	NA	100	NA					0.000		
		2	Garden, kitchen wastes	NA	ND	NA	15	NA					0.000		
		3	Green materials, not impacted environments	NA	ND	NA	5	NA					0.000		
	e		**Waste oil disposal**						**0**	**0**	**0**	**0**	**0**	**0**	
		1	All fractions	ND	ND	ND	ND	ND							
9			**Disposal/landfill**							**0.000**	**1.563**	**19.0**	**0.000**	**23.411**	

Table abbreviations: NA = not applicable (ie, no releases expected), ND = no data (for calculation of release factors).

Table A10: Category 10 – Identification of potential hot-spots

Cat.	Subcat.	Class	Subcategories	Product (µg TEQ/tonne)	Occurrence (tonne)	g TEQ identified				
						Air	Water	Land	Product	Residue
10			**Identification of hot spots**			**x indicates need for site-specific evaluation**				
	a		**Production sites of chlorinated organics**							
		1	Chlorophenols and derivatives or PCB				x	x		
		2	Other chlorinated organics					x		
	b		**Production sites of chlorine**							
		1	With graphite electrodes				x	x		
		2	Without graphite electrodes				x	x		
	c		**Formulation of chlorinated phenols/pesticides**				**x**	**x**		
	d		**Application sites of dioxin-contaminated pesticides**					**465**		
	e		**Timber manufacture**							
		1	Using pentachlorophenol, other dioxin-containing preservatives				x	5,310		
		2	No use of pentachlorophenol not open to the environment				x	x		
	f		**PCB (polychlorintedbiphenyl) containing equipment**		**0**				**0**	
			Low chlorinated, eg, Clophen A30, Aroclor 1242	15,000					0	
			Medium chlorinated, eg, Clophen A40, Aroclor 1248	70,000					0	
			Medium chlorinated, eg, Clophen A50, Aroclor 1254	300,000					0	
			High chlorinated, eg, Clophen A60, Aroclor 1260	1,500,000					0	
		1	Leaching				x	x		
		2	Not leaching				x	x		
	g		**Dumps of waste/residues from categories 1–9**				**x**	**x**		
	h		**Sites of relevant accidents**				**x**	**x**		
	i		**Dredging of sediments**				**x**	**x**		
			Pulp and paper sludges				x	24.8		
			Gasworks sites				x	2.6		
			Landfills				x	660		
10			**Hot spots**					**6,462**	**0**	**0**