

**2018 Update of the New Zealand
Inventory of Dioxin Emissions to Air,
Land and Water, and Reservoir
Sources**

Report to the Ministry for the Environment

Prepared by Alistair Bingham, JCL Air & Environment Limited

March 2019

DISCLAIMER

JCL Air and Environment Ltd accepts no liability with respect to this publication's use other than by the Ministry for the Environment. This publication may not be reproduced or copied in any form without the permission of the Ministry.

Executive Summary

As a signatory to the Stockholm Convention on Persistent Organic Pollutants (POPs) New Zealand has undertaken to assess national releases of dioxins on a regular basis and these assessments take the form of an emission inventory. Dioxins are a useful surrogate for all POPs species, being much studied, with extensive information available on source discharges and environmental distribution. Estimates of releases of dioxin from 49 different sources in New Zealand have been made for the reference year of 2016 to provide an update for New Zealand's Dioxin Inventory previously published for the reference years of 2008 and 2012. The UNEP Dioxin Toolkit methodology was used in which the annual dioxin releases from each source are estimated by multiplying an activity statistic by an emission factor. Activity statistics are chosen from measures such as annual fuel consumption, annual production rates etc. Emission factors are based on data for the average dioxin emissions for a particular category per unit of activity. The Toolkit approach assigns releases to five environmental vectors: air, land, water, products and residues.

Activity data was obtained through published information sources and direct contact with government agencies, and specific industries. Emission factors were based on emissions data for the specific sources, where available, or the default factors given in the UNEP Toolkit.

Although the assessment is quantitative it is important to recognise that there is uncertainty associated with each estimate and that this varies for each category. The uncertainty may be associated not only with the dioxin emission factor but also with the source activity itself. Consequently the value of the emission inventory is not in its ability to produce absolute numbers, rather the inventory is more suited to revealing trends over time and showing which sources are more significant than others. This knowledge can assist with focussing government initiatives for dioxin release reduction.

Annual Dioxin Releases for 2016

The total dioxin release quantity for New Zealand for 2016 has been estimated at 41.0 g TEQ¹. This can be compared with values of 40.7 g TEQ for 2012 and 42.9 g TEQ for 2008. Figure E1 on the next page shows how individual sources contributed to this total.

¹ TEQ is an abbreviation for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents. This is a means of expressing the total content of dioxin-like compounds present, in terms of the most toxic dioxin species – TCDD (see page 4).



Figure E1. Annual Dioxin Releases 2016 by Source (see Appendix 2 for details)

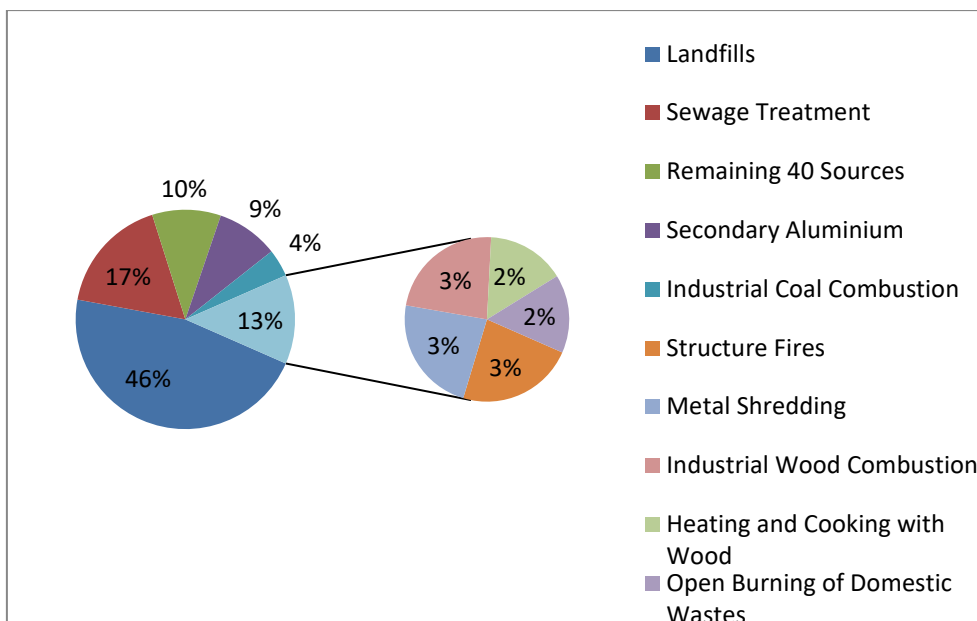


Figure E2*. Plot Showing the Contribution of Major Release Categories for Dioxin

(* The sum of all categories may not total exactly 100.0% due to rounding effects)

- Figure E2 shows that about two thirds of New Zealand's estimated dioxin releases can be attributed to two categories – disposal of municipal waste in landfills and sewage treatment.
- Combined with seven other categories: secondary aluminium processing, industrial coal combustion, structure fires, metal shredding, industrial wood combustion, heating and cooking with wood and open burning of domestic wastes the nine sources comprise 90% of total dioxin releases with the remaining 10% split between 40 other categories and sub-categories.
- All members of New Zealand's 4.7 million population contributed to the sewage treatment release in 2016 and a significant majority will have generated wastes disposed of in municipal solid waste landfills.
- Secondary aluminium production occurs primarily at two larger plants and a number of smaller facilities.
- Releases from industrial coal and wood-waste combustion are associated with about 500 coal-fired boilers and more than 175 wood-fired power plants.
- Structure fires are essentially random events, although nationally a similar number of fires occur from year to year.
- Metal shredding is now confined to a single operator in New Zealand.
- Heating and cooking with wood, primarily the former, occurs in about 550,000 New Zealand households with open burning of wastes in an estimated 5% of households.

Changes between 2012 and 2016

The tables below shows source categories which for 2016 had increases or decreases in their dioxin releases by more than 0.01 g compared with 2012 levels.

Table E1. Source Categories with Increases Compared to 2012

Source Category	Change in Dioxin Release (g TEQ/annum)
Landfills, waste dumps and landfill mining	4.91
Sewage/sewage treatment	0.42
Industrial/commercial coal use	0.22
Structure fires	0.15
Primary iron & steel production	0.065
Forest fires	0.062
Pulp & paper sludge disposal	0.053
Vehicle fires	0.045
Diesel engines	0.028
Open burning of domestic wastes	0.027
Galvanizing	0.025
Lime production	0.020
Fuel oil and gas-fired power plants	0.014
Black liquor combustion	0.012
Crematoria	0.011

- Compared to 2012 levels, releases from landfills have increased partly because the population has increased but more significantly because waste production increased by 125 kg per person from 2009-2016.
- Increased releases from sewage treatment, open burning of domestic wastes and crematoria can be attributed to population increase.
- Increases in releases from industrial and commercial coal use are due to increased coal consumption, particularly by the food industry.
- Structure fires, forest fires and vehicle fires are random, unpredictable events and consequently difficult to assign year on year trends.
- Increases from diesel engines and fuel oil and gas-fired power plants reflect increased fuel consumption nationally. Pulp and paper sludge disposal and black liquor combustion increases can be attributed to larger quantities of pulp being manufactured. Similarly increased releases from the lime industry are due to manufacturing increases.

Table E2. Source Categories with Decreases Compared to 2012

Source Category	Change in Dioxin Release (g TEQ/annum)
Secondary iron & steel production	-2.84
Brass and bronze production	-0.70
Coal-fired electricity generation	-0.58
Metal shredding	-0.52
Secondary aluminium production	-0.43
Medical waste incineration	-0.43
Cement production	-0.13
Iron foundries	-0.072
Grassland and savannah fires	-0.032
4-stroke engines	-0.026
Wood and biomass incineration	-0.018
Landfill fires	-0.013
Household heating & cooking with coal	-0.010
Household heating & cooking with biomass	-0.010

- Plant closures with subsequent decreases in production quantities (or their elimination in the case of secondary iron and steel) were the cause of the reductions for secondary iron and steel production, brass and bronze production, secondary aluminium production, metal shredding and iron foundries.
- Medical waste incineration releases have dropped because of the closure of a quarantine waste incinerator and reductions in waste throughput.
- Cement reductions arise from the closure of one of New Zealand's two cement plants.
- Grassland fires are random unpredictable events and consequently difficult to assign year on year trends.
- Release reductions from 4-stroke engines arise from improvements in vehicle fleet exhaust technology.
- Reductions for household heating and cooking with coal and biomass reflect the gradual adoption of alternative fuels such as natural gas and electricity.

Trends in Dioxin Releases

Figures E3 and E4 display plots of dioxin releases versus source category for 2008, 2012 and 2016. The sources have been categorised as major and minor to make the lesser sources more visible.

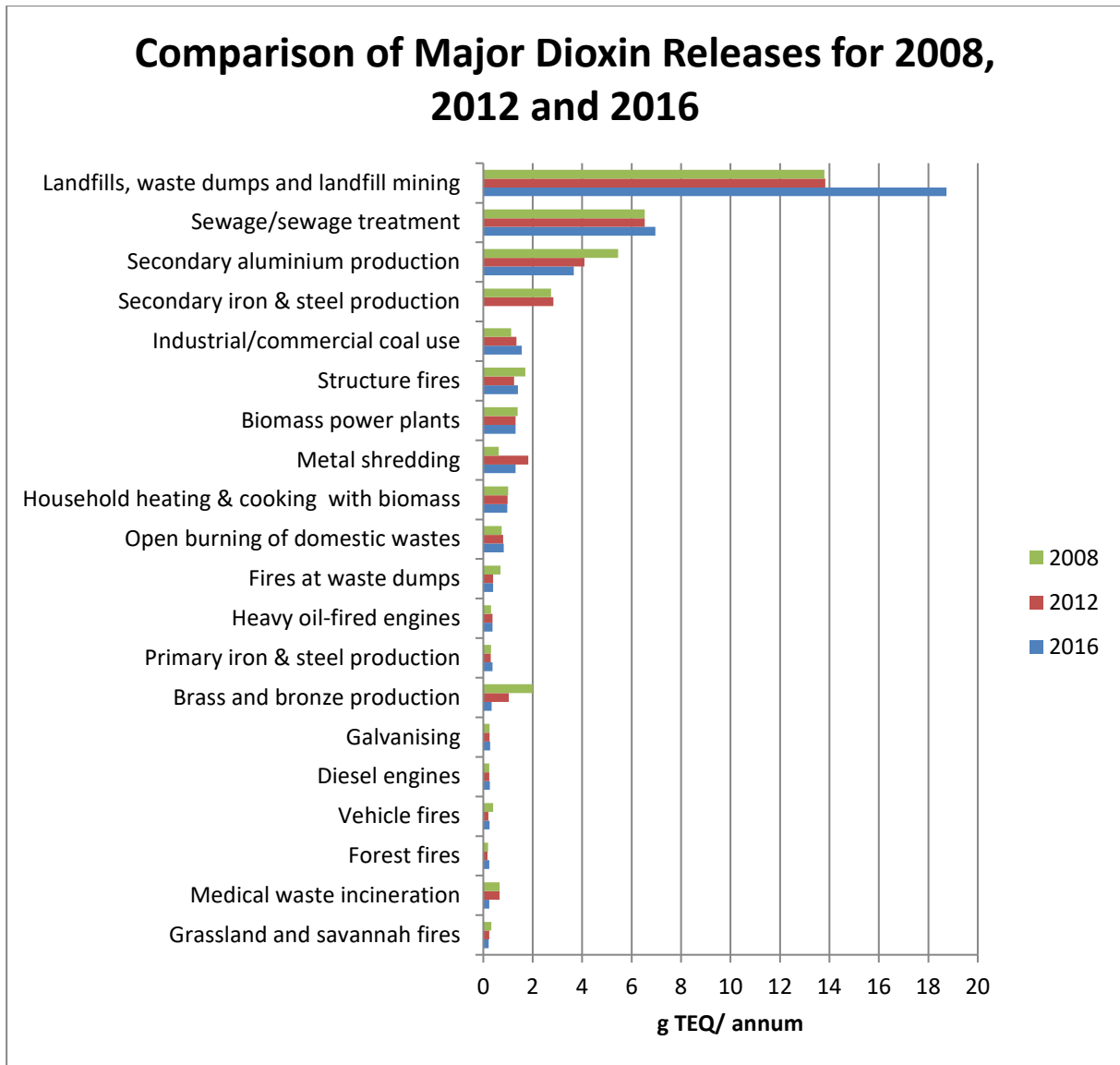


Figure E3. Major Sources' Dioxin Releases for 2008, 2012 and 2016 (see Appendix 2 for details)

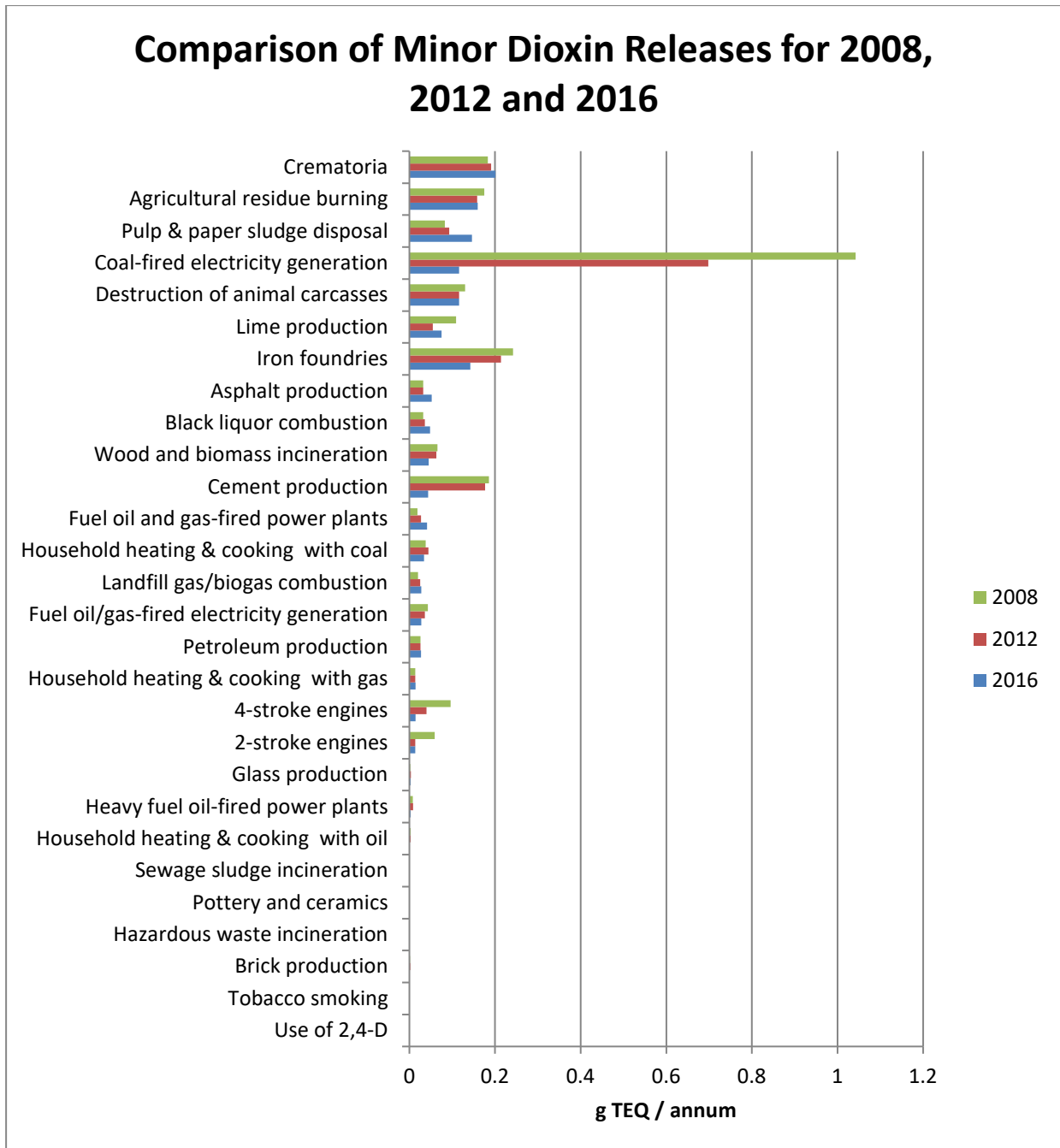


Figure E4. Minor Sources’ Dioxin Releases for 2008, 2012 and 2016 (see Appendix 2 for details)

Regarding Figure E3, an increasing trend of dioxin release is most apparent for industrial and commercial coal use whereas decreasing trends are most pronounced for secondary metal production, that is secondary aluminium, secondary iron and steel, and brass and bronze production.

For the sources shown in Figure E4 increasing trends are visible for crematoria, pulp and paper wastes, including black liquor combustion and fuel oil and gas fired power plants. Decreasing trends are apparent for coal fired electricity generation, iron foundries, cement production, fuel oil and gas fired electricity generation and 4-stroke engines.

Dioxin Reduction Initiatives

Greenhouse Gas Reduction Initiatives

Fossil fuel reduction strategies aimed at reducing greenhouse gases will also have the benefit of reducing dioxin emissions. New Zealand has pledged itself to be a zero net greenhouse gas emitter by 2030 placing pressure on fossil fuel use, particularly coal.

The electricity generation industry is in the process of focussing resources away from thermal power stations fuelled by coal and natural gas and replacing them with power derived from renewable sources, especially geothermal energy. Between 2012 and 2016 annual geothermal electricity generation jumped more than 25% and coal and gas electricity generation reached 20 year lows. Dioxin emissions for coal fired electricity generation fell by 83% in the same period with a 12% drop for gas generation.

The dairy industry is one of the country's largest coal consumers; however dairy companies are signaling their intentions to move from coal fired processes to co-firing with biomass or using electric powered plant. Where the latter are powered by non-thermal generation there will be a reduction in dioxin releases.

Influence of Legislation

National Emission Standards embodied in the Resource Management Act have required improvements in wood burner performance in units installed after 2005. This should result in a reduction in dioxin releases from the domestic heating sector as older units are replaced or other low emission forms of heating adopted in their place. Where towns and cities have compromised air quality because of particulate discharges, older wood burners and open-hearth fires are now actively discouraged by Regional Councils.

Global and national perspectives

Estimates of global per capita releases of dioxins are in the range 15 – 39 g TEQ per million people per year. In comparison New Zealand had releases of 10.0g TEQ per million in 2008, 9.3 g TEQ per million in 2012 and 8.7 g TEQ per million in 2016.

There are no official recommendations for 'acceptable' levels of national dioxin releases and it is also not possible to relate the release estimates directly to any potential health effects. The more relevant information is provided by national surveys of dioxin body burdens, for which there have been several New Zealand studies.

The levels of dioxins in mothers' milk have been measured on 3 occasions in New Zealand; 1988, 1998 and 2008. These studies showed that the dioxin concentrations in New Zealand mothers are relatively low by comparison with many other countries. Also, the levels have been steadily dropping, with a reduction of 70% observed from 1988 to 1998, and a further reduction of 40% from 1998 to 2008.

The levels of dioxins in blood serum have been monitored on two occasions in New Zealand, in 1997 and 2012. Once again, these studies showed the dioxin concentrations in New Zealanders are relatively low by comparison with many other countries, and the levels have dropped over time.

Contents

Units and abbreviations	xiii
1 Introduction	1
1.1 Background.....	1
1.2 Methodology.....	1
1.3 Report layout and content.....	1
2 Dioxin Formation and the UNEP Toolkit.....	2
2.1 Dioxin Formation	2
2.2 The UNEP Toolkit.....	2
2.3 Release estimates	3
2.4 Certainty Estimates.....	4
2.5 Back-calculations	5
2.6 Units	5
3 Waste incineration.....	6
3.1 Municipal solid waste incineration.....	6
3.2 Hazardous waste incineration	6
3.3 Medical waste incineration.....	7
3.4 Light-fraction shredder waste incineration.....	8
3.5 Sewage sludge incineration	8
3.6 Waste wood and waste biomass incineration	8
3.7 Destruction of animal carcasses.....	9
3.8 Summary for this category	10
4 Ferrous and non-ferrous metal production	11
4.1 Iron ore sintering	11
4.2 Coke production (and charcoal).....	11
4.3 Iron and steel production and foundries	12
4.3.1 Primary steel production	12
4.3.2 Secondary steel production	13
4.3.3 Iron foundries	13
4.3.4 Hot-dip galvanising plants	14
4.3.5 Primary aluminium production.....	15
4.3.6 Secondary aluminium production	15
4.4 Lead production.....	15
4.5 Zinc production	15
4.6 Brass and bronze production	16
4.7 Magnesium production.....	17
4.8 Other non-ferrous metal production	17
4.9 Metal shredding.....	17

4.10	Thermal wire reclamation and e-waste recycling	18
4.11	Summary for this category	18
5	Heat and power generation	19
5.1	Fossil fuel power plants	19
5.1.1	Coal-fired power plants	19
5.1.2	Heavy fuel oil-fired power plants	22
5.1.3	Fuel oil and natural gas-fired power plants	22
5.2	Biomass power plants	24
5.3	Landfill, biogas combustion	25
5.4	Household heating and cooking with biomass	26
5.5	Household heating and cooking with fossil fuels	27
5.5.1	Coal	27
5.5.2	Oil	28
5.5.3	Gas	28
5.6	Summary for this category	29
6	Production of mineral products	30
6.1	Cement production	30
6.2	Lime production	31
6.3	Brick production	32
6.4	Glass production	32
6.5	Pottery and ceramics production	33
6.6	Asphalt mixing	34
6.7	Oil shale pyrolysis	34
6.8	Summary for this category	34
7	Transport	36
7.1	4-Stroke engines	36
7.2	2-Stroke engines	38
7.3	Diesel engines	38
7.4	Heavy oil-fired engines	39
7.5	Summary for this category	39
8	Open burning processes	41
8.1	Biomass burning	41
8.1.1	Agricultural residue burning	41
8.1.2	Sugarcane burning	42
8.1.3	Forest fires	42
8.1.4	Grassland and savannah fires	43
8.2	Waste burning and accidental fires	43
8.2.1	Fires at waste dumps	43
8.2.2	Accidental fires in houses, factories	44

8.2.3	Open burning of domestic waste.....	45
8.2.4	Accidental fires in vehicles	46
8.2.5	Open burning of wood (construction/demolition).....	47
8.3	Summary for this category	47
9	Production of chemicals and consumer goods	48
9.1	Pulp and paper production.....	48
9.2	Chlorinated inorganic chemicals	50
9.3	Chlorinated aliphatic chemicals.....	50
9.4	Chlorinated aromatic chemicals	50
9.4.1	1,4-dichlorobenzene.....	50
9.4.2	Polychlorinated biphenyls (PCBs).....	51
9.4.3	Pentachlorophenol and sodium pentachlorophenate	51
9.4.4	2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) and 2,4,6-trichlorophenol.....	51
9.4.5	Chloronitrofen, chlornitrofen, or 2,4,6 trichlorophenyl-4-nitrophenylether (CNP).....	51
9.4.6	Pentachloronitrobenzene (PCNB – Quintozene)	51
9.4.7	2,4-Dichlorophenoxyacetic acid (2,4-D) and derivatives	52
9.4.8	Chlorinated Paraffins	52
9.4.9	p-Chloranil.....	52
9.4.10	Phthalocyanine dyes and pigments	53
9.4.11	Tetrachlorophthalic acid (TCPA) and related pigments	53
9.4.12	Dioxazine dyes and pigments	53
9.4.13	Triclosan	54
9.5	Other chlorinated and non-chlorinated chemicals	54
9.6	Petroleum production	54
9.7	Textile (and leather) production	55
9.8	Leather refining	56
9.9	Summary for this category	56
10	Miscellaneous sources.....	57
10.1	Drying of Biomass.....	57
10.2	Crematoria.....	57
10.3	Smokehouses	58
10.4	Dry cleaning	58
10.5	Tobacco smoking.....	58
10.6	Summary for this category	59
11	Disposal and landfill.....	60
11.1	Landfills, waste dumps and landfill mining.....	60
11.2	Sewage/sewage treatment.....	61
11.3	Open water dumping	63
11.4	Composting	63

11.5	Waste oil disposal.....	63
11.6	Summary for this category	63
12	Contaminated sites and hotspots	65
12.1	Pesticide manufacture.....	65
12.2	Historical use of 2,4,5-T	65
12.3	Historical use of pentachlorophenol for timber treatment	66
12.4	Gasworks sites	66
12.5	Landfills.....	66
13	Summary and discussion	67
13.1	Dioxin release estimates for 2016.....	67
13.2	Changes in the dioxin release estimates over time	69
13.3	New Zealand initiatives leading to reductions in dioxin releases	73
13.4	Global perspective	74
13.5	Other New Zealand studies.....	74
14	List of references	76
	Appendix 1: Summary of the current release estimates	81
	Appendix 2: Total dioxin releases.....	84

Units and abbreviations

Units

g	gram
kg	kilogram (10 ³ grams)
tonne	10 ³ kilograms or 10 ⁶ grams
ktonne	kilotonne (10 ³ tonnes or 10 ⁶ kilograms)
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
kW	kilowatt (10 ³ watts)
kWh	kilowatt-hour
MW	megawatt (10 ⁶ watts)
GWh	gigawatt-hour

Abbreviations

BAT/BEP	best available techniques / best environmental practices
BLS	black liquor solids
CKD	cement kiln dust
dioxins	generic name for the PCDDs and PCDFs
FAO	Food and Agriculture Organization
LPG	liquefied petroleum gas
MDF	medium density fibreboard
PCDD	polychlorinated dibenzo- <i>p</i> -dioxin
PCDF	polychlorinated dibenzofuran
POPs	persistent organic pollutants
TEQ	toxic equivalents
UNEP	United Nations Environment Programme
USA	United States of America
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

Update of the New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources

1 Introduction

This report provides an update of the *New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources 2014* (Ministry for the Environment, 2014) – the 2012 Inventory. It has been prepared under contract to the New Zealand Ministry for the Environment, and covers all of the 49 different sources considered in the 2012 Inventory.

1.1 Background

New Zealand has an obligation under the Stockholm Convention on Persistent Organic Pollutants to periodically prepare inventories of the unintentional releases of two specific groups of persistent organic pollutants: the polychlorinated dibenzo-p-dioxins (PCDDs) and the polychlorinated dibenzofurans (PCDFs). For convenience, these are generally referred to using the collective term ‘dioxins’, or the abbreviations PCDDs and PCDFs.

There have been three previous reports on dioxin releases to air, land and water, and reservoir sources in New Zealand. The first was published in 2000, based on 1998 data (Ministry for the Environment, 2000). This study pre-dated the Toolkit and used emission factors derived from the best information available to the compilers at the time. There were also fewer source categories investigated than in the later inventories. The second was published in 2011 based on 2008 data (Ministry for the Environment, 2011a) with the third published in 2014 based on 2012 data (Ministry for the Environment 2014). This report provides an update of the 2014 inventory report (herein referred to as the 2012 Inventory) for the reference year of 2016.

1.2 Methodology

The methodology used for the inventory update is summarised in Section 2 of this report. It has been based on the use of the latest version (v3) of the *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases* (United Nations Environment Programme, 2013) (herein referred to as the UNEP Toolkit). The methodology involves 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 emissions to air, land or water, per unit of activity.

The required activity data was obtained through published information sources and direct contact with government agencies, and specific industries. The emission factors were based on emissions data for the specific sources, where available, or the default factors given in the UNEP Toolkit.

1.3 Report layout and content

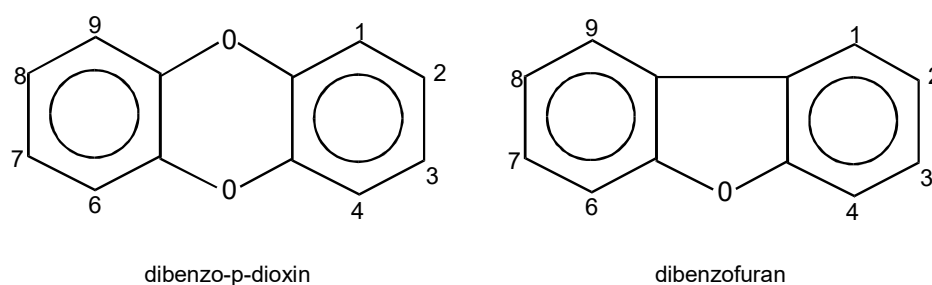
Details of the UNEP Toolkit methodology and related aspects are presented in section 2. This is followed by individual sections covering each of the 10 Toolkit source categories, and a summary and discussion section.

2 Dioxin Formation and the UNEP Toolkit

2.1 Dioxin Formation

The basic structures of the polychlorinated dibenzo-p-dioxins and dibenzofurans 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 of the ring structures. 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.

Figure 2-1: Structures of dibenzo-p-dioxin and dibenzofuran



Dioxins are not produced intentionally, but are released to the environment from a variety of industrial discharges, combustion processes and as a result of their occurrence as unwanted by-products in various chemical products (United Nations Environment Programme, 2013).

Historically the manufacture and use of chlorinated aromatic chemicals has been a major source of dioxins. The most notable examples include the wood preservative and biocide, pentachlorophenol, the herbicide 2,4,5-T (2,4,5-trichlorophenoxy acetic acid), and the industrial chemicals known as PCBs (polychlorinated biphenyls).

Other chemical/industrial processes, such as the production of chlorine-bleached pulp, have led to environmental contamination by dioxins, as well as the trace contamination of pulp and paper products.

Combustion processes are another important source of dioxins. Dioxins have been detected in the emissions from waste incineration, particularly municipal, medical and hazardous wastes, from the production of iron and steel and other metals, including scrap metal reclamation, from fossil fuel plants, domestic coal and wood fires, rubbish burning, and motor vehicles (especially when using leaded fuels), as well as from accidental fires.

2.2 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 (United Nations Environment Programme, 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.

The 2016 Inventory, like its 2012 predecessor, is based on the 3rd edition of the UNEP Toolkit (2013). The 2008 Inventory was based on the second edition of the Toolkit. Back calculations on the source categories which had changes to their release factors were performed to enable meaningful comparisons between the 2008 Inventory and later versions (see Section 2.5).

The UNEP Toolkit methodology involves estimation of the annual releases from each source by multiplying an activity statistic by an emission factor:

$$\text{annual release (g TEQ/year)} = \text{activity (tonnes/year)} \times \text{emission factor (g TEQ/tonne)}$$

Activity statistics are chosen on the basis of fuel consumption, production rates or some other similar measure, and are specific to each country. Emission factors can also be country specific, if sufficient emissions data is available for individual sources. However, the UNEP Toolkit provides default factors for use when this data is not available.

The UNEP Toolkit classifies all potential dioxin sources into the following 10 categories:

1. Waste incineration
2. Ferrous and non-ferrous metal production
3. Heat and power generation
4. Production of mineral products
5. Transportation
6. Open burning processes
7. Production of chemicals and consumer goods
8. Miscellaneous sources
9. Disposal
10. Contaminated sites and hotspots.

Within the Toolkit, each of the categories is divided into sub-categories on the basis of the different types of processes (eg, incineration of hazardous wastes, municipal wastes, medical wastes, etc), and each of the sub-categories 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 dioxin releases. The highest Toolkit 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.

The default emission factors given for each class represent the best-estimate of 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. In order 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 source sub-categories and classes.

Emission factors have been recommended for the following release vectors: to air, water, land, or in products or residues, although not all vectors are applicable to each subcategory. The UNEP 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. However, for consistency with the UNEP Toolkit approach they have been recorded as releases via residues unless the wastes are known to be disposed at the company's own (usually on-site) landfill.

2.3 Release estimates

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.

The estimates for the dioxin releases are expressed in terms of Toxic Equivalents. There are 210 different chlorinated dioxins, but only 17 have significant toxicity. When reporting the results of dioxin monitoring the quantities of all 210 congeners are converted to a single Toxic Equivalent (or TEQ) value, which reflects the overall toxicity of the mixture in terms of the most toxic congener; 2,3,7,8-tetrachlorodibenzo-p-dioxin (which, for simplicity is usually referred to as TCDD).

Historically, there have been several TEQ systems, but the most widely recognised are the “International” system, referred to as I-TEQs, and the World Health Organization (WHO) regime, referred to as WHO-TEQs. The most recent review of toxic equivalence was undertaken by WHO in 2005 and this is now the internationally preferred system (United Nations Environment Programme, 2013). Unlike the older I-TEQ system, the 2005 WHO TEQ system includes factors for 12 dioxin-like PCBs.

All of the dioxin release estimates presented in this inventory are reported as TEQ, with no distinction as to the TEQ system used. This is consistent with the approach taken in the UNEP Toolkit, which notes that, for the purposes of national inventories, the differences between I-TEQs and WHO-TEQs are relatively minor (United Nations Environment Programme, 2005). In addition, the primary focus of a national inventory should be on the relative (ie, order of magnitude) differences between different types of sources, and the broad-scale changes in releases over time.

The reference date for this inventory is taken as the 2016 calendar year, and 2016 activity data has been used whenever possible in deriving the estimates. The use of data from earlier years has been noted where relevant.

2.4 Certainty Estimates

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 modeled data.

Emission factor

- A high certainty ranking was assigned if a reasonable amount of recent emissions data was available for the specific New Zealand sources.
- A medium certainty ranking was assigned if the New Zealand emissions data was limited or dated, but the emission factors compared well with the UNEP Toolkit factors.

- 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 the UNEP Toolkit factors.

2.5 Back-calculations

The UNEP Toolkit provides emission factors for a total of about 400 different sub-categories and classes spread across the 10 source groupings. The accuracy and relevance of these factors is subject to periodic review by an Expert Group established under the auspices of the Stockholm Convention. The latest version (v3) of the UNEP Toolkit was produced by the Expert Group in January 2013.

One of the key functions of an emissions inventory is to allow changes in emissions to be tracked over time. Primarily, these changes should relate to changes in the mixture of different sources in the country, and the source activity rates. However, tracking these changes becomes more complicated if the emission factors are also changed. Because the 2012 and 2016 Inventories have been compiled with the same emission factors (Toolkit version 3) there have been fewer back calculations required than for the 2012 Inventory. In this inventory back calculations have been performed for pottery and ceramic and galvanizing production due to changes in the way activity is determined. It should be recognised that where reference is made to 2008 results in this report, these figures have undergone back calculation, where necessary.

2.6 Units

The use of different units within this report is potentially very confusing, because the data cover such a wide range of values. For example, the release factors for individual sources are usually measured in nanograms per gram (10^{-9} grams/gram), or micrograms per tonne (10^{-6} grams/tonne), while the annual activity rates for different sources may be measured in kilograms, tonnes or Megatonnes (10^6 tonnes).

The complexity is further compounded by the use of different types of units. For example, most activity rates are measured in mass units (ie, tonnes/year) but those for fuels are measured in energy terms, such as Joules, and TeraJoules (10^{12} Joules). In addition, the activity rates for releases to water are measured on a volume basis (ie, litres or cubic metres (10^3 litres)).

This issue has been partially addressed by standardising the release factors given in the report to units of micrograms (μg , or 10^{-6} grams) TEQ per tonne, for releases to air or land, and in residues or products, and picograms (pg , or 10^{-12} grams) TEQ per litre, for releases to water. In addition, all of the annual releases are given in standard units of g TEQ per year. Where necessary, the numbers may also be given in alternative units, in brackets, to assist with the overall understanding.

3 Waste incineration

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 1a Municipal solid waste incineration
- 1b Hazardous waste incineration
- 1c Medical waste incineration
- 1d Light-fraction shredder waste incineration
- 1e Sewage sludge incineration
- 1f Waste wood and waste biomass incineration
- 1g Destruction of animal carcasses

Waste incineration is well-recognised as a potential source of dioxins, with the dioxins being formed mainly as a result of incomplete combustion of the waste materials. The extent of dioxin formation is strongly influenced by the waste composition (eg, presence of chlorinated materials) and condition (eg, loose or compacted, wet or dry), the combustion conditions, the temperature and composition of the discharges, and the overall design and operation of the incinerator. The presence of metals such as copper in some of the wastes, can also have a catalytic effect on dioxin formation. In addition, the final emissions can be strongly influenced by the performance characteristics and efficiency of any pollution control equipment.

3.1 Municipal solid waste incineration

There are no large-scale facilities in New Zealand dedicated to the incineration of wastes, and most municipal solid wastes are disposed to landfill (Ministry for the Environment, 2005).

3.2 Hazardous waste incineration

There is one high-temperature hazardous waste incinerator in New Zealand, which is operated by Dow AgroSciences Ltd at their agrichemical formulation plant in New Plymouth.

The air emissions from the incinerator are usually tested twice a year for dioxins by an external contractor. The results for 2016 indicate an average dioxin emission rate of 39.7 ng TEQ per hour (3.97×10^{-8} g TEQ/hr) (T Gellen, Dow AgroSciences, pers comm, 2018). This emission rate is higher than that used for the 2012 inventory (5.96 ng/hr) although more recent testing has seen a return to this level. The incinerator was operated for 8200 hours in 2016, giving an annual dioxin emission rate of 0.00033 grams TEQ/year.

A very small proportion of the total waste burned is left as an ash residue, which is periodically removed from the unit and stored in drums, prior to disposal in an approved landfill. The quantity of ash generated in 2016 was 0.696 tonnes. This was less than the 2.1 tonnes reported for 2012 but similar to the total reported for the 2008 Inventory. The 2008 and 2012 estimates for releases via these residues were based on a 2002 analysis which indicated a dioxin concentration of 25 μ g TEQ per tonne (25×10^{-6} g TEQ/tonne). Applying this factor to the current waste quantities gives an annual release in residues of 0.000017 g TEQ per year.

The current release estimates for the hazardous waste incinerator are shown in Table 3-1, along with the estimates from the 2012 Inventory. There are no direct releases to water, land or in products.

Table 3-1: Dioxin releases from hazardous waste incineration

Year	Activity Rate	Release factors		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	8000 hrs/year operation	5.96 ng TEQ/hr	-	0.000048	-
	2.1 tonnes ash/year	-	25 µg TEQ/t	-	0.000053
2016	8200 hrs/year operation	39.7 ng TEQ/hr	-	0.00033	-
	0.676 tonnes of ash/year	-	25 µg TEQ/t	-	0.000017

Certainty assessment for 2016

Activity data: Medium (because they are based on operator estimates)

Emission factors: Air, High and residues, Low (because they are based on actual measurements, and historical analytical data, respectively)

3.3 Medical waste incineration

Quarantine waste incineration, which is not covered in the UNEP Toolkit, has been covered in this section because the incinerator design and operation are quite similar.

There is only one medical waste incinerator in New Zealand. This is a diesel-fired, dual-chamber unit, with no add-on emission controls. In 2016 the total waste throughput was 78 tonnes (C. Shaw, Grey Hospital, pers comm, 2017). This is significantly lower than the 200 tonnes/year used for the 2012 Inventory and waste consumption has been consistently at this level for a number of years. The emissions have not been tested for dioxins.

The only incinerator burning quarantine waste in New Zealand was closed between 2014 and 2015. (R. Sowden, Ohakea Air base, pers comm 2018). Consequently there is no longer a release from this source.

The UNEP Toolkit recommends default factors of 3000 µg TEQ/tonne for releases to air and 20 µg TEQ/tonne for residues (ash), for batch-operated medical waste incinerators with minimal or no air pollution control systems (1 µg TEQ/tonne = 1×10^{-6} g TEQ/tonne). This is the appropriate sub-category for the Grey Hospital incinerator and the release estimates for 2016 based on these factors are shown in Table 3-2. There are no releases to water, land or in products.

Table 3-2: Dioxin releases from medical and quarantine waste incineration

Source	Activity Rate, tonnes of waste/year	Release factors, µg TEQ/t		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012 Medical waste and quarantine waste	219	3000	-	0.657	-
		-	20	-	0.0044
2016 Medical waste	78	3000	-	0.234	-
		-	20	-	0.00156

Certainty assessment for 2016

Activity data: Medium (because they are based on operator estimates)

Emission factors: Low (because they are based on default factors given in the UNEP Toolkit)

3.4 Light-fraction shredder waste incineration

Metal shredders are used for the processing of a range of scrap metals, including car bodies, white-ware and roofing iron. There are two outputs: a relatively clean ferrous metal stream and a ‘fluff’ or ‘flock’, which contains fragments of metals plus other waste materials from the input stream. This Toolkit category covers the disposal of the latter material by incineration, which is a potential source of dioxins. However, in New Zealand the material is disposed to a landfill (see section 4.3.2), so need not be considered here.

3.5 Sewage sludge incineration

There is one sewage sludge incinerator in New Zealand, operated by the Dunedin City Council at its wastewater treatment plant in Dunedin. The incinerator is a diesel-fired, fluidised bed unit, and the exhaust gases are treated in a high-efficiency venturi scrubber, followed by a packed-tower caustic scrubber. The gases are then passed through a bark biofilter which acts as a final scrubber, primarily for odour control.

The plant was closed for refurbishment from 2014 to 2016 but since then the incinerator has been processing about 1424 tonnes of wastewater solids per year, on a dry basis, which is 16% less than in 2012 (B Stevenson-Wright, Dunedin City Council, pers comm, 2017). The dioxin emissions to air are tested on an annual basis and historical results were used to determine an average release factor for use in the 2008 and 2012 Inventory. Test results obtained in February 2017 showed higher dioxin concentrations and the emission factor has been correspondingly revised. The UNEP Toolkit default factors will be used for the releases in residues.

The release estimates for 2016 are shown in Table 3-3. There are no releases to water, land or in products.

Table 3-3: Dioxin releases from sewage sludge incineration

Year	Activity Rate, tonnes of waste/year	Release factors, µg TEQ/t		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	1700	0.057	-	0.000097	-
		-	0.5	-	0.00085
2016	1424	0.160	-	0.000228	-
		-	0.5	-	0.00071

Certainty assessment for 2016

Activity data: Medium (because they are based on operator estimates)

Emission factors: High for air and Low for residues (because they are based on emission test data and the Toolkit default factors, respectively)

3.6 Waste wood and waste biomass incineration

School incinerators are not specifically covered in the UNEP Toolkit, but they fit reasonably well in this sub-category because at least some of the school wastes can be considered as biomass.

For the 2008 and 2012 Inventories it was estimated that there were 70 school incinerators operating in New Zealand, mainly in small rural schools without easy access to waste collection services or a local waste transfer station. The total waste quantity burned by these incinerators was estimated to be 70 tonnes per year. The Ministry of Education does not have any more recent records on these incinerators but believes that the best estimate of the current number in operation is 50 (C Mallett, Ministry of Education, pers comm 2018). The estimate of the annual waste quantity burnt has been reduced proportionally to 50 tonnes.

The release estimates for both 2012 and 2016, based on the default factors given in the UNEP Toolkit, are shown in Table 3-4. There are no releases to water, land or in products.

Table 3-4: Dioxin releases from school waste incinerators

Source	Activity Rate, tonnes/year	Release factors, µg TEQ/t		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
School incinerators 2012	70	300	-	0.021	
			600		0.042
School incinerators 2016	50	300		0.015	
			600		0.030

Certainty assessment for 2016

Activity data: School incinerators, Low (because it is based on a very rough estimate)

Emission factors: Low (because they are based on default factors given in the UNEP Toolkit)

3.7 Destruction of animal carcasses

The disposal of animal carcasses in New Zealand using combustion falls into two categories depending on whether the animals are commercial livestock or domestic pets. On-farm disposal of dead livestock occurs by open burning and any releases should be captured under the general “Open Burning” sub-categories of section 8. On the other hand domestic pets and other small animals are disposed of by controlled incineration.

For the 2012 Inventory a survey was conducted of regional councils and local authorities issuing consents for animal cremators and those disposing of animal pathological waste by combustion. Then there were a total of 15 consented animal cremators spread throughout the country and this was also the case in 2016. The total cremator activity of 231 tonnes per annum estimated for the 2012 Inventory has been used here.

To place this amount in perspective, there were 560,511 registered dogs in New Zealand as at 31 May 2018 (Department of Internal Affairs, 2018). Assuming that the dog population is relatively stable, the average lifespan is 10 years and the average weight is 20 kg, the maximum canine weight available for disposal each year is 1,120 tonnes. The cat population is less well recorded. Assuming a third of New Zealand households owns a cat with average longevity of ten years and average weight of 5kg gives a feline quantity for disposal of 750 tonnes.

The UNEP Toolkit classifies animal cremators into 3 classes depending on whether the process is continuous or occurs in batches, and on the performance of air pollution control equipment installed, and the extent to which combustion gas monitoring occurs during operation.

Lower equipment cost and the expectation of many customers that they will receive the unique ashes of their pet are two strong factors that have led to batch cremators being exclusively installed in New Zealand. To date there

have been no examples of discharge consents issued in New Zealand which make specific reference to the installation of air pollution control equipment. The emphasis in consent conditions is on maintaining elevated temperatures in the primary and secondary chambers thereby ameliorating the discharge of particulate matter and products of incomplete combustion to air.

Consequently all cremators are covered by the Toolkit’s Class 1. This assigns an emission factor of 500 µg/tonne of carcasses (500 x 10⁻⁶ g TEQ/tonne) to emissions to air, with no releases to other compartments.

The release estimates for 2016 are shown in Table 3-5, along with the previous estimates for 2012.

Table 3-5: Dioxin releases from animal carcass disposal

	Source	Activity Rate, tonnes/year	Release factors, µg TEQ/t	Annual releases (g TEQ/yr)
			Air	Air
2012	Class 1 cremators	231	500	0.116
2016	Class 1 cremators	231	500	0.116

Certainty assessment for 2016

Activity data: Medium (because it is based on a mixture of different source information)

Emission factor: Low (because it is based on default factors given in the UNEP Toolkit)

3.8 Summary for this category

The 2016 release estimates for waste incineration are summarised in Table 3-6, along with the revised comparative totals for 2008 and 2012.

Table 3-6: Summary of the release estimates for waste incineration

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Hazardous waste incineration	0.00033	-	-	-	0.000017
Medical waste incineration	0.234	-	-	-	0.0016
Sewage sludge incineration	0.00023	-	-	-	0.00071
Wood and Biomass Incineration*	0.015	-	-	-	0.030
Destruction of animal carcasses	0.116	-	-	-	-
2008 totals	0.811	-	-	-	0.047
2012 totals	0.794	-	-	-	0.047
2016 totals	0.366	-	-	-	0.032

(* this category covers school incinerators)

4 Ferrous and non-ferrous metal production

This category covers the following sub-categories (United Nations Environment Programme, 2013)

- 2a Iron ore sintering
- 2b Coke production
- 2c Iron and steel production and foundries
- 2d Copper production
- 2e Aluminium production
- 2f Lead production
- 2g Zinc production
- 2h Brass and bronze production
- 2i Magnesium production
- 2j Other non-ferrous metal production
- 2k Shredders
- 2l Thermal wire reclamation

The dioxin releases from metal production processes are nearly all combustion-related. They simply arise from the incomplete burning of small amounts of organic materials involved in the production processes. For primary metal production the organic material may be present as a contaminant in the metal ore, or may come from the carbon-based materials (eg, coke) used to promote ore reduction. In the case of secondary metal production, the most significant sources of organic matter are usually contaminants such as oil, grease, paint or plastic coatings that may be present on the surfaces of the input metals. In addition, metals such as copper are known to have a catalytic effect on the rate of dioxin formation.

4.1 Iron ore sintering

Iron ore sintering is a pre-treatment step in the production of iron. The sintering process involves heating of fine iron ore particles with flux and coke or coal fines, to produce a semi-molten mass that solidifies into porous pieces of sinter with the size and strength characteristics necessary for feeding into a blast furnace. This process is not used in the New Zealand steel-making process (see section 4.3.1).

4.2 Coke production (and charcoal)

Coke is produced by heating coal under vacuum in a process known as carbonisation. Along with iron ore and limestone it is an essential ingredient in the blast furnace method of steel production, and millions of tonnes of coke are produced globally for this purpose each year. However New Zealand uses a substantially different process to reduce iron sands to raw iron, which employs coal rather than coke (see s 4.3.1). Coke does find a use in the steel making plant (New Zealand Steel, 2010), but only as a relatively minor additive compared to the tonnages of steel produced – for 1 tonne of steel product only 14.6 kg of coke is used (Jaques, 2002). Total steel production at the plant in 2016 was 585,770 tonnes (see s 4.3) which would have required 8550 tonnes of coke. This coke is not produced in New Zealand, but is imported from China. New Zealand has no production of coke. (Ministry for the Environment, 2018)

Production of charcoal also involves heating under low oxygen conditions, except that wood rather than coal is used as the starting material. The 2012 inventory found that most charcoal available for sale in New Zealand was

imported product and the small amounts produced domestically were likely to have a dioxin burden significantly less than 0.001 grams TEQ per year. Consequently release estimates were not reported and this approach has been taken here.

4.3 Iron and steel production and foundries

This section of the UNEP Toolkit covers iron and steel plants, iron foundries, and galvanising.

4.3.1 Primary steel production

The only primary iron and steel production in New Zealand is at the Glenbrook Mill south of Auckland, which is owned and operated by New Zealand Steel Ltd. This plant is relatively unique in that the primary source of iron is obtained from nearby reserves of iron sand, which is a mixture of magnetite and titanomagnetite (NZ Institute of Chemistry, 1998). Most conventional steel mills use an iron ore, which is usually haematite. The total steel production for 2016 was 585,770 tonnes and the mill also used 847,920 tonnes of coal. (C Jewel, New Zealand Steel, pers comm, 2018).

The dioxin release estimates for the previous Inventories were based on emission test results from the 1990s. An average air emission factor of 0.134 µg TEQ per tonne of steel produced was derived from these results. In the absence of any more recent data, this factor will also be used for the 2016 estimates. The default factors given in the UNEP Toolkit are not relevant because they relate to conventional steel mills using iron ore.

The wastewater produced by the steel mill is passed through a treatment plant and then both this and the site stormwater are discharged to a waterway. The total discharge from the site is approximately 8700 m³ per day and no dioxins have ever been detected in the (now historical tests) on the discharge. The previous inventories used a water concentration factor of 4.7 pg TEQ per litre (4.7 x 10⁻¹² g TEQ/litre), based on a value of 50% of the limit of detection, and this will be used for the 2016 estimates in the absence of any more suitable factor.

The steel mill generated approximately 60,300 tonnes (dry weight) of solid wastes in 2016, which were disposed in a site landfill. There have been no recent tests for the dioxin content of these wastes, so the historical factors used in the 2008 and 2012 Inventories will also be used here. It should be noted that for this source the waste residues are shown as a release to land, because they are disposed on-site. When wastes are disposed off-site they are recorded as a residue release, mainly because the actual disposal method is often not certain.

The current release estimates for primary steel production are shown in Table 4-1, along with the estimates from the 2012 Inventory. There are no releases in residues or in products.

Table 4-1: Dioxin releases from primary steel production

Year	Activity Rates	Release factors (µg TEQ/tonne or pg TEQ/litre (for water))			Annual releases (g TEQ/yr)		
		Air	Water	Land	Air	Water	Land
2012	609,000 tonnes of steel	0.134	-	-	0.082	-	-
	3.05 x 10 ⁶ m ³ water	-	4.7	-	-	0.0143	-
	45,320 tonnes of waste	-	-	4.55	-	-	0.206
2016	585,770 tonnes of steel	0.134	-	-	0.078	-	-
	3.2 x 10 ⁶ m ³ water	-	4.7	-	-	0.0149	-
	60,300 tonnes of waste	-	-	4.55	-	-	0.274

Certainty assessment for 2016

Activity data: Medium (because they are based on company estimates)

Emission factors: Medium (because they are based on historical site data)

4.3.2 Secondary steel production

Until October 2015 Pacific Steel operated an electric arc furnace at its Otahuhu site in Auckland processing recycled scrap steel. The company's production assets were then purchased by New Zealand Steel Ltd. Consequently all steel manufactured in New Zealand is now made at New Zealand Steel's Glenbrook site from newly produced iron – that is there is no domestic steel production using recycled steel scrap (Ministry for the Environment, 2018).

The 2016 release estimates for secondary steel production are shown in Table 4-2.

Table 4-2: Dioxin releases from secondary steel production

Year	Activity Rate, tonnes/yr		Release factors (µg TEQ/tonne of steel or dust)		Annual releases (g TEQ/yr)	
	Steel	Dust	Air	Residue	Air	Residue
2012	240,000		0.15	-	0.036	
	-	4.0	-	700	-	2.8
2016	0		0.15		0.0	
		0		700		0.0

Certainty assessment for 2016

Activity data: High (because there is no secondary steel production)

Emission factors: High (because they are based on annual test data)

4.3.3 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. 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 dioxin releases to air, especially when processing contaminated scrap, and there can also be releases via furnace residues, such as slag and dross (United Nations Environment Programme, 2013).

For the 2012 Inventory a special survey of secondary metal production processes estimated the total annual metal production by iron foundries to be 16,000 tonnes per year. Since then there have been significant changes in the foundry industry including the receivership of New Zealand's largest two foundries, A and G Price in Thames and Precision Foundries (formerly Masport Foundry) in Auckland. Bradken took over the site of the former New Zealand Railways Hillside Workshop in Dunedin after staff were made redundant in 2013. New Zealand foundry production for 2016 was estimated to be 8,800 tonnes.

The current release estimates for iron foundries are shown in Table 4-3, along with the estimates from the 2012 Inventory. The estimates for releases to air for both years are based on a factor of 8.2 µg TEQ per tonne of metal (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne), which was derived from a 2002 industry survey (Ministry for the Environment, 2004) and is marginally lower than the default factor of 10 µg TEQ per tonne given in the UNEP Toolkit. The releases in residues are based on the Toolkit factor of 8 µg TEQ per tonne of metal.

Table 4-3: Dioxin releases from iron foundries

Year	Activity Rate tonnes of iron per year	Release factors (µg TEQ/tonne of iron)		Annual releases (g TEQ/yr)	
		Air	Residue	Air	Residue
2012	16,000	8.2		0.131	
			8		0.083
2016	8,800	8.2		0.072	
			8		0.070

Certainty assessment for 2016

Activity data: Medium (because they are based on survey data)

Emission factors: Medium (because they are based on historical NZ emission data)

4.3.4 Hot-dip galvanising plants

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 has been identified as a potential source of dioxins (United Nations Environment Programme, 2013).

Information on galvanising activity at New Zealand Steel has been obtained directly from the company (C Jewell, pers comm, 2019). For the 2012 Inventory throughput information for the remaining galvanising industry was obtained from the Galvanising Association of New Zealand (J Notley, pers comm, 2014) who requested that the information be kept confidential. It has not been possible to obtain similar information from the Galvanising Association of New Zealand for 2016 so production has been assumed to be at 2012 levels for these plants. Release estimates for 2012 and 2016 are shown in the table below.

Table 4-4: Dioxin releases from hot-dip galvanising

Year	Annual releases (g TEQ/yr)	
	Air	Residue
2012 (recalculation)	0.00557	0.245
2016	0.00727	0.268

Certainty assessment for 2016

Activity data: High (because they are based on industry data)

Emission factors: Low (because they are based on the default factors given in the UNEP Toolkit)

Back-calculations for 2008 and 2012.

2008 and 2012 releases have been revised in order to correct an underestimate of the amount of steel being galvanised. The figure for 2008 is provided in Appendix 1.

4.3.5 Primary aluminium production

The only primary aluminium smelter in New Zealand 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.

Primary aluminium production was listed as a potential source of dioxins in the first edition of the UNEP Toolkit, although no data had been published to show that this was the case. However, more recent assessments indicate that it is no longer thought to be a significant source (United Nations Environment Programme, 2013).

4.3.6 Secondary aluminium production

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 engine parts. 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 can result in increased formation and release of dioxins.

Secondary aluminium processors with estimated annual production over 100 tonnes were surveyed and this information was combined with that from a more detailed survey conducted for the 2012 Inventory. Concerns raised by industry members over production confidentiality have meant that it is possible to publish only the estimated dioxin releases for this category and these are shown in Table 4-5 along with the estimates for the 2012 Inventory.

Table 4-5: Dioxin releases from secondary aluminium production

Year	Annual releases (g TEQ/yr)	
	Air	Residue
2012	0.044	4.05
2016	0.039	3.63

Certainty assessment for 2016

Activity data: Medium (because they are based on survey data)

Emission factors: Medium (because they are based on historical NZ data)

4.4 Lead production

New Zealand's only secondary lead smelter was shut down in 2012 so there are no longer any releases under this sub-category.

4.5 Zinc production

This Toolkit sub-category covers the production of metallic zinc from ore and the recovery and refining of zinc from scrap metal (United Nations Environment Programme, 2013). There is no primary zinc production in New

Zealand (Crown Minerals, undated) and only one firm processing 100 kg was identified in the current secondary metal survey.

4.6 Brass and bronze production

Results of a survey of brass and bronze processors with estimated annual production over 100 tonnes were combined with the results from a more detailed survey conducted for the 2012 Inventory to obtain an estimate for this category. The total annual secondary metal production for copper and other non-ferrous metals was estimated to be 3,900 tonnes per year. Because of a number of plant closures this is well below the production rate estimated for 2012 of 12,000 tonnes per year. The information obtained through the survey does not allow these production rates to be sub-divided into the different types of metals, so the dioxin releases have been accounted for under the brass and bronze sub-category. The Toolkit release factors for brass and bronze production are similar to those for secondary copper production, so the grouping has no marked effect on the overall release estimates.

The current release estimates for this sub-category are shown in Table 4-7, along with the estimates from the 2012 Inventory. The estimates are based on the Toolkit default factors of 3.5 µg TEQ per tonne of metal for releases to air and 125 µg TEQ per tonne for releases to land, but the latter factor was adjusted to allow for only 66% of all plants using bag filters. The factor for releases to air is reasonably consistent with actual release data for New Zealand plants reported from a 2002 industry survey (Ministry for the Environment, 2004).

Table 4-6: Dioxin releases from brass, bronze and other non-ferrous metal production

Year	Activity Rate tonnes of metal per year	Release factors (µg TEQ/tonne of metal)		Annual releases (g TEQ/yr)	
		Air	Residue	Air	Residue
2012	12,000	3.5		0.042	
			82.75		0.993
2016	3,900	3.5		0.014	
			82.75		0.323

Certainty assessment for 2016

Activity data: Medium (because they are based on survey data)

Emission factors: Medium (because they are based on historical NZ emission data)

4.7 Magnesium production

This Toolkit sub-category covers the production of metallic magnesium, for which there is no such activity in New Zealand (Crown Minerals, undated).

4.8 Other non-ferrous metal production

This Toolkit sub-category covers the primary production of other non-ferrous metals, such as cadmium and nickel, for which there is no such activity in New Zealand (Crown Minerals, undated).

4.9 Metal shredding

Metal shredding in New Zealand is conducted by Sims Pacific at two facilities in Auckland and Christchurch. The company collects scrap metal from their branches throughout the country, and from numerous other scrap metal dealers.

Metal shredders are used for the processing of 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 other waste materials in the input stream. Dioxins have been detected in the air discharges 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 (United Nations Environment Programme, 2013).

The Sims Pacific Auckland operation has an annual steel throughput of about 320,000 tonnes per year and about 60% of this is shredded (ie, 190,000 tonnes per year (Auckland Regional Council, 2010)). With the closure of Pacific steel most of the production is exported. Sims Pacific also operate a shredder in Christchurch, which was assessed in the 2008 Inventory as having an annual throughput of around 60,000 tonnes per year. It has not been possible to obtain more recent data from the Company.

Until its closure in June 2016 (E. Reeve, Phoenix Recycling pers comm, 2018), CMA Recycling operated a second metal shredding operation in Auckland with a capacity of around 100,000 tonnes per year (J Osman, Auckland Council, pers comm, 2013).

The amount of data available on dioxin releases to air from metal shredding is very limited, but the UNEP Toolkit recommends a single release factor of 0.2 µg TEQ per tonne of steel (0.2×10^{-6} g TEQ/tonne). This has been used for the current release estimates based on a total combined throughput of 250,000 tonnes per year, which is significantly less than the 350,000 tonnes per year used for the 2012 Inventory.

The primary waste produced from metal shredding is a so-called fluff, which is stabilised prior to disposal to landfill. The UNEP Toolkit provides a release factor of 5 µg TEQ per tonne of steel (5×10^{-6} g TEQ/tonne), and this has been used for the current estimates.

The 2016 release estimates for metal shredding are shown in Table 4-7, along with the estimates from the 2012 Inventory. With the departure of the CMA shredder operation releases to air and residues have decreased. There are no releases to water, land or in products.

Table 4-7: Dioxin releases from metal shredding

Year	Activity Rate (tonnes of steel)	Release factors (µg TEQ/tonne of steel)		Annual releases (g TEQ/yr)	
		Air	Residue	Air	Residue
2012	350,000	0.2	-	0.070	
		-	5	-	1.75
2016	250,000	0.2	-	0.050	
		-	5	-	1.25

Certainty assessment for 2016

Activity data: Low (because they are based on indirect information on nominal plant capacities)

Emission factors: Low (because they are based on the default factors given in the UNEP Toolkit)

4.10 Thermal wire reclamation and e-waste recycling

This Toolkit sub-category covers the burning of electrical cables for the purposes of copper recovery, and thermal processing of other electronic wastes to recover a variety of potentially valuable metals, including copper, silver and gold. Some secondary metal businesses process the copper in electrical cables as part of their feedstock. However, the releases from these operations have already been accounted for in section 4.8. Other than that, the open burning of plastic-coated wire is prohibited by most regional councils, so should not be occurring to any significant extent. The same restrictions would apply to the burning of other types of e-waste.

4.11 Summary for this category

The 2008, 2012 and 2016 release estimates for metal production are summarised in Table 4-8.

Table 4-8: Summary of the release estimates for metal production

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Primary steel production	0.078	0.015	0.274	-	-
Secondary steel production	-	-	-	-	-
Iron Foundries	0.072	-	-	-	0.070
Hot dip galvanizing plants	0.0073	-	-	-	0.268
Secondary aluminium production	0.039	-	-	-	3.62
Lead production	-	-	-	-	-
Brass and bronze production	0.014	-	-	-	0.323
Metal shredding	0.050	-	-	-	1.25
2008 totals	0.686	0.0146	0.21	-	10.76
2012 totals	0.404	0.014	0.206	-	9.71
2016 totals	0.261	0.015	0.274	-	5.54

5 Heat and power generation

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 3a Fossil fuel power plants (coal, oil, gas, shale oil, and co-combustion of waste)
- 3b Biomass power plants (wood, straw, other biomass)
- 3c Landfill, biogas combustion
- 3d Household heating and cooking with biomass (wood, other biomass)
- 3e Household heating and cooking with fossil fuels (coal, oil, gas)

The dioxin releases from heat and power generation processes are all combustion-related, and they mainly arise from the incomplete combustion of the fuels being burned. For this reason, the dioxin release rates tend to be greatest for the more complex fuels (eg, coal and oil versus gas). They are also highly dependent on the types and design of the fuel-burning equipment (eg, industrial furnaces versus simple domestic ovens).

5.1 Fossil fuel power plants

It is important to note that the UNEP Toolkit uses the term power in its broadest technical sense, meaning energy produced by mechanical, thermal, electrical, or other means, whereas in New Zealand it is commonly used to refer specifically to electricity. The previous inventory reports avoided this potential confusion by having separate sections for electricity generation and other industrial/commercial fuel use, and this distinction will be maintained here through the use of sub-sections within each of the fuel-based sub-categories covered below.

The UNEP Toolkit lists 6 different classes within this sub-category, on the basis of fuel type. These are: fossil fuel/waste mixtures, coal, peat, heavy fuel oil, shale oil and light fuel oil/natural gas. The latter group may also be taken to include LPG. There is no co-firing of wastes or usage of peat or shale oil as fuels in New Zealand, but all other fuels have been considered below.

5.1.1 Coal-fired power plants

Electricity Generation

The only coal-fired power station in New Zealand is the Huntly Power Station which, when first built, had a capacity of 1000 MW. This was based on four separate boiler/generation units of 250 MW each – known as Units 1 to 4 – which could be fired on natural gas or coal. More recently, additional generation units have been added to the power station (Units 5 and 6), giving it a nominal total capacity of 1435 MW. However, the newer units are gas-turbine systems, which use natural gas, and minor amounts of diesel.

Units 1 to 4 are over 30 years old and are now rarely utilised to their full capacity. One of the units was ‘retired’ in 2012 (Ministry of Business, Innovation and Employment, 2013) so that the total available capacity for coal burning is now only 750 MW. Coal utilisation reached a peak of 70,000 TJ in 2005 and 2006 and has been dropping steadily since. Values of 43,000 TJ and 29,300 TJ were used for the 2008 and 2012 Inventories respectively. In 2016 only 4,820 TJ was consumed (Ministry of Business Innovation and Employment, 2017). The Ministry attribute this low level of consumption to a number of factors. Firstly strong renewable-based generation, particularly from new geothermal plants, reduced the need for thermal base load electricity generation. 2016 saw particularly strong hydro inflows and subsequent strong hydro-electric generation. Secondly residential electricity demand decreased 2.6% (321 GWh) over the year as result of warmer than average temperatures in autumn and winter. Warmer temperatures would have reduced the need for electricity for heating purposes at the coldest time of the year, when household electricity use peaks. Thirdly demand by the agriculture sector was down 7.7% (213 GWh) in 2016 as higher rainfall in the year reduced the need for

irrigation. Fourthly residential electricity demand per household continues to decline. Despite continued population growth the amount of electricity households are using is decreasing over time continuing a downward trend that began in 2009.

The coal used at Huntly Power Station is a mixture of Waikato sub-bituminous coal, and coal imported from Indonesia. The total coal consumption by Huntly Power Station in 2016 was 223,242 tonnes (N Goodhue, Genesis Energy, pers. comm, 2017).

The power station emissions to air have been tested for dioxins on several occasions, and most recently in 2010 (Sinclair Knight Merz, 2011). However, the results from this and the other previous tests noted in the 2008 Inventory are quite comparable to the factor of 10 µg TEQ per TJ given in the UNEP Toolkit (10 x 10⁻⁶ g TEQ per TJ). Therefore, the toolkit default has been used for the current estimates.

The Huntly Power Station units are fitted with electrostatic precipitators for the control of particulate emissions to air. The fly ash collected by the precipitators is disposed to land in a specially designed ash disposal facility. No information has been obtained on the exact quantities of ash collected by the precipitators, nor the dioxin content. However, the releases to land can be calculated from the fuel consumption rate using the default factors given in the UNEP Toolkit.

The 2016 release estimates for coal-fired electricity generation are shown in Table 5-1, along with the estimates from the 2012 Inventory. As shown, the releases have dropped significantly since 2012 because of the reduced coal consumption. There are no direct releases to water or in products, and the residue (ash) is disposed to land.

Table 5-1: Dioxin releases from coal-fired electricity generation

Year	Activity Rate (TJ of coal/year)	Release factors (µg TEQ/TJ of coal)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	29,090	10	-	0.291	-
		-	14	-	0.407
2016	4,840	10	-	0.0484	-
		-	14	-	0.0678

Certainty assessment for 2016

Activity data: High (because it is based on actual fuel consumption data)

Emission factors: High for air and low for residues (because they are both based on the Toolkit default factors, but the factor for air has been validated by testing at the power station)

Coal-fired industrial manufacturing and commercial appliances

The total New Zealand coal consumption for consumer energy uses in 2016 was 26,680 TJ (1 TJ = 10¹² Joules) (Ministry of Business Innovation and Employment, 2017). Consumer energy uses include agricultural, industrial, commercial, residential and transport with the industrial sector leading consumption. The figures for coal consumption include two sources that are covered under other sections of the inventory: cement manufacture and domestic heating². In 2016 they accounted for 3,400 TJ. Subtracting this amount from the consumer energy total

² Coal use in steel production is also not included here, but this is counted in an Energy Transformation heading in the MBIE energy data summaries, rather than as Consumer Energy.

gives a total annual energy consumption associated with the remaining coal combustion sources of 23,280 TJ (1 TJ = 10^{12} Joules).

Just under half of New Zealand's coal use in 2016 was used by industry primarily to generate heat for industrial processes (Ministry of Business Innovation and Employment, 2017). Dairy companies such as Fonterra and Synlait use coal for this purpose with Fonterra using coal to power 10 out of 29 of its manufacturing sites. In 2017 the dairy industry used 665,680 tonnes of coal with total industrial consumption being 949,000 tonnes (excluding steel manufacture). Both companies recently announced their intentions to reduce coal consumption in the future with Fonterra pledging to install no new coal boilers after 2030. Synlait has also committed to install no new coal fired capacity across the company and has recently installed a 6MW electricity powered electrode boiler at its Dunsandel plant (Evans, 2017).

Fonterra has entered into a collaborative partnership with the Ministry for the Environment with the aim of transitioning to low emission, 100% renewable energy sources thereby helping the country meet its 2030 climate change target to reduce greenhouse gas emissions by 30% below 2005 levels by 2030. (Ministry for the Environment, 2019). Fonterra recently introduced co-firing on wood for one of its coal boilers at its Brightwater plant in Nelson (Fonterra, 2018).

The estimates for the releases to air from industrial and commercial coal combustion have been based on the same approach as adopted for the 2012 Inventory. For plant greater than 10 MW, the UNEP Toolkit emission factor of 10 μg TEQ per TJ has been applied (10×10^{-6} g per TJ), while a factor of 100 μg TEQ per TJ has been used for plants less than 10 MW (100×10^{-6} g per TJ). The 23,280 TJ of total coal consumption in this source category has been assigned to the two size ranges in accordance with the proportion of the total boiler capacity they comprise in the National Heat Plant Database (CRL Energy, 2011). The total capacity of boilers of 10 MW or greater is 662 MW (52.3% of the total), while those less than 10 MW have a total capacity of 603 MW (47.7%). Accordingly the energy distribution used was 12,175 TJ and 11,105 TJ, respectively.

The default release factor of 14 μg TEQ per TJ (14×10^{-6} g TEQ per TJ) given in the UNEP Toolkit has been used for estimating the annual releases in residues from these coal fired sources.

The 2016 release estimates for industrial and commercial coal use are shown in Table 5-2, along with the estimates from the 2012 Inventory. As shown, the releases both to air and in residues have increased, due to a rise in coal consumption. There are no direct releases to water or in products. The ash production is assigned to the residues Toolkit vector, because the final place of disposal is not known with any certainty.

Table 5-2: Dioxin releases from industrial and commercial coal use

Year	Plant size	Activity Rate (TJ of coal/year)	Release factors (μg TEQ/TJ of coal)		Annual releases (g TEQ/yr)	
			Air	Residue	Air	Residue
2012	> 10 MW	10,500	10	-	0.105	-
			-	14	-	0.147
	< 10 MW	9,570	100	-	0.957	-
			-	14	-	0.134
Totals		20,070			1.062	0.281

2016	> 10 MW	12,175	10	-	0.122	-
			-	14	-	0.171
	< 10 MW	11,105	100	-	1.11	-
			-	14	-	0.156
Totals	23,280			1.232	0.327	

Certainty assessment for 2016

Activity data: High (because it is based on national fuel consumption data)

Emission factors: Low (because they are both based on the Toolkit default factors)

5.1.2 Heavy fuel oil-fired power plants

The survey of waste oil production shown in Appendix 3 of the 2012 Inventory estimated that about 35 million litres of waste oil were available for recycling annually in New Zealand. The use of 15.4 million litres (with an energy content of 630 TJ) was attributed to a variety of industrial process including pulp and paper, bitumen, brick and food manufacturing and various horticultural activities.

The total heavy fuel oil used in New Zealand industrial applications was estimated to be 1,020 TJ (Ministry of Business Innovation and Employment, 2017) significantly less than the 3,310 TJ used in 2012. There was a further 5,490 TJ used in coastal shipping, but this should be accounted for under the Transport category. The UNEP Toolkit provides a default factor for releases to air and indicates there are no data available on the releases via other pathways, such as in residues (ash).

The 2016 release estimates for heavy fuel oil-fired power plant are shown in Table 5-3. Releases are lower because of a decrease in consumption.

Table 5-3: Dioxin releases from heavy fuel oil-fired power plant

Year	Activity Rate (TJ of fuel oil/year)	Release factors ($\mu\text{g TEQ/TJ}$ of oil)	Annual releases (g TEQ/yr)
		Air	Air
2012	3,310	2.5	0.0083
2016	1,020	2.5	0.0026

Certainty assessment for 2016

Activity data: High (because it is based on actual fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.1.3 Fuel oil and natural gas-fired power plants

Fuel oil and natural gas-fired electricity generation

There are 8 gas-fired power stations in New Zealand with individual electricity generation capacities of 10 MW or greater and a combined capacity of 1150 MW (www.transpower.co.nz/power-system-live-data). Three of these are combined-cycle or open-cycle gas turbines, and the other 5 are cogeneration plants. There are 4 other cogeneration plants fired predominantly on biomass (2) or coal (2), which may also burn gas.

In 2016 the total consumption of natural gas for electricity generation was 56,360TJ (1 TJ = 10¹² Joules), including that used in cogeneration plants (Ministry of Business Innovation and Employment, 2017). 2016 saw gas fuel input for electricity production fall to a 35 year low because of the greater availability of hydroelectricity that year and other reasons outlined in Section 5.1.1. However the Ministry sees the long term trend for gas electricity generation as being in decline. In late 2015 two gas-fired combined cycle plants were retired: the Contact Energy 400 MW Otahuhu power station and Mercury Energy's 140 MW Southdown plant.

The total consumption of diesel for electricity generation in 2016 was only 20 TJ, which suggests it was simply being used when running standby for other plants undergoing annual maintenance.

There are no dioxin emission data available for gas-fired electricity plants in New Zealand, so the UNEP Toolkit default factors have been used. These make no distinction between the use of gas or oil, and indicate that the only relevant release route is to air.

The 2016 release estimates for fuel oil (diesel) and natural gas-fired electricity generation are shown in Table 5-4, along with the corresponding estimates made in the 2012 Inventory.

Table 5-4: Dioxin releases from fuel oil and natural gas-fired electricity generation

Year	Activity Rate (TJ of fuel/year)	Release factors (µg TEQ/TJ of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	72,190	0.5	0.036
2016	56,380	0.5	0.028

Certainty assessment for 2016

Activity data: High (because it is based on actual fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

Industrial/commercial fuel oil and gas-fired power plants

The major industrial uses of fuel oil (diesel), LPG and natural gas are in dairy factories, meat processing plants, pulp and paper and other wood processing industries, and steel manufacture. However, there are also numerous small boilers found in industrial/commercial businesses, and institutions, such as schools and hospitals.

The industrial and commercial consumption of natural gas (excluding electricity generation) accounted for 73,460 TJ of energy in 2016 (Ministry of Business Innovation and Employment, 2017). In addition, the industrial and commercial uses of LPG were 4790 TJ, half of which has been assumed to be used in heat-raising appliances. The industrial sector has been growing rapidly since 2006, primarily being driven by growth in chemical manufacturing and food processing.

The industrial and commercial combustion of diesel in boilers is not easily distinguished from that used in stationary combustion engines³ on the basis of the available statistical information. An estimate of the heat produced by diesel-fired boilers has been made using the plant capacities recorded in the Heat Plant Database (CRL Energy, 2011). The total installed capacity is 189 MW. If it is assumed these boilers operate 24 hours a day for 320 days a year, at 75% efficiency, the total energy consumed would be about 3900 TJ per year.

³ In the UNEP Toolkit, stationary combustion engines are considered under the Transport category (see section 7).

The UNEP Toolkit provides an emission factor of 0.5 µg TEQ per TJ (0.5×10^{-6} g TEQ per TJ), for the discharges to air from power plants fired with natural gas and light fuel oil. There are no factors for releases to any of the other release routes. The UNEP Toolkit factor has been used in the absence of any relevant New Zealand data.

The 2016 release estimates for industrial/commercial fuel oil and gas-fired power plant are shown in Table 5-5, along with the corresponding estimates made in the 2012 Inventory. Releases have increased because of an increase in fuel consumption.

Table 5-5: Dioxin releases from fuel oil and gas-fired power plant

Year	Activity Rate (TJ of fuel/year)	Release factors (µg TEQ/TJ of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	53,530	0.5	0.027
2016	82,150	0.5	0.041

Certainty assessment for 2016

Activity data: High (because it is based on actual fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.2 Biomass power plants

There are 2 large biomass-fired cogeneration plants in New Zealand. (Ministry of Business Innovation and Employment, 2017). These are the power boilers at the Kinleith pulp and paper mill and the thermo-mechanical pulp plant in Napier. Biomass is also burned in the recovery boilers at the pulp and paper mills, and in numerous other power boilers in board mills, fibreboard plants, and sawmills. The Heat Plant Database lists about 175 industrial wood-fired installations rated at greater than 1 MW capacity, with a total combined capacity of more than 1035 MW (CRL Energy, 2011). Altogether, these account for about 80% of New Zealand wood combustion.

This section addresses the industrial biomass power plants, and any incidental incineration of wood waste. 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 8.

There have been no new significant biomass –fuelled facilities constructed in the last 5 years in New Zealand so the dioxin releases from this source category were assessed by the same procedure used in the 2012 Inventory. The gross heat energy ratings for relevant plant listed in the Heat Plant Database (CRL Energy, 2011) were summed and an estimate of the annual energy consumption was made based on the assumption that the facilities operated 24 hours a day, at 70% capacity, for 320 days per year. The total energy consumption was estimated at 20,000 TJ ($1 \text{ TJ} = 10^{12}$ Joules), not including the contribution from black liquor combustion in the pulp and paper industry. If black liquor is taken into account, the total energy consumption is 29,440 TJ.

The latter figure (black liquor included) compares very well with the results of a manufacturing energy use survey conducted by Statistics New Zealand, which determined a total annual energy usage in 2008, for wood and wood waste production, of 29,250 TJ (Statistics New Zealand, 2009).

The 2012 Inventory estimates were based on the default factors given in the UNEP Toolkit, of 50 µg TEQ per TJ for releases to air, and 15 µg TEQ per TJ for releases in residues (ash) (1 µg TEQ/TJ = 1 x 10⁻⁶ g TEQ/TJ). These factors have also been used for the current estimates.

The 2016 release estimates for biomass-fired power plant are shown in Table 5-6, along with the corresponding estimates made in the 2012 Inventory. There are no direct releases to water or in products. The ash production is assigned to the residues Toolkit vector, because the final place of disposal is not known with any certainty.

Table 5-6: Dioxin releases from biomass-fired power plant

Year	Activity Rate (TJ of biomass/year)	Release factors (µg TEQ/TJ of biomass)		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	20,000	50	-	1.000	-
		-	15	-	0.300
2016	20,000	50	-	1.000	-
		-	15	-	0.300

Certainty assessment for 2016

Activity data: Medium (because it is based on an estimate of fuel consumption)

Emission factor: Low (because it is based on the Toolkit default factors)

5.3 Landfill, biogas combustion

Landfill gas from solid waste disposal and biogas from domestic wastewater treatment are both generated from anaerobic digestion of organic matter. The resulting gas is predominantly methane but may also contain carbon monoxide, carbon dioxide, ammonia and smaller fractions of volatile organic compounds (United Nations Environment Programme, 2013). Dioxins can be produced when the gases are burned, either in a flare or a gas engine (eg, for electricity generation).

The New Zealand Greenhouse Gas Inventory publishes data on the amount of methane that is recovered and flared or utilised from both of these sources (Ministry for the Environment, 2018)). No direct data are available on biogas emissions from landfills or sewage treatment facilities. Estimates are based on electricity generation data which are collected for 15 individual plants including 11 landfill facilities totaling 29.4 MW and four wastewater treatment co-generation facilities totaling 11.3 MW. Fuel gas input estimates are then based on gross generation using a default electrical efficiency factor of 30%.

The Toolkit emission factor for landfill and biogas utilisation is 8 µg TEQ/TJ gas burned (8 x 10⁻⁶ g TEQ/TJ), and the estimated releases to air are shown in the table below. There are no releases to any other environmental compartments.

Table 5-7: Dioxin releases from landfill gas and biogas combustion

Year	Activity Rate (TJ of gas/year)	Release factors (µg TEQ/TJ of gas)	Annual releases (g TEQ/yr)
		Air	Air
2012	3,104	8	0.025
2016	3,250	8	0.026

Certainty assessment for 2016

Activity data: Medium (because it is based on a national data source)

Emission factor: Low (because it is based on the Toolkit default factor)

5.4 Household heating and cooking with biomass

Estimates of the amount of energy used in household heating and cooking with biomass are based on the proportion of households with wood burners which is obtained from the National Census. This number is combined with Building Research Association estimates of the average amount of energy used by households that use wood for heating, to produce total annual energy use estimates for this fuel type in TJ. Trends such as the declining use of wood are factored in. Current estimates are still based on the 2013 Census as release of the 2018 Census results has been delayed until 2019. The number of homes burning wood for heat has decreased over time, but it is still an important home-heating method in New Zealand. Wood burners heated 33 percent of North Island homes and 47 percent of South Island homes in 2013, with even higher percentages in some rural areas (Ministry for the Environment and Stats NZ, 2018).

The Energy Efficiency and Conservation Authority (EECA) produces an energy end use database which provides details on energy consumption for a wide variety of end use categories including household consumption. (Energy Efficiency and Conservation Authority, 2018) (www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database). For household heating and cooking with biomass in 2016, the database shows a total energy consumption of 8118 TJ for wood. The bulk of this (7789 TJ) was for space heating, with 271.3 TJ used for water heating and 57.2 TJ used for cooking.

The database reports a wood energy consumption of 8327 TJ for 2012 which compares well with the 8200 TJ used in the 2012 Inventory which used a different data source.

National emission standards introduced particulate emission performance criteria for new wood burners in 2005. The statistical data is not yet available to confirm whether these regulations have led to significant reductions in wood burner numbers since 2012. However PM₁₀ concentration measurements (particulate matter concentrations for particles below 10 µm in diameter) made between 2007 and 2016 where the majority of sites were predominantly influenced by home-heating emissions showed that PM₁₀ concentrations have decreased at many locations mostly during spring and winter. Winter is the season when home-heating emissions are at their highest (Ministry for the Environment and Stats NZ, 2018). This suggests that wood burner use is indeed declining.

The 2016 release estimates for domestic wood combustion are shown in Table 5-8 along with the corresponding estimates made in the 2012 Inventory. There are no direct releases to water or in products. The ash production is assigned to the residues Toolkit vector, because the final place of disposal is not known with any certainty.

Table 5-8: Dioxin releases from domestic wood combustion

Year	Activity Rates (TJ wood/year)	Release factors ($\mu\text{g TEQ/TJ wood}$)		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	8,200	100		0.820	
			20		0.164
2016	8118	100	-	0.812	-
		-	20	-	0.162

Certainty assessment for 2016

Activity data: High (because it is based on a national survey of energy use coupled with census data)

Emission factors: Low (because they are based on the Toolkit default factors)

5.5 Household heating and cooking with fossil fuels

This sub-section addresses the dioxin emissions from the domestic burning of oil, coal and gas. The oil category covers both fuel oil and diesel, while gas consumption includes both natural gas and LPG.

5.5.1 Coal

The total amount of coal burned in domestic appliances in 2016 was 343 TJ (Ministry of Business Innovation and Employment, 2017), (1 TJ = 10^{12} Joules). Most of the coal burned was for space heating (320 TJ) with 21 TJ used for water heating and about 2 TJ for cooking. (Energy Efficiency and Conservation Authority, 2018).

As with the 2012 dioxin inventory the Toolkit factor of $100 \mu\text{g TEQ/TJ}$ of coal has been used for estimating the releases to air ($1 \mu\text{g TEQ/TJ} = 1 \times 10^{-6} \text{ g TEQ/TJ}$). Also, the releases via ash have been determined using a factor of $0.41 \mu\text{g TEQ/tonne}$ of ash, which was originally used in the 2000 Inventory report. This was derived from a UK study, but it was considered more appropriate than the Toolkit factor of $5 \mu\text{g TEQ/tonne}$ of ash, which relates to the dioxin concentrations in soot rather than ash. The ash quantities were calculated using a factor of 1265 tonnes/PJ, which was derived from an assumed average ash content of 3.15% for New Zealand coal and a calorific value of 25 MJ/kg ($25 \times 10^6 \text{ J/kg}$).

The 2016 release estimates for domestic coal combustion are shown in Table 5-9, along with the corresponding estimates made in the 2012 Inventory. There are no direct releases to water or in products. The ash production is assigned to the residues Toolkit vector, because the final place of disposal is not known with any certainty.

Table 5-9: Dioxin releases from domestic coal combustion

Year	Activity Rates		Release factors		Annual releases (g TEQ/yr)	
	(TJ coal/year)	(tonnes ash/year)	Air ($\mu\text{g TEQ/TJ coal}$)	Residues ($\mu\text{g TEQ/tonne ash}$)	Air	Residues
2012	440		100		0.044	
		557		0.41		0.00023
2016	343	-	100	-	0.034	-
	-	434	-	0.41	-	0.00018

Certainty assessment for 2016

Activity data: High for coal, medium for ash (because the coal quantities are based on national fuel data but the ash quantities are derived using an assumed average ash content)

Emission factors: Low (because the air release is based on the Toolkit default factor, and the ash release factor is taken from a now relatively dated UK publication)

5.5.2 Oil

A total of 119.6 TJ was used for diesel fueled space heating in 2016 (Energy Efficiency and Conservation Authority, 2018). The 2016 release estimates for domestic oil combustion are shown in Table 5-11, along with the corresponding estimates made in the 2012 Inventory. The Toolkit factor shown is the same as that used for the 2012 inventory and there are no releases to land, water, or in products or residues.

Table 5-10: Dioxin releases from domestic oil combustion

Year	Activity Rate (TJ of oil/year)	Release factors (µg TEQ/TJ of oil)	Annual releases (g TEQ/yr)
		Air	Air
2012	290	10	0.0029
2016	120	10	0.0012

Certainty assessment for 2016

Activity data: High (because it is based on national fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.5.3 Gas

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 2016 was reported to be 6360 TJ, and LPG usage was 3221 TJ giving a combined consumption of 9581 TJ. (Ministry of Business Innovation and Employment, 2017) (1 TJ = 10¹² Joules).

The 2016 release estimates for domestic gas combustion are shown in Table 5-11, along with the corresponding estimates made in the 2012 Inventory. The Toolkit factor shown is the same as that used for the 2012 inventory and there are no releases to land, water, or in products or residues.

Table 5-11: Dioxin releases from domestic gas combustion

Year	Activity Rate (TJ of gas/year)	Release factors (µg TEQ/TJ of gas)	Annual releases (g TEQ/yr)
		Air	Air
2012	9020	1.5	0.0135
2016	9581	1.5	0.0144

Certainty assessment for 2016

Activity data: High (because it is based on national fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.6 Summary for this category

The 2016 release estimates for heat and power generation are summarised in Table 5-12, along with the revised comparative totals for 2012 and 2008.

Table 5-12: Summary of the release estimates for heat and power generation

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Coal-fired power plants: electricity generation	0.048	-	0.068	-	-
Coal-fired power plants: Industrial and commercial	1.232	-	-	-	0.327
Heavy fuel oil-fired power plants	0.0026	-	-	-	-
Fuel oil and gas-fired power plants: electricity generation	0.028	-	-	-	-
Fuel oil and gas-fired power plants: industrial and commercial	0.041	-	-	-	-
Biomass power plants	1.000	-	-	-	0.300
Landfill gas/biogas combustion	0.026	-	-	-	-
Household heating & cooking with biomass	0.812	-	-	-	0.162
Household heating & cooking with coal	0.034	-	-	-	0.00018
Household heating & cooking with oil	0.0012	-	-	-	-
Household heating & cooking with gas	0.0144	-	-	-	-
2008 totals	3.32	-	0.608	-	0.779
2012 totals	3.329	-	0.407	-	0.745
2016 totals	3.241		0.068		0.788

6 Production of mineral products

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 4a Cement production
- 4b Lime production
- 4c Brick production
- 4d Glass production
- 4e Ceramics production
- 4f Asphalt mixing
- 4g Oil shale pyrolysis

The dioxin releases from the production of mineral products are all basically combustion-related. However, the alkaline nature of many of the materials being processed may help to reduce dioxin formation, either by neutralising some of the active chlorine species or by surface absorption of the dioxins after they are formed.

6.1 Cement production

There were two cement plants in operation in New Zealand in 2012; Golden Bay Cement in Northland and the Holcim plant at Cape Foulwind, Westport in the West Coast region. However the Holcim plant was closed in June 2016 and will not be included in the 2016 Inventory.

The Golden Bay plant uses a 'dry' process in which the raw materials are fed into the system in a dry state. Coal is used as the primary fuel but is supplemented with wood waste. The total cement production at the plant in 2016 was 887,025 tonnes (O.Khanal, Northland Regional Council, pers comm, 2017).

The default factor given in the UNEP Toolkit for dry process kilns is 0.05 µg TEQ per tonne. There are no releases of cement kiln dust (CKD) from the Golden Bay plant, although this did occur in the now-closed Holcim plant.

The 2016 release estimates for cement production are shown in Table 6-1, along with the corresponding estimates made in the 2012 Inventory.

Table 6-1: Dioxin releases from cement production

Year	Plant	Activity Rate (tonnes/year)		Release factors (µg TEQ/tonne of cement or CKD)		Annual releases (g TEQ/yr)	
		Cement	CKD	Air	Land	Air	Land
2012	Golden Bay	690,000	-	0.05	-	0.035	-
	Holcim	420,000	-	0.02	-	0.008	-
		-	20,000	-	6.7	-	0.134
2016	Golden Bay	887,025	-	0.05	-	0.044	-

Certainty assessment for 2016

Activity data: High (because it is based on actual cement production data)

Emission factor: Low because it is based on the Toolkit default factor

6.2 Lime production

There are 5 lime kilns in New Zealand located at Te Kuiti, Otorohanga (2) and Te Kumi, all in the Waikato region and Dunback in Otago, which produce burnt lime from limestone. The total burnt lime production from these kilns in 2016 was 238,480 tonnes per year (Ministry for the Environment, 2018)

Two North Island Kraft pulp and paper mills also operate lime kilns but these process the so-called “lime-mud” produced in the recovery process.

The 2012 Inventory estimates for releases to air were based on the default UNEP Toolkit factor of 0.07 µg TEQ per tonne of lime (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). For releases to land it was assumed that there would be about 3000 tonnes of dust collected from the air pollution control equipment on the kilns, with a dioxin content of 6.7 µg TEQ per tonne, and 17,000 tonnes of product (lime) applied to land, with a dioxin content of 1.24 µg TEQ per tonne. The same factors and assumptions have been applied to the current estimates, but the calculations have only been applied to the annual burnt lime production at the 5 limestone kilns (ie excluding the pulp mill kilns). An additional factor of 1.4 has been applied to these estimates to reflect increased production from 170,000 to 238,480 tonnes.

The lime kilns used at the pulp and paper mills do produce some dioxin emissions to air. These emissions were tested on the 2 kilns at the Bay of Plenty mill in 2002, and showed dioxin concentrations of 23 and 14 pg TEQ/Nm³ (1 pg TEQ/Nm³ = 1 x 10⁻¹² g TEQ/Nm³) (Beca Amec, 2006). On the basis of the gas flow data provided in a more recent report (Beca Amec, 2009), and assuming the same release rate for the Waikato mill, the total annual dioxin release is estimated at 0.0006 g TEQ per year. There would be no releases to land or water from these kilns.

The release estimates for both 2012 and 2016 for lime production are shown in Table 6-2. Releases have increased because of an increase in lime production.

Table 6-2: Dioxin releases from lime production

Year	Activity Rate (tonnes of lime/year)		Release factors (µg TEQ/tonne of lime)		Annual releases (g TEQ/yr)	
			Air	Land	Air	Land
2012	Lime production	170,000	0.07	-	0.0119	-
	Lime application to land	17,000	-	1.24	-	0.022
	APC equipment dust	3,000	-	6.7	-	0.020
	Pulp mill lime kilns	-	-	-	0.0006	-
Total					0.0125	0.042
2016	Lime production	238,480	0.07	-	0.0167	-
	Lime application to land	23,800	-	1.24	-	0.0295
	APC equipment dust	4200	-	6.7	-	0.0281
	Pulp mill lime kilns				0.0006	
Total					0.0173	0.0576

Certainty assessment for 2016

Activity data: Medium (because it is based on estimated production data)

Emission factor: Low (because it is based on the Toolkit default factors and other published information)

6.3 Brick production

With the closure of New Zealand's largest brick manufacturing facility, CSR Building Products (Monier Bricks), there are now only two significant manufacturers of bricks in New Zealand located in Huntly and Christchurch. The Huntly plant is fired by gas and produces about 5,000 tonnes per annum, whereas the Christchurch plant produces 5,000 tonnes per annum and is fired with oil (R Thomas, Canterbury Clay Bricks, pers comm, 2018). Consequently total brick production for 2016 was 10,000 tonnes.

The UNEP Toolkit differentiates between small, poorly controlled kilns (which it assigns as Class 1) and larger better-controlled kilns (Class 2). Kilns can qualify for the class 2 category if they have either emission control technology in place or state of the art process control, in which case they can burn fuels of any type including those which the Toolkit refers to as "contaminated". Alternatively larger kilns with no emission control technology, but which use uncontaminated fuels, also qualify as class 2. On this basis the two New Zealand brick-making facilities should be assigned to Class 2.

The Toolkit provides emission factors for releases to air, in products and in residues. The residues produced in brick making are the ash products resulting from the combustion of solid fuels. Where the fuel is natural gas or a liquid fuel such as oil or diesel, virtually no ash is produced. Consequently there are no significant releases via residues for the New Zealand plants.

The 2016 release estimates for brick production are shown in Table 6-3, along with the corresponding estimates reported for the 2012 Inventory.

Table 6-3: Dioxin releases from brick production

Year	Activity Rate (tonnes/year)	Release factors ($\mu\text{g TEQ/tonne}$)		Annual releases (g TEQ/yr)	
		Air	Products	Air	Products
2012	44,546	0.02	-	0.00089	-
		-	0.006	-	0.00027
2016	10,000	0.02		0.00020	
			0.006		0.00006

Certainty assessment for 2016

Activity data: High (because it is based on industry production data)

Emission factor: Low (because it is based on the Toolkit default factors)

6.4 Glass production

There are two industrial glass manufacturers in New Zealand both based in Auckland. O-I Glass Ltd produces glass bottles and jars, while Tasman Insulation, produces fibreglass insulation. The latter process uses recycled window glass as its feedstock and an electric melter (M Burgess, Fletcher Building, pers comm, 2018) so its production does not contribute to the sector's activity. Production for 2016 was 209,077 tonnes per year of glass product (J. Wright, O-I Glass Limited, pers comm, 2018).

The emission estimate in the 2012 Inventory was based on the UNEP Toolkit default factor of 0.015 µg TEQ per tonne of glass (0.015×10^{-6} g TEQ/tonne) for releases to air, and there were no significance releases via any other media. The same approach has been adopted here. The 2016 release estimates for glass production are shown in Table 6-4, along with the corresponding estimate made in the 2012 Inventory.

Table 6-4: Dioxin releases from glass production

Year	Activity Rate (tonnes of glass/year)	Release factors (µg TEQ/tonne of glass)	Annual releases (g TEQ/yr)
		Air	Air
2012	230,511	0.015	0.0035
2016	209,077	0.015	0.0031

Certainty assessment for 2016

Activity data: High (because it is based on actual production data)

Emission factor: Low (because it is based on the Toolkit default factor)

6.5 Pottery and ceramics production

Statistics for the annual production of clay for pottery and ceramics in New Zealand are kept by the New Zealand Petroleum and Minerals group of the Ministry of Business Innovation and Employment (MBIE). Most production comes from a single site in Northland (C. McCabe, MBIE, pers comm, 2018). The statistical records show that the amount of clay listed can vary significantly from year to year. For instance: 2013 – 13,066 tonnes, 2014 – 61,382 tonnes, 2015 – 13,659 tonnes and 2016 – 61,650 tonnes. Given the annual production variability the activity for 2016 has been assigned as the average of the clay tonnage for 2013 – 2016 inclusive, that is 37,439 tonnes. Using a similar approach for the 2012 Inventory, that is averaging production from 2009 – 2012 inclusive, would have given an activity of 37,475 tonnes. This is significantly higher than the 16,055 tonnes reported in the Inventory. As a result a back calculation has been performed for the 2012 figures as shown in Table 6.5. A back calculation for the 2008 Inventory is not necessary as its four yearly average estimate (14,630 tonnes) is sufficiently close to the 18,000 tonnes used in the Inventory.

The UNEP Toolkit notes that dioxins will most likely be released to air during ceramics production, as a result of the thermal processes involved. However, no specific emission data has been reported, and it recommends using the emission factors developed for brick making to give an indication of the likely releases (United Nations Environment Programme, 2013). The Toolkit differentiates between small, poorly controlled kilns (which it assigns as Class 1) and other types of kilns (Class 2). The Class 2 category covers a variety of situations, including kilns with no emission control technology, but which use uncontaminated fuels. It has been assumed that all New Zealand kilns should be assigned to Class 2. The 2016 release estimates for pottery and ceramics production are shown in Table 6-5, along with the revised estimate for the 2012 Inventory.

Table 6-5: Dioxin releases from pottery and ceramics production

Year	Activity Rate (tonnes/year)	Release factors (µg TEQ/tonne)	Annual releases (g TEQ/yr)
		Air	Air
2012	37,475 (back calculation)	0.02	0.00075
2016	37,439	0.02	0.00075

Certainty assessment for 2016

Activity data: High (because it is based on national clay production data)

Emission factor: Low (because it is based on the Toolkit default factor)

6.6 Asphalt mixing

Civil Contracting New Zealand have estimated that the annual asphalt production for 2016 in New Zealand was 1.4 million tonnes per year, significantly higher than the 850,000 tonnes used for the previous inventory (S. Goldsworthy, pers comm, 2019)

The 2012 Inventory estimates for this source category were based on the UNEP Toolkit default factors of 0.007 µg TEQ per tonne of asphalt for emissions to air, and 0.06 µg TEQ per tonne of asphalt for releases in residues (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). However, the latter factor was only applied to 50% of the total production, because in about half of the plants the dust collected in the air pollution control equipment is recycled back to the process. The same factors have been applied to the current estimates.

The 2016 release estimates for asphalt production are shown in Table 6-6 along with the estimates for 2012.

Table 6-6: Dioxin releases from asphalt production

Year	Activity	Activity Rate (tonnes of asphalt)	Release factors (µg TEQ/tonne of asphalt)		Annual releases (g TEQ/yr)	
			Air	Residues	Air	Residues
2012	Asphalt production	850,000	0.007	-	0.006	-
	Plant residues (dust)	50% of the above	-	0.06	-	0.026
2016	Asphalt production	1,400,000	0.007		0.0098	
	Plant residues (dust)	50% of the above		0.06		0.042

Certainty assessment for 2016

Activity data: Medium (because it is based on estimated production data)

Emission factor: Low (because it is based on the Toolkit default factors and other published information)

6.7 Oil shale pyrolysis

Oil shale is a general term applied to a group of hard rocks (only some of which are described geologically as shales) rich enough in bituminous material to yield petroleum upon pyrolysis and distillation (Ministry of Economic Development, 2008). Some of New Zealand's oil reserves occur in soft clay-based rocks that are also described as shales. However, the oil is extracted from these *in situ* rather than by pyrolysis. Hence this is not a potential source for New Zealand.

6.8 Summary for this category

The 2016 release estimates for mineral production are summarised in Table 6-7, along with the revised comparative totals for 2008 and 2012.

Table 6-7: Summary of the release estimates for mineral production

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Cement production	0.044	-		-	-
Lime production	0.0173	-	0.0576	-	-
Brick production	0.00020	-	-	0.00006	-
Glass production	0.0031	-	-	-	-
Pottery and ceramics	0.00075	-	-	-	-
Asphalt production	0.0098	-	-	-	0.042
2008 totals	0.0866	-	0.218		0.026
2012 totals	0.066	-	0.176	0.00027	0.026
2016 totals	0.076	-	0.0576	0.00006	0.042

7 Transport

This source category 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 also captures fuel consumption by other forms of transport, such as trains, boats and off-road vehicles, and also fuel use in stationary engines, such as generators (United Nations Environment Programme, 2013). Aircraft are not included because the combustion of aviation fuel is believed to not result in any significant releases of dioxins. The category is broken down into the following sub-groups:

- 5a 4-Stroke engines
- 5b 2-Stroke engines
- 5c Diesel engines
- 5d Heavy oil-fired engines

The dioxin releases from transport are all combustion-related, and they mainly arise from the incomplete combustion of the fuels being burned. For this reason, the dioxin release rates tend to be greatest for the more complex fuels (eg, oil versus petrol versus LPG). They are also affected by the different engine designs and the use of catalytic converters on the engine exhausts. An additional factor specific to leaded petrol is noted below.

In 2016 4.7 million New Zealanders owned 4 million vehicles of all kinds driven on public roads. These included:

- 3 million light petrol vehicles
- 650,000 diesel powered light vehicles (mostly vans, utes, light trucks and 4-WDs)
- 145,000 diesel heavy vehicles (trucks and buses)
- 110,000 motor cycles
- 30,000 mopeds (a significant proportion of which have 2-stroke engines)
- 2,900 CNG powered vehicles
- 5,000 LPG powered vehicles.

(source: www.transport.govt.nz/assets/uploads/research/Documents/NZ-Vehicle-fleet-fact-and-fiction-2017.pdf)

An unusual feature of this vehicle fleet in global terms is its age. 780,000 vehicles (20%) are more than 20 years old, of which 3% are more than 35 years old.

Significant quantities of petrol are also combusted in engines in off-road situations. The Ministry of Transport list the following principal users and estimated annual petrol use. (I McGlinchy, Ministry of Transport, pers comm, 2018):

- 50,000 motocross bikes and quad bikes using an estimated 15 million litres
- 40,000 agricultural quad bikes using an estimated 56 million litres
- 1.1 million motor mowers using an estimated 13.2 million litres
- 175,000 boats and jet skis using an estimated 65.6 million litres (many of which have 2-stroke engines)

7.1 4-Stroke engines

The use of leaded petrol was the major cause of dioxin emissions from motor vehicles, due to the presence of chemicals such as dichloroethane that were used as scavengers for the lead (United Nations Environment Programme, 2013). Dioxins 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 almost negligible levels.

The engines of most petrol-fuelled vehicles operate on a 4-stroke cycle and, in New Zealand, all petrol has been unleaded since the late 1990s. The total petrol consumption in 2016 was 112,500 TJ, or about 2,393,820 tonnes (1 TJ = 10^{12} Joules) (Ministry of Business Innovation and Employment, 2017).

The Ministry of Transport estimates that 95% of the on-road use of petrol in 2016 was in vehicles fitted with catalytic converters (I McGlinchy, Ministry of Transport, pers comm, 2018). This number is significantly higher than the estimates of 60% and 83% used in the 2008 and 2012 Inventories respectively. The effect of increasing proportions of catalytic converters can be seen in the results of a long term air quality study commissioned by the Ministry. Remote testing measurements of carbon monoxide (CO) concentrations from thousands of individual vehicles as they drove past in 10-day monitoring periods from 2003 to 2015 were made at two high traffic density sites in Auckland and Christchurch. Over the years CO concentrations from New Zealand new vehicles dropped steadily from 0.32% to 0.02% with Japanese second hand imports dropping from 0.28% to 0.08% over the same period (Bluett, Aguiar, & Smit, 2016)

The UNEP Toolkit provides different emission factors for 4-stroke vehicles with or without catalysts, and also for vehicles operated on petrol/ethanol blends containing 50% or more ethanol. Petrol/ethanol blends are available in New Zealand but the proportion of ethanol is limited under the *Engine Fuel Specifications Regulations 2011* to no more than 10%. The total amount of bioethanol produced in New Zealand in 2016 was only 110 TJ, and the consumption for transport has already been included in the total petrol figure given above.

The use of LPG in vehicles is also included in this category, and the emissions are expected to be similar to those from 4-stroke engines fitted with exhaust catalysts. The total LPG consumption for transport in 2016 was only 310 TJ or 6,330 tonnes,

The 2016 release estimates for 4-stroke engines are shown in Table 7-1, along with the corresponding estimates made in the 2012 Inventory. The activity rates were obtained by subtracting the petrol used in 2-stroke engines (see section 7.2 below) and then distributing 5% of the remainder to non-catalyst vehicles and 95% to those fitted with catalysts. The annual LPG consumption has been added to the latter figure.

Table 7-1: Dioxin releases from 4-stroke petrol engines

Year	Type of 4-stroke engine	Activity Rate (tonnes of fuel/year)	Release factors ($\mu\text{g TEQ/tonne of fuel}$)	Annual releases (g TEQ/yr)
			Air	Air
2012	no catalyst	383,758	0.1	0.038
	catalyst	1,881,442	0.001	0.002
	Totals			0.040
2016		119,411	0.1	0.012
		2,268,809	0.001	0.0023
				0.014

Certainty assessment for 2016

Activity data: High (because it is based on national fuel data)

Emission factor: Low (because it is based on the Toolkit default factor)

7.2 2-Stroke engines

Petrol engines operating on a 2-stroke cycle were commonly used in the past in applications that required relatively small light-weight power units, such as chain saws, lawn mowers, outboard motors, motor bikes and jet-skis. However, the 2-stroke engines were generally less fuel-efficient than 4-stroke engines and also produced proportionately higher quantities of exhaust pollutants, including dioxins (eg, see (Maritime New Zealand, undated-2). As a result the engines used in many of these applications are now 4-stroke.

Much of the fuel used in 2-stroke engines will be in off-road or non-road applications. The Ministry of Transport has estimated that the total annual off-road and non-road fuel use in New Zealand would account for about 4 to 5% of total fuel consumption in transport applications (Ministry of Transport, 2018). This includes about 1.1 million motor mowers and 175,000 boats and jet-skis which together consume an estimated 76 million litres of fuel annually or about 57,000 tonnes. The proportion of 2-stroke engines involved is difficult to establish because the Ministry does not differentiate between engine types in its statistics. Jet-skis are required to be registered with the regional Harbourmaster. Of the 3717 active jet-skis in the Auckland, Northland and Bay of Plenty regions registered with the Auckland Harbourmaster, it has been estimated that about 10% have 2-stroke engines. With regard to other vessels around 10-20% of new vessels and 50% of older vessels in the Auckland region are estimated to be powered by 2-stroke engines. (M. Madsen, Auckland Harbourmasters Office, pers. comm., 2019)

For the 2012 Inventory it was estimated that the annual fuel consumption in 2-stroke motor bikes was 2,800 tonnes per year and that the fuel consumption in other types of 2-stroke engines, was unlikely to be more than that that used in motor bikes giving a total annual fuel consumption of 5,600 tonnes per year. With no further information available for 2016 this amount will also be used for this Inventory.

Table 7-2: Dioxin releases from 2-stroke petrol engines

Year	Activity Rate (tonnes of fuel/year)	Release factors ($\mu\text{g TEQ/tonne of fuel}$)	Annual releases (g TEQ/yr)
		Air	Air
2012	5,600	2.5	0.014
2016	5,600	2.5	0.014

Certainty assessment for 2016

Activity data: Low (because it is based on assumed annual fuel consumption)

Emission factor: Low (because it is based on the Toolkit default factor)

7.3 Diesel engines

The total consumption of diesel in transport, industrial and commercial applications, agriculture and residential uses in 2016 was 125,860 TJ (1 TJ = 10^{12} Joules) (Ministry of Business Innovation and Employment, 2017). However, some of this usage has already been accounted for under sections 5.1.3 (industrial/commercial heat and power, 3900 TJ) and 5.5.2 (domestic heating and cooking, 120 TJ). Subtracting these figures from the total gives an annual diesel usage in transportation and stationary engines of 121,860 TJ or 2,660,722 tonnes.

The UNEP Toolkit includes a separate release factor for biodiesel, although it is only marginally lower than that for normal diesel (0.07 vs 0.1 $\mu\text{g TEQ/tonne}$)(1 $\mu\text{g TEQ/tonne} = 1 \times 10^{-6}$ g TEQ/tonne). However, the total biodiesel produced in New Zealand in 2016 was only 20 TJ (440 tonnes) so this has not been considered

separately under this category. The variation introduced by using the lower biodiesel factor would only change the total release estimate by 0.00001g TEQ.

The 2016 release estimates for diesel consumption in transport and stationary engines are shown in Table 7-3, along with the corresponding estimates from the 2012 Inventory.

Table 7-3: Dioxin releases from diesel engines

Year	Activity Rate (tonnes of fuel/year)	Release factors (µg TEQ/tonne of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	2,380,000	0.1	0.238
2016	2,660,722	0.1	0.266

Certainty assessment for 2016

Activity data: High (because it is based on national fuel data)

Emission factor: Low (because it is based on the Toolkit default factor)

7.4 Heavy oil-fired engines

The consumption of heavy fuel oil for transportation is primarily confined to its use in coastal shipping, for which the total fuel consumption in 2016 was 4110 TJ, or about 94,340 tonnes (Ministry of Business, Innovation and Employment, 2017). This total includes both ‘new’ fuel oil and recycled waste oil.

The 2016 release estimates are shown in Table 7-4, along with the corresponding estimates made in the 2012 Inventory.

Table 7-4: Dioxin releases from heavy fuel oil-fired engines

Year	Activity Rate (tonnes of fuel/year)	Release factors (µg TEQ/tonne of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	92,000	4	0.368
2016	94,340	4	0.377

Certainty assessment for 2016

Activity data: High (because it is based on national fuel data)

Emission factor: Low (because it is based on the Toolkit default factor)

7.5 Summary for this category

The 2016 release estimates for fuel use in transportation and stationary engines are summarised in Table 7-5, along with the revised comparative totals for 2008 and 2012.

Table 7-5: Summary of the release estimates for transport

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
4-stroke engines	0.0142	-	-	-	-
2-stroke engines	0.014	-	-	-	-
Diesel engines	0.266	-	-	-	-
Heavy oil-fired engines	0.377	-	-	-	-
2008 totals	0.705				
2012 totals	0.660	-	-	-	-
2016 totals	0.672	-	-	-	-

8 Open burning processes

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 6a Biomass burning
- 6b Waste burning and accidental fires

Open burning processes are usually characterised by the presence of mixtures of waste materials, with little or no control over the condition of these (ie wet or dry), and little or no control over the burning processes. As a result, there is often a high potential for dioxins to be formed as a result of incomplete combustion processes. Despite this, the potential for dioxin formation from the burning of clean biomass is relatively low, unless the material is contaminated with specific dioxin precursors, such as chlorinated phenoxy herbicides (see section 9). Also, it is much higher for waste burning and accidental fires because of the potential presence of chlorinated materials (eg some plastics, such as PVC) and catalytic metals, such as copper.

8.1 Biomass burning

. The category is divided into the following sub-categories:

- i. Agricultural residue burning
- ii. Sugarcane burning
- iii. Forest fires
- iv. Grassland and savannah fires

The activity data for all of these sources is taken from the annual greenhouse gas inventory reports produced by the Ministry for the Environment. (Ministry for the Environment, 2018) The activity rates for biomass burning show a significant amount of variation from year to year so, as was done in the previous dioxin inventory, the activity rates for 2016 will be based on the average data from the previous 3 years; ie 2014 to 2016.

8.1.1 Agricultural residue burning

This source category covers the burning of crop residues in the fields where the crops were originally grown, usually as a land clearance activity prior to the planting of the next crop. This practice is used in New Zealand for barley, wheat and oats, but not for maize or legumes (Ministry for the Environment, 2018). The total area of crop land burned is obtained through annual surveys carried out by Statistics New Zealand, and then converted to a mass basis using biomass density factors.

The total mass of crop residues burned in New Zealand in 2014, 2015 and 2016 was 353,240 256390 and 279,620 tonnes/year, respectively, which gives an annual average rate of 290,417 tonnes/year. This average activity rate has been used for the 2016 release estimates, coupled with the UNEP Toolkit factors for burning under relatively favourable combustion conditions. The alternative Toolkit factors for burning under poor combustion conditions and in the presence of dioxin precursors, such as chlorinated pesticides, are not relevant to the New Zealand practices. The release estimates are shown in the table below, along with the corresponding estimates from the report on the 2012 inventory.

Table 8-1: Dioxin releases from agricultural residue burning

Year	Activity Rate (tonnes biomass burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	288,474	0.5	-	0.144	-
		-	0.05	-	0.014
2016	290,417	0.5	-	0.145	-
		-	0.05	-	0.0145

Certainty assessment for 2016

Activity data: High (because they are based on the national greenhouse gas inventory data)

Emission factor: Low (because they based on the Toolkit default factors)

8.1.2 Sugarcane burning

This source has not been assessed because there are no sugarcane plantations in New Zealand. All local sugar production at New Zealand's only sugar refinery is based on imported sugarcane (NZ Sugar Company, 2010).

8.1.3 Forest fires

This source category covers wildfires and controlled burn-offs in forests. Both of these activities are addressed in the greenhouse gas inventory reports, and estimates for the total area of forest land burned are obtained through surveys of forestry owners and data available from the National Rural Fire Authority. These are converted to a mass basis using a single biomass density factor for all forest types (Ministry for the Environment, 2018).

The total mass of forest biomass burned in New Zealand in 2014, 2015 and 2016 was 125,653, 281,594 and 207,613 tonnes/year, respectively, which gives an average rate of 204,953 tonnes/year. This activity rate has been used for the 2016 release estimates, coupled with the UNEP Toolkit factors. The release estimates are shown in the table below, along with the corresponding estimates from the report on the 2012 inventory.

Table 8-2: Dioxin releases from forest fires

Year	Activity Rate (tonnes biomass burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	151,129	1	-	0.151	-
		-	0.15	-	0.023
2016	204,953	1	-	0.205	-
		-	0.15	-	0.0307

Certainty assessment for 2016

Activity data: Medium (because they are based on the national greenhouse gas inventory data)

Emission factor: Low (because they based on the Toolkit default factors)

8.1.4 Grassland and savannah fires

This source category covers both controlled and accidental burning of grassland and savannah. In New Zealand, the savannah category is used for land covered in tussock. The total area of grassland and savannah burned is obtained through national information on changes in land-use and data from the National Rural Fire Authority. These are converted to a mass basis using biomass density factors (Ministry for the Environment, 2018).

The total mass of grassland and savannah material burned in New Zealand in 2014, 2015 and 2016 was 332,437, 240,688 and 412,497 tonnes/year, respectively, which gives an average rate of 328,541 tonnes/year. This activity rate has been used for the 2016 release estimates, coupled with the UNEP Toolkit factors. The release estimates are shown in the table below, along with the corresponding estimates from the report on the 2012 inventory.

Certainty assessment for 2016

Activity data: Medium (because they are based on the national greenhouse gas inventory data)

Emission factor: Low (because they based on the Toolkit default factors)

Table 8-3: Dioxin releases from grassland and savannah fires

Year	Activity Rate (tonnes biomass burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	378,763	0.5	-	0.189	-
		-	0.15	-	0.057
2016	328,541	0.5	-	0.164	-
		-	0.15	-	0.0493

8.2 Waste burning and accidental fires

The category is divided into the following sub-categories:

- v. Fires at waste dumps
- vi. Accidental fires in houses, factories
- vii. Open burning of domestic waste
- viii. Accidental fires in vehicles
- ix. Open burning of wood (construction/ demolition)

8.2.1 Fires at waste dumps

Landfill fires were identified in the first dioxin inventory as New Zealand's most significant source of dioxin releases to air (Ministry for the Environment, 2000). 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*.

The 2008 and 2012 dioxin inventories showed that the numbers of fires at landfills and rubbish dumps had dropped significantly over time; from an estimated 274 fires in 1998, to 50 fires in 2008 and 28 fires in 2012. (Ministry for the Environment, 2011a). These estimates were based on fire incident data published by the NZ

Fire Services, now known as Fire and Emergency New Zealand (FENZ). The landfill fire estimate for 2016 based on FENZ data supplied is 27 (S. Quirke, FENZ, 2019 pers comm).

Carterton District Council has commented that increasing numbers of landfill fires have occurred in the last two years (www.cdc.govt.nz/prohibited-items-causing-landfill-fires/). Two landfill fires occurring in 2016 were reported by the press. A fire in January at the Central Hawkes Bay Landfill took multiple fire brigades 18 hours to extinguish (Hawkes Bay Today, 2016) and an overnight fire in April at the Dunedin Green Island Landfill required nearby residents to stay inside and close windows (Otago Daily Times, 2016).

The previous inventories assumed an average waste quantity of 45 tonnes of waste per fire which has been retained. The Toolkit recommends a factor of 300 µg TEQ per tonne for releases to air, and 10 µg TEQ per tonne for releases to land (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne) (United Nations Environment Programme, 2013). Release estimates for 2016 are shown in Table 8-4 along with 2012 estimates from the previous inventory.

Table 8-4: Dioxin releases from waste dump fires

Year	Activity Rate (tonnes of waste burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1260	300	-	0.378	-
		-	10	-	0.0126
2016	1215	300		0.365	
			10		0.0122

Certainty assessment for 2016

Activity data: Low (because it based on national fire statistics but coupled with a highly uncertain conversion factor for the mass of material burned)

Emission factors: Low (because they are based on the Toolkit default factors)

8.2.2 Accidental fires in houses, factories

The release estimates for the previous dioxin inventories were based on New Zealand Fire Service statistics for the numbers of structure fires attended each year. The quantities of materials involved in the fires were estimated using an approximate size distribution, which was first presented in the 2000 Inventory Report, and subsequently modified for the 2008 and 2012 Inventories. The approach used in 2012 has also been applied to the current estimates.

Annual fire incident data has been obtained from the New Zealand Fire Service, for 2015/2016 (5,379 fires) and 2016/2017 (5,236 fires) (New Zealand Fire Service, 2017) so a figure of 5,308 structure fires has been used for 2016. This is higher than the 4,754 structure fires recorded in 2012 but lower than the 6467 fires used for the 2008 estimates.

Applying the mass calculation methodology gives a total quantity of 1744 tonnes for material consumed by fire in 2016. The UNEP Toolkit gives default factors of 400 µg TEQ per tonne for dioxin releases to both air and land (400 x 10⁻⁶ g TEQ/tonne). These factors have been used for the current release estimates, which are shown in Table 8-5, along with the corresponding estimates made in the 2012 Inventory.

Table 8-5: Dioxin releases from structure fires

Year	Activity Rate (tonnes burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1562	400	-	0.625	-
		-	400	-	0.625
2016	1744	400		0.698	
			400		0.698

Certainty assessment for 2016

Activity data: Medium (because it is based on national fire statistics coupled with an approximate conversion factor for the mass of material burned)

Emission factor: Low (because it is based on the Toolkit default factors)

8.2.3 Open burning of domestic waste

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.

A review was conducted in 2015 of the current state and main sources of dioxin around the world. One of its conclusions was that domestic waste was probably the most important non-industrial source and one of the most difficult to determine precisely given the variability in composition of waste and mostly uncontrolled combustion techniques (Dopico & Gomez, 2015)

Controls on domestic waste burning in regional plans, national and regional incident data for waste burning, and a summary of recent regional surveys were reviewed in the 2012 Inventory. The regional surveys provided the key information required for determining the dioxin releases from waste burning, which is an estimate of the number of households that burn rubbish and the average quantities burned per household. More recent regional surveys which have included domestic waste burning have seen no change in the estimate of the number of households that burn rubbish (Wilton, E, 2015), (Wilton, E, 2016).

For the 2008 and 2012 dioxin inventories it was assumed that waste burning was practiced by 5% of all households on 5 to 10 occasions per year, and the average quantity of material burned was 250 kg per household, per year (ie 25 to 50 kg per burn). The total number of occupied dwellings in New Zealand in 2016 was about 1,613,490 (based on the average annual increase between the census figures for 2006 and 2013 of 0.9% per annum and the Census record of 1,570,695 occupied dwellings in 2013). If 5% of these households (ie, 80,695) burn waste, the total quantity of waste burned would be 20,170 tonnes per year.

The UNEP Toolkit gives default factors of 40 µg TEQ per tonne of waste, for dioxin releases to air, and 1 µg TEQ per tonne of waste, for releases to land (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). These factors have been used for the current release estimates, which are shown in Table 8-6, along with the corresponding estimates made in the 2012 Inventory.

Table 8-6: Dioxin releases from open domestic waste burning

Year	Activity Rate (tonnes/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	19,500	40	-	0.780	-
		-	1	-	0.020
2016	20,170	40	-	0.807	-
		-	1	-	0.0202

Certainty assessment for 2016

Activity data: Low (because it is based on limited survey data)

Emission factor: Low (because it is based on the Toolkit default factors)

8.2.4 Accidental fires in vehicles

The release estimates for the previous dioxin inventories were based on New Zealand Fire Service statistics for the numbers of mobile property fires attended each year, and the same approach has been taken here. Annual fire incident data has been obtained from the New Zealand Fire Service (Official Information Request OIA2017 – 4076 FENZ Incident Statistics for NZ Fire Service). For 2015/2016 2094 mobile property fires were recorded with an average of 1973 mobile fires per year for the three years preceding. In comparison 1712 were recorded in 2012.

The UNEP Toolkit gives default factors of 100 µg TEQ per fire, for dioxin releases to air, and 18 µg TEQ per fire, for releases to land (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). These factors have been used for the 2016 release estimates shown in Table 8-7, along with the corresponding estimates made in the 2012 Inventory.

Certainty assessment for 2016

Activity data: High (because it is based on national fire statistics)

Emission factor: Low (because it is based on the Toolkit default factors)

Table 8-7: Dioxin releases from vehicle fires

Year	Activity Rate (vehicle fires/year)	Release factors (µg TEQ/fire)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1712	100	-	0.171	-
		-	18	-	0.031
2016	2094	100	-	0.209	-
		-	18	-	0.038

8.2.5 Open burning of wood (construction/demolition)

The on-site burning of waste timber produced during construction or demolition works is either prohibited or restricted in most urban areas, but is still likely to occur on rural properties and in urban areas where restrictions have not been applied. There may also be some illegal burning in the controlled areas.

In 2006 it was estimated that construction and demolition (C&D) wastes made up about 14% of the total wastes disposed in landfills; ie, about 440,000 tonnes per year (Ministry for the Environment, 2007). An additional 300,000 tonnes per year was disposed at cleanfill sites. There is no more recent data available on C&D waste quantities, and nor is there any information on the quantities of C&D wastes disposed by burning. As a result, it is not possible to provide any reliable estimates of the dioxin releases associated with this activity.

Some indication of the potential releases can be obtained by assuming that the quantities of C&D wastes disposed by burning are equivalent to no more than 1 % of the total disposed of at landfills and cleanfill sites; ie, 7,400 tonnes per year. If the amount of material burned in each fire was 1 tonne (ie, a small rubbish skip full), the total annual quantity would equate to 7,400 fires per year⁴, or just over 20 fires per day. The UNEP Toolkit recommends an emission factor of 60 µg TEQ per tonne (60 x 10⁻⁶ g TEQ/tonne), for dioxin releases to air. Applying this factor to 1% of the total C&D waste quantities indicates possible annual releases to air of 0.2 g TEQ per year. If correct, this would make C&D waste burning a small, but not insignificant, contributor to the total dioxin releases to air. It therefore suggests the need for continuing support for, and enforcement of, the regional controls on open burning.

8.3 Summary for this category

The 2016 release estimates for accidental fires are summarised in Table 8-8, along with the revised comparative totals for 2008 and 2012.

Table 8-8: Summary of the release estimates for open burning processes

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Agricultural residue burning	0.145	-	0.015	-	-
Forest fires	0.205	-	0.031	-	-
Grassland and savannah fires	0.164	-	0.049	-	-
Fires at waste dumps	0.365	-	0.0122	-	-
Structure fires	0.698	-	0.698	-	-
Open burning of domestic wastes	0.807	-	0.020	-	-
Vehicle fires	0.209	-	0.038	-	-
2008 totals	3.155	-	1.068	-	-
2012 totals	2.439	-	0.782	-	-
2016 totals	2.593		0.863	-	-

⁴ The NZ Fire Services attends about 4000 to 5000 fires per year that are specifically identified as involving some form of 'rubbish'.

9 Production of chemicals and consumer goods

This category covers dioxin releases from the following sub-categories (United Nations Environment Programme, 2013):

- 7a Pulp and Paper Production
- 7b Chlorinated Inorganic Chemicals
- 7c Chlorinated Aliphatic Chemicals
- 7d Chlorinated Aromatic Chemicals
- 7e Other Chlorinated and Non-Chlorinated Chemicals
- 7f Petroleum Production
- 7g Textile Production
- 7h Leather Refining

The dioxin releases from these sources are not combustion-related, apart from black-liquor combustion in the pulp and paper mills, and the various releases from petroleum production. Historically, pulp and paper mills were a significant source of dioxin releases due to the use of elemental chlorine as a bleaching agent, which reacted with phenolic species in the pulp to form dioxins. The dioxins associated with most of the other chemical products are also similar, in that they are formed as reaction by-products of the chemical processes used in manufacturing. Generally, the dioxins are accounted for as releases into products, and these then lead on to the last two sub-categories in this group, where the dioxins are transferred to textile and leather products through the use of treatment chemicals contaminated with dioxins.

9.1 Pulp and paper production

The total wood pulp production in New Zealand for 2016 was about 1.73 million tonnes (air dry basis), of which 38% was produced by thermo-mechanical or chemi-thermo-mechanical pulping, and 62% by chemical pulping (Ministry for Primary Industries, 2018). Mechanical pulp is produced at four plants in the Bay of Plenty, Hawke's Bay and Manawatu–Wanganui regions. 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. Chemical (kraft) pulp is produced at two pulp and paper mills in Kawerau and Tokoroa. The bleached kraft pulp mills are the source of primary interest for dioxin releases, and are the only ones considered below.

Black liquor combustion

There are two primary sources of dioxin 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 5.2, so only the recovery boilers are covered here.

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. Releases from black liquor combustion are directly related to pulp production figures, and the total annual production of kraft pulp at the two mills in 2016 was about 1,070,000 tonnes on an air-dry basis (Ministry for Primary Industries, 2018) In the previous dioxin inventories it was estimated that approximately 1.8 tonnes of black liquor solids were produced per tonne of pulp, and this indicates a current annual production rate of about 1.93 million tonnes of black liquor solids.

The release estimates for the two previous inventories were based on the results of emission testing on the two recovery boilers at the Waikato mill. There have been no more recent tests, but the emissions are unlikely to have changed significantly since the last test was done. Hence the previously estimated release factor of 0.025 µg TEQ per tonne of black liquor solids has been used for the current estimates (0.025 x 10⁻⁶ g TEQ/tonne).

The 2016 estimates for releases to air from black liquor combustion are shown in Table 9-1, along with the corresponding estimates made in the 2012 Inventory. There are no releases to water, land, or in products or residues from this source.

Table 9-1: Dioxin releases from black liquor combustion

Year	Activity Rate (tonnes of black liquor solids/year)	Release factors (µg TEQ/tonne of BLS)	Annual releases (g TEQ/yr)
		Air	Air
2012	1,440,000	0.025	0.0360
2016	1,930,000	0.025	0.0483

Certainty assessment for 2016

Activity data: High (because it is based on actual production data)
 Emission factor: Medium (because it is based on historical emission data)

Releases to land

The wastewater treatment systems used at both mills result in the production of both primary and secondary sludge, and these are the only solid waste streams expected to contain dioxin residues. Consistent with the approach used in 2008 and 2012, the release calculations have been based on an annual production rate for bleached pulp only and using the UNEP Toolkit default emission factor of 0.2 µg TEQ per tonne of air dry pulp. Total bleached pulp production in 2016 was 732,000 tonnes (Ministry for Primary Industries, 2018).

The 2016 estimates for releases to land from bleached pulp production are shown in Table 9-2, along with the corresponding estimates made in the 2012 Inventory. Releases have increased because bleach pulp production has increased.

Table 9-2: Dioxin releases to land from bleached pulp production

Year	Activity Rate (tonnes of air dried pulp/year)	Release factors (µg TEQ/tonne of pulp)	Annual releases (g TEQ/yr)
		Land	Land
2012	464,000	0.2	0.093
2016	732,000	0.2	0.146

Certainty assessment for 2016

Activity data: High (because it is based on actual production data)
 Emission factor: Low (because it is based on the Toolkit default factors)

Releases to water

The dioxins in the pulp mill wastewaters are absorbed onto suspended solids and are therefore removed with the sludge. As such, they have already been accounted for in the estimates given above for releases to land, and the releases to water should be taken as zero.

Additions to existing land reservoir

The disposal of primary and secondary sludge produced in the pulp mills contributes to existing reservoirs of dioxins which have been created at the company's various waste disposal sites (landfills). The overall size of the reservoir was estimated in the 2012 Inventory at 25.3 g TEQ on the basis of historical sludge production. This figure can now be updated for an additional 5 years' input, based on the 2016 release rate shown in Table 9-2. If this rate is assumed to apply for all of the last 5 years, the additional inputs to the reservoir would be 0.730 g TEQ, and the total current reservoir would be 26.00 g TEQ.

9.2 Chlorinated inorganic chemicals

This sub-category covers dioxin releases from the manufacture of chlorine gas by electrolysis of solutions of sodium chloride. Prior to the 1980s most chlorine plants used either mercury cells or a diaphragm system, and both of these processes were shown to be significant sources of dioxins (United Nations Environment Programme, 2013). Nowadays, most plants use an alternative membrane cell process which, until recently, had not been shown to produce any dioxins. However, the latest version of the Toolkit indicates that dioxins have also been detected in the releases from these plants, albeit at very low levels.

There are two chlorine plants in New Zealand and these use the modern membrane cell process, and have a total capacity of about 20,000 tonnes per year of chlorine. However, these are associated with the two pulp and paper mills discussed in section 9.1 and their dioxin releases have already been accounted for under the mill-wide release estimates given in that section. However, for the sake of completeness, it can be noted that the releases from the chlorine plants would be in the order of about 0.00004 g TEQ to water, and 0.006 g TEQ to land, if considered separately from the rest of the mill.

9.3 Chlorinated aliphatic chemicals

This sub-section covers dioxin releases from the manufacture of polyvinyl chloride (PVC) resin, which usually starts with the manufacture of ethylene dichloride (EDC), followed by conversion to vinyl chloride monomer (VCM), and then a final polymerisation process to form PVC. Almost without exception, the first two of these steps are carried out in petrochemical manufacturing complexes, while the third may be done in a separate manufacturing plant, using imported VCM. However, there are no such facilities in New Zealand and the manufacture of PVC products is carried out using imported resin (Plastics New Zealand, 2011). Hence this source category is not relevant to New Zealand.

9.4 Chlorinated aromatic chemicals

This sub-section covers a range of different chemicals, only some of which are relevant to New Zealand. Each of the chemicals is discussed under separate sub-headings below.

9.4.1 1,4-dichlorobenzene

Dichlorobenzene may be contaminated with dioxins during manufacturing, and can therefore represent a potential source of releases via products, in subsequent uses. The chemical is not manufactured in New Zealand but it is listed in the New Zealand Inventory of Chemicals maintained by the Environmental Protection Authority (see www.epa.govt.nz). The UNEP Toolkit indicates that 1,4-dichlorobenzene has been used as an insecticide

and fungicide, but the chemical is not registered for any such uses under the *Agricultural Compounds and Veterinary Medicines Act (ACVM) 1997* (see www.foodsafety.govt.nz/industry/acvm/registers-lists.htm). Other possible uses are as a disinfectant and odour control agent in waste containers and restrooms, but products such as these are not subject to any specific controls in New Zealand that would allow these uses to be readily identified. Hence it is not possible to provide a quantitative assessment for this chemical.

9.4.2 Polychlorinated biphenyls (PCBs)

PCBs were used in the past as transformer oils and in other related applications (United Nations Environment Programme, 2013). In New Zealand the import, manufacture, and use of PCBs is prohibited under the *Hazardous Substances and New Organisms Act (HSNO) 1996* without an exemption, and any stocks of old PCBs must be safely stored, managed and disposed in accordance with the *Hazardous Substances (Storage and Disposal of Polychlorinated Biphenyls) Notice 2007*. There are no facilities in New Zealand for the destruction of PCB-containing wastes, so disposal is by export to a suitable facility overseas (Ministry of Health, 2008).

The UNEP Toolkit provides no specific factors for estimating the possible dioxin releases from the storage of PCBs. However, if the storage is being carried out properly in accordance with the HSNO requirements, the releases due to leakages should be minimal.

9.4.3 Pentachlorophenol and sodium pentachlorophenolate

The primary use of pentachlorophenol (PCP) in New Zealand was in the timber industry, either as sodium pentachlorophenolate, for use as an antisapstain treatment, or as a preservative in diesel oil (Ministry for the Environment, 2011a). 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 voluntarily ceased in 1988, and PCP was deregistered for all uses by the Pesticides Board in 1991.

Past releases of dioxins from the use of PCP have resulted in a number of contaminated sites throughout New Zealand, and these are discussed further in Section 12 of this report.

9.4.4 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) and 2,4,6-trichlorophenol

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 (Ministry for the Environment, 2011a). 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) were formed as a by-product of this reaction.

The residual soil contamination resulting from the past uses of 2,4,5-T is discussed in section 12 of this report.

9.4.5 Chloronitrofen, chlornitrofen, or 2,4,6 trichlorophenyl-4-nitrophenylether (CNP)

This chemical is not listed in the New Zealand Inventory of Chemicals or in any of the other registers of approved substances maintained by the Environmental Protection Authority (see www.epa.govt.nz). Hence it should not be found in New Zealand.

9.4.6 Pentachloronitrobenzene (PCNB – Quintozene)

Quintozene is a broad-spectrum, contact fungicide which was approved in New Zealand for the control of soil fungi in vegetable and ornamental seedlings, and non-grazed turf. However, this approval was revoked in January 2011 because of concerns about the presence of dioxin impurities (ERMA New Zealand, 2011). The presence of these impurities had only come to the attention of regulatory agencies, both here and overseas, in the preceding 2 years.

It is not known what quantities of Quintozene were previously used in New Zealand, but the Environmental Risk Management Authority (now EPA) determined that the uses were mainly limited to bowling greens and golf courses, and the quantities were “not large”. For the purposes of this inventory, it can be assumed that the usage in 2016 was nil, and hence there were no associated dioxin releases.

9.4.7 2,4-Dichlorophenoxyacetic acid (2,4-D) and derivatives

The phenoxy herbicide 2,4-D is used in New Zealand, mainly on hill country farms, to control thistles and other broadleaf weeds. This agrichemical has been shown in the past to contain dioxin residues as production by-products, although with current manufacturing technologies the contamination levels are very low (United Nations Environment Programme, 2013). For the 2008 and 2012 Inventories the annual usage in New Zealand was estimated at about 335 tonnes per year. However current usage is estimated to be significantly higher at about 500 tonnes per year (A Cliffe, Nufarm NZ, Auckland, pers comm, 2018).

The Toolkit puts the dioxin contamination level at 0.1 µg TEQ/tonne of product (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). Release estimates for 2012 and 2016 are shown in Table 9-3.

Table 9-3: Dioxin releases to land (via product) from the use of 2,4-D

Year	Activity Rate (tonnes of 2,4-D used/year)	Release factors (µg TEQ/tonne of product)	Annual releases (g TEQ/yr)
		Land/Product	Land
2012	335	0.1	0.000034
2016	500	0.1	0.000050

Certainty assessment for 2016

Activity data: High (because it is based on an industry estimate of national production)

Emission factor: Medium (because it is based on the Toolkit default factor supported by analytical data obtained previously from one of the manufacturers)

9.4.8 Chlorinated Paraffins

Chlorinated paraffins (CPs) are produced by chlorination of straight-chain hydrocarbons, with chain lengths generally ranging from C₁₀ to C₃₀. The largest use of CPs is in industrial cutting fluids, but they may also be present in paints, adhesives, sealants and caulks, as well as plasticizers for PVC and flame retardants in other plastics and rubber.

Given the nature of their uses, most chlorinated paraffins are likely to be imported as minor constituents of a wide range of manufactured products. As such, it would be virtually impossible to determine the total quantities of CPs entering the country, or the dioxin contamination levels.

9.4.9 p-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 (e.g., for the detection of primary and secondary amines). Chloranil has been shown to be contaminated with dioxins, but the level of contamination is highly dependent on the method of manufacture (United Nations Environment Programme, 2013).

Chloranil is listed in the New Zealand Inventory of Chemicals maintained by the Environmental Protection Authority (see www.epa.govt.nz). The HSNO approval for chloranil lists it as a pesticide, veterinary medicine or pharmaceutical active ingredient. However, the substance is not currently registered under the Agricultural Chemicals and Veterinary Medicines Act 1997 (see www.foodsafety.govt.nz/-industry/acvm/registers-lists.htm), and therefore cannot be used in New Zealand for any of these applications.

No current uses of chloranil have been specifically identified for New Zealand, although there may be some minor uses as a laboratory reagent.

9.4.10 Phthalocyanine dyes and pigments

Phthalocyanine dyes are artificial organic pigments which can be used in a wide range of dye applications. However, the UNEP Toolkit is primarily concerned with two specific substances; phthalocyanine copper (blue) and phthalocyanine green. The first of these can have minor levels of dioxin contamination (70 µg TEQ/tonne, i.e. 70×10^{-6} g TEQ/tonne) while the contamination levels in the latter can be 200 times greater. These substances are mainly used on textiles.

Phthalocyanine copper is listed in the New Zealand Inventory of Chemicals but phthalocyanine green is not. There is no readily available information on the quantities of phthalocyanine copper imported into New Zealand. However, the total value of all synthetic organic dye imports for New Zealand in 2012 was about \$12 million (data obtained from the Statistics New Zealand InfoSearch database). A search of the websites of international chemical suppliers indicates that the cost of these dyes is typically in the range of \$1,000 to \$20,000 per tonne. This suggests that the total quantity of synthetic organic dyes brought into New Zealand would be around 2000 tonnes per year. There are literally hundreds of different dyes in this group, so the average import quantity for any individual dye is likely to be no more than about 10 tonnes per year.

If the quantity of phthalocyanine copper used annually in New Zealand is assumed to be 10 tonnes per year, it would contribute 0.0007 g TEQ per year. This would make only a very minor contribution to the total dioxin releases in New Zealand so, given the lack of any specific import data, no releases will be reported for this Toolkit sub-category.

9.4.11 Tetrachlorophthalic acid (TCPA) and related pigments

TCPA is listed in the Toolkit as a potential source of dioxins but there are no data available on the possible contamination levels. There is no readily available information on the quantities of TCPA-based pigments imported into New Zealand.

9.4.12 Dioxazine dyes and pigments

The dioxazine pigments with the potential for dioxin contamination are CI Pigment Violet 23, and CI Direct Blue 106 and 108. However, the contamination has only been reported for dyes made by a specific chemical process, which was replaced by a 'cleaner' method in the 1990s (United Nations Environment Programme, 2013).

These pigments can be used in a wide range of materials, including plastics, paints and printing inks, and they 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 Inventory of Chemicals. It is also listed in Schedule 7 to the ACVM Act as being acceptable for use as a seed treatment, provided the total levels of dioxins are no more than 20 µg/kg (note: this refers to total dioxins rather than TEQ). This indicates that the pigment should be essentially dioxin-free, and is therefore not one of the highly contaminated forms of the product that are considered in the Toolkit.

9.4.13 Triclosan

Triclosan (5chloro2(2,4dichlorophenoxy)phenol) is used throughout the world as an antibacterial and antifungal agent in consumer products, including soaps, deodorants, toothpastes, shaving creams, mouth wash, and cleaning supplies. In New Zealand, its use in cosmetics is limited to a concentration of no more than 0.3%, under the *Cosmetics Products Group Standard*, issued under the HSNO Act.

There is no readily available information on the extent of triclosan usage in New Zealand. However, a recent assessment for Australia indicated total annual imports there of between 21 and 31 tonnes per year (NICNAS, 2009). On a simple pro rata basis this would suggest annual imports for New Zealand of between 4 and 6 tonnes per year (based on 2016 population figures of 24.2 million and 4.7 million, respectively).

The UNEP Toolkit indicates that triclosan can have dioxin contamination levels of 3 to 60 µg TEQ/tonne (i.e. 3 to 60 x 10⁻⁶ g TEQ/tonne) when made using current manufacturing technologies. This suggests that the overall contribution to New Zealand releases would be in the range of 0.000011 and 0.000342 g TEQ/year. This would make only a very minor contribution to the total dioxin releases in New Zealand so, given the lack of any specific import data, no releases will be reported for this Toolkit sub-category.

9.5 Other chlorinated and non-chlorinated chemicals

This section of the Toolkit covers dioxin releases from the manufacturing of titanium dioxide (via titanium tetrachloride) and caprolactam, which is a starting material for the manufacture of nylon (United Nations Environment Programme, 2013). Neither of these substances is produced in New Zealand.

9.6 Petroleum production

New Zealand's petroleum refining needs are served by a single refining plant in Northland. In 2016 the refinery processed what was then a record 42.7 million barrels of crude oil. In that year the refinery contributed about 58% of New Zealand's petrol consumption, 85% of jet fuel consumption and 67% of the country's diesel consumption (Refining NZ, 2016). The refining process involves a catalytic reforming unit where naphtha is turned into high octane petrol products, but there is no coking unit at the plant.

Dioxin production during petroleum refining results from the combustion of volatile process gases in flares and complex reactions of hydrocarbons at elevated temperatures on catalytically active surfaces (United Nations Environment Programme, 2013). There can also be releases via wastewater and solid wastes.

For the emissions to air, the UNEP Toolkit assigns an emission factor for flares of 0.25 µg TEQ per TJ of fuel burnt and for the catalytic refining unit an air emission factor of 0.017 µg TEQ per tonne of fuel processed is applicable (1 µg = 10⁻⁶ g, and 1 TJ = 10¹² Joules). In 2016 259 TJ of gas were combusted in the flares (L Gillingham, Refining NZ, pers comm, 2018). This amount was significantly higher than the 37.5 TJ used in the 2012 Inventory and is the result of a prolonged shut period. The flared gas corresponds to a release to air of 0.000065 g TEQ per annum. Also 1,104,885 tonnes of oil were passed through the catalytic converter unit (G Roberstson, Refining NZ, pers comm, 2018), resulting in a release to air of 0.0187 g TEQ/annum.

Refinery-wide wastewater treatment is assigned an emission factor of 5pg TEQ per litre by the Toolkit (1 pg = 10⁻¹² grams). In 2016 a total of 1.68 million cubic metres of wastewater was processed through the plant's wastewater treatment system (Refining NZ, 2017). This gives a release of 0.0084 g TEQ/annum.

For releases in residues, the Toolkit assigns a factor of 14 µg TEQ per tonne of waste generated from the catalytic refining unit. A total of 1.2 tonnes of waste was produced by this unit in 2016 (G Robertson, Refining NZ, pers comm, 2018) giving a release to residues of 0.000017g TEQ/annum. This is significantly less than the

release for 2012 which was 0.00007 g TQ/annum. This improvement results from the introduction of a new continuous catalyst regeneration unit at the plant.

The 2016 estimates for releases from petroleum production are shown in Table 9-4. In the interests of clarity, the entries in the table have been limited to only the release estimates, rather than showing all of the different types of activity data and related releases factors noted above.

Table 9-4: Dioxin releases from petroleum production

Year	Annual releases (g TEQ/yr)		
	Air	Water	Residues
2012	0.018	0.0078	0.00007
2016	0.019	0.0084	0.000017

Certainty assessment for 2016

Activity data: High (because they are based on actual production data)

Emission factor: Low (because they are based on the Toolkit default factors)

9.7 Textile (and leather) production

The UNEP Toolkit indicates that dioxins may be found in textile and leather products and production wastes as a result of a number of factors, including:

- the treatment of raw materials with agrichemicals, especially pentachlorophenol,
- the use of dioxin-contaminated dyestuffs (e.g., dioxazine dyes)
- the formation of dioxins 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 9.4.3), but they may have also been used in the textiles and leather industries, mainly as a fungicide or preservative. All uses of pentachlorophenol were deregistered by the Pesticides Board in 1989, and the substance approval under the HSNO Act was formally withdrawn in 2008 (Environmental Risk Management Authority, 2008). In the 2008 Inventory it was noted that the testing of New Zealand pelts and hides intended for export had not shown any detectable levels of pentachlorophenol.

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 or is no longer approved for use in at least 45 countries and is prohibited from import in a further 42 (Secretariat of the Rotterdam Convention, 2013). Imports and/or uses may still be permitted in other countries, including Australia, and Canada, but with conditions; for example, a residue limit in finished products.

The potential for dioxin contamination from dioxazine dyes was discussed in section 9.4.12. In the previous inventory report it was noted that some of these dyes have been used in the past in the New Zealand leather and textiles industries, but there were no current known uses.

Dioxins 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 noted above (United Nations Environment Programme, 2013). There is also the potential for dioxin production as unintentional by-products when incineration processes are used for waste disposal. However, incineration is not used in New Zealand.

On the basis of the above information, there is no reason to expect any significant dioxin 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.

In the previous inventory report it was estimated that the total annual releases from dioxins present in imported textiles and leather goods would be no more than about 0.036 g TEQ. There is no new information available to suggest that this estimate will have changed significantly since 2012. The 2012 estimate was not included in the inventory results because of the associated very high uncertainties, and the same approach will be adopted here.

9.8 Leather refining

See section 9.7.

9.9 Summary for this category

The 2016 release estimates for the production of chemicals and consumer goods are summarised in Table 9-5, along with the revised comparative totals for 2008 and 2012.

Table 9-5: Summary of the release estimates for the production of chemicals and consumer goods

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Black liquor combustion	0.048	-	-	-	-
Pulp & paper sludge disposal	-	-	0.146	-	-
Use of 2,4-D	-	-	-	0.000050	-
Petroleum production	0.019	0.0084	-	-	0.000017
2008 totals	0.051	0.0078	0.083	0.000034	0.00007
2012 totals	0.054	0.0078	0.093	0.000034	0.00007
2016 totals	0.067	0.0084	0.146	0.000050	0.000017

10 Miscellaneous sources

This category covers dioxin releases from the following sub-categories (United Nations Environment Programme, 2013):

- 8a Drying of Biomass
- 8b Crematoria
- 8c Smoke houses
- 8d Dry cleaning
- 8e Tobacco smoking

The dioxin releases from most of these sources are combustion-related, and they mainly arise from the incomplete combustion of the fuels and/or materials being burned. The only exception is dry cleaning, where the dioxins arise as a result of incoming contamination on the materials being cleaned.

10.1 Drying of Biomass

This Toolkit category refers to the drying of biomass such as wood chips or animal fodder using direct heating methods, in which the material to be dried is exposed directly to combustion off-gases. The biomass can become contaminated with dioxins if the fuel being used is contaminated with dioxin precursor materials, such as pentachlorophenol. Thus, the category mainly applies to biomass drying using other biomass as the fuel.

The most significant biomass drying operations in New Zealand, by size, take place in the board and fibreboard mills already considered in section 5.2, and the potential releases have already been accounted for under the heat and power generation source category. Other biomass drying in New Zealand (eg, grain drying) is carried out using dryers fired by fossil fuels, especially natural gas, LPG or diesel. The dioxin releases from these activities have already been accounted for under section 5.

10.2 Crematoria

The Law Commission reported that in 2013 there were 52 crematoria in New Zealand, 15 of which are operated by local authorities with the remainder being run by private providers. (New Zealand Law Commission, 2013)

The release estimates for the 2012 Inventory were based on the annual numbers of cremations multiplied by the default factor given in the UNEP Toolkit for releases to air. There were no significant releases to land, water, or in products or residues. Annual data obtained from the Department of Internal Affairs (V Millar, pers comm, 2017) show that for 2016 there were 31,333 registered deaths with 20,129 estimated cremations⁵ or 64% of the total. Applying the UNEP Toolkit factor of 10 µg TEQ per cremation (10×10^{-6} g TEQ/cremation) gives the release estimates shown in Table 10-1, along with the corresponding estimates from the 2012 Inventory.

Table 10-1: Dioxin releases from crematoria

Year	Activity Rate (no of cremations/year)	Release factors (µg TEQ/cremation)	Annual releases (g TEQ/yr)
		Air	Air
2012	19,053	10	0.1905
2016	20,129	10	0.201

⁵ The cremation/burial split is a little uncertain because the records note the place of disposal rather than the method of disposal.

Certainty assessment for 2016

Activity data: Medium (because it is based on national death registration data)

Emission factor: Low (because it is based on the default factor given in the UNEP Toolkit)

10.3 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.

The release factors given in the UNEP Toolkit relate to smoking processes based on wood pyrolysis. No data is available on the amount of fuel used in New Zealand for this purpose and there is also no information on the proportion of smoked meats that are produced in this way. Hence, there is insufficient information to allow any reliable estimates of the releases for this source. However, it can be noted that the 2008 Inventory produced a worst-case estimate, based on total smoked food production, of no more than 0.15 g TEQ per year (Ministry for the Environment, 2011a). This estimate was not included in the inventory totals because of the associated very high uncertainties.

10.4 Dry cleaning

Dioxins have been detected in the distillation residues from dry cleaning, but this is believed to originate from contaminants already present on the textiles from the use of chemicals such as pentachlorophenol and dioxazine dyes (United Nations Environment Programme, 2013). The dry cleaning process itself does not generate any dioxins. The UNEP Toolkit recommends release factors of 3000 µg TEQ per tonne of residue for cleaning of textiles with high levels of PCDD/PCDF contamination, and 50 µg TEQ per tonne of residue for 'normal' textiles (1 µg = 10⁻⁶ g). These factors are based on European work published in 1992 and 1993, and it is likely that the current contamination levels in New Zealand will be much lower than those reported, simply because there is now little or no use of the contaminated chemicals.

There is no accurate data available on the quantities of dry cleaning distillation residues produced in New Zealand. In the 2008 Inventory report it was estimated that the potential releases could be in the order of only 0.007 grams TEQ per year, but this figure was not included in the inventory totals because it was highly uncertain (Ministry for the Environment, 2011a). There is no reason to believe that the current releases would be substantially different from the 2008 estimate.

10.5 Tobacco smoking

The release estimates for the 2008 Inventory were based on total tobacco consumption in 2007 of 2445 million cigarettes and 904 tonnes of tobacco, or 3349 million cigarette equivalents (based on a factor of 1 million cigarettes per tonne of loose tobacco). This indicated an overall drop in tobacco consumption of about 17% over the previous 10 years.

National statistics on tobacco consumption are only available up to the end of 2009⁶. The 2012 Inventory estimated tobacco consumption rates of 2112 million cigarettes and 675 tonnes of tobacco, or 2769 million cigarette equivalents. In 2016 the Ministry of Health stated that between 2010 and 2014 the volume of tobacco consumed fell by nearly 23% (Ministry of Health, 2016). Assuming reductions have occurred at a similar rate for

⁶ Statistics New Zealand stopped publishing these on the basis that the data was commercially sensitive.

cigarette and tobacco products since 2012 then the 2016 tobacco consumption rates can be estimated at 2132 million cigarette equivalents.

The UNEP Toolkit default factor of 0.1 pg TEQ per cigarette for releases to air (0.1×10^{-12} g TEQ/cigarette), has been applied to this total to give the 2016 estimates shown in Table 10-2, along with the corresponding estimates from 2012

Table 10-2: Dioxin releases from tobacco smoking

Year	Activity Rate (million cigarettes/year)	Release factors (pg TEQ/cigarette)	Annual releases (g TEQ/yr)
		Air	Air
2012	2769	0.1	0.00028
2016	2132	0.1	0.00021

Certainty assessment for 2016

Activity data: Medium (because it is based on national statistics)

Emission factor: Low (because it is based on the default factor given in the UNEP Toolkit)

10.6 Summary for this category

The 2008, 2012 and 2016 release estimates for miscellaneous sources are summarised in Table 10-3.

Table 10-3: Summary of the release estimates for miscellaneous sources

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Crematoria	0.201	-	-	-	-
Tobacco smoking	0.00021	-	-	-	-
2008 totals	0.183	-	-	-	-
2012 totals	0.191	-	-	-	-
2016 totals	0.202	-	-	-	-

11 Disposal and landfill

This category covers dioxin releases from the following sub-categories (United Nations Environment Programme, 2013):

- 9a Landfills, waste dumps and landfill mining
- 9b Sewage/sewage treatment
- 9c Open water dumping
- 9d Composting
- 9e Waste oil disposal

All of the sources in this category should be considered as secondary dioxin sources, in that there are no new dioxins being produced. The dioxins are simply associated with the incoming and outgoing wastes.

11.1 Landfills, waste dumps and landfill mining

According to the UNEP Toolkit this category covers wastes generated at a national level which are landfilled. In 2016 there were 45 landfill facilities in New Zealand receiving municipal solid waste (Ministry for the Environment, 2017). These are defined as Class 1 landfills and receive treated hazardous waste, industrial waste, commercial waste, household waste, municipal solid waste, construction and demolition waste, managed fill material and clean-fill material. In addition to these there were a number of clean fills or construction and demolition fills assigned to landfill Classes 2 – 4. (Ministry for the Environment, 2017). The latter are not adjudged to be significant sources of dioxins and their activity has not been included in this dioxin release assessment. There is one example of a dedicated hazardous waste landfill in New Zealand which no longer receives wastes (Bell & Wilson, 1988). There are also a small number of private industrial landfills. Industrial wastes containing dioxins have already been accounted for in the other sections of this report dealing with individual processes, and there is no landfill mining done in New Zealand. Consequently municipal solid waste is the sole focus for this waste category.

New Zealand's waste disposal levy scheme is currently the best means of estimating domestic waste activity. The Waste Minimisation Act was introduced in 2008 with the purpose of encouraging waste minimisation and a decrease in waste disposal. To achieve this aim a levy of \$10 for every tonne of waste arriving at domestic waste landfills was introduced in 2009. Imposition of the levy has resulted in more accurate monitoring of waste quantities disposed.

Waste deposition data is available on the Waste Levy web site www.mfe.govt.nz/waste/guidance-and-technical-information/waste-disposal-levy/monthly-levy-graph and this shows that in 2016 the total quantity of waste disposed to municipal landfills was 3,406,031 tonnes. Since the introduction of the levy in 2009, levied waste has increased by 124 kg per person, an increase of 20.3 %. A review of the levy system in 2017 concluded that the public was not responding appropriately to price signals generated by the levy as an incentive to reduce waste (Ministry for the Environment, 2017).

The UNEP Toolkit gives three classifications for landfills:

- Class 1 applies to landfills where wastes from (Toolkit) source groups 1 to 8 are deposited.
- Class 2 applies to landfilling of waste which may contain some hazardous components. A typical situation is where a country has no organised waste management systems.
- Class 3 applies to landfilling of non-hazardous wastes.

The greenhouse gas inventory report commented that New Zealand has insufficient data to categorise solid waste as either municipal solid waste or industrial solid waste, because many municipal landfills accept industrial waste (Ministry for the Environment, 2018). However current New Zealand landfill practice does involve waste assessment and would reject for disposal any industrial wastes which were known to contain significant quantities of dioxins. Landfills in New Zealand are engineered facilities where the wastes deposited are contained by impermeable liners and water ingress prevented by capping materials. Consequently the Toolkit class 3 category is considered appropriate for all waste currently being deposited in landfills.

With regard to releases to water the situation is more complicated. The leachate produced by a landfill is not solely associated with the waste currently being deposited. It may originate, or come in contact with waste from earlier periods, which may have had higher concentrations of dioxins. Class 2 emission factors are seen as more appropriate for New Zealand landfill leachate.

The estimates for dioxin releases from landfilling for 2016 are shown in Table 11-1, along with the corresponding estimates made in the 2012 Inventory.

Table 11-1: Dioxin releases from landfills, waste dumps and landfill mining

Year	Activity Rate	Release factors		Annual releases (g TEQ/yr)	
		Water (µg TEQ/m ³)	Land (µg TEQ/tonne)	Water	Land
2012	2,514,182	0.5	-	1.257	-
		-	5	-	12.57
2016	3,406,031	0.5	-	1.703	-
		-	5	-	17.03

Certainty assessment for 2016

Activity data: High (because it is based on the national waste levy data)

Emission factors: Low (because they are based on the Toolkit default factors)

11.2 Sewage/sewage treatment

About 320 wastewater treatment plants (WWTPs) treat the domestic sewage produced by 80% of New Zealand's population. Approximately 70% of these people are connected to 25 high rate WWTPs, many of which have full secondary treatment and produce digested dewatered sludge. The majority of the remaining WWTPs use small waste stabilisation ponds which accumulate sludge for infrequent removal (New Zealand Water and Wastes Assn, 2003).

Both large and small WWTPs discharge treated water on a continuous basis. Water New Zealand collate information on the volumes of liquid waste treated through New Zealand wastewater plants and this data is presented in a publicly available spreadsheet (www.waternz.org.nz/WWTPInventory). The councils that provided data in the 2015-2016 calendar year had jurisdictions covering 4,053,598 of New Zealand's population, with 3,511,857 on reticulated wastewater systems. Using the 2013 data for the usually resident population count this would leave 841,341 New Zealander's not covered by the data in the spreadsheet. (L. Smith, pers comm, Water New Zealand, 2017). For the purposes of the inventory these people are assumed to use septic tank disposal and are assumed to discharge waste water at the same rate as individuals who are connected to a wastewater treatment plant.

Water New Zealand reported that for 2015-2016 New Zealand waste water treatment plants handled 447,676,145 m³/year. Consequently septic plant discharges are assumed to be 107,250,464 m³/year giving a total wastewater production figure of 554,926,609 m³/year. This is somewhat lower than the figure of 657,000,000 m³/year given in the 2012 Inventory Report, but that was based on less detailed data.

Total dewatered sludge production for all WWTPs in 2012 was estimated at 320,000 tonnes per annum (Walmsley, 2012). This figure was derived from the assumption of a per capita biological oxygen demand (BOD) of between 70 and 90 g per person per day. Septic tank sludge would be included in this estimate because most of this material is emptied to treatment plants after septic tank cleaning. Statistics NZ estimate the 2016 population to have been 4.75 million (www.archive.stats.govt.nz/infoshare – see population and population estimates) and this number has been used to generate a pro rata increase in sludge loading based on the 2012 population of 4.43 million. This gives an annual sludge production for 2016 of 343,120 tonnes.

With regard to the Toolkit emission factors Class 2 – “urban and industrial inputs” and class 3 – “domestic inputs” are appropriate for New Zealand. For the 2012 Inventory it was decided that the distinction between the two classes should be on the basis of whether or not the wastewater is reticulated and that Class 2 should be used for all WWTP releases and Class 3 for septic tank releases. It was also decided that all WWTP releases to water be classified as “sludge removed”. This approach has been continued here. For Class 2 discharges of treated wastewater from a WWTP to water involving sludge removal, the emission factor is 0.2 pg TEQ/litre (0.2 x 10⁻¹² g TEQ/litre). For Class 3 discharges of wastewater the emission factor is 0.04 pg TEQ/litre (0.04 x 10⁻¹² g TEQ/litre). For Class 2 releases of sludge, the emission factor is 20 µg TEQ/tonne dried sludge (20 x 10⁻⁶ g TEQ/tonne of sludge).

2016 release estimates are shown in Table 11-2, along with the corresponding estimates made in the 2012 Inventory. The reduction in the water release estimate can be attributed to improved data on wastewater processed for 2016.

Table 11-2: Dioxin releases from sewage/sewage treatment

Year	Class	Activity Rates		Release factors		Annual releases	
		Water (10 ⁹ litres/yr)	Residue (tonnes/yr)	Water (pg TEQ/litre)	Residue (µg TEQ/tonne)	Water (g TEQ/yr)	Residue (g TEQ/yr)
2012	Class 2	657		0.2		0.131	
			320,000		20		6.40
	Class 3	54.6		0.04		0.0022	
	Total releases						0.1336
2016	Class 2	447.7		0.2		0.090	
			343,120		20		6.86
	Class 3	107.3		0.04		0.0043	
	Total releases						0.0938

Certainty assessment for 2016

Activity data: Medium (because they are based on national estimates, rather than complete data)
 Emission factor: Low (because they are based on the Toolkit default factors).

11.3 Open water dumping

This Toolkit source category refers to the practice of discharging untreated wastewater or other liquid wastes directly into surface waters, such as streams, rivers, lakes or the sea. It was not considered for inclusion in the report on the 2008 Inventory, mainly because of the unavailability of any relevant data.

New Zealand has 425,000 kilometres of rivers and streams, almost 4,000 lakes that are larger than 1 hectare, and about 200 aquifers (Ministry for the Environment, 2008a). Water quality is generally poorest in rivers and streams in urban and farmed catchments and in coastal areas adjacent to urban centres. This reflects the impact of non-point-sources of pollution, such as urban stormwater, animal effluent, or fertiliser run-off. Urban stormwater is the most likely of these to be contaminated with dioxins. However, it would be almost impossible to determine stormwater volumes on a national basis, or their likely contamination levels, with any reasonable degree of accuracy. In addition, the most significant dioxin contributions should have already been accounted for under other environmental compartments, especially air and land. Similarly, the most significant point source discharges should have already been accounted for under other source sub-categories (eg WWTP effluents).

Waste discharges within New Zealand's EEZ are controlled by Maritime New Zealand, in accordance with standards derived from the 1996 Protocol to the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (Maritime New Zealand, 2001). Permits may be issued for the disposal at sea of a variety of solid and liquid wastes, provided it can be shown that any adverse effects will be avoided, remedied or mitigated. There is some national data available on the quantities of these wastes but the dioxin contamination levels are unknown. This therefore precludes any estimates of the likely dioxin discharges.

11.4 Composting

This source was not considered in the 2008 Inventory and will similarly not be included here. The Toolkit category mainly relates to compost made from the organic fraction of municipal solid wastes, whereas most New Zealand compost is made from green waste which should have little or no dioxin contamination.

11.5 Waste oil disposal

The UNEP Toolkit refers to this source sub-category as Waste Oil Treatment (non-thermal), but provides no release factors because of the highly variable nature of the possible treatment processes and the lack of any reliable release data. It also notes that no new dioxins are created in the treatment processes. The dioxins are simply present as contaminants introduced via previous uses of the oil (United Nations Environment Programme, 2013). There are several waste oil processors in New Zealand, and any potential discharges from their operations are subject to controls in resource consents issued under the *Resource Management Act 1991*. The consents are mainly targeted at minimising oil releases, rather than dioxins. However, it would be reasonable to assume that any dioxin releases will also be minimised if the oil discharges are properly controlled. No data has been found that would allow for any specific estimates of the releases from this source.

11.6 Summary for this category

The 2016 release estimates for the waste disposal and landfill sources are summarised in Table 11-3, along with the comparative totals for 2008 and 2012.

Table 11-3: Summary of the release estimates for the disposal and landfill category

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Landfills, waste dumps and landfill mining	-	1.703	17.03	-	-
Sewage/sewage treatment	-	0.0943	-	-	6.86
2008 totals	-	1.362	12.28	-	6.40
2012 totals	-	1.391	12.57	-	6.40
2016 totals	-	1.797	17.03	-	6.86

12 Contaminated sites and hotspots

This section of the UNEP Toolkit does not generate any data for inclusion in the national inventory. Rather, it is simply intended to provide ‘an indicative list of activities that might have resulted in the contamination of soils and sediments with PCDD/PCDF and other unintentional POPs, including related deposits’ (United Nations Environment Programme, 2013). No significant new work has been undertaken in the preparation of this section, which simply provides an update of the information given in section 28 of the previous inventory report for the following sources:

- the manufacture of phenoxy herbicides
- the use of the herbicide 2,4,5-T
- timber treatment using pentachlorophenol
- gasworks
- landfills.

12.1 Pesticide manufacture

This sub-section is concerned with the dioxins 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 3.2 of this report.

Although dioxins are known to be present in the Waireka facility, insufficient data is available to enable an accurate estimate of the quantity present.

12.2 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 dioxins, primarily 2,3,7,8-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 (Ministry for the Environment, 2000). 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. 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 TEQ.

The size of the reservoir from 2,4,5-T usage was estimated in the previous inventory reports by making an allowance for TCDD degradation over time, using a half-life of 15 years. Thus, for 1998 the residual amount of TCDD was estimated to have dropped to a level of 620 to 860 g TEQ, and by 2008 and 2012 it was down to 390 to 540 g TEQ and 324 to 437 g TEQ respectively (calculated using a factor of $A = A_0 \cdot 1/2^{t/h}$, where A = amount remaining, A_0 = original amount, t = time elapsed (years) and h = half-life (years)). Using the same methodology, the 2016 quantity of TCDD remaining in soil as a result of the past use of 2,4,5-T is estimated to be 270 – 374 g TEQ.

12.3 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 antispain treatment, or as a preservative mixed with diesel oil. The use of PCP in the timber industry commenced in the mid- to late-1950s and voluntarily ceased in 1988, and the chemical was deregistered for all uses by the Pesticides Board in 1991. The total amount of PCP imported into New Zealand for use in the timber industry is believed to be about 6000 tonnes (Ministry for the Environment, 2011a), and the total input of dioxins into the New Zealand environment was estimated to be 9.9 kg TEQ.

The concentrations of dioxins in the antispain formulations marketed in NZ were believed to be in the range 0.2 –1.85 g TEQ per tonne, with a mean of 0.9 g TEQ per tonne. Investigations at some of the timber treatment sites have been used to produce an estimate of the total dioxin contamination resulting from antispain use (Ministry for the Environment, 2011a), and in 2008 the residual amount remaining was estimated to be 0.81 kg TEQ. This estimate was based on site assessments completed in 2002, and some of the sites have since been remediated. However, there have been no specific treatments aimed at removing the dioxin contaminants. In addition, much of the remediation work is based simply on soil removal and replacement. Hence, the quantities of dioxins in the reservoirs are unlikely to have changed, but they may have been moved to other locations.

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 total usage of PCP was estimated to be approximately 2700 tonnes and the average contamination level of the PCP was believed to be 1.65 g TEQ per tonne, which gives a total dioxin input of 4.5 kg TEQ. As reported in the previous inventory, it was estimated that 0.23 kg TEQ of this total would have contributed to soil contamination at the sawmill sites, and the remaining 4.27 kg 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 prior to the disposal of waste materials.

12.4 Gasworks sites

Prior to the introduction of natural gas in New Zealand, ‘town gas’ was produced by coal gasification plants at gasworks sites throughout the country. There were approximately 54 gasworks sites, which operated for varying periods from the mid-1800s through to 1988. Internationally, dioxins have not been recognised as a priority contaminant of gasworks waste. However, New Zealand studies have found that some dioxins may be present in the wastes produced from coal gasification and can be found at some of the sites where gasworks were previously located (Ministry for the Environment, 2011a).

In the first dioxin inventory report it was noted that at least five of the 54 gasworks sites had been remediated, and the reservoir estimates for the remaining 49 sites were reported to be between 0.028 and 6.4 g TEQ (Ministry for the Environment, 2000). The second inventory reported that a further 10 sites had been remediated and the 2008 dioxin reservoir was estimated at 0.022 to 5.2 g TEQ. No reports have been found of any more recent remediation work, so the 2012 estimate should still apply for 2016.

12.5 Landfills

Solid waste landfills also represent a reservoir of dioxins. In the 2012 Inventory it was estimated that the total mass of waste stored in landfills in 2012 was 120 million tonnes, and the associated dioxin reservoir would be 0.72 kg TEQ (based on a Toolkit factor of 6×10^{-6} g TEQ per tonne). In the following 4 years, the quantity of waste will have increased by about 12 million tonnes (see section 11.1). Thus the existing reservoir in 2016 will be 0.79 kg TEQ.

13 Summary and discussion

The key points arising from the 2016 inventory are summarised and discussed below, along with some comparative data from the previous inventories for 2008 and 2012. A table showing the complete data for all source categories and release vectors for 2008, 2012 and 2016 is given in Appendix 1.

13.1 Dioxin Release Estimates for 2016

The total estimated quantity of dioxin released in New Zealand for 2016 was 41.0 g TEQ. A plot of dioxin release estimates versus source category for 2016 is shown in Figure 13-2. Viewing the plot it is apparent that most dioxin emissions can be attributed to a relatively small number of categories and that many categories make only a very minor contribution to the total. Figure 13-1 illustrates the share that major source categories have for the total dioxin release. It shows that about two thirds of New Zealand’s estimated dioxin releases can be attributed to two categories – disposal of municipal waste in landfills and sewage treatment. Combined with seven other categories: secondary aluminium processing, industrial coal combustion, structure fires, metal shredding, industrial wood combustion, heating and cooking with wood and open burning of domestic wastes the nine sources comprise 90% of total dioxin releases with the remaining 10% split between about 40 other categories and sub-categories.

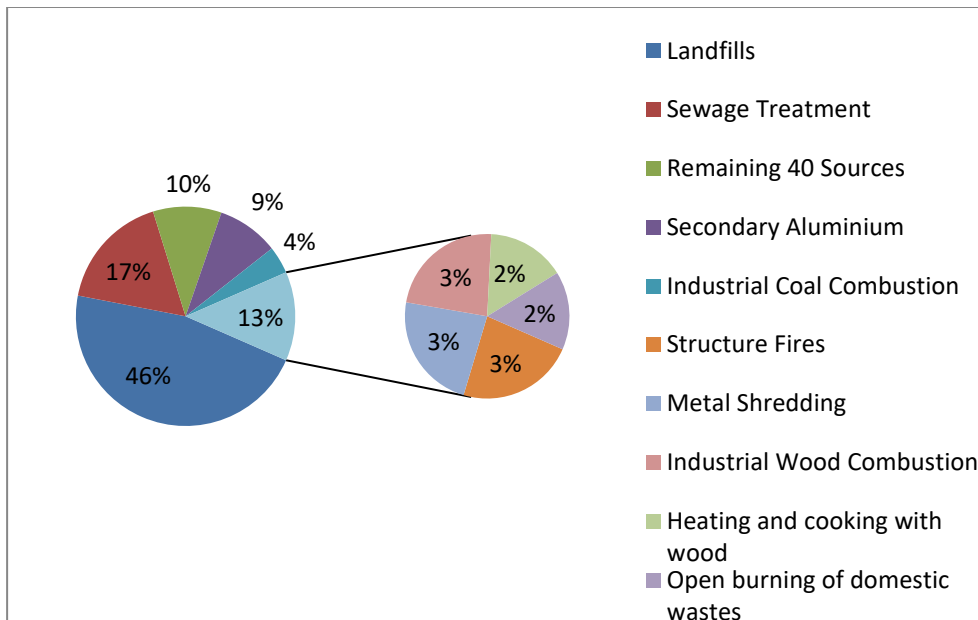


Figure 13.1. Plot Showing the Contribution of Major Release Categories for Dioxin

(* The sum of all categories may not total exactly 100.0% due to rounding effects)

All members of New Zealand’s 4.7 million population contributed to the sewage treatment release in 2016 and a significant majority will have generated wastes disposed of in municipal solid waste landfills. Releases from industrial coal and biomass combustion (the latter largely wood-waste) are associated with about 500 coal-fired boilers and more than 175 biomass-fired power plants. Secondary aluminium production occurs primarily at two larger plants and a number of smaller facilities. Structure fires are essentially random events, although nationally a similar numbers of fires occur from year to year. Metal shredding is now confined to a single plant in New Zealand. Heating and cooking with wood, primarily the former, occurs in about 550,000 New Zealand households with open burning of wastes in an estimated 5% of households.

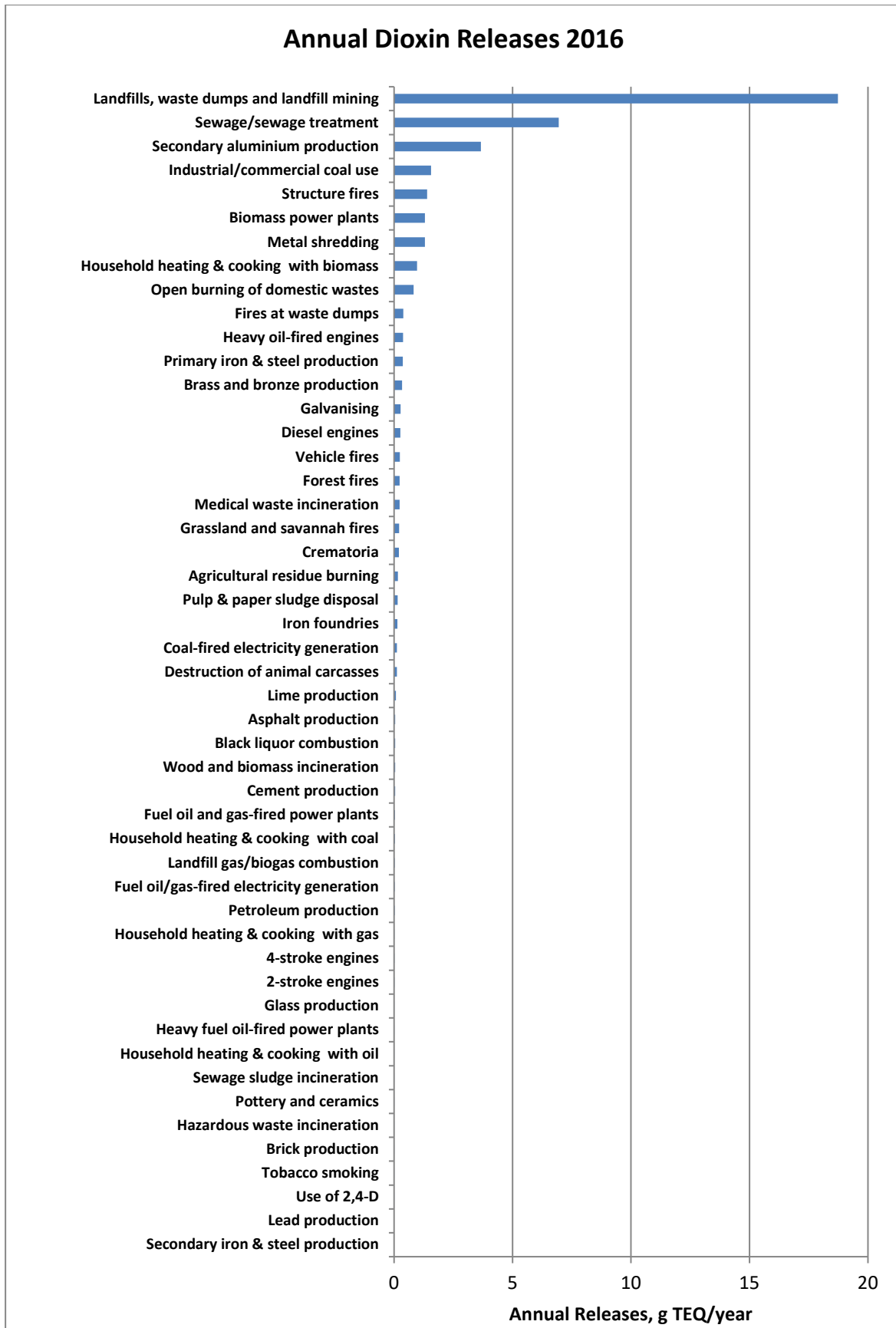


Figure 13.2. Annual Dioxin Releases 2016 by Source (see Appendix 2 for details)

13.2 Changes in the dioxin release estimates over time

The dioxin release estimates for 2008 and 2012 and 2016 are summarised in Table 13-1 below. This summary is based on nine of the Toolkit major source categories, which is the summary level used for country reports under the Stockholm Convention. As shown in the Table the total release of dioxin in New Zealand for 2016 was 41.00 g TEQ. This can be compared with releases of 42.86 g TEQ in 2008 and 40.73 g TEQ in 2012.

Table 13-1: Summary of the release estimates for 2008, 2012 and 2016

Major Source Categories		Annual Releases (g TEQ/a)											
		Air			Water			Land			Residue		
		2008	2012	2016	2008	2012	2016	2008	2012	2016	2008	2012	2016
1	Waste Incineration	0.81	0.79	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.03
2	Ferrous and Non-Ferrous Metal Production	0.69	0.40	0.26	0.02	0.01	0.02	0.21	0.21	0.27	10.76	9.71	5.54
3	Heat and Power Generation	3.32	3.33	3.24	0.00	0.00	0.00	0.61	0.41	0.07	0.78	0.75	0.79
4	Production of Mineral Products	0.09	0.07	0.08	0.00	0.00	0.00	0.22	0.18	0.06	0.03	0.03	0.04
5	Transportation	0.71	0.66	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Uncontrolled Combustion	3.16	2.44	2.60	0.00	0.00	0.00	1.07	0.78	0.86	0.00	0.00	0.00
7	Production of Chemicals and Consumer Goods	0.05	0.05	0.07	0.01	0.01	0.01	0.08	0.09	0.15	0.00	0.00	0.00
8	Miscellaneous	0.18	0.19	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Waste Treatment	0.00	0.00	0.00	1.36	1.39	1.80	12.28	12.57	17.03	6.40	6.40	6.86
Totals		8.99	7.94	7.47	1.38	1.41	1.82	14.47	14.24	18.44	18.01	17.14	13.26
Totals* for all release vectors		2008			2012			2016					
		42.86			40.73			41.00					

(* The sums of the figures in some columns may not agree exactly with the totals shown, due to rounding effects)

The estimates for releases in products have not been shown in the table because there are only two very minor sources: brick production and the use of the herbicide 2,4-D, with a total annual release of only 0.00009 g TEQ for 2016.

Tables 13-2 and 13-3 show source categories which for 2016 had increases or decreases in their dioxin releases greater than 0.01 g compared with 2012 levels.

Table 13-2: Categories which had increases in release estimates for 2016 compared with 2012

Source Category	Change in Dioxin Release (g TEQ/annum)
Landfills, waste dumps and landfill mining	4.91
Sewage/sewage treatment	0.42
Industrial/commercial coal use	0.22
Structure fires	0.15
Primary iron & steel production	0.065
Forest fires	0.062
Pulp & paper sludge disposal	0.053
Vehicle fires	0.045
Diesel engines	0.028
Open burning of domestic wastes	0.027
Galvanizing	0.025
Lime production	0.020
Asphalt production	0.020
Fuel oil and gas-fired power plants	0.014
Black liquor combustion	0.012
Crematoria	0.011

Compared with 2012 levels, releases from landfills have increased partly because the population has increased but more significantly because waste production increased by 125 kg per person from 2009-2016. However increased releases from sewage treatment, open burning of domestic wastes, and crematoria can be attributed to population increase. Increases in releases from industrial and commercial coal use are due to increased coal consumption, particularly by the food industry. Structure fires, forest fires and vehicle fires are random unpredictable events. Increases from diesel engines and fuel oil and gas-fired power plants reflect increased fuel consumption. Pulp and paper sludge disposal and black liquor combustion increases can be attributed to larger quantities of pulp being manufactured. Similarly increased releases from the lime industry are due to manufacturing increases.

Table 13-3: Categories which had decreases in release estimates for 2016 compared to 2012

Source Category	Change in Dioxin Release (g TEQ/annum)
Secondary iron & steel production	-2.84
Brass and bronze production	-0.70
Coal-fired electricity generation	-0.58
Metal shredding	-0.52
Secondary aluminium production	-0.43
Medical waste incineration	-0.43
Cement production	-0.13
Iron foundries	-0.072
Grassland and savannah fires	-0.032
4-stroke engines	-0.026
Wood and biomass incineration	-0.018
Landfill fires	-0.013
Household heating & cooking with coal	-0.010
Household heating & cooking with biomass	-0.010

Plant closures with subsequent decreases in production quantities were the cause of the reductions for secondary iron and steel production, secondary aluminium production, brass and bronze production, metal shredding and iron foundries. Medical waste incineration releases have dropped because of the closure of a quarantine waste incinerator and reductions in waste throughput. Cement reductions arise from the closure of one of New Zealand’s two cement plants. Grassland and savannah fires are random unpredictable events. Release reductions from 4-stroke engines arise from improvements in vehicle fleet exhaust technology. Reductions for household heating and cooking with coal and biomass reflect the gradual adoption of alternative fuels such as gas and electricity.

Trends in Dioxin Releases

Figures 13.3 and 13.4 display plots of dioxin releases versus source category for 2008, 2012 and 2016. The sources have been categorised as major and minor to make the lesser sources more visible.

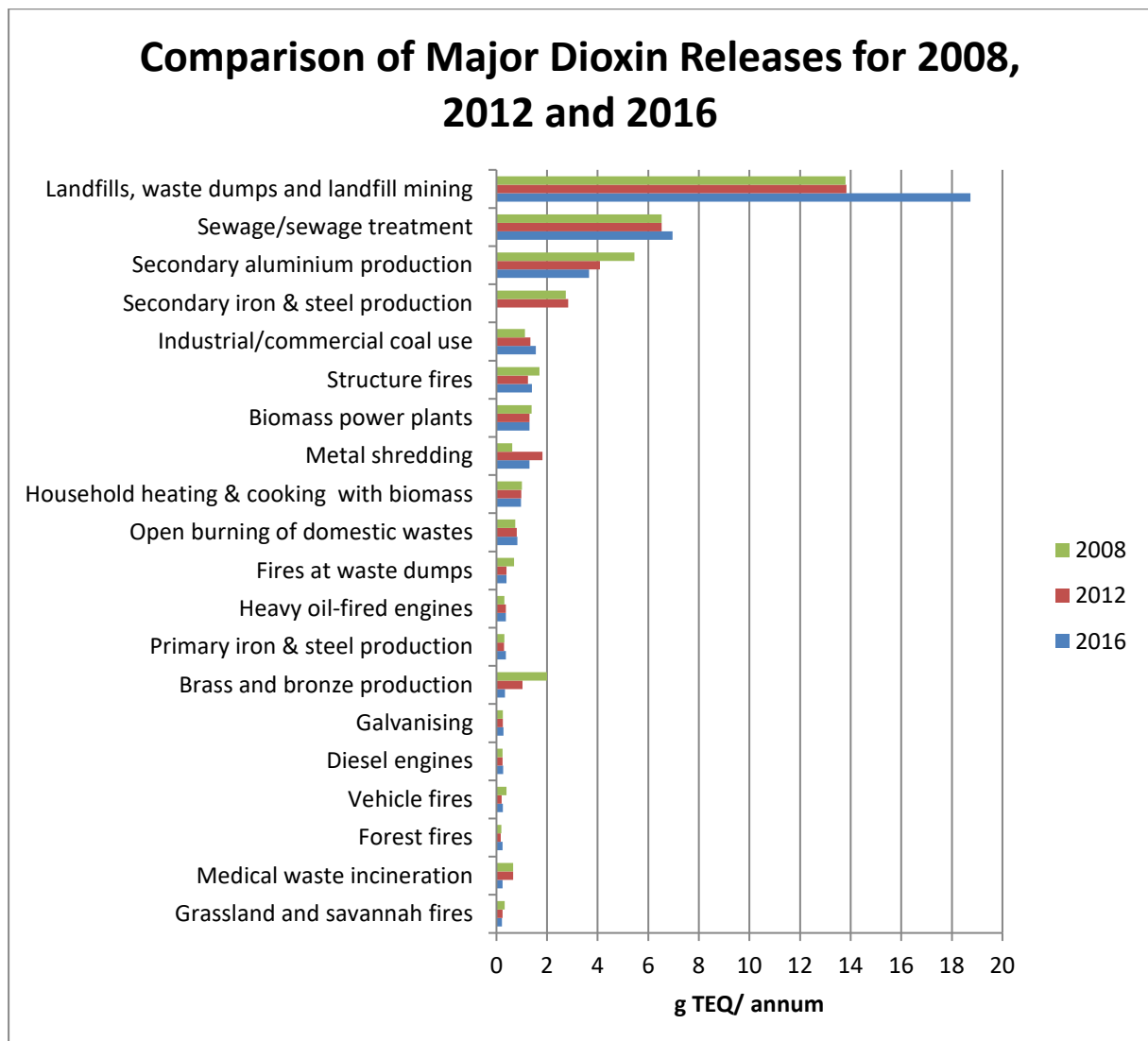


Figure 13.3 Major Sources’ Dioxin Releases for 2008, 2012 and 2016 (see Appendix 2 for details)

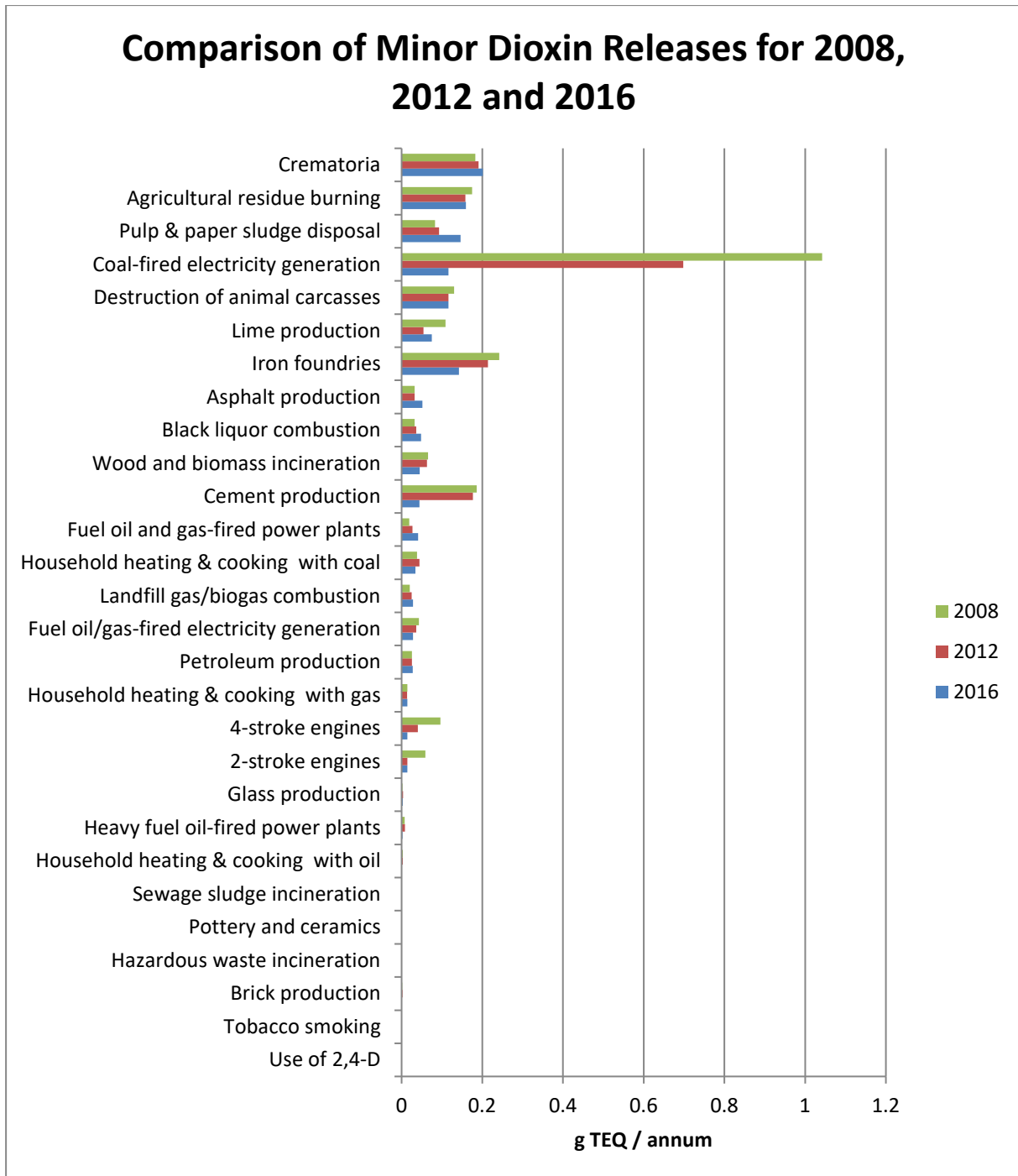


Figure 13.4 Minor Sources' Dioxin Releases for 2008, 2012 and 2016 (see Appendix 2 for details)

Regarding Figure 13.3 an increasing trend of dioxin release is most apparent for industrial and commercial coal use whereas decreasing trends are most pronounced for secondary metal production – secondary aluminium, secondary iron and steel, and brass and bronze production.

For the sources shown in Figure 13.4 increasing trends are visible for crematoria, pulp and paper wastes, including black liquor combustion and fuel oil and gas fired power plants. Decreasing trends are apparent for coal fired electricity generation, iron foundries, cement production, fuel oil and gas fired electricity generation and 4-stroke engines.

13.3 New Zealand Initiatives Leading to Reductions in Dioxin Releases

Greenhouse Gas Reduction Strategies

Strategies aimed at reducing greenhouse gases are often complementary to initiatives aimed at reducing dioxin emissions particularly with respect to fossil fuel combustion. New Zealand has adopted a policy to reduce greenhouse gas emissions by 30% below 2005 levels by 2030. Inevitably this policy will place pressure on fossil fuel use, particularly coal which has the highest CO₂ factor of all fossil fuels.

The electricity generation industry is in the process of focussing resources away from thermal power stations fuelled by coal and gas and replacing them with power derived from renewable sources, particularly geothermal energy. Between 2012 and 2016 annual geothermal electricity generation jumped more than 25%, from 21.0 PJ to 26.7 PJ. Correspondingly coal and gas electricity generation reached 20 and 21 year lows respectively in 2016 (Ministry of Business Innovation and Employment, 2017). Dioxin emissions for coal fired electricity generation fell by 83% in the same period with a 12% drop for gas generation (see Sections 5.1.1 and 5.1.3).

The dairy industry is one of the country's largest coal consumers. New Zealand's largest dairy company, Fonterra, has entered into a collaborative partnership with the Ministry for the Environment with the aim of transitioning to low emission, 100% renewable energy sources. Both Fonterra and another dairy manufacturer, Synlait, have expressed interest in replacing coal fired plant with electricity with Synlait recently announcing the introduction of a major electricity fired boiler.

Changes in Production Focus

Oji Fibre Solutions, which operates New Zealand's two Kraft pulp mills, recently announced it would be closing its bleaching operations at its Tasman Mill in March 2019 to allow the company to produce more fibre cement pulp and other unbleached products (Oji Fibre Solutions, 2017). As discussed in Section 9.1, pulp bleaching is a source of dioxins, and this contribution will now be removed from the plant's output.

National and Local Government Legislation

The Resource Management (National Environmental Standards for Air Quality) Regulations 2004 introduced measures aimed at reducing dioxin releases to air including:

- Prohibiting the burning of tyres, bitumen, coated wire and oil
- Prohibiting the operation of school incinerators unless consented
- Prohibiting the operation of high temperature waste incinerators unless specifically mentioned
- Introducing particulate emission performance standards for urban wood burners installed after 2005.

These measures have been adopted as rules in the regional air plans issued by Regional Councils who have statutory responsibility for air quality in their region. With regard to the last point, older, inefficient wood burners are slowly being replaced by compliant models or alternative forms of heating such as electric heat pumps and heaters. Where towns and cities have compromised air quality because of particulate discharges, older wood burners and open-hearth fires are now actively discouraged by Regional Councils (see for example (Bay of Plenty Regional Council, 2016). It is not yet possible to establish the magnitude of the change nationally since 2012 because the process is dependent on responses to a question on fuel use asked in the 2018 Census for which results have been delayed.

As emphasised in the previous inventory, nationally only limited control of domestic rubbish combustion is exercised by Regional Councils through rules in regional air plans and there is no consistent approach between regions. Improved controls and stricter enforcement represents an avenue for dioxin release reduction from this source in the future.

13.4 Global Perspective

A review of the current state and main sources of dioxins around the world was conducted in 2015 (Dopico & Gomez, 2015). The annual global dioxin production for 2015 was estimated at approximately 287 kg TEQ. About 57% of this quantity was deposited in land areas of the globe and 40% in the oceans with the remaining 3% in the air. Industrialised countries in North America, Europe and South and East Asia were considered the biggest producers of dioxins. The authors commented that for many industrialised countries, following peak dioxin emissions in the 1970s and 80s, emissions decreased after the implementation of policies of flue gas treatment, social awareness campaigns and application of strict legislative emission controls. On the other hand in countries where non-industrial sources have been traditionally high contributors, emissions have remained more or less constant because it is more difficult to control this type of process.

It is possible to estimate a global per capita release of 38.7 g TEQ per million people per year based on the world's dioxin release of 287 kg TEQ and its 2016 population of 7.42 billion (Population Reference Bureau, 2016).

A predictive global dioxin release model was developed by Wang and co-authors (Wang et al, 2016). This used markers of human social economic activities including gross national income and per capita national income, carbon dioxide emissions per unit GDP combined with land area to estimate releases for individual nations. The total dioxin release for 189 countries was estimated to be 100.4 kg TEQ per year with the authors giving a global per capita average release of 15.4 g TEQ per million people per year.

In comparison New Zealand's 2016 release of 41.0 g TEQ combined with a population of 4.72 million gives a per capita value of 8.7 g TEQ per million people. The values for 2008 and 2012 were 10.0 and 9.3 g TEQ per million people respectively.

13.5 Other New Zealand studies

There are no official recommendations for 'acceptable' levels of national dioxin releases and it is also not possible to relate the release estimates to any potential health effects. The more relevant information is provided by national surveys of dioxin body burdens, for which there have been several New Zealand studies.

The levels of dioxins in mothers' milk have been measured on 3 occasions in New Zealand, 1988, 1998 and 2008 (Mannetje, Douwes, & Duckett, Concentrations of Persistent Organic Pollutants in the Milk of New Zealand Women, 2010). These studies showed that the dioxin concentrations in New Zealand mothers are relatively low by comparison with many other countries. Also, the levels have been steadily dropping, with a reduction of 70% observed from 1988 to 1998, and a further reduction of 40% from 1998 to 2008.

Figure 13-5: Serum dioxin concentrations in New Zealanders, 1997 and 2012

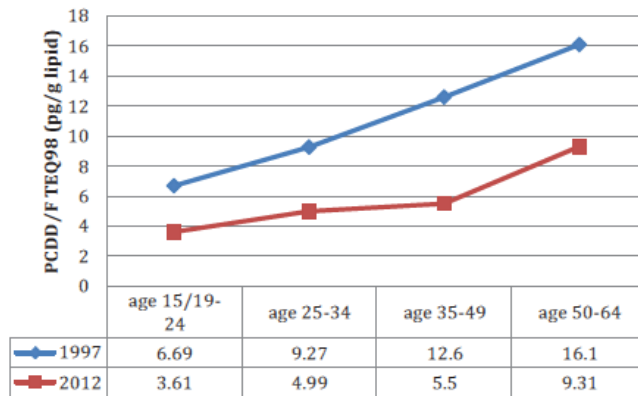


Figure 5.1. Comparison of PCDD/F serum concentrations between 2001 and current POPs studies (PCDD/F TEQ₉₈)

(Reproduced from (Mannetje, Coakley, Bates, Borman, & Douwes, 2013))

The levels of dioxins in blood serum have been monitored on two occasions in New Zealand, in 1997 and 2012 (Mannetje, Coakley, Bates, Borman, & Douwes, 2013). Once again, these studies showed the dioxin concentrations in New Zealanders are relatively low by comparison with many other countries, and the levels have dropped over time. This reduction is illustrated in Figure 13-5 and shows both a reduction from one ‘generation’ to the next (eg 25-34 year olds had lower dioxin levels in 2012 compared to 1997) but also a reduction as people get older (eg, 50-64 year olds have lower dioxin levels in 2012 than in 1997, when they were 35-49 years old).

14 List of References

- APR Consultants. (2012). *Rotorua Heating Survey 2012*. Rotorua: APR Consultants Ltd.
- Auckland Regional Council. (1999). *Oil Refining and Recovery. Information Sheet 11*. Auckland: Auckland Regional Council.
- Auckland Regional Council. (2010). *Decision Report on the application for resource consent for the discharges to air from the Sims Pacific Metals Limited operation at 193 James Fletcher Drive*. Auckland: Auckland Regional Council.
- Bay of Plenty Regional Council. (2016). *Draft New Regional Air Plan 26 April 2016*. Whakatane: Bay of Plenty Regional Council.
- Beca Amec. (2006). *Air Permit Technical Review on the Carter Holt Harvey Tasman Kraft Pulp Mill. Report prepared for the Bay of Plenty Regional Council*. Auckland: Beca Amec.
- Beca Amec. (2009). *Technical Air Discharges Report – Tasman Pulp Mill. Report prepared for Carter Holt Harvey in support of an air discharge consent application*. Christchurch: Beca Amec.
- Bell, D. H., & Wilson, D. (1988). Hazardous Waste Disposal in New Zealand. *Bulletin of the International Association of Engineering Geology*, 37, 15-26.
- Bioenergy in the News. (2015). *Fonterra Clean Energy Shift Not so Simple*. Bioenergy association of New Zealand.
- Bluett, J., Aguiar, M., & Smit, R. (2016). *Understanding Trends in Roadside Air Quality*. Wellington: Ministry of Transport.
- Camilleri, M., Fraser, R., French, L., Isaacs, N., Pollard, A., Saville-Smith, K., et al. (2006). *Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household End-use Energy Project (HEEP). Study Report No. SR 155*. Wellington: BRANZ.
- CRL Energy. (2011). *Heat Plant in New Zealand: Heat Plant Sized Greater than 100 Kilowatt Thermal Segmented by Industry Sector as at August 2011*. Wellington: CRL Energy Ltd on behalf of the Energy Efficiency and Conservation Authority.
- Crown Minerals. (undated). *Fact Sheet: Metallic Mineral Occurrences*. Wellington: Ministry of Economic Development.
- Department of Internal Affairs. (2018). *National Dog Database*. Wellington: Department of Internal Affairs.
- Dopico, M., & Gomez, D. (2015). Review of the Current State and Main Sources of Dioxins Around the World. *Journal of the Air and Waste Management Association*, 1033-1049.
- Energy Efficiency and Conservation Authority. (2018). *Energy End Use Database*. Wellington: Energy Efficiency and Conservation Authority.
- Environment Southland. (2013). *Dust Suppression- Keeping Your Air Clean!*. Invercargill: Environment Southland.
- Environmental Protection Authority. (2012 and 2013). *Climate Change Response Act 2002; 2011 and 2012 Annual Reports*. Wellington: Environmental Protection Authority.
- Environmental Protection Authority. (2013). *Management and Handling of Used Oil. HSNO COP 63*. Wellington: Environmental Protection Authority.
- Environmental Risk Management Authority. (2008). *Decision Report on Application HRC07004*. Wellington: ERMA New Zealand.
- ERMA New Zealand. (2011). *Application for the Reassessment of a Hazardous Substance under Section 63 of the Hazardous Substances and New Organisms Act 1996; No. HS200692*. Wellington: New Zealand Environmental Risk Management Authority.
- Evans, G. (2017). Why Electricity Will Replace Coal in Dairy Plants. *Newsroom*.
- Fonterra. (2018). *Co-firing on all Cylinders – Fonterra Brightwater Site to Reduce Emissions by 25 per cent.* . Fonterra New Zealand Ltd.

- Halliday, L., Slaughter, G., Rynne, M., & Totty, B. (2007). *Ten Years of the New Zealand Used Oil Recovery Programme. Paper presented at the Annual Conference*. Auckland: Waste Management Institute of New Zealand.
- Hawkes Bay Today. (2016). *Landfill Fire May Cause \$50,000 by Victoria White*. Napier: Hawkes Bay Today.
- Jaques, R. (2002). *Environmental Impacts Associated with New Zealand Structural Steel Manufacture – Preliminary Study. Study Report No. 113*. Wellington: BRANZ.
- Lubrication Engineers. (1991). *Notes on Oil Consumption*. Kansas: Lubrication Engineers Inc.
- Mannetje, A., Coakley, J., Bates, M., Borman, B., & Douwes, J. (2013). *Concentrations of Selected Persistent Organic Pollutants in the Serum of New Zealanders*. Wellington: Report prepared by the Centre for Public Health Research for the Ministry of Health.
- Mannetje, A., Douwes, J., & Duckett, H. (2010). *Concentrations of Persistent Organic Pollutants in the Milk of New Zealand Women*. Wellington: Ministry of Health, Public Health Research Centre, Massey University.
- Maritime New Zealand. (2001). *National Policy on the Sea Disposal of Waste*. Wellington: Maritime New Zealand.
- Maritime New Zealand. (undated-2). *Oil Spill Prevention in Recreational Boating: Two-Stroke vs. Four Stroke Engines*. Wellington: Maritime New Zealand.
- Ministry for the Environment. (2004). *Dioxin and Furan Emissions to Air from Secondary Metallurgical Processes in New Zealand*. Wellington: Prepared by Sinclair Knight Merz Ltd for Ministry for the Environment.
- Ministry for Primary Industries. (2013). *Forestry Production and Trade Statistics, Quarterly Statistics obtained from the MPI web site*. Wellington: Ministry for Primary Industries.
- Ministry for Primary Industries. (2018). *Production of pulp in New Zealand, 1951 to 2017*. Wellington: Ministry for Primary Industries -<https://www.mpi.govt.nz/dmsdocument/788-production-of-wood-pulp-1951-2016/sitemap>.
- Ministry for the Environment . (2019). *Road Map to Transition to a Low Emission Future – a Fonterra and Ministry for the Environment Initiative*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (1997). *National Waste Data Report*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2000). *New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources, 2000*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2005). *Waste Management in New Zealand: A Decade of Progress*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2007). *Targets in the New Zealand Waste Strategy: 2006 Review of Progress*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2008). *Proposed National Environmental Standard for On-Site Wastewater Systems: Discussion Document*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2008a). *Water (Chapter 10) in Environment New Zealand 2007*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2009). *Proposed National Environmental Standard for On-Site Wastewater Systems: Report on submissions*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2011). *New Zealand's Greenhouse Gas Inventory 1990–2009*. Wellington: Ministry for the Environment, report no ME113.
- Ministry for the Environment. (2011a). *New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Source, 2011*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2011b). *Review of the effectiveness of the waste disposal levy, 2011: In accordance with section 39 of the Waste Minimisation Act 2008*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2014). *New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources 2014*. Wellington: Ministry for the Environment.

- Ministry for the Environment. (2014). *New Zealand's Greenhouse Gas Inventory 1990-2012*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2017). *Review of the Effectiveness of the Waste Disposal Levy 2017*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2017). *Review of the Effectiveness of the Waste Disposal Levy 2017*. Wellington: Ministry for the Environment.
- Ministry for the Environment. (2018). *New Zealand's Greenhouse Gas Inventory 1990-2016*. Wellington: Ministry for the Environment report ME 1351.
- Ministry for the Environment and Stats NZ. (2018). *New Zealand's Environmental Reporting Series: Our Air 2018*. Wellington: Ministry for the Environment and Stats NZ.
- Ministry of Business Innovation and Employment. (2017). *Energy in New Zealand 2017*. Wellington: Ministry of Business Innovation and Employment.
- Ministry of Business, Innovation and Employment. (2013). *Energy in New Zealand 2013*. Wellington: Ministry of Business, Innovation and Employment.
- Ministry of Economic Development. (2008). *Oil: An Introduction for New Zealanders*. Wellington: Ministry of Economic Development.
- Ministry of Economic Development. (2008b). *Liquid Fuel Use in New Zealand. report prepared by Outcome Management Services Ltd*. Wellington: Ministry of Economic Development.
- Ministry of Economic Development. (2009). *New Zealand Energy Data File 2009*. Wellington: Ministry of Economic Development.
- Ministry of Health. (2008). *Safe Management of PCBs; Code of Practice*. Wellington: Ministry of Health.
- Ministry of Health. (2016). *Report Back on New Zealand's Tobacco Control Programme*. Wellington: Ministry of Health – www.health.govt.nz/systemfiles/documents/pages/cabinet-paper-8-april-2016.
- Ministry of Primary Industries. (2018). *Production of Pulp In New Zealand 1951 – 2017*. Wellington: Ministry of Primary Industries – <https://www.mpi.govt.nz/dmsdocument/788-production-of-wood-pulp-1951-2016/sitemap>.
- Ministry of Transport. (2013). *Annual Fleet Statistics 2012*. Wellington: Ministry of Transport.
- Ministry of Transport. (2018). *The New Zealand 2017 Vehicle Fleet: Data Spreadsheet version 4, 2018*. Wellington: Ministry of Transport.
- New Zealand Fire Service . (2017). *Annual Report for the Year Ended 30 June 2017* . Wellington: New Zealand Fire Service.
- New Zealand Law Commission. (2013). *The legal framework for burial and cremation in New Zealand – a first principles review*. Wellington: NZ Law Commission – issues paper 34.
- New Zealand Steel. (2010). *Submission to the Ministry of Economic Development in respect of its discussion paper entitled "Reviewing the Crown Minerals Act 1991"*. Auckland: New Zealand Steel.
- New Zealand Water and Wastes Assn. (2003). *Guidelines for the Safe Application of Biosolids to Land in New Zealand*. Wellington: New Zealand Water and Wastes Association.
- NICNAS. (2009). *Priority Existing Chemical Assessment Report No 30*. Canberra: Department of Health and Aging, Australian Government.
- NZ Institute of Chemistry. (1998). *Steel Making, in Chemical Processes in New Zealand, 2nd Edition, volume 2*. Auckland: NZ Institute of Chemistry.
- NZ Petroleum and Minerals. (2014). *Industrial Minerals Production Data; 2012 Mining Production Statistics*. Wellington: Ministry of Business, Innovation and Employment.
- NZ Refining Company. (2009). *Annual Report, 2008*. Whangarei: NZ Refining Company.
- NZ Sugar Company. (2010). *Fact Sheet 5: from Canefield to Crystal and Beyond*. Auckland: New Zealand Sugar Company Ltd.
- Oji Fibre Solutions. (2017). *Sustainability Report 2017*. Auckland: Oji Fibre Solutions (NZ) Ltd.

- Otago Daily Times. (2016). *Toxic Smoke Fears in Landfill Fire by Rhys Chamberlain*. Dunedin: Otago Daily Times.
- Plastics New Zealand. (2011). *Annual Production Statistics*. Auckland: Plastics New Zealand.
- Population Reference Bureau. (2016). *2016 World Population Datasheet*. Population Reference Bureau.
- Radio New Zealand. (2013). *Pet Cremation. Podcast of This Way Up, Saturday June 8 2013*. Wellington: Radio New Zealand.
- Refining NZ. (2013). *Annual Report 2012*. Whangarei: Refining NZ.
- Refining NZ. (2016). *Annual Report 2016*. Whangarei: Refining NZ.
- Refining NZ. (2017). *Annual Report 2017*. Whangarei: Refining NZ.
- Secretariat of the Rotterdam Convention. (2013). *PIC Circular XXXVIII*. Rome: Secretariat of the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.
- Sinclair Knight Merz. (2011). *Genesis Energy Limited, Huntly Re-Consenting of Thermal Power Stations: Technical Report – Discharges to Air*. Wellington: Sinclair Knight Merz.
- Slaughter, G., & Halliday, L. (2008). *Disposal of New Zealand's Used Oil. Paper presented to the Annual Conference*. Auckland: Waste Management Institute of New Zealand.
- Statistics New Zealand. (2008). *Subnational population estimates: 30 June 2008*. http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/SubnationalPopulationEstimates_HOTP30Jun08/Commentary.aspx. Wellington: Statistics New Zealand.
- Statistics New Zealand. (2009). *Update of the Manufacturing Energy Use Survey: Year Ended March 2006 – Revised 3 March 2009*. Wellington: Statistics New Zealand.
- Statistics New Zealand. (2013). *2013 Census: Totals by Topics (Excel spreadsheets)*. Wellington: Statistics New Zealand.
- Taranaki Regional Council. (2012). *Dow AgroSciences (NZ) Ltd Monitoring Programme: Annual Report 2011-2012*. Stratford: Taranaki Regional Council, Technical report 2012-46.
- Tyler, H., & Anderson, G. (2011). Making Good Use of Cement Kiln Dust. *Waste Awareness*, p20-21 and 25, November/December.
- United Nations Environment Programme. (2005). *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases*. Geneva: UNEP Chemicals, United Nations Environment Programme.
- United Nations Environment Programme. (2013). *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases*. Geneva: UNEP Chemicals, United Nations Environment Programme.
- Walmsley, N. (2012). *New Zealand Biosolids – Lost opportunity or Just Lost?* Rotorua: Paper presented to the Water New Zealand Annual Conference.
- Wang, B., Fiedler H., Huang J., Deng, S., Wang Y., & Yu, G. A primary estimate of global PCDD/F release based on the quantity and quality of national economic and social activities. *Chemosphere*, 303 – 309.
- Waste Management Institute of New Zealand. (2013). *Technical Guidelines for the Disposal to Land of Residual Waste and Other Material (Land Disposal Technical Guidelines: Draft for Consultation)*. Auckland: Waste Management Institute of New Zealand.
- Wilton, E. (2016). *Air Emission Inventory – Tokoroa and Morrinsville 2016 (Waikato Regional Council Technical Report 2016/31)*. Hamilton: Waikato Regional Council.
- Wilton, E. (2011). *Emission Inventory for Invercargill and Gore – 2011*. Christchurch: Environet Ltd.
- Wilton, E. (2012). *Air Emission Inventory – Hamilton and Tokoroa 2012*. Hamilton: Waikato Regional Council.
- Wilton, E. (2013). *Reefton Air Emission Inventory – 2012*. Christchurch: Environet Ltd.
- Wilton, E. (2015). *Air Emission Inventory for Invercargill and Gore – 2011 (2015 update)*. Christchurch: Environet Ltd.
- Wilton, E., & Baynes, M. (2010). *Air Emission Inventory – Napier, Hastings and Havelock North 2010*. Christchurch: Environet Limited.

Wilton, E., & Baynes, M. (2010a). *Air Emissions inventory – Taumaranui and Taihape 2010*. Palmerston North: Horizons Regional Council.

Appendix 1: Summary of release estimates

Category ¹	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2008	2012	2016	2008	2012	2016	2008	2012	2016	2008	2012	2016
Hazardous waste incineration	0.000029	0.000048	0.00033	-	-	-	-	-	-	0.000019	0.000053	0.00017
Medical waste incineration	0.657	0.657	0.234	-	-	-	-	-	-	0.0044	0.0044	0.0016
Sewage sludge incineration	0.000086	0.000097	0.00023	-	-	-	-	-	-	0.00075	0.00085	0.00071
Wood and biomass incineration ²	0.0235	0.021	0.015	-	-	-	-	-	-	0.042	0.042	0.03
Destruction of animal carcasses	0.130	0.116	0.116	-	-	-	-	-	-	-	-	-
Primary iron & steel production	0.083	0.082	0.078	0.0146	0.0143	0.0149	0.210	0.206	0.274	-	-	-
Secondary iron & steel production	0.24	0.036	0	-	-	-	-	-	-	2.50	2.80	0
Iron foundries	0.148	0.131	0.072	-	-	-	-	-	-	0.094	0.083	0.07
Galvanising	0.0057	0.0056	0.0073	-	-	-	-	-	-	0.247	0.245	0.268
Secondary aluminium production	0.058	0.044	0.039	-	-	-	-	-	-	5.40	4.05	3.63
Lead production	0.046	-	0	-	-	-	-	-	-	-	-	-
Brass and bronze production	0.081	0.042	0.014	-	-	-	-	-	-	1.920	0.993	0.323

Dioxin Inventory Update

Category ¹	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2008	2012	2016	2008	2012	2016	2008	2012	2016	2008	2012	2016
Metal shredding	0.024	0.070	0.05	-	-	-	-	-	-	0.60	1.75	1.25
Coal-fired electricity generation	0.434	0.291	0.0484	-	-	-	0.608	0.407	0.0678	-	-	-
Industrial/commercial coal use	0.829	1.062	1.232	-	-	--	-	-	-	0.291	0.281	0.327
Heavy fuel oil-fired power plants	0.0077	0.0083	0.0026	-	-	-	-	-	-	-	-	-
Fuel oil/gas-fired electricity generation	0.043	0.036	0.028	-	-	-	-	-	-	-	-	-
Fuel oil and gas-fired power plants	0.019	0.027	0.041	-	-	-	-	-	-	-	-	-
Biomass power plants	1.068	1.000	1.000	-	-	-	-	-	-	0.320	0.300	0.300
Landfill gas/biogas combustion	0.020	0.025	0.028	-	-	-	-	-	-	-	-	-
Household heating & cooking with biomass	0.84	0.82	0.812	-	-	-	-	-	-	0.168	0.164	0.162
Household heating & cooking with coal	0.038	0.044	0.034	-	-	-	-	-	-	0.00020	0.00023	0.00018
Household heating & cooking with oil	0.0028	0.0029	0.0012	-	-	-	-	-	-	-	-	-
Household heating & cooking with gas	0.0140	0.0135	0.0144	-	-	-	-	-	-	-	-	-
Cement production	0.052	0.043	0.044	-	-	-	0.134	0.134	-	-	-	-

Dioxin Inventory Update

Category ¹	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2008	2012	2016	2008	2012	2016	2008	2012	2016	2008	2012	2016
	Lime production	0.025	0.0125	0.0173	-	-	-	0.084	0.042	0.0576	-	-
Brick production	0.00108	0.00089	0.0002	-	-	-	-	-	-	-	-	-
Glass production	0.0022	0.0035	0.0031	-	-	-	-	-	-	-	-	-
Pottery and ceramics	0.00036	0.00032	0.00075	-	-	-	-	-	-	-	-	-
Asphalt production	0.006	0.006	0.0098	-	-	-	-	-	-	0.026	0.026	0.042
4-stroke engines	0.096	0.040	0.0142	-	-	-	-	-	-	-	-	-
2-stroke engines	0.059	0.014	0.014	-	-	-	-	-	-	-	-	-
Diesel engines	0.239	0.238	0.266	-	-	-	-	-	-	-	-	-
Heavy oil-fired engines	0.311	0.368	0.377	-	-	-	-	-	-	-	-	-
Agricultural residue burning	0.159	0.144	0.145	-	-	-	0.016	0.014	0.0145	-	-	-
Forest fires	0.166	0.151	0.205	-	-	-	0.025	0.023	0.0307	-	-	-
Grassland and savannah fires	0.252	0.189	0.164	-	-	-	0.076	0.057	0.0493	-	-	-
Fires at waste dumps	0.675	0.378	0.365	-	-	-	0.0225	0.0126	0.0122	-	-	-
Structure fires	0.850	0.625	0.698	-	-	-	0.850	0.625	0.698	-	-	-
Open burning of domestic wastes	0.720	0.780	0.807	-	-	-	0.018	0.020	0.0202	-	-	-
Vehicle fires	0.333	0.171	0.209	-	-	-	0.060	0.031	0.038	-	-	-

Dioxin Inventory Update

Category ¹	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2008	2012	2016	2008	2012	2016	2008	2012	2016	2008	2012	2016
Black liquor combustion	0.0325	0.036	0.0483	-	-		-	-		-	-	
Pulp & paper sludge disposal	-	-	-	-	-		0.083	0.093	0.146	-	-	
Use of 2,4-D	-	-	-	-	-		-	-		-	-	
Petroleum production	0.018	0.018	0.019	0.00775	0.00775	0.0084	-	-		0.00007	0.00007	0.000017
Crematoria	0.1829	0.1905	0.201	-	-		-	-		-	-	
Tobacco smoking	0.00033	0.00028	0.00021	-	-		-	-		-	-	
Landfills, waste dumps and landfill mining	-	-	-	1.228	1.257	1.703	12.28	12.57	17.03	-	-	
Sewage/sewage treatment	-	-	-	0.134	0.134	0.0938	-	-		6.40	6.40	6.86
Totals³	8.99	7.94	7.47	1.38	1.41	1.82	14.47	14.24	18.44	18.01	17.14	13.26

Footnotes

- 1 The estimates for releases in products have not been shown in the table because there are only two very minor sources: brick production and the use of the herbicide 2,4-D, with a total annual release of only 0.00009 g TEQ for 2016.
- 2 This category covers school incinerators. In 2008 the releases to air included an additional contribution of 0.0025g TEQ from a document incinerator.
- 3 The sums of the figures in some columns may not agree exactly with the totals shown due to rounding effects.

Appendix 2: Total dioxin releases

Category	Total Dioxin for 2008 (g TEQ / annum)	Total Dioxin for 2012 (g TEQ / annum)	Total Dioxin for 2016 (g TEQ / annum)
Hazardous waste incineration	0.000048	0.000101	0.000347
Medical waste incineration	0.6614	0.6614	0.2356
Sewage sludge incineration	0.000836	0.000947	0.00094
Wood and biomass incineration	0.0655	0.063	0.045
Destruction of animal carcasses	0.13	0.116	0.116
Primary iron & steel production	0.3076	0.3023	0.3669
Secondary iron & steel production	2.74	2.836	0
Iron foundries	0.242	0.214	0.142
Galvanising	0.2527	0.2506	0.2753
Secondary aluminium production	5.458	4.094	3.669
Lead production	0.046	0	0
Brass and bronze production	2.001	1.035	0.337
Metal shredding	0.624	1.82	1.30
Coal-fired electricity generation	1.042	0.698	0.1162
Industrial/commercial coal use	1.12	1.343	1.559
Heavy fuel oil-fired power plants	0.0077	0.0083	0.0026
Fuel oil/gas-fired electricity generation	0.043	0.036	0.028
Fuel oil and gas-fired power plants	0.019	0.027	0.041
Biomass power plants	1.388	1.300	1.300
Landfill gas/biogas combustion	0.02	0.025	0.026
Household heating & cooking with biomass	1.008	0.984	0.974
Household heating & cooking with coal	0.0382	0.04423	0.03418
Household heating & cooking with oil	0.0028	0.0029	0.0012
Household heating & cooking with gas	0.014	0.0135	0.0144
Cement production	0.186	0.177	0.044
Lime production	0.109	0.0545	0.0749
Brick production	0.0014	0.00116	0.00026
Glass production	0.0022	0.0035	0.0031
Pottery and ceramics	0.00036	0.00075	0.00075
Asphalt production	0.032	0.032	0.0518
4-stroke engines	0.096	0.04	0.0142

Dioxin Inventory Update

2-stroke engines	0.059	0.014	0.014
Diesel engines	0.239	0.238	0.266
Heavy oil-fired engines	0.311	0.368	0.377
Agricultural residue burning	0.175	0.158	0.1595
Forest fires	0.191	0.174	0.2357
Grassland and savannah fires	0.328	0.246	0.2133
Fires at waste dumps	0.6975	0.3906	0.377
Structure fires	1.700	1.250	1.396
Open burning of domestic wastes	0.738	0.800	0.8272
Vehicle fires	0.393	0.202	0.247
Black liquor combustion	0.0325	0.036	0.0483
Pulp & paper sludge disposal	0.083	0.093	0.146
Use of 2,4-D	0.000034	0.000034	0.00005
Petroleum production	0.02582	0.02582	0.027417
Crematoria	0.1829	0.1905	0.201
Tobacco smoking	0.00033	0.00028	0.00021
Landfills, waste dumps and landfill mining	13.508	13.827	18.733
Sewage/sewage treatment	6.534	6.534	6.954