Mercury Inventory for New Zealand: 2016

Report to the Ministry for the Environment

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Executive Summary

This report provides an inventory of the annual distribution of mercury and mercury-containing goods and materials in New Zealand, from anthropogenic (man-made) sources, for a base year of 2016. It has been produced under a contract to the New Zealand Ministry for the Environment, and builds on the information reported in previous inventories for 2008 and 2012.

The inventory has been prepared generally in accordance with the guidance provided in the UNEP *Toolkit for identification and quantification of mercury releases* (the Toolkit). The latest version of the Toolkit has been used to provide the basic framework for this work. The methodology involves the collection of activity data for a wide range of possible mercury sources, coupled with calculations to determine the quantities of mercury brought into, or mobilised, within the country (the **Inputs**), and the quantities of mercury released into the different environmental compartments of air, water, land, and releases in wastes or in products (the **Outputs**).

Estimated mercury inputs and outputs

The primary results of this assessment are summarised in the table below.

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
1. Extraction and use of fuels/energy sources	318.3 – 2515.7 (1417.0)	302.4 – 2.133.8 (1,218.1)	8.9 – 97.7 (53.3)	1.53 – 5.32 (3.42)	-	5.51 – 278.8 (142.1)
2. Primary (virgin) metal production	1570.8 – 13,305.2 (5,044.7)	85.7 – 614.2 (254.2)	38.2 – 270.3 (106.4)	1,365 – 11,811 (4.426)	60.3 – 525 (196.7)	21.4 -85.6 (53.5)
3. Production of other minerals and materials	61.4 – 123.5 (92.4)	1.19 – 3.77 (2.5)	-	59.7 – 118.1 (88.9)	0.51 – 1.62 (1.1)	-
4. Intentional use in industrial processes	-	-	-	-	-	-
5. Consumer products with intentional use	117.2 – 225.5 (171.3)	2.2 – 12.7 (7.4)	0.6 – 5.7 (3.1)	0.9 – 9.4 (5.2))	40.2	73.3 – 157.5 (115.4)
6. Other intentional products/processes	43.8	1.0	5.7	-	24.1	13.1
7. Production of recycled metals	20	-	-	-	20	-
8. Waste incineration	19.7 – 184.2 (102.4)	18.9 – 183.4 (101.6)	-	-	-	0.8
9. Waste deposit/landfill and wastewater treatment	3,687.5 – 39,650 (21,668.8)	34 – 341 (187.6)	139.1 – 2,778.4 (1,458.8)	55.5 – 1110 (582.8)	-	83.3 – 1,665 (874.1)
10. Crematoria and cemeteries	31.3 – 125.3 (78.3)	20.1 – 80.5 (50.3)	-	11.2 – 44.8 (28.0)	-	-
Totals	**5,857 – 56,192 (28,632)**	**465 – 3,370 (1,822)**	**192 – 3,158 (1,627)**	**1,494 – 13,098 (5,142)**	**145 – 610 (282)**	**185 – 2,200 (1,192)**

(Note: the numbers shown in brackets in the table are the means of the reported ranges)

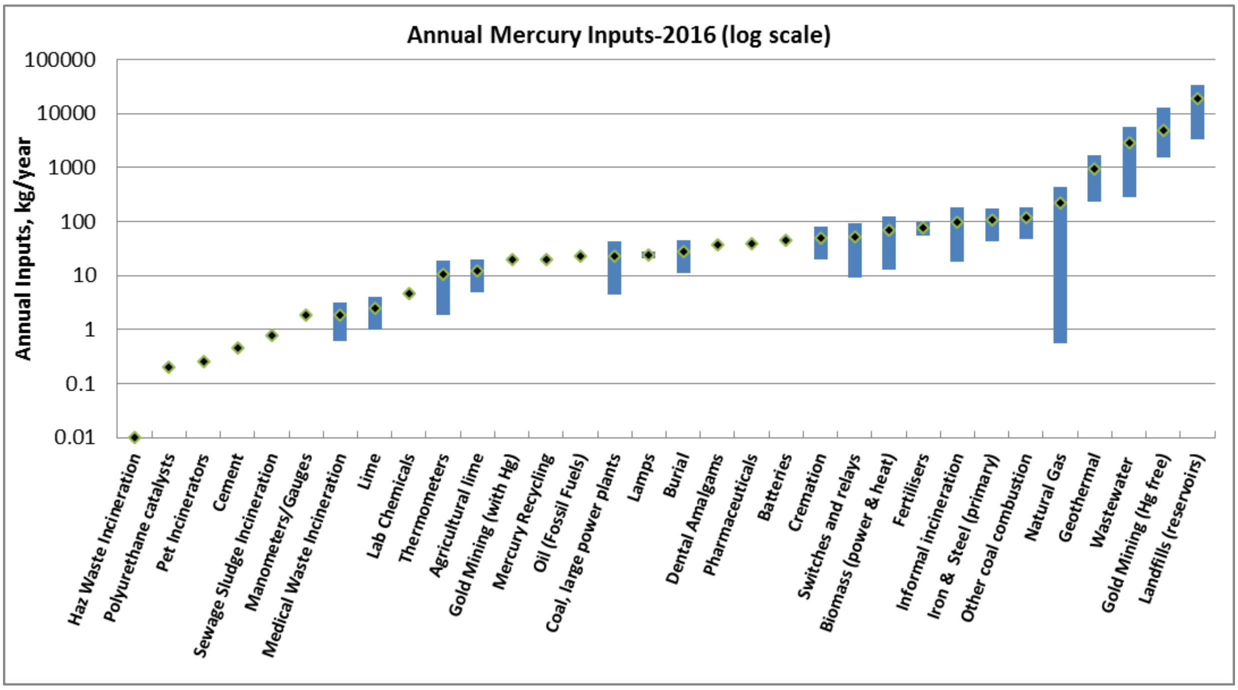
By far the greatest quantities in the inputs column are for category 9, waste disposal. However, most of the mercury in the solid waste stream is placed into long-term storage (ie. controlled landfill), rather than being mobilised into the environment. This was assigned to a 'Reservoir' output category, which has not been included in the table. As a result, the total quantity of outputs shown in the table is much less than the total inputs.

Apart from the waste category, the next highest input is from primary metal production and, in particular gold and silver mining. In this case, the bulk of the inputs and outputs are associated with the extraction of very large volumes of ore, which contains very small amounts of mercury. The ore is processed to remove the gold and silver, and then it is returned to the land.

The next highest input category is the extraction and use of fuels and other energy sources, with the dominant contributor here being geothermal energy.

Inputs from individual sources

The relative inputs from each of the individual sources identified in the inventory are illustrated in the figure below, with the size of each bar giving an indication of the level of uncertainty associated with each estimate. As shown in the figure, the most significant input sources are solid waste disposal (landfills), gold and silver mining, wastewater treatment and disposal, and the extraction and utilisation of geothermal energy. The extraction and processing of natural gas may also be a significant contributor but the uncertainties associated with the estimates for this source are very high, as indicated by the relative size of the error bar.



Changes in mercury inputs since 2012

Many of the mercury input estimates for 2016 show changes from those given in the 2012 Inventory Report. Some of these changes are simply due to the normal year to year variations in commercial or industrial activity while others simply relate to changes in the population. However, the changes for about half of the sources are believed to be due to specific causes. These are discussed in section 14 and summarised briefly below.

Plant Closures: The estimates for cement manufacture are down by about 20% due to closure of the Westport plant, and those from secondary steel production have been eliminated by the closure of the

Pacific Steel plant in Auckland. The only known mercury recycling operation has ceased operation although there may be other unidentified small scale operators working in that area.

Changes in Energy Production and Use: The estimated releases from coal burning at the Huntly Power station are down by more than 80% from 2012 because the use of the coal-fired units is being phased out as they reach the end of their operational life. The estimated releases from extraction and use of natural gas and geothermal energy are up by about 25 and 30%, respectively, due to the increased utilisation of these energy sources.

Agriculture Activity: The mercury releases from agricultural lime show a reduction of 30% but the activity data was based on 2011 and 2015 rather than 2012 and 2016. The national data for this mineral show marked fluctuations from year to year.

Reductions in Mercury Use in Consumer Goods and Related Products: There have been some marked reductions in this area and especially in the following: mercury thermometers, mercury-containing lamps, mercury-based light sources in computer screens, batteries, and dental amalgams.

Waste Disposal: The mercury input estimates for landfills increased by 35% which simply reflects the annual growth in national solid waste quantities.

Data Quality Changes: Significant changes were also found in the estimates for gold and silver mining, mercury use in sphygmomanometers, use of superphosphate fertiliser, and releases from wastewater. However, these were all due to changes in the quality and/or in the amount of detail provided in the data used for the 2016 estimates as compared to that available in 2012.

Estimated mercury outputs

The distributions of outputs to air, water, land, waste, and in products, are summarised in a series of charts given in Section 14 of this report, and the key points noted from these charts are as follows:

- The outputs to air are dominated by fuel/energy use, especially geothermal. Other notable contributors, in decreasing order of significance are primary metal production (gold and silver), waste disposal, waste incineration and crematoria.
- The outputs to water are totally dominated by waste disposal, especially wastewater discharges. Primary metal production and fuel/energy use are the next most significant contributors.
- The outputs to land are dominated by primary metal production (gold and silver) with other notable contributions from waste disposal and the production and use of other minerals and materials.
- The outputs via products are dominated by primary metal production (gold and silver) but with other significant contributions coming from other intentional products/processes, consumer products and metal (mercury) recycling.
- The outputs to waste are dominated by the waste disposal category, with other notable contributions from consumer products, fuel/energy use, primary metal production and other intentional products/processes.

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Units and abbreviations

Units

°C	degrees Celsius or centigrade
g	gram
kg	kilogram (10^3 or 1 thousand grams)
tonne	10^6 or 1 million grams
Mt	megatonne (10^6 or 1 million tonnes)
µg	microgram (10^{-6} grams or 1 millionth of a gram)
MJ	megajoule (10^6 or 1 million joules)
GJ	gigajoule (10^9 or 1 thousand million joules)
TJ	terajoule (10^{12} or 1 million million joules)
PJ	petajoule (10^{15} or 1 thousand million million joules)
L	litre
m^3	cubic metre
ppm	parts per million
kW	kilowatt (10^3 or 1 thousand watts of thermal or electrical energy)
kWh	kilowatt-hour (equivalent to 1 kilowatt generated or consumed over 1 hour)
MW	megawatt (10^6 or 1 million watts of thermal energy)
MWe	megawatt of electrical energy
GWh	gigawatt-hour (equivalent to 1 thousand million watts consumed over 1 hour)

Abbreviations

EECA	Energy Efficiency & Conservation Authority
EU	European Union
LPG	liquefied petroleum gas
RMA	Resource Management Act 1991
UNEP	United Nations Environment Programme
USA	United States of America
US EPA	United States Environmental Protection Agency

Mercury Inventory for New Zealand: 2016

1 Introduction

This report provides an inventory of the annual distribution of mercury and mercury-containing goods and materials in New Zealand, from anthropogenic (man-made) sources, for a base year of 2016. It has been produced under a contract to the New Zealand Ministry for the Environment, and builds on the information reported in previous inventories for 2008 and 2012 (MfE, 2008a and MfE, 2013).

The inventory has been prepared generally in accordance with the guidance provided in the UNEP *Toolkit for identification and quantification of mercury releases* (the UNEP Toolkit), which aims to assist countries to build a knowledge base that identifies the sources of mercury releases in their country and estimates or quantifies the releases. This information is expected to assist in decision-making with regard to possible control measures on mercury releases; in communicating with stakeholders; and in monitoring changes over time.

1.1 Background

The Minamata Convention on Mercury was formally adopted at a Diplomatic Conference in October 2013, and was signed by New Zealand at that time. The New Zealand government is currently working towards ratification of the Convention, which is due to enter into force on 16 August 2017.

The Convention aims to control most aspects of the mercury 'life cycle', including: man-made supplies and uses of mercury and mercury compounds; emissions to air, and releases to land and water; the environmentally sound management of mercury wastes and mercury-containing wastes, including trans-boundary movements; and the management of mercury contaminated sites.

The previous New Zealand mercury inventories provided background information for the government leading up to the decision to sign the Convention, while the current work is intended to provide an update of that information. In particular it will assist in identifying the most significant sources of mercury and mercury-containing goods and materials in New Zealand, and the activities, and key individuals or organisations, associated with these (the stakeholders).

1.2 Methodology

The basic methodology used for this work was the latest version of the UNEP Toolkit, which was published in January 2017. This methodology was applied using the following general approach:

1. Reviews of the information given in the updated Toolkit for each source category, noting in particular any significant changes since the previous version, which was published in April 2013.
2. Contacts with government agencies, importers, manufacturers, industry associations, regional and local councils, as appropriate, to obtain up to date activity data and/or release information.
3. Input/output calculations using the Toolkit spreadsheet and drafting of the relevant subsections of the inventory report, including overall summary and analysis sections.

1.3 Report layout and content

Details of the UNEP Toolkit methodology and related aspects are presented in section 2 of this report. This is followed by individual sections covering each of the 11 Toolkit source categories, a summary and discussion section, and a section containing relevant industry profiles.

2 Inventory methodology

2.1 The UNEP Mercury Toolkit

The UNEP Toolkit was first published as a pilot draft in November 2005, and this was the version used in the preparation of the 2008 Inventory Report. A revised version of the Toolkit (v1.2) was published in 2013 (UNEP, 2013), and that was used for the preparation of the 2012 inventory for New Zealand, while the most recent version (v1.4) was published in January 2017 (UNEP, 2017). This version of the Toolkit was used for the current work, although no significant changes were noted between that and the earlier version in relation to the various input and output factors applied to New Zealand sources.

The Toolkit is intended to provide a simple methodology and accompanying database to enable the assembly of consistent national and regional mercury inventories. It comprises a UNEP recommended procedure for the effective compilation of source and release inventories of mercury. Comparable sets of mercury source release data are intended to enhance international co-operation, discussion, goal definition and assistance.

The Toolkit includes two levels for inventory assessment; an overview Level 1, and a detailed source by source assessment, Level 2. The Level 2 option is designed to be adaptable to differences between countries, but it must be stressed that it is still just a screening tool. It is designed to ensure the positive identification of the bulk of significant sources, rather than the unattainable goal of 100 per cent accuracy.

Both the current inventory and that prepared for 2012 are based on the use of the Level 2 option. The Toolkit documentation is supported by an Excel spreadsheet, which has also been used for this assessment.

2.2 Toolkit methodology

The Toolkit considers potential mercury inputs and outputs for the following source categories[1]:

1. Extraction and use of fuels/energy sources
2. Primary (virgin) metal production
3. Production of other minerals and materials with mercury impurities
4. Intentional use of mercury in industrial processes
5. Consumer products with intentional use of mercury
6. Other intentional product/process uses
7. Production of recycled metals (secondary metal production)
8. Waste incineration
9. Waste deposition/landfilling and wastewater treatment
10. Crematoria and cemeteries
11. Identification of potential hot-spots

[1] The source categories are numbered 5.1, 5.2, 5.3, etc in the Toolkit, simply because the detailed source coverage appears in section 5 of the Toolkit document. This numbering has been included in the sub-category tables given at the start of each section, but in all other text references to category numbers the 5 has been ignored.

Terminology

The two key terms used in the Toolkit are inputs and outputs.

Inputs: refers to the quantities of mercury brought into, or mobilised, within the country.

Outputs: refers to the quantities of mercury released into different environmental compartments of air, water, land, and releases in wastes or in products.

There is potential for confusion round the use of some of the output terms, and especially the differences between discharges to land, materials disposed to land as wastes; and wastes that are recycled or reused. The following approach has been adopted for differentiating between these terms:

The **land** output category has only been used for materials which are deposited directly to land during processing (eg drilling muds from oil exploration and production) or which are disposed in a waste treatment facility directly associated with the processing operation (eg. a tailings dam for a mining operation, or an ash disposal facility for a large power plant).

Wastes that are sent directly to a municipal landfill and those taken away by a waste contractor for treatment and disposal (which may include disposal to landfill) have all been classified as **wastes**.

Wastes that are sold, or taken away by a contractor, for recycling and reuse have been classified as **products**.

Methodology for estimating inputs and outputs

The basic methodology for estimating inputs and outputs starts with the annual activity rate for a source, which is multiplied by the mercury content of the input material. The activity data may be based on the numbers of individual items imported, the quantities of raw materials or fuels used, or the annual production rate.

The outputs are estimated from the information available for each source on the rates of release to the different environmental compartments. Generally this information takes the form of individual factors showing the proportion of inputs distributed to each compartment.

The overall methodology is summarised in the Toolkit as follows:

*Estimated mercury release to each pathway = activity rate * input factor * output distribution factor for that pathway*

Toolkit default factors

The Toolkit provides default input and output factors for some, but not all, of the mercury sources. These are based on reviews of published information, and are intended for use when national factors are not available. Each of the default factors is usually expressed as a range of possible values, along with a recommended 'intermediate' value. The Toolkit default factors have been used for many of the current estimates.

2.3 Reference year

The reference year for this inventory is the 2016 calendar year, and the activity data for that year has been used wherever possible. However, the use of data from earlier years has been noted where relevant.

2.4 Reporting

The estimated mercury inputs and outputs have been reported for each source in units of kilograms of mercury per year. In most cases, the results are reported as a range of values, to reflect the uncertainties in the estimates. The results for each source are also given certainty estimates, in accordance with the following general approach:

Activity data

- A high certainty ranking was assigned if the assessment was based on national or specific industry data, or was derived from comprehensive survey data;
- A medium certainty ranking was applied if limited data were available, or the data were 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.

Input and output estimates

- A high certainty ranking was assigned if a reasonable amount of mercury content data and/or emissions data were available for the specific sources;
- A medium certainty ranking was assigned if the mercury content data and/or emissions data was limited;
- A low certainty was assigned if there were no New Zealand data available, and the estimates were based solely on the Toolkit default factors.

Precision

The input and output estimates have been calculated to a high level of precision – typically to 1 to 3 decimal places. However, the results have been rounded off when calculating group and overall totals, to better reflect the uncertainties in the estimates. As a result, the totals shown in some tables may not exactly equal the sum of the displayed data.

Double accounting

Wherever possible, double accounting has been avoided. For example the inputs and outputs from the coal used in steel manufacture were subtracted from the estimates for national coal usage. Another example of potential double accounting relates to the differentiation noted previously for waste materials that are taken away for recycling and reuse. One example of this is liquid mercury, which can be collected from a variety of sources; but is then transferred to a mercury recycler; and is then sold to small-scale gold miners and ultimately becomes a discharge to air, water and land. The double accounting here has been avoided by classifying the initial waste as a product.

Reservoirs/stocks/exports

The focus of the inventory is on annual inputs and outputs for New Zealand. However, there are also some significant reservoirs or stock holdings, which may not change very much from year to year. One example of this is the mercury in blood pressure devices (sphygmomanometers) that are still used by many medical professionals. These reservoirs or stocks have been noted at the relevant points in the main body of the report and have also been identified separately in the data summaries.

Another matter that has also been noted is the export of mercury-containing products and materials. These are identified in the overall national accounting, usually as a product or waste, but should also be flagged as eventually being removed from the national stocks.

3 Extraction and use of fuels/energy sources

This category covers all forms of energy use including fossil fuels, biomass, biogas and geothermal energy (UNEP, 2017). It includes the fuel and energy used for electricity generation and in cogeneration plants, direct fuel use in industrial facilities[2], and the fuel used for commercial and residential cooking and heating. It also covers fuel used for transportation, and the energy used in the initial production (refining) of that fuel. The seven sub-categories within this source group are shown in Table 3-1 below, which has been copied directly from the Toolkit. The main pathways of mercury releases are to air, water and waste/residues. Land may also be a release pathway in domestic heating and cooking, either using woody biomass or fossil fuels, and from the extraction of mineral oil. In addition, land is often the ultimate receptor for wastes and residues.

Table 3-1: Toolkit framework for category 1 - extraction and use of fuels/energy sources

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.1.1	Coal combustion in large power plants	**X**	x	x	x	**X**	PS
5.1.2	Other coal combustion	**X**		x	x	x	OW
5.1.3	Extraction, refining and use of mineral oil	**X**	**X**	x	x	x	OW/PS
5.1.4	Extraction, refining and use of natural gas	**X**	**X**	**X**		**X**	OW/PS
5.1.5	Extraction and use of other fossil fuels	**X**	x	x		x	OW
5.1.6	Biomass fired power and heat production	**X**	x	x		x	OW
5.1.7	Geothermal power production	**X**					PS

Notes: PS = Point source by point source approach; OW = National/overview approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

3.1 Coal combustion in large power plants

The UNEP Toolkit defines large power plants as those with a capacity greater than 300MW. The only coal-fired installation of this size within New Zealand is the Huntly Power Station which, when first built, had a capacity of 1000 MW (MBIE, 2013). This was based on four separate Rankine units of 250 MW each – known as Units 1 to 4 - which could be fired on natural gas or coal. In 2004 and 2008, additional generation units were 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. In addition, two of the Rankine units have since been decommissioned, so that the current operational capacity of the power station is now only 935 MW (Genesis, 2017).

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[2] Some industrial fuel use is also considered under other categories (eg. metal production, minerals) and is therefore excluded from the general fuel use category, to avoid double accounting.

Coal consumption at the power station has steadily decreased over the last decade from 54 PetaJoules (PJ)[3] per annum in 2005 to 4.8 PJ/annum in 2016. (MBIE, 2016)[4].

The coal used at Huntly Power Station is a mixture of Waikato sub-bituminous coal, mainly from the Rotowaro mine, and coal imported from Indonesia. The latter supply accounted for about 10% of total coal consumption in 2012 and a similar proportion will be assumed for 2016 as the current stockpiles contain a mixture of local and imported coal. The total coal consumption by Huntly Power Station in 2016 was 223,242 tonnes, compared to 550,006 tonnes in 2015 and 1,270,000 tonnes in 2012 (N Goodhue, Genesis Energy, pers comm, 2017).

Information on the mercury content of the coal used at Huntly Power Station was summarised in the 2012 Inventory Report and no new data is available. Therefore the mercury input calculations have been based on the same range as used for the 2012 estimates (ie 0.02 – 0.19 mg/kg, with no distinction between Waikato and Indonesian coal).

The Huntly Power Station units are fitted with electrostatic precipitators for the control of particulate emissions to air, and the output calculations are based on the Toolkit default factors of 90% being released to air and 10% to ash. The fly ash collected by the Huntly precipitators is disposed to land in a specially designed ash disposal facility and, in accordance with the rationale provided in section 2.2, has been classed as a release to land.

The mercury input and output calculations for the power station are shown in Table 3-2, along with the previous estimates for 2012. As shown, there has been a marked reduction in both inputs and outputs due to the reduction in total coal consumption.

Table 3-2: Input and output estimates for coal combustion in large power plants

Source	Activity Rate, tonnes/yr	Mercury content, mg/kg	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
				Air	Land
Huntly Power Station, 2012	1,270,000	0.02 - 0.19	25.4 – 241.3 (133.4)	22.9 – 217.2 (120.0)	2.5 – 24.1 (13.3)
Huntly Power Station, 2016	223,242	0.02 - 0.19	4.5 – 42.4 (23.4)	4.0– 38.2 (21.1)	0.5 – 4.2 (2.3)

(Note: the numbers shown in brackets in this and most other tables are the means of the reported ranges)

Certainty assessment

Activity data: HIGH (because it was obtained from the plant operator)

Input estimates: MEDIUM (because they are based on a range of coal analyses)

Output estimates: LOW (because they are based on the default Toolkit output factors).

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3 1 Petajoules = 1 x 10^{15} Joules of energy. Most of the energy data in this section is expressed on both an energy and mass basis. The latter values will be more meaningful to the reader, but the energy-based values are used as a more precise measure of usage, because the energy content of coal is variable.

4 Most of the energy data used here has been taken from the annual energy data reports produced by MBIE, along with the more recent data available on-line, at http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/energy-in-new-zealand.

3.2 Other coal use

This Toolkit sub-category covers all other uses of coal. It also considers potential releases from coal washing.

Coal production and use

The Energy Data File (MBIE, 2016) shows a total national coal consumption in 2016 of about 2,391,573 tonnes, with a further 1,187,133 tonnes being exported, entirely from the West Coast. The distribution of the domestic coal consumption across different sectors was as follows:

Electricity generation (Huntly)	226,727[5]
Use in co-generation plants	355,120 tonnes
Other transformation (steel manufacture)	540,705 tonnes
Industrial use, agriculture, forestry and fishing	1,097,206 tonnes
Commercial/institutional use	66,151 tonnes
Transport	76 tonnes
Residential use	18,979 tonnes
Production losses	86,609 tonnes

The figure for total coal consumption (2,391,573 tonnes) has been used as a starting point for the input estimates. However, the following uses have been subtracted from this total, because they are covered elsewhere:

Electricity generation	226,727 tonnes
Steel manufacturing	847,920 tonnes[6]
Cement and lime manufacturing	140,000 tonnes. (Note this is based on 2012 data since a more recent figure is not available. The quantity may have dropped in 2016 due to the closure of the Westport cement plant.)

This gives a result for total coal consumption for the Other Coal Use category, of 1.177 million tonnes. This coal is produced in different parts of the country, with the following approximate distribution, which is based on the distribution of the coal production data for 2015[7], after adjustment for the major uses noted previously:

Waikato coal	224,000 tonnes
South Island coal[8]	640,000 tonnes
Southland lignite	313,000 tonnes

Coal mercury content

5 There is a discrepancy of 3,485 tonnes between this figure and the one noted in section 3.1, which was provided by Genesis energy. This is most likely because the NZEDF figure is based on supply while Genesis' figure is based on actual consumption. It is considered more appropriate to use the NZEDF figure in this section, because the calculations here are all based on the national data.

6 The coal used in steel manufacturing is a combination of that used in a cogeneration plant and in the actual manufacturing process (other transformation).

7 The distribution data for 2016 is not yet available, so 2015 values have been used. However, the distribution doesn't appear to change significantly from year to year.

8 Most South Island coal is produced in the West Coast and Southland regions, but with some minor quantities from Otago and Canterbury.

The mercury content of coal varies across different coal mines, and can also vary markedly within each coal seam. For example, Li (2002) reported a range of 0.009 to 0.193 mg/kg, with a mean value of 0.034 mg/kg, for thirty samples taken from within a single coal seam at the Stockton mine.

The only published data available on the mercury content of New Zealand coals is that quoted previously for Huntly Power Station, the Stockton data noted above, and the following indicative values listed by Li (2002) from an unpublished CRL Energy report: West Coast coal, 0.07 mg/kg; Southland coal, 0.06 - 0.07 mg/kg; Waikato coal, 0.07 – 0.12 mg/kg. In addition, CRL Energy has provided the following indicative values: Waikato coal, 0.2 mg/kg; West Coast coal, 0.1 mg/kg, Southland lignite, 0.25 mg/kg (N. Newman, CRL Energy, pers comm, 2013).

The CRL Energy estimates for mercury content are either towards the top of, or above, the ranges given in the published sources, and have been taken as upper estimates for the range of possible mercury contents. In addition, the West Coast figure has been assumed to apply to all South Island coal. The lower limit for each of the coal types has been based on the following values: Waikato coal, 0.04 mg/kg; South Island coal, 0.03 mg/kg; Southland lignite, 0.06 mg/kg.

Input and output estimates

The coal usage in this category is split across numerous industrial and commercial boilers, with a very minor proportion (0.1%) used for domestic heating and cooking. There are about 160 coal-fired boilers in New Zealand ranging in size from 1 to 43 MW (CRL Energy, 2011). Most New Zealand boilers have cyclones for the control of particulate emissions and some also have bag filters. However, the Toolkit makes no distinction between these systems and suggests default distribution factors of 95% mercury discharges to air and 5% to waste. As noted previously in section 3.1, some of the studies noted in the Toolkit have suggested a 75/25% distribution. Hence, the output calculations shown below may be over-estimating the releases to air and under-estimating the releases via ash. The Toolkit default factors have been applied to all of the coal usage in this category.

The mercury input and output calculations for Other Coal Combustion are shown in Table 3-3.

Table 3-3: Input and output estimates for other coal combustion

Source	Activity Rate, tonnes/yr	Mercury content, mg/kg	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
				Air	Waste
Waikato Coal, 2012	300,000	0.04 - 0.20	12 - 60	11.4 – 57.0	0.6 – 3.0
Waikato Coal, 2016	224,000	0.04 – 0.20	9.0 – 44.8	8.5 – 42.6	0.5 – 2.1
South Island Coal, 2012	505,000	0.03 – 0.10	15.2 – 50.5	14.4 – 48.0	0.8 – 2.5
South Island Coal, 2016	640,000	0.03 – 0.10	19.2 - 64	18.2 – 60.8	1.0 – 3.2
Southland lignite, 2012	307,000	0.06 – 0.25	18.4 – 76.8	17.5 – 72.9	0.9 – 3.8
Southland Lignite, 2016	313,000	0.06 – 0.25	18.8 – 78.3	17.9 – 74.4	0.9 – 3.9
Totals, 2012	**1,112,000**		**45.57 – 187.25 (116.4)**	**43.3 – 177.9 (110.6)**	**2.3 – 9.3 (5.8)**
Totals, 2016	**1,177,000**		**47.0 – 187.1 (117.1)**	**44.6 – 177.8 (111.2)**	**2.4 – 9.2 (5.8)**

Certainty assessment

Activity data: HIGH (because it was obtained from a national database)

Input estimates: LOW (because they are based on a limited range of published data and industry estimates)

Output estimates: LOW (because they are based on the default Toolkit output factors).

3.3 Mineral oils - extraction, refining and use

This Toolkit sub-category covers the extraction, refining, and uses of mineral oil (ie. petroleum products). This includes the combustion of oil to provide power, heat, and transportation, and other related uses, such as in bitumen. However, despite the relative potential complexity of these different areas, the input and output estimates can be broken down into a set of relatively straightforward calculations for the following three basic stages: oil extraction, oil refining and oil/petroleum combustion.

Oil extraction

There are currently 19 productive oil fields in New Zealand, although the majority of production is accounted for by six of these; Maui, Pohokura, Tui, Maari, Mangahewa and Kupe (MBIE, 2016). The combined production is a mixture of crude oil, natural gas liquids, condensates and naphtha, with a total production in 2016 of 1,584,650 tonnes. This is about 15% lower than the 2012 production of 1,851,700 tonnes. No data are available on the mercury content of any of this production, but the Toolkit recommends a default factor of 3.4 mg/tonne. Using this factor gives a total annual mercury input for New Zealand oil extraction of 5.39 kg in 2016.

The Toolkit indicates that there may be some minor releases of mercury (and other oil components) via the wastewater produced during oil extraction. This wastewater is usually processed through oil/water separators so only minor amounts of contaminants are released via the waste discharge. The Toolkit classifies the discharge as being to water but at the New Zealand on-shore oil fields it is more likely to be to land. The default distribution factor is 0.2 (ie 20%), which indicates a potential release to land of 1.08 kg/year.

Virtually all of New Zealand's indigenous oil production is exported (MBIE, 2016). Hence, the remainder of the 5.39 kg of mercury inputs noted above (ie. 4.3 kg) has not been included in this inventory.

Oil refining

The total intake of crude oil and refinery feedstock for the Marsden Point oil refinery in 2016 was 5,529,950 tonnes (MBIE, 2016), which is only slightly higher than the 5,529,000 tonnes reported for 2012. No data are available on the mercury content of any of the refinery inputs. The Toolkit default factor of 3.4 mg/tonne for crude oil has been used for the input calculations, to give a mercury input to the refinery of 18.8 kg/year.

The Toolkit indicates that just over 40% of the mercury inputs to a refinery are lost through discharges to air, and releases in refinery wastes and by-products, such as sulphur and bitumen. No data are available on the actual distribution through the Marsden Point refinery, so the Toolkit default factors have been used: 0.25 (25%) to air, 0.01 (1%) to water and 0.15 (15%) to wastes. The remaining 59% of mercury inputs (11.09 kg/year) are assumed to carry over into the refinery products, such as petrol, diesel, and heavy fuel oil, and are accounted for under the use category discussed below.

Use of refined products

The Toolkit makes very little distinction between the different ways in which oil products may be used, because it assumes that most of them will ultimately be burned, and all of the mercury will be discharged to air. The only sub-classes considered are residential heating and cooking, and industrial combustion facilities with a high degree of emission control. Residential heating and cooking is a very minor component of total petroleum product consumption in New Zealand (MBIE, 2016), and there are no oil-fired industrial facilities in New Zealand with an advanced level of emission control. Hence the total consumption of refined oil products has been accounted for under the 'other combustion' Toolkit category, which includes all uses in transportation, and in industrial and commercial applications.

As indicated above, the mercury inputs via products distributed from the Marsden Point refinery are 11.09 kg/year. However, 31% of New Zealand's domestic petroleum consumption is contributed from imported refined product. There is no data available on the mercury content of these imports, but it should be reasonable to assume they would be similar to those produced in-country. This indicates a total mercury input from petroleum products of about 14.53 kg/year, and the same output quantity, in the form of discharges to air.

Input and output estimates

The mercury input and output calculations for Mineral Oils – Extraction, Refining and Use are summarised in Table 3-4.

Table 3-4: Input and output estimates for mineral oils - extraction, refining and use

Source	Activity Rate, tonnes/yr	Mercury content, mg/kg	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr			
				Air	Water	Land	Waste
Extraction, 2012	1,851,000	0.0034	1.26[a]	-	-	1.3	-
Extraction, 2016	1,584,650	0.0034	1.08[a]	-	-	1.1	-
Refining, 2012	5,529,000	0.0034	18.8	4.7	0.2	-	2.8
Refining, 2016	5,529,950	0.0034	18.8	4.7	0.2	-	2.8
Use, 2012	-	-	14.42	14.4	-	-	-
Use, 2016	-	-	14.5	14.5	-	-	-
Totals, 2012	**-**	**-**	**23.4[b]**	**19.1**	**0.2**	**1.3**	**2.8**
Totals, 2016	**-**	**-**	**23.2[b]**	**19.1**	**0.2**	**1.1**	**2.8**

Notes: a a further 5.04 kg was removed through exports in 2012, and 5.39 kg in 2016.

b individual inputs do not add up to this total because 59% of the refining input (11.09 kg/yr) carries over into the oil use inputs.

Certainty assessment

Activity data: HIGH (because it was obtained from a national database)

Input estimates: LOW (because they are based on the default Toolkit input factors)

Output estimates: LOW (because they are based on the default Toolkit output factors).

3.4 Natural gas - extraction, refining and use

As with mineral oils, the mercury releases from natural gas are considered through all three stages of gas extraction, processing and use.

Gas extraction, processing and use

Natural gas is produced from the same 19 fields as noted previously for oil (MBIE, 2016). About 88% of the gas production comes from the Maui, Pohokura, Kapuni, Mangahewa and Kupe fields, and the total gas production in 2016 from all fields was 5,557 million cubic metres (Mm^3), with an energy content of 221 PJ. This is 23% up on the 4,642 million cubic metres (Mm^3), or 180 PJ produced in 2012. The net gas production is only about 87% of these totals due to losses from reinjection, flaring, and other production processes.

A limited amount of data for the mercury content of New Zealand natural gas was used for calculating the input estimates for the 2012 Inventory Report. Applying the same factors to the 2016 gas volumes gives a total mercury input of between 0.56 and 445 kg, with a mid-range value of 223 kg for 2016.

The Toolkit notes that where natural gas is used as an industrial feedstock, there is a requirement for low residual levels of mercury to prevent problems such as catalyst poisoning and deterioration of aluminium surfaces. In addition, treatment processes designed for hydrogen sulphide removal will also be effective in removing mercury. Consequently the output factors given by the Toolkit for gas processing with mercury removal are appropriate as a starting point for the New Zealand distribution calculations. These assume that 10% of mercury in the gas is discharged to air, 20% to water, 10% in product and 60% in wastes. However, when the product gas is used (by burning) the mercury in the product is discharged to air. Hence the overall distribution becomes 20% to both air and water and 60% to waste.

Input and output estimates

The mercury input and output calculations for Natural Gas – Extraction, Refining and Use are summarised in Table 3-5.

Table 3-5: Input and output estimates for natural gas - extraction, refining and use

Source	Activity Rate, Mm^3/yr	Mercury content, $\mu g/m^3$	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr			
				Air	Water	Waste	Product
Gas Extraction and Use, 2012	4,642	0.1 - 80	0.46 – 371.4 (185.9)	0.09 – 74.3 (37.2)	0.09 – 74.3 (37.2)	0.27 – 219.1 (109.7)	<0.01 – 3.7[a] (1.86)
Gas Extraction and Use, 2016	5,557	0.1 - 80	0.56 – 444.6 (222.6)	0.1 – 89 (44.5)	0.1 – 89 (44.5)	0.3 – 266.8 (133.6)	-

Note: a: The releases in product were reported separately in 2012 but for 2016 they have been included in the total releases to air because that is where they will ultimately be released when the gas is burned.

Certainty assessment

Activity data: HIGH (because it was obtained from a national database)

Input estimates: LOW (because they are based on the default Toolkit input factors)

Output estimates: LOW (because they are based on the default Toolkit output factors).

3.5 Other fossil fuels – extraction and use

This Toolkit sub-category covers materials such as oil shale and peat. There is no oil shale extraction in New Zealand and peat is not used as a fuel. There may be some mercury releases from accidental fires in peat bogs, but the quantities involved in these (ie the activity rate) would be virtually impossible to determine. Hence this sub-category has not been assessed.

3.6 Biomass-fired power and heat production

The mercury in wood and other biomass originates from that taken up naturally from the soil, and mercury deposition from the atmosphere as a result of natural and anthropogenic emissions to air. Most of the mercury is discharged back into the air when the biomass is burned. This Toolkit sub-category is concerned with the burning of wood and other biomass as an industrial fuel, and in residential heating and cooking.

The total amount of energy consumed in New Zealand from biomass in 2015 was estimated by MBIE to be 58.9 PJ, which is very similar to the total of 60.59 PJ reported for 2012 (MBIE, 2016). However, these figures are based on the assumption that industrial plants operate at full load for 24 hours a day and 365 days a year, which is not the case. The estimates given in the 2012 Inventory were based on the assumption that plants are operated at 70% load (on average) for 320 days a year. Applying these assumptions to the industrial wood-burning plant listed in the Heat Plant Database (CRL Energy, 2011) gave an estimated total annual wood consumption of 36.8 PJ (including residential heating). This usage is roughly equivalent to 1.8 million tonnes/year of dry wood. There have been no significant new industrial biomass-fuelled facilities constructed in the last five years in New Zealand so this estimate has been taken as also applying to 2016.

There is no published data available on the mercury content of New Zealand wood so the input estimates have been based on the Toolkit default factor of 0.0385 mg/kg, or a range of 0.007 – 0.07 mg/kg. It also assumed that all of the mercury is released to air.

The mercury input and output calculations for the biomass-fired power and heat production are shown in Table 3-6, with the same figures applying to both 2012 and 2016.

Table 3-6: Input and output estimates for biomass-fired power and heat production

Source	Activity Rate, tonnes/yr	Mercury content, mg/kg	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr
				Air
Biomass usage, 2012 & 2016	1,800,000	0.007 - 0.07	12.6 – 126 (69.3)	12.6 – 126 (69.3)

Certainty assessment

Activity data: MEDIUM (because it was obtained from a combination of national data and estimated operating loads)

Input estimates: LOW (because they are based on the default Toolkit input factors)

Output estimates: LOW (because they are based on the default Toolkit output factors).

3.7 Geothermal power production and use

Geothermal steam contains small quantities of mercury, and most of this is released to air if the steam is discharged to air after direct use as a source of heat, or if the steam is used for electricity generation. Most geothermal power stations in New Zealand re-inject the geothermal fluids back into the ground after use, to assist in maintaining reservoir pressures. However, the mercury is mainly present in the steam and non-condensable gases which are separated from the fluids, and are not ‘captured’ by the re-injection process (Thain, 2009).

The New Zealand Geothermal Association lists fifteen geothermal sites where electrical power is generated with a total installed capacity of 909 MWe (NZGA, 2017). In 2015 New Zealand’s total electricity generation from geothermal power was reported to be 7411 Gigawatt-hours, which is almost 30% higher than the 5,770 Gigawatt-hours reported for 2012 (MBIE 2016)

The mercury content of geothermal fluids varies between different geothermal fields. The mercury emission rates for 10 of the existing and proposed power stations have been obtained from the estimates given in the application documents for various power station developments in the Bay of Plenty and Waikato regions (Contact Energy, 2007, 2009 and 2012, and Mighty River Power, 2010a and 2010b). The emission rates indicate mercury emission factors, for the discharges to air, in the range of 0.03 – 0.22 grams per Megawatt-hour (MWh), with an average of 0.114 g/MWh. There are no input or output factors given in the Toolkit for this sub-category, so the calculated emission factors will be used for the release estimates.

The Wairakei Power Station differs from all of the others in that most of the condensed steam, is not re-injected after use, but is discharged to the Waikato River. This includes a portion of the mercury present in the associated gases, which in other stations is all discharged to air. The estimated discharge from the Wairakei Power Station for 2016 was <8.6 kg (D Palmer, Waikato Regional Council, pers comm, 2017).

The mercury input and output calculations for geothermal power are shown in Table 3-7 below. In addition to electricity generation, an allowance has been made for direct uses of total geothermal energy. These accounted for an additional 3.8% of geothermal use, on an energy basis, (MBIE, 2016). The inputs from these have simply been assessed on a proportional basis from the power generation inputs.

Table 3-7: Input and output estimates for geothermal power production and use

Source	Activity Rate, GWh/yr	Mercury content, g/MWh	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
				Air	Water
Geothermal power, 2012	5,770	0.03 - 0.22	173.1 – 1,269.4	126.6-1,222.9[a]	46.5
Geothermal power, 2016	7,411	0.03 - 0.22	222 – 1,630	213.4 – 1,621.4 [a]	8.6
Direct use, 2012	based on 6% of the above		10.4 – 76.1	10.4 – 76.1	-
Direct use, 2016	based on 3.8% of the above		8.5 – 62.4	8.5 – 62.4	-
Totals, 2012	**-**	**-**	**183.5 – 1,345.5 (764.5)**	**136.9 – 1,298.6 (718)**	**46.5**
Totals, 2016	**-**	**-**	**230.5 – 1,692.4 (961.5)**	**221.9 – 1683.8 (952.9)**	**8.6**

Notes: a the Wairakei releases to water have been subtracted from the total inputs to give the releases to air.

Certainty assessment

Activity data: HIGH (because it was obtained from a national database)

Input estimates: MEDIUM (because they are based on a range of published data)

Output estimates: MEDIUM (because they are based on a range of published data).

3.8 Summary for this category

The estimated inputs and outputs for the Fuel/Energy Use category are summarised in Table 3-8. From this it can be seen that the greatest inputs are associated with the use of geothermal energy, followed by natural gas extraction and refining. The dominant release route is to air.

Table 3-8: Summary of inputs and outputs for the fuel use category, for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Coal – large power plants	4.5 – 42.4 (23.4)	4.0– 38.2 (21.1)	-	0.5 – 4.2 (2.3)	-	-
Other coal combustion	47.0 – 187.1 (117.1)	44.6 – 177.8 (111.2)	-	-	-	2.4 – 9.2 (5.8)
Oil extraction, refining and use	23.2	19.1	0.2	1.1	-	2.8
Gas extraction, refining and use	0.56 – 444.6 (222.6)	0.1 – 89 (44.5)	0.1 – 89 (44.5)	-	-	0.3 – 266.8 (133.6)
Other fossil fuels	-	-	-	-	-	-
Biomass fuel	12.6 – 126 (69.3)	12.6 – 126 (69.3)	-	-	-	-
Geothermal power	230.5 – 1,692.4 (961.5)	221.9 – 1683.8 (952.9)	8.6	-	-	-
Totals	**318.3 – 2,515.7 (1,417.0)**	**302.4 – 2.133.8 (1,218.1)**	**8.9 – 97.7 (53.3)**	**1.5 – 5.3 (3.4)**	**-**	**5.5 – 278.8 (142.1)**

4 Primary (virgin) metal production

This category covers mercury releases from the mining and processing of metal-containing ores for the purposes of primary (virgin) metal production (UNEP, 2017). The sub-categories and the primary release pathways are summarised in Table 4-1, which has been copied directly from the UNEP Toolkit.

Table 4-1: Toolkit framework for category 2 – primary metal production

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.2.1	Mercury	X	X	X	X	X	PS
5.2.2	Gold and silver, using mercury amalgamation	X	X	X			OW
5.2.3	Zinc	X	X	X	X	X	PS
5.2.4	Copper	X	X	X	X	X	PS
5.2.5	Lead	X	X	X	X	X	PS
5.2.6	Gold and silver, not using mercury	X	X	X	X	X	PS
5.2.7	Aluminium	X		x		X	PS
5.2.8	Other non-ferrous metals	X	X	X		X	PS
5.2.9	Ferrous metals (iron & steel)	X				x	PS

Notes: PS = Point source by point source approach; OW = National/overview approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

4.1 Primary metals not produced in New Zealand

There is no significant primary metal production in New Zealand for the following Toolkit sub-categories: mercury, zinc, copper, lead and other non-ferrous metals.

4.2 Gold and silver, using mercury amalgamation

The use of mercury amalgamation is a traditional method for recovering gold and silver from ore and it is still practised in many countries, including New Zealand, for small-scale gold mining (UNEP, 2017). Amalgamation was replaced at an industrial scale in the early 1900s by a cyanide extraction process. However, the cyanide process is relatively expensive and labour intensive, and not without its own potential hazards, so mercury amalgamation remains the method of choice for small-scale operations, which are referred to in the Toolkit as artisanal gold mining.

A New Zealand study published in 2008 indicated that mercury amalgamation was still being used by small-scale gold miners on the West Coast in 2007 (Newcombe, 2008). In 2013, the West Coast Regional Council advised that there were up to 70 sites in the region where mercury may be used for gold recovery. However, more specific information on which sites actually use mercury and the amount of mercury being used is not readily available from the council files. The 2013 estimate of site numbers has not been updated.

Information obtained from several waste processing companies for the 2012 Inventory Report indicated that at least 20kg of liquid mercury was sold to small-scale gold miners in 2012. In the absence of any more recent data (see section 9.1), this has been taken as a minimum estimate of the total mercury inputs for small-scale gold mining in New Zealand. Newcombe (2008) indicates that most of the mercury is recovered and recycled using simple retorts, although there are inevitably some mercury losses from these systems. On this basis, the Toolkit distribution factors for ‘extraction from ore concentrate with use of retorts and recycling’ can be used, which indicate that 20% of the mercury will ultimately be discharged to air, and 40% each to water and to land.

The mercury input and output calculations for gold and silver production using mercury are shown in Table 4-2.

Table 4-2: Input and output estimates for gold and silver production using mercury

Source	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr		
		Air	Water	Land
Gold & silver, with mercury	20	4	8	8

Certainty assessment

Activity data: not relevant (because ore quantities were not considered in the estimates)

Input estimates: LOW (because the data was only obtained from indirect sources)

Output estimates: LOW (because they are based on the default Toolkit output factors).

4.3 Gold and silver, not using mercury amalgamation

Oceana Gold Corporation operate major gold and silver mining operations at two locations in New Zealand. The McRaes Operations in Otago include the McRaes open pit gold mines and Frasers underground mine. The Waihi Gold Mine Operations in the Waikato include the Martha open pit (currently undergoing stabilisation works) and the Correnso underground gold mine. Another mine on the West Coast, the Reefton gold mine was put into care and maintenance by the Company at the start of 2016 and in December 2016 it was announced that the mine would be closed (Oceana Gold, 2017).

In 2016 153,653 ounces of gold and 5,842 ounces of silver were produced from the McRaes’ operation, while Waihi produced 116,028 ounces of gold and 246,560 ounces of silver.

In order to produce this gold and silver a total of 6,067,798 tonnes of ore was processed at McRaes’ and 489,300 tonnes at Waihi’s processing plants. The reason for the disparity in ore quantities between the two regions, despite each yielding similar quantities of gold, lies with the gold concentration of the ore. In 2016 McRaes’ ore had an average gold concentration of 0.94 g/tonne whereas that for Waihi was 8.1 g/tonne (Oceana Gold, 2017).

There are no recent results available for the mercury content of ore at either location. The 2012 Mercury Inventory reported that the average mercury content for McRaes’ ore was 0.5 to 1 g/tonne. For Waihi ore, 23 samples analysed in 2012 had a range of 0.23 – 2.0 g mercury/tonne with an average of 0.47 g/tonne (D. Bertoldi, pers comm., 2017).

The reported mercury concentrations in ore have been used for the mercury input factors: a range of 0.23 – 2.0 g and a mid-point value of 0.75 g mercury per tonne of ore. The latter value reflects the lower overall concentrations in the McRaes’ ore, which accounts for 93% of the total ore processed. The Toolkit default factors for estimating the output distributions are 0.04 (4%) releases to air, 0.02 (2%) releases to water, 0.9 (90%) releases to land, and 0.04 (4%) releases in product.

The mercury input and output calculations for gold and silver production not using mercury are shown in Table 4-3, along with the previous estimates for 2012. The data appear to show a marked increase in mercury inputs but that is not the case. Improvements in data quality for 2016, with ore figures supplied directly by the company, have led to a more accurate estimate of the mercury input. For 2012 it was assumed in error that a proportion of the ore estimate was waste rock. Because waste rock is not processed and does not release mercury this treatment of the data led to an underestimate of the 2012 mercury input.

Table 4-3: Input and output estimates for gold and silver production not using mercury

Source	Activity Rate, Mt/yr	Mercury content, g/tonne	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr			
				Air	Water	Land	Product
Gold/silver production, 2012	2.5	0.5 – 1.0	1,250 – 2,500 (1,875)	50 – 100 (75)	25 – 50 (37.5)	1,125 – 2,250 (1,687.5)	50 - 100 (75)
Gold/silver production, 2016	6.56	0.23 – 2.0	1,508 – 13,114 (4,918)	60.3 – 525 (196.7)	30.2 – 263 (98.4)	1,357 – 11,803 (4,426)	60.3 – 525 (197)

The figures shown in brackets for 2016 are based on the lower mid-range ore factor noted above rather than the mean value of each range.

Certainty assessment

Activity data: HIGH (because they are based on company data (for 2016))

Input estimates: MEDIUM (because they are based on incomplete company data)

Output estimates: LOW (because they are based on the default Toolkit output factors).

4.4 Aluminium production

The Toolkit covers two stages in the aluminium production cycle; initial refining of alumina from bauxite, and the production of aluminium metal from alumina, by smelting. The only primary aluminium production plant in New Zealand is the aluminium smelter at Tiwai Point in Southland and this fits into the latter category. As indicated in the 2012 Inventory Report, the alumina is imported from other countries in a highly refined form, and is believed to contain no significant concentrations of mercury.

There may be some minor releases of mercury on the refinery site from the use of fuel oil in ancillary processes, such as anode manufacture. However, the releases from fuel combustion were previously assessed in section 3.3 so do not need to be covered here.

On the basis of the above, the inputs and outputs from primary aluminium manufacture can be assessed as zero.

4.5 Ferrous metal production (iron and steel)

The only primary iron and steel production in New Zealand is at the New Zealand Steel[9] plant located in Glenbrook, south of Auckland. This plant is quite unique in that it obtains the iron input from nearby reserves of iron sand, which is a mixture of magnetite and titanomagnetite, plus sand and clay (NZIC, 1998a). A concentrate of the iron sand is mixed with coal, and heated in special gas-fired multi-hearth furnaces, followed by further processing in rotary kilns, to form Reduced Primary Concentrate (RPC). The RPC is then heated in electric arc melters to produce metallic iron, which is further processed in a KOBM (Klockner Oxygen Blown Maxhutte) Converter to produce steel. The total steel production for the 2016 calendar year was 585,770 tonnes and the mill

9 New Zealand Steel is a wholly owned subsidiary of BlueScope Steel Limited.

used 847,920 tonnes of Waikato and Indonesian coal[10], and 61,398 tonnes of lime (C Jewell, New Zealand Steel, pers comm, 2017). A further 37,480 tonnes of calcium oxide was used in the final stages of steel production

The ferrous metal sub-category in the Toolkit refers to a much more common iron making process which involves the processing of iron ore – usually haematite - in a sintering plant, followed by treatment in a blast furnace to produce pig iron, and subsequent processing into iron and steel. In terms of mercury inputs, the key differences between this and the New Zealand process would be the mercury content of the iron sand or iron ore, and the relative amounts of coal used. In both processes most of the mercury is likely to be released to air during the first two processing stages (ie. for New Zealand, in the manufacture of RPC and processing in the KOBM).

The only information on mercury releases from the New Zealand plant relates to the solid wastes produced by the iron sand processing plant. The mercury levels in the synthetic leaching procedure conducted on Wash Tailings were found to be less than 0.00008 g/m^3 for tests conducted in both 2015 and 2016 (C Jewell, New Zealand Steel, pers comm, 2017).

An initial assessment of the likely mercury inputs and releases can be obtained from consideration of the coal and limestone inputs to the process, as these are likely to be the main contributors to the releases. The mercury content of Waikato coal was discussed in section 3.2, and the content of lime is discussed in section 5.3, and the same ranges of values have been used for the steel input estimates. The steel mill air emissions are passed through bag filters prior to discharge, so the Toolkit distribution factors for fabric filters on coal combustion plants have been used for the output distribution; ie. 50% to air and 50% to waste.

The mercury input and output calculations for primary ferrous metal production are shown in Table 4-4.

No allowance has been made for the potential contributions from any mercury present in the iron sand, although the leaching tests suggest that this is most likely very low.

Table 4-4: Input and output estimates for primary ferrous metal production

Source	Activity Rate, tonnes/yr	Mercury content, mg/kg	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
				Air	Waste
Waikato Coal, 2012	805,000	0.05 - 0.20	40.3 – 161	20.15 – 80.5	20.15 – 80.5
Waikato Coal, 2016	847,920	0.05 – 0.20	42.4 - 170	21.2 – 85.0	21.2 – 85.0
Limestone, 2012	43,000	0.005 – 0.02	0.22 – 0.86	0.11 – 0.43	0.11 – 0.43
Limestone, 2016	61,398	0.005 – 0.02	0.31 – 1.23	0.16 – 0.62	0.16 – 0.62
Total, 2012			**40.5 – 161.9 (101.2)**	**20.3 – 80.9 (50.6)**	**20.3 – 80.9 (50.6)**
Total, 2016			**42.71 - 171.2 (106.9)**	**21.4 – 85.6 (53.5)**	**21.4 – 85.6 (53.5)**

Certainty assessment

Activity data: HIGH (because it was based on company data)

Input estimates: LOW (because they are based on a limited range of published data and industry estimates)

Output estimates: LOW (because they are based on default Toolkit output factors for another category).

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10 30 – 35 % of the coal was from Indonesia.

4.6 Summary for this category

The estimated inputs and outputs for the Primary Metal Production category are summarised in Table 4-5. From this it can be seen that the inputs are totally dominated by the use of ore in gold and silver production, most of which is returned to the land via the tailings disposal facilities.

Table 4-5: Summary of inputs and outputs for the primary metal production category for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Mercury	-	-	-	-	-	-
Gold & silver, with mercury amalgamation	20	4	8	8	-	-
Zinc, copper, lead…	-	-	-	-	-	-
Gold & silver, without mercury	1,508.1 – 13,114 (4,918)	60.3 – 525 (196.7)	30.2 – 263 (98.4)	1,357 – 11,803 (4,426)	60.3 – 525 (196.7)	-
Aluminium	-	-	-	-	-	-
Ferrous metals	42.71 - 171.2 (106.9)	21.4 – 85.6 (53.5)		-	-	21.4 – 85.6 (53.5)
Totals	**1570.8 – 13,305.2 (5,044.7)**	**85.7 – 614.2 (254.2)**	**38.2 – 270.3 (106.4)**	**1,365 – 11,811 (4.426)**	**60.3 – 525 (196.7)**	**21.4 -85.6 (53.5)**

The figures shown in brackets are the means of the reported ranges, except for gold/silver mining where a lower mid-point factor has been used.

5 Production of minerals and materials with mercury impurities

This category covers mercury releases from the production of minerals and related materials with mercury impurities (UNEP, 2017). The sub-categories and the primary release pathways are summarised in Table 5-1, which has been copied directly from the UNEP Toolkit. For the New Zealand inventory, the use of phosphate-based fertilisers and agricultural lime has also been considered under the catch-all sub-category of 'other minerals and materials'.

Table 5-1: Toolkit framework for category 3 –production of minerals and materials with mercury impurities

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.3.1	Cement production	**X**		x	x	**x**	PS
5.3.2	Pulp and paper production	**X**	x	x		x	PS
5.3.3	Lime production and light-weight aggregate kilns	**X**			x		PS
5.3.4	Other minerals and materials						PS

Notes: PS = Point source by point source approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

5.1 Cement production

There were two cement plants 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 Westport plant was closed in June 2016 and will not be included in the 2016 inventory[11] (Holcim, 2017).

Coal is used as the primary fuel in the Northland plant but supplemented with wood waste, and the total cement production at the plant in 2016 was 887,025 tonnes (O Khanal, Northland Regional Council, pers comm, 2017).

The primary raw ingredient for cement manufacture is limestone, which contains traces of mercury (see section 5.3). There is also mercury in the coal used as fuel and in the supplementary fuels. The emissions from the kiln are tested annually, and the average mercury emission rate for testing carried out in 2014 and 2015 was 0.33 kg/year. This figure has been used to estimate the annual mercury inputs for cement production, including those due to fuel use.

The input factors given in the Toolkit cover a range of 0.004 to 0.5 g/tonne of cement. Applying these factors to a total annual production rate of 887,025 tonnes gives mercury inputs of from 3.6 to 444 kg/year. The bottom of this range is an order of magnitude higher than the Northland data, while the upper value is based on a highly conservative assessment of international information. The Toolkit default factors have not been used for this source category because the available emissions data provides a more relevant estimate.

The Toolkit indicates that there is some partitioning of the mercury between the air emissions and the clinker product. In the Toolkit terminology, the New Zealand plant would be described as having simple particulate

[11] This is based on the assumption that production would have been drastically scaled back during the final 6 months of operation. Also, the information on possible mercury outputs is not really needed for future planning purposes.

controls[12], with output distribution factors of 0.7 (70%) to air and 0.3 (30%) to product. Applying these to the air emission rate of 0.33 kg/year, gives an estimated release in product of 0.14 kg/year, and a total production input of 0.47 kg/year.

The mercury input and output estimates for cement production are shown in Table 5-2. The 2012 estimates were much higher than in 2016 because the emissions from the Westport plant were much higher than at the Northland plant.

Table 5-2: Input and output estimates for cement production

Source	Activity Rate, tonnes/yr	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
			Air	Product
Cement production, 2012	1,110,000	6.3	4.4	1.9
Cement production, 2016	887,025	0.47	0.33	0.14

Certainty assessment

Activity data: HIGH (because it was based on plant production data).

Input estimates: MEDIUM (because they are based on a limited amount of measured data).

Output estimates: MEDIUM (because the product release was estimated from a default factor).

5.2 Pulp and paper production

Pulp and paper production is treated as a separate sub-category in the Toolkit because historically there were significant uses of mercury within the industry; especially in chlor-alkali plants (see section 6.1), and as a slimicide (see section 7.6). However, both of these uses no longer occur in New Zealand, so the only significant source of mercury inputs and outputs is via the use of wood, as both a fuel and a raw material. These mercury releases have already been addressed under section 3.5 (biomass combustion).

5.3 Production of lime and light-weight aggregate

This Toolkit sub-category covers the production of burnt lime from the high-temperature treatment (calcination) of limestone, and the similar processes used for manufacturing light-weight aggregate from clay, shale or slate. There are a number of lime kilns in New Zealand, but no evidence has been found to indicate any significant production of the type of aggregate covered by the Toolkit.

There are 5 lime kilns in New Zealand, which produce burnt lime from limestone. The two North Island pulp and paper mills also operate lime kilns but these do not process limestone[13]. The other 5 kilns are located in Te Kuiti, Otorohanga (2), and Te Kumi, all in the Waikato region, and Dunback, in Otago. No data has been obtained for the total burnt lime production in New Zealand in 2016, but data given in the most recent New Zealand Greenhouse Gas Inventory report indicates an annual production rate of 245,700 tonnes in 2015 (MfE, 2017).

The Toolkit does not recommend any default factors for lime manufacture because the available data is very limited. However, it does note a US EPA study which reported a mercury release rate of 9 mg/tonne of lime

[12] The particulate control system on the New Zealand plant is actually quite complex. However, it does not include advanced control systems, such as selective non-catalytic reduction for NOx control.

[13] The pulp mill lime kilns form part of an internal chemical recycling process for the so-called 'lime mud' produced in the pulp making process. Some minor calcium additions are required to make up for losses in wastes, but these are obtained from baked lime rather than limestone.

produced. This is consistent with the results of <10 and 20 mg/tonne reported by McBride and Spiers (2001) for two samples of agricultural lime (limestone) sourced from the north-eastern United States. Within New Zealand, Curtis (2007) reported that a sample of Otago limestone collected had a mercury content of 20 mg/tonne.

In the absence of any recommended Toolkit factors, a range of 5 to 20 mg/tonne[14] will be used for the mercury inputs estimates. Some of the lime kilns are fired on coal but the inputs and outputs from this component have already been accounted for under section 3.2. In accordance with the Toolkit guidance, the output distribution factors will be assumed to be the same as those used for cement production.

The mercury input and output estimates for lime production are shown in Table 5-3.

Table 5-3: Input and output estimates for lime production

Source	Activity Rate, tonnes/yr	Mercury content, mg/t	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
				Air	Product
Lime production, 2012	170,000	5 - 20	0.85 – 3.4 (2.1)	0.595 – 2.38 (1.5)	0.255– 1.02 (0.64)
Lime production, 2016	245,700	5 - 20	1.23 – 4.91 (3.07)	0.86 – 3.44 (2.15)	0.37 – 1.47 (0.92)

Certainty assessment

Activity data: HIGH (because it was based on published data)

Input estimates: LOW (because they are based on limited published data)

Output estimates: LOW (because the releases were estimated from default factors for cement production).

5.4 Other minerals and materials

Two other New Zealand sources of mercury releases from minerals have been identified for this inventory; the application of phosphatic fertilisers and agricultural lime to land.

Phosphate fertilisers

New Zealand agriculture uses a significant amount of superphosphate fertiliser, which is manufactured from imported phosphate rock (NZIC, 1998b). There are 6 manufacturing plants in New Zealand, located in Northland, Bay of Plenty, Hawkes Bay, Canterbury, Otago and Southland regions.

The phosphate rock is imported from numerous other countries and contains varying amounts of mercury. Within this country, the two major suppliers of superphosphate have adopted a maximum mercury guideline of 10 mg/kg in their products, but indicate that the levels are usually much lower (NZFRMA, 2013). Measurements in 2015 and 2016 conducted on 65 monthly samples had values in the range < 0.05 - 2.7 mg/kg product with a mean of 0.09 mg/kg product (G Sneath, pers comm 2017). This latter concentration figure has been used for the upper limit[15] in the input and output estimates, along with a lower level of 0.05 mg/kg.

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14 The lower figure of 5 is based on half the limit of detection (LOD) reported by McBride and Spiers. This is the approach normally used when laboratory results are reported as being less than the LOD.

15 The use of the mean value for the upper input factor instead of the maximum value was used because the analytical data is highly skewed towards the mean.

The total New Zealand imports of phosphate rock in 2016 were 559,137 tonnes (import data obtained from Statistics New Zealand, 2017), which is equivalent to 1,096,000 tonnes of superphosphate. It is not known whether any of the mercury is released from the rock during processing but, for the purposes of an initial estimate, it has been assumed to remain in the product and be discharged to land. On the basis of the import data, the total mercury inputs can be estimated at 54.8 – 98.6 kg per year, and it is assumed that this will all be released to land.

Note: The estimates for inputs from phosphate fertiliser are up by about 75% on 2012, but this is because the previous estimates were incorrectly based on the import quantities of phosphate rock rather than the superphosphate product sold by the fertiliser companies. This difference has been offset to some extent by the use of lower mercury content factors for the 2016 estimates.

Agricultural lime

Agricultural lime is applied directly to pastures in New Zealand as a soil conditioner. This material is manufactured simply by grinding limestone to produce a coarse powder, and the total quantity produced in 2015 was 975,538 tonnes (MBIE, 2016a). This is 30% lower than the quantity reported for 2012 but the national data for this mineral show marked fluctuations from year to year.

The mercury content has been assumed to be the same as that noted previously in section 5.3; ie. 5 to 20 mg/tonne.

Input and output estimates

The mercury input and output estimates for the use of other mineral products are shown in Table 5-4.

Table 5-4: Input and output estimates for other mineral products

Source	Activity Rate, tonnes/yr	Mercury content, g/tonne	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr
				Land
Phosphate fertiliser, 2012	630,750	0.05 – 0.34	31.5 – 214.5 (123)	31.5 – 214.5 (123)
Phosphate fertiliser, 2016	1,096,000	0.05 – 0.09	54.8 – 98.6 (76.7)	54.8 – 98.6 (76.7)
Agricultural lime, 2012	1,370,000	0.005 -0.02	7 – 27 (17)	7 – 27 (17)
Agricultural lime, 2016	975, 538	0.005 – 0.02	4.88 – 19.51 (12.20)	4.88 – 19.51 (12.2)

Certainty assessment

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

Input estimates: LOW (because they are based on limited published data)

Output estimates: LOW (because the no manufacturing release factors were available).

5.5 Summary for this category

The estimated inputs and outputs for the minerals category are summarised in Table 5-5, which shows that the inputs and outputs are totally dominated by the application of superphosphate to land.

Table 5-5: Summary of inputs and outputs for production of minerals and related materials with mercury impurities for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Cement	0.47	0.33	-	-	0.14	-
Pulp and paper	-	-	-	-	-	-
Lime	1.23 – 4.91 (3.07)	0.86 – 3.44 (2.15)	-	-	0.37 – 1.47 (0.92)	-
Phosphate fertiliser	54.8 – 98.6 (76.7)		-	54.8 – 98.6 (76.7)	-	-
Agricultural lime	4.88 - 19.51 (12.20)	-	-	4.88 - 19.51 (12.20)	-	-
Totals	**61.4 – 123.5 (92.4)**	**1.2 – 3.8 (2.5)**	**-**	**59.7 – 118.1 (88.9)**	**0.5 – 1.6 (1.1)**	**-**

6 Intentional use of mercury in industrial processes

This category covers mercury releases from several industrial chemical processes (UNEP, 2017), none of which exist in New Zealand. However, for the sake of completeness, the sub-categories and the primary release pathways are summarised in Table 6-1, which has been copied directly from the UNEP Toolkit, and information on the relevance to New Zealand is presented below.

Table 6-1: Toolkit framework for category 4 – intentional use of mercury in industrial processes

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.4.1	Chlor-alkali production with mercury technology	**X**	**X**	**X**	**X**	**X**	PS
5.4.2	VCM (vinyl chloride monomer) production with $HgCl_2$ catalyst	x	x			**X**	PS
5.4.3	Acetaldehyde production with $HgSO_4$ as catalyst						PS
5.4.4	Other chemicals and polymers with mercury catalysts						PS

Notes: PS = Point source by point source approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

6.1 Industrial uses of mercury in New Zealand[16]

Chlor-alkali plants were used at one of the pulp and paper mills until the early 1980s, when they were replaced with a modern system based on a membrane cell technology which does not involve mercury (NZIC, 1998b).

Vinyl chloride monomer is not manufactured in New Zealand, although significant volumes of the polymerised form of vinyl chloride (ie polyvinyl chloride, PVC) are imported for use in making PVC products.

Similarly, there is no manufacturing of acetaldehyde in New Zealand, or of two-part polyurethanes involving mercury catalysts.

16 A more detailed discussion of each of these potential sources was given in the 2012 Inventory Report.

7 Consumer products with intentional use of mercury

This category covers mercury uses in a wide range of different consumer products (UNEP, 2017). The various sub-categories and the primary release pathways are summarised in Table 7-1.

Table 7-1: Toolkit framework for category 5 – consumer products with intentional use of mercury

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.5.1	Thermometers with mercury	**X**	**X**	**X**	**X**	**X**	OW
5.5.2	Electrical switches, contacts and relays with mercury	**X**	x	**X**	**X**	**X**	OW
5.5.3	Light sources with mercury	**X**	x	**X**	**X**	**X**	OW
5.5.4	Batteries containing mercury	**X**	x	**X**	**X**	**X**	OW
5.5.5	Polyurethane with mercury catalyst	**X**	x	**X**	**X**	**X**	OW
5.5.6	Biocides and pesticides	**X**	**X**	**X**	**X**	**X**	OW
5.5.7	Paints	**X**	x	x	**X**	x	OW
5.5.8	Pharmaceuticals for human and veterinary uses	**X**	x	x	x	**X**	OW
5.5.9	Cosmetics and related products		**X**		**X**	x	OW

Notes: OW = National/overview approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

7.1 Mercury thermometers

No New Zealand manufacturers of mercury in glass thermometers were identified in this survey.

Imports/sales

(Note: this category would also include hygrometers, which are listed in the proposed text for the Minamata Convention, but are not specifically noted in the Toolkit. The most common form of hygrometer is also known as a wet-and-dry bulb thermometer, and these would have been picked up by the various enquiries on sales and use, noted below.)

Import data for Customs' code 9025.11.00.00 (liquid-filled, direct-reading, thermometers and pyrometers) was obtained from Statistics New Zealand for 2016. However, this only indicates the total value of the imports, which was $321,900 in 2016. In addition, the data cover all types of thermometers, including those not containing mercury, such as alcohol-filled thermometers.

As an alternative approach, 12 suppliers of medical and veterinary equipment were approached for information on their current imports. Responses were obtained from all of the firms contacted, but only two companies reported any imports of mercury thermometers, with total sales of 2,897 units over the last 12 months. Three laboratory supply companies were also contacted and they reported annual sales of 913 units, which gives an overall total of 3,810 units. An estimate of the amount of mercury included in these thermometers is given below.

Current Stocks

An estimate of 'current' thermometer stocks in New Zealand was prepared for the 2012 Inventory Report through a survey of hospitals and laboratories throughout the country. The total stocks were estimated at 53,400 units, with a total mercury content of between 26.7 and 267 kg. This work has not been repeated for the current inventory, but it could be expected that the total will have declined slightly, as the organisations continue to move towards using non-mercury alternatives.

Input and output estimates

The Toolkit indicates that medical thermometers typically contain 0.5 – 1.5 grams of mercury each, while laboratory thermometers can contain 1 – 40 grams per unit. The upper limit for laboratory thermometers appears quite extreme, so for the purposes of this inventory, the estimate has been based on an overall range of 0.5 – 5 grams/unit (also noting that the majority of units are 'medical' size).

For estimating outputs, the Toolkit recommends distribution factors of 0.1 (10%) to air, 0.3 (30%) to water and 0.6 (60%) to waste, for countries with publicly controlled waste collection services. It should be noted that these factors should only be applied to the annual imports/sales numbers, rather than the total thermometer stocks in a country, on the basis that the former most likely represent the annual turnover rate for the current stocks. In addition, the current stocks should not be counted as part of the annual inputs because the mercury is not 'mobilised' until the thermometers are disposed.

The mercury input and output estimates for the use of thermometers are shown in Table 7-2.

Table 7-2: Input and output estimates for mercury thermometers

Source	Activity Rate, units/yr	Mercury content, g/unit	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr		
				Air	Water	Waste
Annual sales, 2012	6,500	0.5 – 5	3.25 – 32.5 (17.9)	0.325 – 3.25 (1.8)	0.975 – 9.75 (5.4)	1.95 – 19.5 (10.7)
Annual sales, 2016	3,810	0.5 - 5	1.91 – 19.05 (10.48)	0.19 – 1.91 (1.05)	0.57 – 5.72 (3.14)	1.14 – 11.4 (6.29)

Certainty assessment

Activity data: MEDIUM (because it is based on survey data plus estimates)

Input estimates: LOW (because they are based on the Toolkit default factors)

Output estimates: LOW (because they are based on the Toolkit default factors).

7.2 Electrical and electronic switches, contacts and relays

Mercury has been used, and continues to be used, in a variety of electrical switches and relays. Historically, one of the largest uses by volumes of mercury, per unit, was in electrical rectifiers and mercury arc valves, which were used in electricity distribution networks and industrial facilities. This type of equipment has a long service life, so there may still be a significant number of items still in use, despite the ready availability of non-mercury alternatives. At the consumer level, small mercury tilt switches have been widely used in many electrical appliances, and in car boot light switches and ABS braking systems. Mercury switches can also be found in some electrical thermostats, flame sensors, and bilge pumps for boats (UNEP, 2017).

2012 survey of current stocks, imports, sales and use

The work for the 2012 Inventory included an extensive survey of possible importers, distributors and users of electrical equipment to identify possible stocks of mercury-containing equipment. No significant imports were identified but one supplier was found to have about 200 small switches in stock, with a mercury content of about 1 gram per switch, and annual sales of about 10 switches. It was concluded that the total quantities of mercury possibly being distributed through sales of switches would be very small.

The survey of possible users of electrical equipment identified total current stock holdings of about 170 kg of mercury, mainly in old relays and switches. This survey has not been repeated for the current inventory, but it should be expected that the stock holdings will be gradually decreasing, as most people contacted in 2012 indicated that they were phasing out any mercury-containing equipment.

Input and output estimates

The methodology given in the Toolkit is based on a simple population-based estimate, using recommended default factors of 0.02 – 0.25 grams/year per capita for current mercury inputs via electrical switches and relays. However, these factors are based on data which is 10 to 20 years old, and they are also dominated by relatively high usage rates in the USA. For the 2012 Inventory it was decided to use lower factors of 0.002 - 0.02 grams/year per capita for the New Zealand estimates, and the same approach has been taken here.

For outputs, the Toolkit recommends distribution factors of 0.1 (10%) to air, 0.1 (10%) to land and 0.8 (80%) to waste, for countries with publicly controlled waste collection services, but only limited waste separation. These factors have been applied to the per capita inputs estimated using the modified Toolkit factors.

The mercury input and output estimates for mercury switches and relays are shown in Table 7-3.

Table 7-3: Input and output estimates for mercury switches and relays

Source	'Activity' (population)	Mercury input rate, g/capita	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr		
				Air	Land	Waste
Annual usage, 2012	4.4 x 10^6	0.002 – 0.02	8.8 – 88 (48.4)	0.9 – 8.8 (4.84)	0.9 – 8.8 (4.84)	7.0 – 70.4 (38.7)
Annual usage, 2016	4.7 x 10^6	0.002 – 0.02	9.4 - 94 (51.70)	0.94 – 9.4 (5.17)	0.94 – 9.4 (5.17)	7.5 – 75.2 (41.36)

Certainty assessment

Activity data: HIGH (because it is based on national population)

Input estimates: LOW (because they are based on the Toolkit default factors)

Output estimates: LOW (because they are based on the Toolkit default factors).

7.3 Light sources (lamps)

Mercury is used in small amounts (per lamp) in fluorescent tubes (LFLs) and compact fluorescent lamps (CFLs), and in high-pressure discharge types, such as metal halide, mercury vapour, sodium, and neon lamps (UNEP, 2017). The most common use for the discharge lamps is in street lighting. Significant progress has been made by some producers to reduce the amount of mercury per lamp, with reductions of about a factor of 10 achieved in newer mercury-lamps as compared to traditional types. Increasingly in New Zealand high discharge street lamps are being replaced by light emitting diode (LED) lights which do not contain mercury and which are more energy efficient, have lower maintenance costs and produce a safer driving environment due to improved white light clarity and colour recognition for drivers. (IPWEA, 2016).

LFLs and CFLs

Import data for fluorescent lamps and tubes was obtained from Statistics New Zealand, covering the period 2013 to 2016 (HS Code: 8539.31.00.00). This indicated total annual imports of LFLs and CFLs of between 4.0 and 6.5 million units per year, with 4.0 million units imported in 2016. The Lighting Council of New Zealand estimates that the split between LFLs and CFLs is approximately 3:2 (ie 60% LFLs), and the current mercury contents are about 4mg for both types of lamps. (B. King, Lighting Council New Zealand, pers. comm). The import quantities are 15 to 30% lower than those quoted in the 2012 Inventory Report, and this trend of declining fluorescent sales can be attributed to their replacement by LED lamps.

The Energy Efficiency & Conservation Authority (EECA) collects sales data for all regulated appliances. For the year ending July 2016 the organisation recorded sales of over 1.4 million CFLs and 1.6 million LFLs. Mercury levels in the CFLs ranged from 1.12 mg – 5 mg. (L. Sinclair, EECA, pers. comm.). This sales data has been used in estimating the mercury inputs, rather than the bulk import information noted above.

Other discharge lamps

Import data was also obtained for a range of other discharge lamps, using 7 different HS codes (ie. those in the range 8539.32.00.01 to 8539.49.90.00). This showed total imports in 2016 of about 197,000 high-intensity discharge lamps, and about 92,000 'other' lamps. The mercury content for these varies from 5 to 30 mg/lamp (UNEP, 2017). These quantities are markedly lower than those given in the 2012 Inventory Report, especially for the high-intensity discharge lamps, which is consistent with the comments given above regarding the increasing use of LEDs for street lighting.

Input and output estimates

The estimates for the total mercury inputs for all types of lamps are summarised in Table 7-4. This has been based on the mercury content information given above or the Toolkit default factors when local information was not available.

For outputs, the Toolkit recommends distribution factors of 0.05 (5%) to air, and 0.95 (95%) to waste, for countries with publicly controlled waste collection services, but only limited waste separation. These factors will be applied to the New Zealand input estimates, although the output calculations should be applied to the mercury inputs from, say, 10 or more years ago, rather than the 2016 data (because the outputs occur when the lamps come to their end of the useful life). However, this older data is not available, so the indicated outputs should be regarded as a conservative over-estimate (but also a good indicator of future outputs). It should also be noted that a small proportion of lamps are collected by a specialist waste company and exported to Australia. The 2012 Inventory Report indicated that these exports were estimated to contain about 3 kg of mercury and more recent data provided by the company indicates that similar quantities were exported in 2016.

Table 7-4: Input estimates for lamps

Lamp type	Mercury content, mg/lamp	Number of lamps, thousands	Total mercury input, kg/year
Fluorescent Tubes (LFLs), 2012	2 – 5	3,000 – 3,500	6 – 17.5
Fluorescent Tubes (LFLs), 2016	1.1 - 5	1,600	1.76 – 8.0
Compact Fluorescent Lamps (CFLs), 2012	1 – 3	2,500 – 3,500	2.5 – 10.5
Compact Fluorescent Lamps (CFLs), 2016	1.1 - 5	1,400	1.54 – 7.0
High Pressure Mercury Vapour, 2012	30	50	1.5
High Pressure Mercury Vapour, 2016	30	35	1.1
High Pressure Sodium Lamps (HPS), 2012	10 - 30	120	1.2 - 3.6
High Pressure Sodium Lamps (HPS), 2016	10 – 30	56	1.7 – 2.8
UV lamps for tanning, 2012	5 – 25	50 - 100	0.25 – 2.5
UV lamps for tanning, 2016	5 – 25	92	0.46 – 2.3
Metal halide lamps, 2012	25	500	12.5
Metal halide lamps, 2016	25	106	1.6 – 5.3

The mercury input and output estimates for mercury lamps are shown in Table 7-5.

Table 7-5: Input and output estimates for mercury lamps

Source	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
		Air	Waste
All lamps (see details above), 2012	24 – 48.1 (36.0)	1.2 – 2.4 (1.8)	22.8 – 45.7 (34.2)
All lamps (see details above), 2016	8.16 – 26.5 (17.33)	0.41 – 1.33 (0.88)	7.75 – 25.18 (16.47)

Certainty assessment

Activity data: HIGH (because it is based on national import data)

Input estimates: MEDIUM (because they are based on published data and industry estimates)

Output estimates: LOW (because they are based on the Toolkit default factors).

7.4 Light sources (LCD screens)

LCD screens containing cold cathode fluorescent lamps (CCFLs) as the lighting source were considered a significant source of mercury for the 2012 Mercury Inventory. The intervening years have seen a period of rapid technological growth where light emitting diode (LED) lighting has completely replaced CCFL lighting in LCD television screens and computer monitors. In 2013 the LED lighting had penetrated 90% of LCD television sales with 100% of notebook, tablet and cell phone backlights powered by LED, and was predicted to reach 100% by

2015-2016. Similarly the 86% of desktop TV monitors lit by LEDs were predicted to reach 100% by 2015. (source: www.news.ihsmarkit.com/press-release/design-supply-chain-media-/led-backlighting-reach-90-percent-penetration-lcd-tvs-2013)

Because LEDs are mercury free, television screens and computer monitors need no longer be considered as a continuing source of mercury inputs.

7.5 Batteries

Mercury is added to batteries for technical reasons such as the prevention of gas production and corrosion, although in mercury oxide cells it is a major active ingredient accounting for 32% of battery weight. Its uses are predominantly restricted to non-rechargeable (primary) batteries (UNEP, 2017).

The composition of New Zealand household batteries was reviewed in 2013 as part of an assessment for battery disposal options (Tonkin and Taylor, 2013). Single use alkaline manganese and zinc carbon batteries, (e.g. AA, AAA and 9V types) comprised 89% of battery use. The remaining 11% comprised rechargeable batteries (2%) and button cell batteries (9%).

In 2006 the European Union enacted Directive 2006/66/EC which prohibited the sale of batteries containing more than 0.0005% by weight of mercury. Button cells with a mercury content of no more than 2% by weight were exempted from this prohibition until October 2015 although button cells for hearing aids remain under review. This legislation has helped remove mercury from the global market for alkaline manganese and zinc carbon batteries. Some button cell batteries available for sale in New Zealand may still contain mercury, although many of them are now labelled as mercury free.

There are four different types of mercury containing button cell available in New Zealand: mercuric oxide, zinc air, silver oxide and alkaline button cell. They are used for their compact properties, high energy density and voltage stability in devices such as calculators, watches and cameras. Zinc air batteries are used predominantly in hearing aids. Energizer button cell batteries are believed to hold about 50-60% of the market and all of this brand now contain no added mercury. (Roger Spice, Energizer NZ Ltd, pers comm.) Some of the datasheets available from other importers indicate that some but not all other batteries are mercury free, so for the purposes of this inventory it has been assumed that the overall distribution for all brands is 75% mercury free.

In order to estimate mercury inputs from batteries, import data was obtained for each battery type, using HS codes 8506.10.00.01 to 8506.80.00.19, and the quantities of mercury were calculated by multiplying the number of units by their respective average weights and by the mercury content of each cell. The latter factors were based on the values given in the Toolkit but for button cells these factors were reduced by 75% to account for the proportion of mercury-free units.

The estimated mercury inputs for the different battery types are shown in Table 7-6[17]. For the outputs it was assumed that all of the batteries were disposed to waste. Recently some local initiatives have been introduced to encourage consumer recycling such as a battery recycling depot at the Lincoln New World supermarket in Canterbury. Ecowaste also offer a consumer battery disposal service, but there is no evidence of large scale battery collection and/or export for recycling. The input and output calculations are shown in Table 7-7. The figures shown in brackets are the means of the reported ranges.

[17] The data given in Table 7-6 of the 2012 Inventory report included small contributions from Zinc-Carbon, and Other MnO_2 batteries. However, according to the Toolkit these can be regarded as mercury-free. Hence these batteries have not been included the current table 7-6. In addition, the 2012 totals given in Table 7-7 have been adjusted to exclude the zinc carbon and other MnO_2 data.

Table 7-6: Estimated mercury inputs for batteries, 2016

Type	Size, cm^3	Mercury content g/kg	Number of batteries	Weight per battery, g	Total weight of batteries, kg	Mercury inputs, kg
Mercuric oxide button, 2012	<300	320	98,126	1	98	31.4
Mercuric oxide button, 2016	<300	320	2.543	1	2.5	0.81
Silver oxide button, 2012	all	3.4 – 10	653,266	1	653	2.2 – 6.5
Silver oxide button, 2012	all	1	815,320	1	815	0.82
Zinc air button, 2012	all	0 - 30	2,754,161	1	2,754	0 – 82.6
Zinc air button, 2016	all	3	3,748,150	1	3,748	11.2
Alkaline button, 2016[a]	all	5	6,828,996	1	6,829	8.54
Alkaline MnO_2, 2012	<300	0 – 0.00006[b]	36,705,233	12	440,462	0 – 0.026
Alkaline MnO_2, 2016	<300	0.25	31,167,321	12	374,004	23.4

Footnotes:

a the import data provided in 2012 did not provide separate data for alkaline button batteries

b the mercury content factor used in 2012 was not correct.

Table 7-7: Input and output estimates for batteries

Source	Activity Rate, units/yr	Mercury content, g/kg	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr
				Waste
Batteries, 2012	40,240,776	0 - 320	33.6 – 120.6 (77.1)	33.6 – 120.6 (77.1)
Batteries, 2016	42,936,897	0 - 320	44.77	44.77

Certainty assessment

Activity data: HIGH (because it was obtained from national import statistics)

Input estimates: MEDIUM (because they are based on product data and the default Toolkit factors)

Output estimates: HIGH (because essentially all batteries are disposed to landfill).

7.6 Polyurethanes with mercury catalyst

Until recently, organic mercury compounds were an important catalyst in the production of polyurethane elastomers (flexible plastics) that could be used for the moulding of complex shapes, synthetic (rubberised) flooring and a range of specialist surface coating or insulation materials (UNEP, 2017). For the 2012 Inventory Report a limited number of these products were identified through an internet search of New Zealand resin importers and distributors. However, only one of the companies reported any sales. Four others reported that their products no longer contained mercury, with one noting in particular, that mercury was no longer allowed under EU regulations.

The one importer still selling polyurethanes with these catalysts indicated that they had made 3 sales to New Zealand manufacturing companies in 2012, with a total quantity of about 200 grams of mercury-containing catalyst. An update on that data has been requested from the importer but not yet provided, so the 2012 figure has been carried over for 2016.

7.7 Biocides and pesticides

Most substances intended for use as agricultural or veterinary medicines in New Zealand are required to be registered under the Agricultural Chemicals and Veterinary Medicines Act. A database of current registrations is maintained by the Ministry for Primary Industries, and a search of this database in early May 2017 showed no mercury-containing chemicals.

On the basis of the above, it can be concluded that there is no current use of mercury-based biocides as agricultural or veterinary medicines in New Zealand. However, it should be noted that some minor uses have been identified in animal vaccines and eye drops, where the mercury compounds act as a preservative. These uses are covered under section 7.9.

7.8 Paints

The report for the 2012 Inventory indicated that mercury pigments were believed to be no longer used in New Zealand, and there is no reason to expect that this situation has changed. Some additional support for this position can be taken from the fact that no mercury – based products could be identified in a search of the national databases of substances approved under the *Hazardous Substances and New Organisms Act 1996*. (EPA, 2017).

7.9 Pharmaceuticals for human and veterinary use

Mercury compounds have been used in the past in various pharmaceuticals such as vaccines, eye drops, topical antiseptics, and other products, functioning mainly as a preservative. In addition, it is still used today in animal vaccines, with the most common additive being Thiomersal[18]. This chemical is listed in the specific exclusions given in Annex 1 of the Minamata Convention.

A Ministry of Health immunization handbook (Ministry of Health, 2016) states that none of the vaccines on the New Zealand National Immunisation schedule contain thiomersal including the current influenza vaccines. A search of the Medsafe database (www.medsafe.govt.nz/regulatory/DbSearch.asp) showed that there were currently only 4 mercury-containing human pharmaceutical products registered for use in New Zealand (as opposed to the 26 noted in the 2012 Inventory Report). Two of these contain phenylmercuric nitrate, and two contain phenylmercuric acetate. Two of the three companies responsible for distribution provided sales information that allowed calculation of a total inputs of 0.026 kg of mercury for these products in 2016.

A search of the national register of approved veterinary products in 2013 found 92 different products that contain small amounts of mercury preservatives, although this does not on its own indicate that these products are actually being used in New Zealand. Information obtained from local manufacturers of veterinary vaccines for the 2012 Inventory Report, indicated total imports of Thiomersal preservative of about 30 kg per year. An additional input of 10 kg per year was assumed from information obtained from two vaccine importers and distributors.

18 The chemical name for Thiomersal is ethyl(2-mercaptobenzoato-(2-)-O,S) Mercurate (1-) sodium, and it is also known as thiomerosal, and merthiolate)

Information received to date from current vaccine suppliers indicates similar quantities for 2016. Total mercury inputs and outputs have been assumed to be the same as those for 2012.

7.10 Cosmetics and related products

The use of chemical substances in cosmetics is governed by the *Cosmetic Products Group Standard (2006, with amendments to July 2012)* issued under the *Hazardous Substances and New Organisms Act 1996*. Generally, the Group Standard prohibits the use of mercury compounds, but Thiomersal and phenylmercuric salts are permitted for use as preservatives, at concentrations of no more than 0.007% (as Hg). Checks with 5 cosmetics manufacturers found no evidence of mercury use in 2012, and there is no reason to expect that this situation will be any different for 2016.

7.11 Summary for this category

The estimated inputs and outputs for the consumer products category are summarised in Table 7-8, which shows that the most significant inputs are from pharmaceuticals (vaccines) and mercury switches and relays, lamps and batteries. The quantities shown for vaccines are based on the import data provided by one manufacturer, and this is believed to be the only such operation in New Zealand.

Table 7-8: Summary of inputs and outputs for consumer products with intentional use of mercury for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Thermometers with mercury	1.91 – 19.05 (10.48)	0.19 – 1.91 (1.05)	0.57 – 5.72 (3.14)	-	-	1.14 – 11.4 (6.29)
Switches, contacts and relays	9.4 - 94 (51.70)	0.94 – 9.4 (5.17)	-	0.94 – 9.4 (5.17)	-	7.5 – 75.2 (41.36)
Lamps	8.16 – 26.5 (17.33)	0.41 – 1.33 (0.87)	-	-	-	7.75 – 25.18 (16.47)
Batteries	44.77	-	-	-	-	44.77
Polyurethane with mercury catalyst	0.2	-	-	-	0.2	-
Biocides/pesticides	-	-	-	-	-	-
Paints	-	-	-	-	-	-
Pharmaceuticals	40	-	-	-	40	-
Cosmetics	-	-	-	-	-	-
Totals	**104.4 – 224.5 (164.5)**	**1.5 – 12.6 (7.1)**	**0.6 – 5.7 (3.1)**	**0.9 – 9.4 (5.2)**	**40.2**	**61.2 – 156.6 (108.9)**

8 Other intentional product/process uses

This category covers mercury uses in a range of other intentional products and uses (UNEP, 2017). The various sub-categories and the primary release pathways are summarised in Table 8-1, which has been copied directly from the UNEP Toolkit.

Table 8-1: Toolkit framework for category 6 – other intentional product/process uses

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.6.1	Dental mercury amalgam fillings	x	**X**		**X**	**X**	OW
5.6.2	Manometers and gauges	x	**X**	x	**X**	**X**	OW
5.6.3	Laboratory chemicals and equipment	x	**X**		**X**	**X**	OW
5.6.4	Mercury use in religious rituals and folklore	**X**	**X**	**X**	**X**	**X**	OW
5.6.5	Miscellaneous product uses, mercury metal and other sources	**X**	**X**	**X**	**X**	**X**	OW

Notes: OW = National/overview approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

8.1 Dental mercury amalgam fillings

Mercury is used in a range of dental amalgams, with the mercury content typically around 45 to 50%. These amalgams are still used in New Zealand, although non-mercury alternatives are readily available (MoH, 2010, and H Trengrove, NZ Dental Association, pers comm, 2013).

Import data were obtained from Statistics New Zealand for the HS code 3006.40.01.00, dental cements and other dental fillings. The total imports under this code over the last 4 years have averaged 9,278 kg/year, which is about 30% down on the 13,500 kg/year reported for 2012. However, these figures are for gross weight (ie. including packaging) rather than the weight of amalgam.

For the 2012 inventory, three major suppliers of dental amalgam were contacted and the information provided by 2 of these indicated total imports for New Zealand of about 320 kg/year of dental amalgam, which equate to a total annual mercury input of about 150 kg/year. For 2016 four suppliers of dental amalgam were contacted. Two of these said they no longer sold mercury amalgam products and the other two reported 2016 sales equivalent to a mercury input of 37.3 kg.

Input and output estimates

The Toolkit recommends default factors of 0.05 – 0.2 grams/year per capita for estimating current mercury inputs via dental amalgams, which would give input rates for New Zealand (pop. 4.7 million) of between 237 and 948 kg/year. However, the information obtained from amalgam suppliers indicate that a more appropriate figure would be 37.3 kg/year, and this has been used for the estimates.

The output factors given in the Toolkit are 0.02 (2%) to air, 0.14 (14%) to water, 0.6 (60%) in products (ie teeth), and 0.24 (24 %) to waste. The outputs to water and wastes may be modified if the dental surgeries are fitted with high efficiency amalgam filters, which can remove up to 95% of the mercury from the water outputs. However, it was noted in the 2012 Inventory Report that these are not widely used in New Zealand, with about 50% of dentists using basic filter systems and the remainder having no filtration at all. The limited quantities of wastes collected by the filters are either disposed to landfill, recycled or exported but no specific data is available on the quantities of dental wastes that are recycled or exported.

The mercury input and output estimates for mercury dental amalgam are shown in Table 8-2. The figure shown for product represents an annual addition to the existing stocks of mercury in the teeth of most New Zealanders, which have not been assessed. Similarly, the figure shown for wastes does not include any amounts removed during filling replacement or tooth extraction, which would be very difficult to determine.

Table 8-2: Input and output estimates for mercury dental amalgam

Source	Activity, kg /yr	Mercury content, %	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr			
				Air	Water	Product	Waste
Dental amalgam, 2012	320	47%	150	3	21	90	36
Dental amalgam, 2016	79.4	47%	37.3	0.75	5.22	22.38	8.95

Certainty assessment

Activity data: HIGH (because it is based on supplier estimates)

Input estimates: LOW (because they are based on the Toolkit default factors)

Output estimates: LOW (because they are based on the Toolkit default factors).

8.2 Manometers and gauges

The most common uses of mercury in this sub-category are in blood pressure devices (sphygmomanometers) and in barometers. However, mercury may also be used for pressure (or vacuum) measurement in a range of industrial and laboratory applications (UNEP, 2017).

Fifteen New Zealand suppliers of medical equipment were contacted with regard to current stocks and annual sales of sphygmomanometers but only two of these reported any sales, with a total of 23 units sold in 2016. This is significantly up on the 3 units reported for 2012, but that information was only obtained from one supplier. The Toolkit indicates that each sphygmomanometer contains 75 grams of mercury, on average.

It was noted in the 2102 Inventory Report that there was a general move towards phasing out the use of sphygmomanometers and a similar situation was noted for mercury barometers.

Input and output estimates

On the basis of the above, the annual mercury inputs for this sub-category will be taken as 1.73 kg/year, with the same quantity estimated as an output in the Product category.

8.3 Laboratory chemicals and equipment

Mercury is used in laboratories in instruments, reagents, preservatives, and catalysts. Some of this mercury is released to air, primarily through lab vents. However, most of the mercury may be released in wastewater or disposed of as hazardous or municipal wastes (UNEP 2013).

The report on the 2012 Inventory included survey data for laboratory supply companies and most of the major government and commercial chemical laboratories. The results suggested total stock holdings of about 200 kg of elemental mercury and 60 kg of mercury-containing chemicals, and annual inputs of about 3 kg/year.

For the 2016 inventory the survey has been limited to current sales by laboratory supply companies. The three main laboratory supply companies were contacted for details of 2016 sales of mercury and mercury containing products. A total of 0.5 kg elemental mercury and 5.78 kg of mercury containing compounds were sold in 2016. Specific details for the types of mercury containing compounds were not provided. Conservatively, these have been assumed to be mercuric chloride, which gives a total mercury contribution of 4.77 kg (including the 0.5 kg of elemental mercury).

Input and output estimates

The annual sales data for elemental mercury has been taken as representing the total annual inputs for this sub-category. The Toolkit doesn't provide any specific output factors and notes that this is highly dependent on the waste management practices of individual laboratories. The feedback received from some of the New Zealand laboratories and universities in 2012 indicated that the bulk of the wastes are taken away by waste contractors. On that basis it has been assumed (through familiarity with laboratory practices) that only 5% of the inputs are discharged to air and 10% to wastewater, with the remainder going to wastes.

The mercury input and output estimates for laboratory chemicals are shown in Table 8-3.

Table 8-3: Input and output estimates for laboratory chemicals

Source	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr		
		Air	Water	Waste
Annual sales, 2012	55	2.75	5.5	46.75
Annual sales, 2012	4.77	0.24	0.48	4.05

Certainty assessment

Activity data: not relevant

Input estimates: MEDIUM (because they are based on the import statistics and partial survey responses)

Output estimates: LOW (because they are based on the assumed output factors).

8.4 Mercury use in religious rituals and folklore medicine

According to the Toolkit, mercury is used in certain cultural and religious practices, such as some Latin American and Afro-Caribbean communities, in the USA, Mexico, and probably elsewhere. Uses include carrying it in a sealed pouch or in a pocket as an amulet, sprinkling mercury on floors of homes or automobiles, burning it in candles, and mixing it with perfumes (UNEP, 2017). However, no information has been found on any such uses in New Zealand.

8.5 Miscellaneous product uses and other sources

The only other possible use considered for this category was explosives. Mercury fulminate has been used as an explosive in the past, but it is believed that this use was phased out about 50 or more years ago. Three explosives distributors were contacted for the 2012 Inventory Report and they all confirmed that there was no longer any mercury in any of their products. There is no reason to believe that this situation will be any different for 2016.

8.6 Summary for this category

The estimated inputs and outputs for the other intentional product/process uses are summarised in Table 8-4.

Table 8-4: Summary of inputs and outputs for other intentional product/process uses for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Dental mercury amalgam fillings	37.3	0.75	5.22	-	22.38	8.95
Manometers and gauges	1.73	-	-	-	1.73	-
Laboratory chemicals and equipment	4.77	0.24	0.48	-	-	4.05
Mercury use in religious rituals and folklore	-	-	-	-	-	-
Miscellaneous product uses, mercury metal, other sources	-	-	-	-	-	-
Totals	**43.8**	**1.0**	**5.7**	**-**	**24.1**	**13.1**

9 Production of recycled metals (secondary metal production)

This category covers mercury releases from the production of recycled metals, which is also referred to as secondary metal production (UNEP, 2017). The various sub-categories and the primary release pathways are summarised in Table 9-1, which has been copied directly from the UNEP Toolkit.

Table 9-1: Toolkit framework for category 7 –production of recycled metals (secondary metal production)

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.2.1	Recycled mercury	**X**	**X**	**X**	**X**	**X**	PS
5.2.2	Ferrous metals (iron and steel)	**X**	x	x		x	PS
5.2.3	Other recycled metals	**X**	x	x		x	PS

Notes: PS = Point source by point source approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

9.1 Recycled mercury

Metallic mercury can be recovered from a variety of waste materials by distillation, or retorting. For the 2012 Inventory Report a single commercial mercury recycling operation was identified in Waihi, which was mainly concerned with metal recovery from dental, photographic and printing wastes. For 2012 the company reported sales of 20 kg of mercury to small-scale gold miners, and exports of a further 240 kg. However, this operation has now closed down.

Other information obtained for the 2012 Inventory Report indicated that small quantities of mercury are occasionally picked up in local authority hazardous waste collection campaigns and some scrap metal dealers are also known to collect small quantities of mercury from old car bodies and home appliances. However, there is no cohesive data available on the overall mercury quantities. Some of the collected material is passed on to small-scale gold miners, but this appears to be a relatively informal arrangement. Several waste management companies are known to have collected waste mercury in the past, but this was mainly for export. There was only one active permit during 2016 for the export of mercury wastes, which may have included metallic mercury (see section 11.4).

In the absence of any definitive data on mercury recycling it has been assumed that the current quantities involved are no more than 20 kg per year, and that this will be for use in small-scale gold mining.

Certainty assessment

Activity data: LOW (because it was based on company data)

Input estimates: LOW (because it related directly to the activity data)

Output estimates: LOW (because the product outputs should be the same as the inputs).

9.2 Ferrous metals (secondary steel)

In the 2012 Inventory Report it was noted that there was only one secondary steel mill in New Zealand, which was operated by Pacific Steel Ltd in South Auckland. However, this plant was shut down in September 2015, with the business being transferred to the New Zealand Steel operations at Glenbrook – see section 4.5 (PSL, 2017). The same types of products are still being produced under the Pacific Steel brand but they are now manufactured from virgin steel rather than recycled materials.

The 2012 estimates for the Pacific Steel plant indicated mercury inputs of 2.0 kg/yr, with the outputs being distributed across air (33%) and waste (67%). However, for 2016 these figures will be reduced to zero.

9.3 Production of other recycled metals

This Toolkit sub-category covers the recycling of aluminium, zinc and other metals, but it is noted that very little is known about the mercury inputs and outputs for these activities. A similar situation applies in New Zealand.

For the 2012 Inventory Report, some survey data from the 2011 Dioxin Inventory for New Zealand (MfE, 2011) was used to estimate total mercury inputs of less than 0.6 kg/year for this source category. This estimate was not included in the 2012 inventory estimates because it was too low to be of any possible concern, and the same approach has been adopted here.

9.4 Summary for this category

The estimated inputs and outputs for the metal recycling category are summarised in Table 9-2.

Table 9-2: Summary of inputs and outputs for production of recycled metals for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Recycled mercury	20	-	-	-	20	-
Ferrous metals (iron and steel)	-	-	-	-	-	-
Other recycled metals	-	-	-	-	-	-
Totals	**20**	**-**	**-**	**-**	**20**	**-**

10 Waste incineration

This category covers mercury releases from the incineration of different types of wastes (UNEP, 2017). The various sub-categories and the primary release pathways are summarised in Table 10-1, which has been copied directly from the UNEP Toolkit.

Table 10-1: Toolkit framework for category 8 – waste incineration

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.8.1	Municipal waste incineration	**X**	x	x	x	**X**	PS
5.8.2	Hazardous waste incineration	**X**	x			**X**	PS
5.8.3	Medical waste incineration	**X**	**x**			**X**	PS
5.8.4	Sewage sludge incineration	**X**	**X**			**X**	PS
5.8.5	Informal waste incineration	**X**	**X**	**X**	**X**		PS

Notes: PS = Point source by point source approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

10.1 Municipal waste incineration

There are no municipal waste incinerators in New Zealand (MfE, 2000).

10.2 Hazardous waste incineration

There is only one high-temperature hazardous waste incinerator in New Zealand, which is operated by Dow AgroSciences Ltd at their agrichemical formulation plant in New Plymouth. This is used for the treatment and disposal of some of the wastes generated on-site that are potentially contaminated with agrichemicals. It is the only high-temperature hazardous waste incinerator currently permitted to operate in New Zealand under the *Resource Management (National Environmental Standards for Air Quality) Regulations 2004*.

The mercury emissions from the incinerator were tested in 2016 by an external contractor and found to be < 1.3 mg/hour for general waste, < 1.1 mg/hr for liquid wastes and 1.2 mg/hr for empty drum incineration. The estimated operating time for 2016 was 8,200 hours giving a maximum mercury emission of 9.84 grams per year (T Gellen, Dow AgroSciences, pers comm, 2017). This is less than the figure of 16.5 grams/year estimated for 2012. There is no information on the possible releases to other media, such as in wastes. However, the unit is not fitted with any particulate control equipment so it is reasonable to expect that all of the mercury will be emitted to air.

Certainty assessment

Activity data: not relevant

Input estimates: MEDIUM (because it was inferred from the air emissions data)

Output estimates: MEDIUM (because the air output was based on a single test exercise).

10.3 Medical waste incineration

There is only 1 medical waste incinerator in New Zealand, at the Grey Hospital in Greymouth. Medical waste incineration was widely practised in the past, but has been phased out in favour of alternative methods, such as steam sterilisation (MfE, 2011a).

The Grey Hospital incinerator is a diesel-fired, dual-chamber unit, with no add-on emission controls. In 2016 an estimated 78 tonnes of medical waste were incinerated (C Shaw, Grey Hospital, pers comm, 2017), which is much lower than the 200 tonnes/year estimated in 2012. The emissions have never been tested for mercury.

The Toolkit recommends default input factors for medical waste of 8 – 40 g/tonne, and indicates that all of the mercury will be emitted to air on units with no emission control equipment. Applying these factors to the Grey Hospital incinerator indicates an annual input rate of 0.62 to 3.12 kg/year for 2016 (mean 1.87 kg/year), compared to the figures of 1.6 to 8 kg/year reported for 2012 (mean 4.8 kg/year). The outputs to air will be the same as the inputs.

Certainty assessment

Activity data: MEDIUM (because it was an operator estimate)

Input estimates: LOW (because it was based on the Toolkit default factor)

Output estimates: LOW (because the output distribution was based on the Toolkit default factors).

10.4 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 (MfE, 2011a).

The incinerator normally processes about 1700 tonnes of wastewater solids per year, on a dry basis. However, the plant was closed for refurbishment for most of 2014 to 2016 and since re-opening has been burning on a 24 hr per day schedule. At current combustion rates an estimated 1,424 tonnes dry sludge will be consumed for the year (B Stevenson-Wright, Dunedin City Council, 2017).

The mercury inputs can be estimated from the composition data for biosolids, which is discussed in section 11.5. This indicates a mercury composition of 0.56 mg/kg for Dunedin (Green Island) biosolids, which suggests an annual input to the incinerator of 0.80 kg/year based on the current burn rate. The incinerator off-gases are tested annually for mercury, and the average mercury emission result for testing conducted in March 2017 indicates emissions of 0.667 kg/year. This agrees reasonably well with the estimate based on biosolids composition. The incinerator off-gases are treated by passing through the biofilter, and the tests on the latter shows that it captures more than 99% of the total mercury.

The Toolkit doesn't recommend any default output factors for sewage sludge incinerators, but quotes some US data that indicates that the emissions to air are minimal when the incinerators are fitted with scrubber systems. The results for the Dunedin plant are totally consistent with this observation, and it has been assumed that all of the mercury will be discharged via solid wastes, either in scrubber residues or in waste bark removed from the biofilter.

Certainty assessment

Activity data: MEDIUM (because it was an operator estimate)

Input estimates: MEDIUM (because it was based on previous data for biosolids composition)

Output estimates: LOW (because the output distribution was based on indicative US information).

10.5 Informal incineration

This Toolkit category covers unregulated waste disposal practices such as backyard rubbish burning. The estimates for this source given in the 2012 Inventory Report were based on data taken from the New Zealand Dioxin Inventory (MfE, 2011) which estimated that the quantity of domestic wastes burned annually in New Zealand, in 2008, was about 18,000 tonnes/year. There was no data available on the mercury content of New Zealand municipal solid wastes, but the Toolkit recommended default factors of 1 – 10 g/tonne. Applying this to the annual waste quantities indicated an annual mercury input of 18 - 180 kg/yr. However it was expected that the inputs were more likely to be at the lower end of this range because much of the waste burned in domestic rubbish fires is unlikely to be contaminated with mercury. For the output calculations, it was assumed that all of the mercury would be discharged to air.

There is no significant new information available on domestic waste burning in New Zealand, so the 2012 estimates will simply be carried over for 2016.

Certainty assessment

Activity data: LOW (because it was based on a limited amount of published survey data)

Input estimates: LOW (because it was based on the default Toolkit factors)

Output estimates: LOW (because the output distribution was assumed).

10.6 Other incineration

(Note: this is not a Toolkit category, but has been added to accommodate several other New Zealand incinerators).

The Dioxin Inventory (MfE, 2011) lists several other incineration sources in New Zealand, including 71 school incinerators, a quarantine incinerator, a single document incinerator, and 13 pet incinerators. However, the document incinerator has since been shut down. The estimated waste throughput for the school incinerators was only 70 tonnes/year, in total, and the quarantine incinerator throughput was 25 tonnes/year, respectively. The wastes burned in these units would have a similar composition to that burned in backyard rubbish fires, and would only add a further 0.5% to the estimated mercury inputs. Therefore, these sources have simply been added to the total informal waste incineration category.

The total estimated throughput for the pet cremators was about 260 tonnes/year, in 2008. This figure may have increased since then but there is no more recent data available. The pet cremators are similar in design to crematoria and can be assessed using the same approach as described in section 12.1, but with adjustment for a lower mercury content. Some indication of the likely mercury level in pets and other animals is given by the following 2 publications. A study on a range of healthy US animals found no mercury in dog tissues at a detection limit of 0.0002 g/kilogram (Penumarthy *et al*, 1980). However, a report on a small dog suspected of suffering from mercury poisoning found concentrations of 0.003 mg/kg (Farrar *et al*, 1994). On the basis of these studies, a mercury concentration of 0.001 g/kg has been used for the input estimates, to give an annual mercury input of 0.26 kg/year. It has been assumed that all of the mercury outputs will be released to air.

Certainty assessment

Activity data: LOW (because it was based on a limited amount of published source information)

Input estimates: LOW (because it was based on the default Toolkit factors for humans)

Output estimates: LOW (because the output distribution was assumed).

10.7 Summary for this category for 2016

The estimated inputs and outputs for waste incineration are summarised in Table 10-2.

Table 10-2: Summary of inputs and outputs for waste incineration for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Municipal waste incineration	-	-	-	-	-	-
Hazardous waste incineration	0.0098	0.0098	-	-	-	-
Medical waste incineration	0.62 – 3.12 (1.87)	0.62 – 3.12 (1.87)	-	-	-	-
Sewage sludge incineration	0.8	-	-	-	-	0.8
Informal waste incineration	18.0 – 180.0 (99.5)	18.0 – 180.9 (99.5)	-	-	-	-
Other (pet incinerators)	0.26	0.26	-	-	-	-
Totals	**19.7 – 184.2 (102.4)**	**18.9 – 183.4 (101.6)**	**-**	**-**	**-**	**0.8**

11 Waste deposition/landfilling and wastewater treatment

This category covers mercury releases from the disposal of solid and liquid wastes by landfilling, dumping, or discharge to wastewater treatment systems (UNEP, 2017). The various sub-categories and the primary release pathways are summarised in Table 11-1, which has been copied directly from the UNEP Toolkit.

Information on the handling and disposal of mercury-containing wastes by specialist waste management companies will also be covered at the end of this section. This includes exporting for treatment and disposal in other countries.

Table 11-1: Toolkit framework for category 9 – waste deposition/landfilling and wastewater treatment

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.9.1	Controlled landfills/deposits	x	x	**X**		**X**	OW
5.9.2	Diffuse deposition with some control	x	**X**	**X**		**X**	OW
5.9.3	Informal local disposal of industrial wastes	**X**	**X**	**X**			PS
5.9.4	Informal dumping of general waste	**X**	**X**	**X**			OW
5.9.5	Wastewater treatment systems	x	**X**	**X**		x	OW/PS

Notes: PS = Point source by point source approach; OW = National/overview approach;
X - Release pathway expected to be predominant for the sub-category;
x - Additional release pathways to be considered, depending on specific source and national situation.

One of the key points to recognise for this category is that the estimated inputs include the wastes that are generated by many of the sources discussed under previous categories. This means that there is inevitably some double accounting. However, the extent of this is not readily determined because the inputs are simply estimated using the default Toolkit factors

11.1 Controlled landfill/deposition

The mercury content in the general municipal waste stream can come from four main sources: 1) intentionally used mercury in spent products and process wastes; 2) mercury impurities in bulk materials (eg. paper, plastics, and metals); 3) mercury as an anthropogenic trace pollutant in bulk materials, and; 4) trace levels of mercury contamination of food wastes. In New Zealand, most municipal solid wastes are disposed to controlled landfills.

The key requirements for quantifying the inputs and outputs for this source are the total quantities of waste disposed to landfill in each year, and the average mercury content of that waste. The first of these is now readily available in New Zealand through the data collected through the Waste Disposal Levy scheme (MfE, 2017). From June 2015 to May 2016 the scheme recorded disposal of 3,276,960 tonnes of waste. Annual disposal quantities have been increasing at a rate of 7 – 10% per annum since 2014 so an additional 4% has been added to this total to give an estimated 3,408,038 tonnes for the 2016 calendar year. For 2012 the total was 2,513,927 tonnes.

The Waste Levy data only applies to commercial landfills accepting household waste, and does not include the waste disposed to cleanfill sites. However, there is no reason to expect significant levels of mercury contamination in cleanfill wastes, because mercury-containing wastes are usually excluded from these sites (eg. see MfE, 2002). The wastes disposed at privately-owned waste facilities, such as those operated by the pulp and paper mills, Huntly Power Station, and the gold mine tailings dams, have already been addressed in other sections (when relevant).

The general composition of the New Zealand municipal waste stream is reasonably well characterised, but there is no information available on the mercury content of the wastes. In the absence of this data, the Toolkit factors have been used. These recommend default factors of 1 – 10 g/tonne of waste for estimating the inputs, and output distribution factors of 0.01 (1%) to air and 0.0001 (0.01%) to water, with the remainder of the inputs being regarded as disposal to a reservoir.

The mercury input and output calculations for controlled landfill are shown in Table 11-2 for both 2012 and 2016. It should be noted that the Toolkit indicates that the lower rates would apply in countries where there was a high rate of removal of mercury-containing wastes from the municipal waste stream, and the upper rates apply where there is none. New Zealand is probably intermediate between these two options.

Table 11-2: Input and output estimates for controlled landfill

Source	Activity Rate, tonnes/yr	Mercury Content, g/tonne	Annual Inputs, kg/yr	Annual Mercury Outputs, kg/yr		
				Air	Water	Reservoir
Landfilling of wastes, 2012	2.5×10^6	1 - 10	2,500 – 25,000 (13,750)	25 – 250 (137.5)	0.25 – 2.5 (1.375)	2,475 – 24,748 (13,611.5)
Landfilling of wastes, 2016	3.41×10^6	1 - 10	3,410 – 34,100 (18,755)	34 – 341 (187.6)	0.34 – 3.41 (1.9)	3,375.6 – 33,756 (18,565.5)

Certainty assessment

Activity data: HIGH (because it is based on national levy data)

Input estimates: LOW (because they are based on the default Toolkit input factors)

Output estimates: LOW (because they are based on the default Toolkit output factors).

11.2 Diffuse deposition, informal disposal and dumping

These three Toolkit sub-categories have not been assessed. The first, controlled diffuse deposition, relates to the use of industrial wastes in road and building foundations. It is not known whether this occurs to any extent within New Zealand, although waste quantities of greater than about 0.5 tonnes would generally require a resource consent under the RMA.

Informal disposal also relates to industrial wastes, and especially those that may have been dumped in the past without any regulatory control. If this has occurred in New Zealand, the sites should show up in the list of hot-spots (ie. contaminated sites) discussed in section 13.

Finally, the informal dumping category relates to uncontrolled dumping of general wastes. There is almost certainly some uncontrolled dumping of solid wastes in New Zealand. However, no data is available on the likely extent of any of this.

11.3 Wastewater treatment systems

The most important factors determining releases of mercury from wastewater are the amount of mercury-containing wastes that are discharged to the system and the concentration of mercury in those wastes. Mercury content in wastewater mainly originates from two source groups: 1) intentionally used mercury in products and processes (such as from dental amalgams, spillage from thermometers and other devices, and industrial discharges); and 2) atmospheric mercury washed out by precipitation and carried in stormwater. As such, waste water treatment is an intermediate mercury release source where mercury inputs from original mercury contamination are treated and then re-distributed to water, land (through the application of sludge) and air (through sludge incineration). In addition some sludge is disposed to landfill (UNEP, 2017).

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 (Water NZ, 2017). 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 m^3/year. Consequently septic plant discharges are assumed to be 107,250,464 m^3/year giving a total wastewater production figure of 554,926,609 m^3/year. This is somewhat lower than the figure of 657,000,000 m^3/year given in the 2012 Inventory Report, but that was based on less detailed data.

There is no information available on the average mercury content of the wastes entering New Zealand wastewater plants. The Toolkit recommends default factors of 0.5 – 10 µg/litre, and output factors of 0.5 (50%) to water, 0.2 (20%) to land[19], and 0.3 (30%) to waste. The latter two factors reflect the fact that some biosolids are disposed to land (including use in compost) and some are disposed to landfills, although the exact distribution for New Zealand is unknown.

The mercury input and output calculations for wastewater treatment plants are shown in Table 11-3.

Table 11-3: Input and output estimates for wastewater treatment plants

Source	Activity Rate, Litres/yr	Mercury Content, µg/L	Annual Inputs, kg/yr	Annual Mercury Outputs, kg/yr		
				Water	Land	Waste
Municipal WWTP, 2012	657 x 10^9	0.5 - 10	328.5 – 6,570 (3,449.3)	164.3 – 3,285 (1,724.7)	65.7 – 1,314 (689.9)	98.5 – 1,971 (1,034.8)
Municipal WWTP, 2016	555 x 10^9	0.5 - 10	277.5 – 5550 (2,913.8)	138.7 – 2,775 (1,456.9)	55.5 – 1110 (582.8)	83.25 – 1,665 (874.1)

Certainty assessment

Activity data: MEDIUM (because it is based on past national data)

Input estimates: LOW (because they are based on the default Toolkit output factors)

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19 The toolkit refers to the land disposal route as "sector specific" wastes.

Output estimates: LOW (because they are based on the default Toolkit output factors).

11.4 Specialist waste disposal services

This category is not specifically listed in the Toolkit, but has been included here for the purposes of providing additional information on some of the New Zealand management practices for mercury-containing wastes.

Waste exports and imports

Exports of mercury-containing wastes require a permit under the *Imports and Exports (Restrictions) Act 1988*. These permits are issued by the Environmental Protection Authority, and in May 2017 there were no current permits listed for exports of mercury-containing wastes (EPA, 2017a). An earlier permit for the export of *miscellaneous mercury bearing waste including crushed lamps and fluorescent* tubes expired in July 2016. In addition, there are current permits for imports of small amounts of mercury metal wastes and mercury lamps, both from New Caledonia.

Waste disposal services

In the 2012 Inventory Report it was noted that there were four companies providing hazardous waste treatment and disposal services in New Zealand. The information obtained from some of these companies indicated that they occasionally accept small quantities of mercury and mercury-containing wastes, especially from dentists, hospitals, schools, universities and laboratories. These are either passed on to other users or diluted and disposed to landfill or wastewater treatment plants. The situation is expected to be much the same for 2016.

11.5 Summary for this category

The estimated inputs and outputs for waste deposition/landfilling and wastewater treatment are summarised in Table 11-4.

Table 11-4: Summary of inputs and outputs for waste deposition/landfilling and wastewater treatment for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Waste	Reservoir
Controlled landfills	3,410 – 34,100 (18,755)	34 – 341 (187.6)	0.34 – 3.4 (1.9)	-	-	3,375.6 – 33,756 (18,565.5)
Diffuse dumping	-	-	-	-	-	-
Informal - industrial wastes	-	-	-	-	-	-
Informal - general waste	-	-	-	-	-	-
Wastewater treatment	277.5 – 5550 (2,913.8)	-	138.7 – 2,775 (1,456.9)	55.5 – 1110 (582.8)	83.25 – 1,665 (874.1)	-
Totals	**3,687.5 – 39,650 (21,668.8)**	**34 – 341 (187.6)**	**139.1 – 2,778.4 (1,458.8)**	**55.5 – 1110 (582.8)**	**83.25 – 1,665 (874.1)**	**3,375.6 – 33,756 (18,565.5)**

12 Crematoria and cemeteries

This category covers mercury releases from cremation and burial of human bodies (UNEP, 2017). The various sub-categories and the primary release pathways are summarised in Table 12-1, which has been copied directly from the UNEP Toolkit.

Table 12-1: Toolkit framework for category 10 – crematoria and cemeteries

Toolkit Chapter	Sub-category	Air	Water	Land	Product	Waste/ residue	Main approach
5.2.1	Crematoria	X				X	OW
5.2.2	Cemeteries			X			OW

Notes: OW = National/overview approach;

X - Release pathway expected to be predominant for the sub-category;

x - Additional release pathways to be considered, depending on specific source and national situation.

12.1 Crematoria and cemeteries

The mercury releases from this source, and also in cemeteries, comes from the mercury present in the corpses, mainly as a result of the mercury in dental amalgam fillings. In cremation, this is predominantly released to air, while in cemeteries it is released to land.

Annual data obtained from the Department of Internal Affairs (V Millar, pers comm, 2013) show that for 2016 there were 31,333 registered deaths with 20,129 estimated cremations or 64% of the total. As might be expected the total is only slightly up on the 30,099 deaths reported in 2012, for which 63% were cremated[20].

No information has been found on the mercury content of New Zealanders, so the Toolkit default factors of 1 – 4 g/body have been used. The input and output estimates for cremation and cemeteries are shown in Table 12-2.

Table 12-2: Input and output estimates for cremation and cemeteries

Source	Activity Rate, corpses/yr	Mercury content, g/corpse	Annual Mercury Inputs, kg/yr	Annual Mercury Outputs, kg/yr	
				Air	Land
Cremation, 2012	19,053	1 – 4	19.1 – 76.2 (47.7)	19.1 – 76.2 (47.7)	-
Cremation, 2016	20,129	1 - 4	20.1 – 80.5 (50.3)	20.1 – 80.5 (50.3)	-
Cemeteries, 2012	11,046	1 - 4	11.0 – 44.2 (27.6)	-	11.0 – 44.2 (27.6)
Cemeteries, 2016	11,204	1 - 4	11.2 – 44.8 (28.0)		11.2 – 44.8 (28.0)

20 The cremation/burial split is a little uncertain because it is based on the place of disposal, rather than the method of disposal (which is not recorded). Also, a small number of the burials may have taken place in other countries.

Certainty assessment

Activity data: MEDIUM (because it was based on national data, but with some uncertainties)

Input estimates: LOW (because it was based on the Toolkit default factors)

Output estimates: MEDIUM (because the air/land distribution is quite clear-cut. The only uncertainty is in the small amounts of mercury that may be present in crematoria ash).

12.2 Summary for this category

The estimated inputs and outputs for crematoria and cemeteries are summarised in Table 12-3.

Table 12-3: Summary of inputs and outputs for crematoria and cemeteries for 2016

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Crematoria	20.1 – 80.5 (50.3)	20.1 – 80.5 (50.3)	-	-	-	-
Cemeteries	11.2 – 44.8 (28.0)	-	-	11.2 – 44.8 (28.0)	-	-
Totals	**31.3 – 125.3 (78.3)**	**20.1 – 80.5 (50.3)**	**-**	**11.2 – 44.8 (28.0)**	**-**	**-**

13 Potential hotspots

This category covers sites where previous land use activities may have caused contamination. Some of the types of sites where mercury might be an issue include the following:

- Historical gold and mercury mining sites
- Closed landfills
- Former agricultural sites, include pesticide manufacturing and storage, and market gardens/orchards
- Old industrial sites, such as tanneries, chlor-alkali plants, and battery manufacturers
- Government properties, including dental schools and defence bases
- Boat repair yards and slipways

For the 2012 Inventory contact was made with all Regional Councils and Unitary Authorities regarding their current knowledge of contaminated sites. Replies were received from 14 of these councils, with 10 indicating that they had no knowledge of any mercury-contaminated sites within their regions (other than sites where the mercury is simply an incidental, low level, contaminant). Other responses covered the following matters:

- A former mercury mine site in Northland is likely to be contaminated, though levels have not been confirmed.
- Both the Tasman and West Coast regions have old gold mining sites that may be contaminated with mercury.
- A power station site in Canterbury is known to be contaminated with mercury, but the extent of contamination has not been determined.
- Elevated mercury levels have been detected in many orchards and ex-mine sites, however generally not above the rural residential standard of 300mg/kg for inorganic mercury in soils. As an example, the Waikato Regional Council noted that at one highly contaminated former tailings dam (the Tui mine), the average concentration of mercury is less than 30mg/kg.

It was also confirmed that there are no contaminated sites specifically associated with the two chlor-alkali plants that were previously operated at the two North Island kraft pulp paper mills (see section 6.1). These plants were shut down in the 1980s and it is believed that the sludge and other residues were disposed to the companies' solid waste disposal facilities.

The above information has not been updated for the current work.

14 Summary and discussion

14.1 High level summary of mercury inputs and outputs

A summary of the mercury inputs and outputs for New Zealand, at the level of the main Toolkit source categories, is given in Table 14-1.

Table 14-1: High level summary of mercury inputs and outputs for New Zealand, 2016*

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
1. Extraction and use of fuels/energy sources	318.3 – 2515.7 (1417.0)	302.4 – 2.133.8 (1,218.1)	8.9 – 97.7 (53.3)	1.5 – 5.3 (3.4)	-	5.51 – 278.8 (142.1)
2. Primary (virgin) metal production	1570.8 – 13,305.2 (5,044.7)	85.7 – 614.2 (254.2)	38.2 – 270.3 (106.4)	1,365 – 11,811 (4.426)	60.3 – 525 (196.7)	21.4 -85.6 (53.5)
3. Production of other minerals and materials	61.4 – 123.5 (92.4)	1.2 – 3.8 (2.5)	-	59.7 – 118.1 (88.9)	0.5 – 1.6 (1.1)	-
4. Intentional use in industrial processes	-	-	-	-	-	-
5. Consumer products with intentional use	117.2 – 225.5 (171.3)	2.2 – 12.7 (7.4)	0.6 – 5.7 (3.1)	0.9 – 9.4 (5.2)	40.2	73.3 – 157.5 (115.4)
6. Other intentional products/processes	43.8	1.0	5.7	-	24.1	13.1
7. Production of recycled metals	20	-	-	-	20	-
8. Waste incineration	19.7 – 184.2 (102.4)	18.9 – 183.4 (101.6)	-	-	-	0.8
9. Waste deposit/landfill and wastewater treatment	3,687.5 – 39,650 (21,668.8)	34 – 341 (187.6)	139.1 – 2,778.4 (1,458.8)	55.5 – 1110 (582.8)	-	83.3 – 1,665 (874.1)
10. Crematoria and cemeteries	31.3 – 125.3 (78.3)	20.1 – 80.5 (50.3)	-	11.2 – 44.8 (28.0)	-	-
Totals, all groups	**5,857 – 56,192 (28,632)**	**465 – 3,370 (1,822)**	**192 – 3,158 (1,627)**	**1,494 – 13,098 (5,142)**	**145 – 610 (282)**	**185 – 2,200 (1,192)**

(* The totals in the table may not exactly equal the sum of displayed data, due to rounding)

By far the greatest quantities in the inputs column are for category 9, waste disposal. However, describing these as inputs is not really correct – they would be better considered as secondary or down-stream inputs, in that they are the result of many of the past and current outputs from all other categories, plus contributions from indirect sources, such as mercury in foods and in airborne dust. In addition, most of the mercury in the solid waste stream is simply placed into long-term storage (ie. controlled landfill), rather than being mobilised into the environment. This was assigned to a ‘Reservoir’ output category, which has not been included in the table (refer section 11.1 for further details).

Apart from the waste category, the next highest input is from primary metal production and, in particular gold and silver mining. In this case, the bulk of the inputs and outputs are associated with the extraction of very large volumes of ore, which contains very small amounts of mercury. The ore is processed to remove the gold and silver, and then it is returned to the land. It is debateable whether this should be regarded as a true mobilisation of mercury.

The next highest input category is the extraction and use of fuels and other energy sources, with the dominant contributor here being geothermal energy. Below that, the most notable source categories are production of recycled metals and consumer products with intentional use of mercury.

The relative inputs from these and all other categories are illustrated in the figure below, which is based on the mid-range values reported for each category.

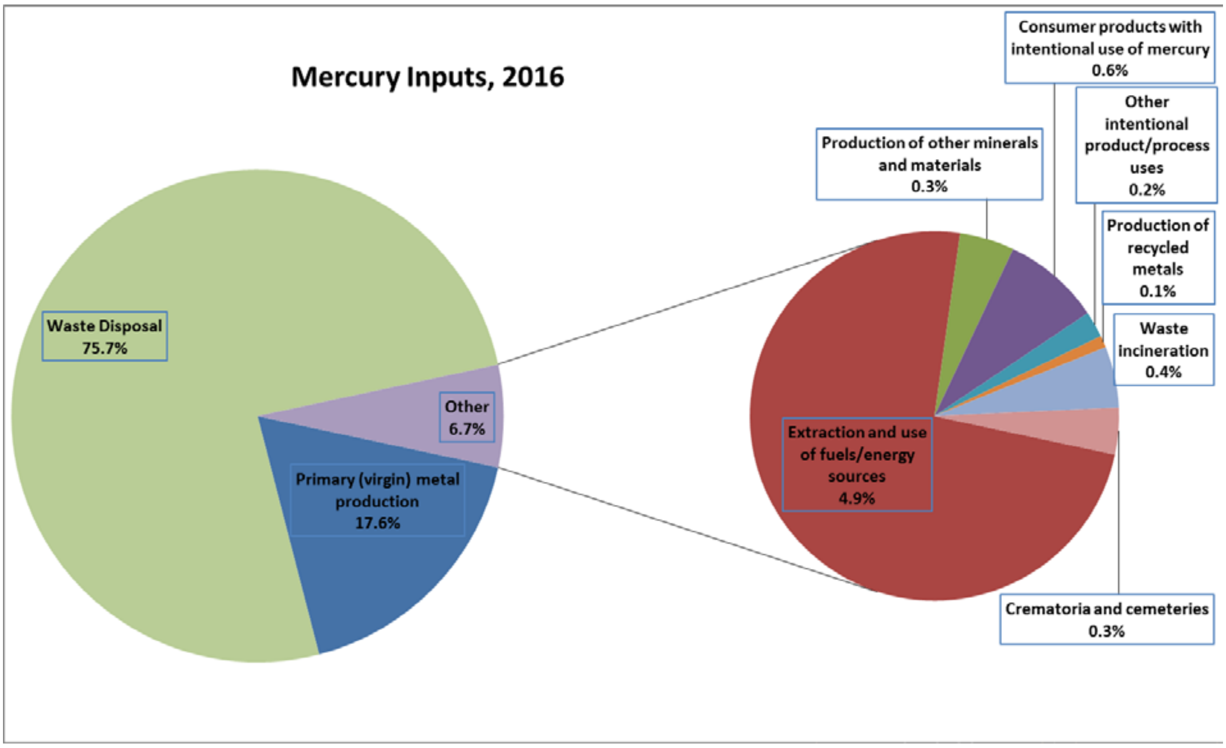


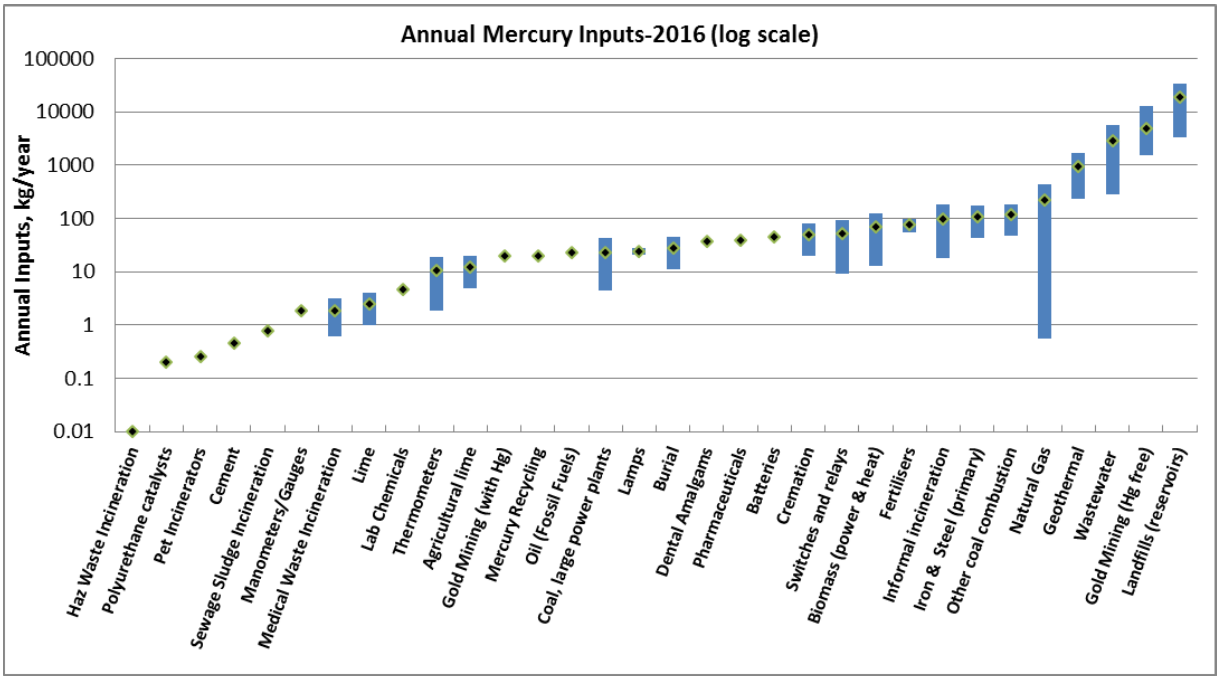
Figure 14-1: High level graphical summary of mercury inputs

14.2 Source by source summary of mercury inputs

A detailed source by source listing of all of the individual inputs and outputs for New Zealand sources is given in Table 14-2 at the end of this section. A relative ranking of the inputs from each of the sources is also illustrated in Figure 14-2 below, with the size of each bar giving a simple indication of the level of uncertainty associated with each estimate.

As shown in the figure, the most significant input sources are solid waste disposal (landfills), gold and silver mining, wastewater treatment and disposal, and the extraction and utilisation of geothermal energy. The extraction and processing of natural gas may also be a significant contributor but the uncertainties associated with the estimates for this source are very high.

Figure 14-2: Ranking of mercury inputs by individual sources



14.3 Changes in mercury inputs since 2012

Many of the mercury input estimates for 2016 show changes from those given in the 2012 Inventory Report. Some of these changes are simply due to the normal year to year variations in commercial or industrial activity while others simply relate to changes in the population. However, the changes for about half of the sources are believed to be due to specific causes, and these are noted below.

Plant Closures

The estimates for cement manufacture are down by about 20% due to closure of the Westport plant, and those from secondary steel production have been eliminated by the closure of the Pacific Steel plant in Auckland.

The only known mercury recycling operation has ceased operation although there may be other unidentified small scale operators working in that area. The known operation was mainly concerned with metal recovery from dental, photographic and printing wastes, so it is likely that these wastes will now be disposed to landfill, with or without pre-treatment.

Changes in Energy Production and Use

The estimated releases from coal burning at the Huntly Power station are down by more than 80% from 2012 because the use of the coal-fired units is being phased out as they reach the end of their operational life. In principle the rate of coal burning could still be maintained at the 2012 levels but this is only likely to occur in the event of a major shortfall in generation from other types of energy sources.

The estimated releases from extraction and use of natural gas and geothermal energy are up by about 25 and 30%, respectively, due to the increased utilisation of these energy sources.

Agriculture Activity

The mercury releases from agricultural lime show a reduction of 30% but the activity data was based on 2011 and 2015 rather than 2012 and 2016. The national data for this mineral show marked fluctuations from year to year.

Reductions in Mercury Use in Consumer Goods and Related Products

There have been some marked reductions in this area and especially in the following:

- Mercury thermometer sales are only 58% of those in 2012
- Imports of mercury-containing lamps are down by 50%
- The use of mercury-based light sources in computer screens has been virtually eliminated
- Battery imports have increased slightly but reductions in the mercury content have reduced the overall mercury inputs by about 40%
- Sales of dental amalgams containing mercury are down by about 75%.

Sales of laboratory chemicals containing mercury have also dropped markedly but this may simply reflect random fluctuations in the relatively small numbers of purchases of these items.

Waste Disposal

The mercury input estimates for landfills increased by 35% which simply reflects the annual growth in national solid waste quantities.

Data Quality Changes

The 2016 estimates for gold and silver mining were up by a factor of 2.6 times on those for 2012. However, this was primarily because of deficiencies in the ore quantity data used for the 2012 estimates.

The estimates for inputs from sphygmomanometers also show a marked increase because annual sales data was obtained from two suppliers as opposed to only one in 2012. Additional information obtained for the 2012 Inventory report indicates that the medical profession is generally moving away from the use of instruments that contain mercury.

The estimates for inputs from phosphate fertiliser are up by about 75% on 2012, but this is because the previous estimates were incorrectly based on the import quantities of phosphate rock rather than the superphosphate product sold by the fertiliser companies.

The estimates for releases from wastewater were down by 15% because the data used for the 2016 estimates was more comprehensive that that available in 2012.

14.4 Summary of mercury outputs

The five charts given below provide summaries of the relative contributions from each source category to the various outputs to air, water, land, waste and in products. The key points to note from these charts are as follows:

- The outputs to air are dominated by fuel/energy use, especially geothermal. Other notable contributors, in decreasing order of significance are primary metal production (gold and silver), waste disposal, waste incineration and crematoria.
- The outputs to water are totally dominated by waste disposal, especially wastewater discharges. Primary metal production and fuel/energy use are the next most significant contributors.
- The outputs to land are dominated by primary metal production (gold and silver) with other notable contributions from waste disposal and the production and use of other minerals and materials.
- The outputs via products are dominated by primary metal production (gold and silver) but with other significant contributions coming from other intentional products/processes, consumer products and metal (mercury) recycling.

- The outputs to waste are dominated by the waste disposal category, with other notable contributions from consumer products, fuel/energy use, primary metal production and other intentional products/processes.

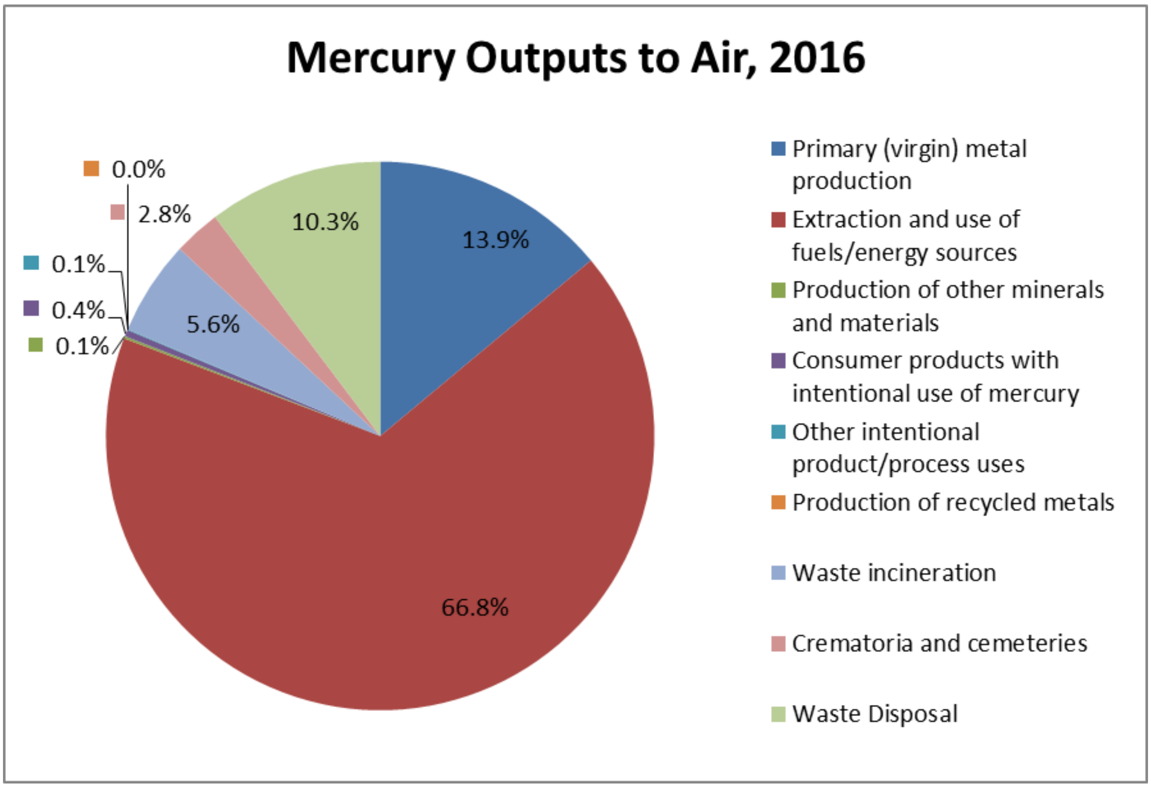


Figure 14-3: Relative mercury outputs to air, by source category

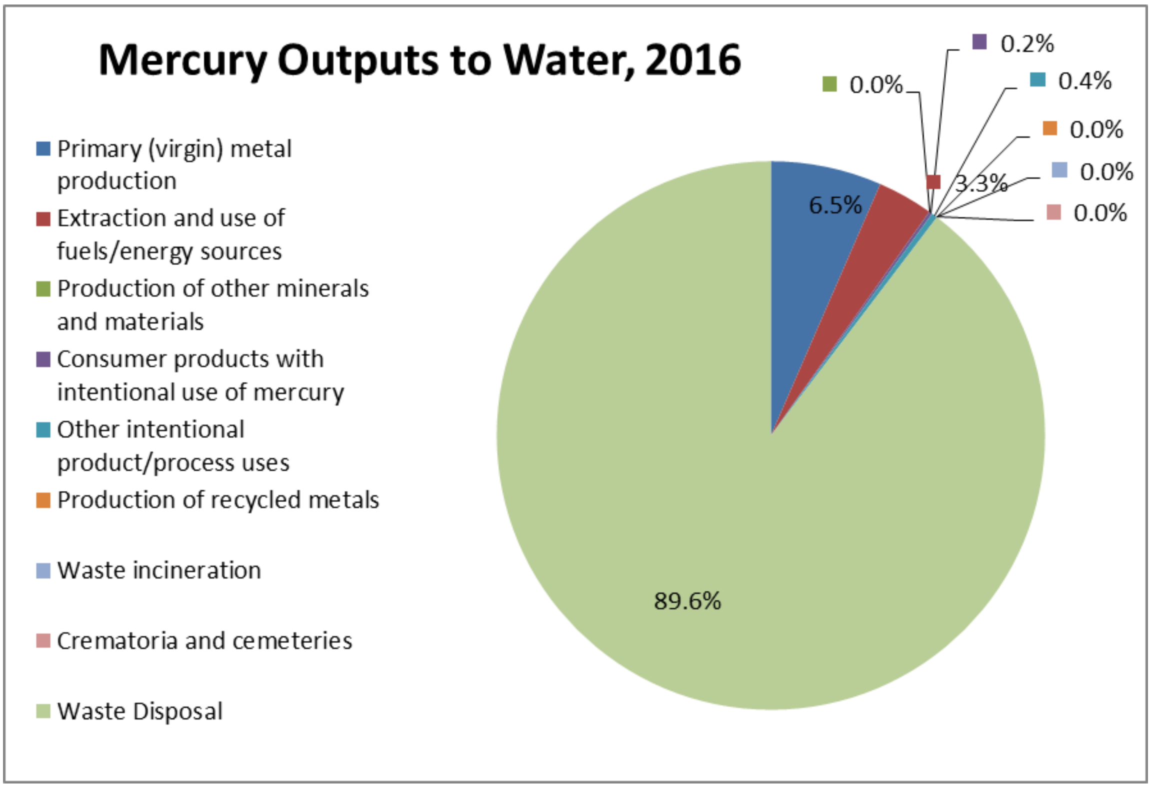


Figure 14-4: Relative mercury outputs to water, by source category

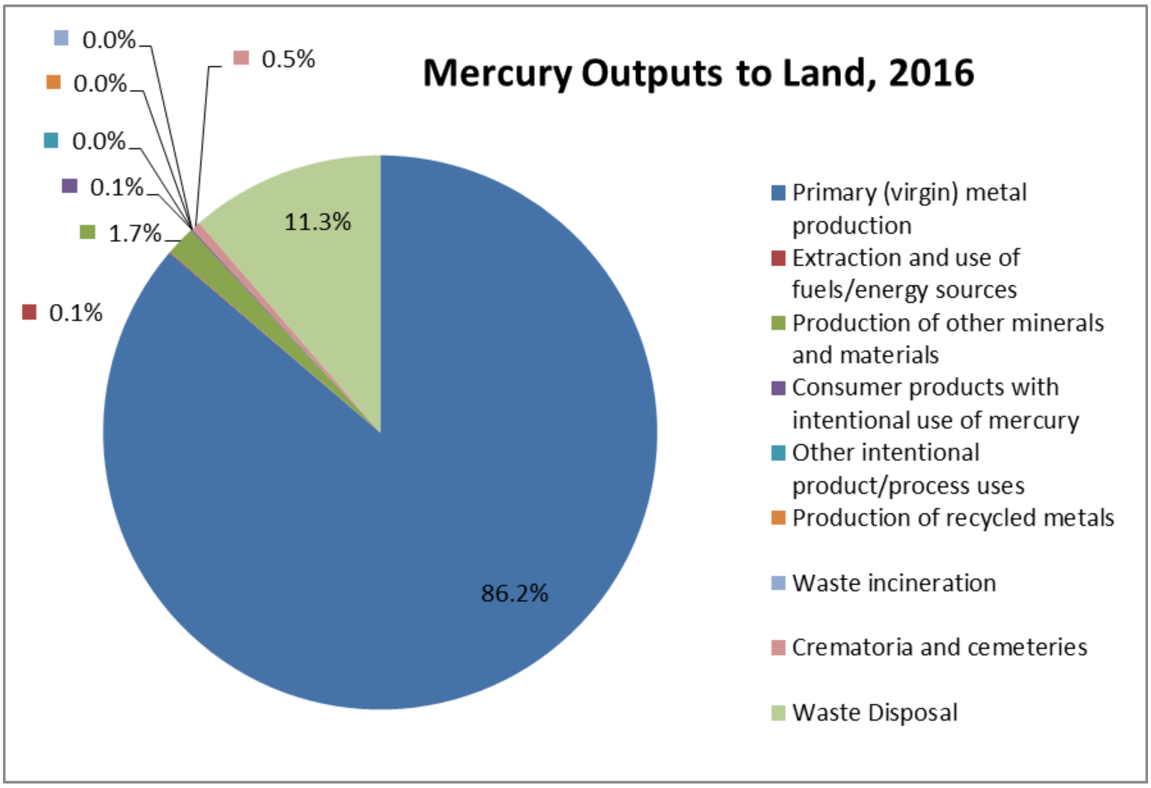


Figure 14-5: Relative mercury outputs to land, by source category (excluding primary metal production)

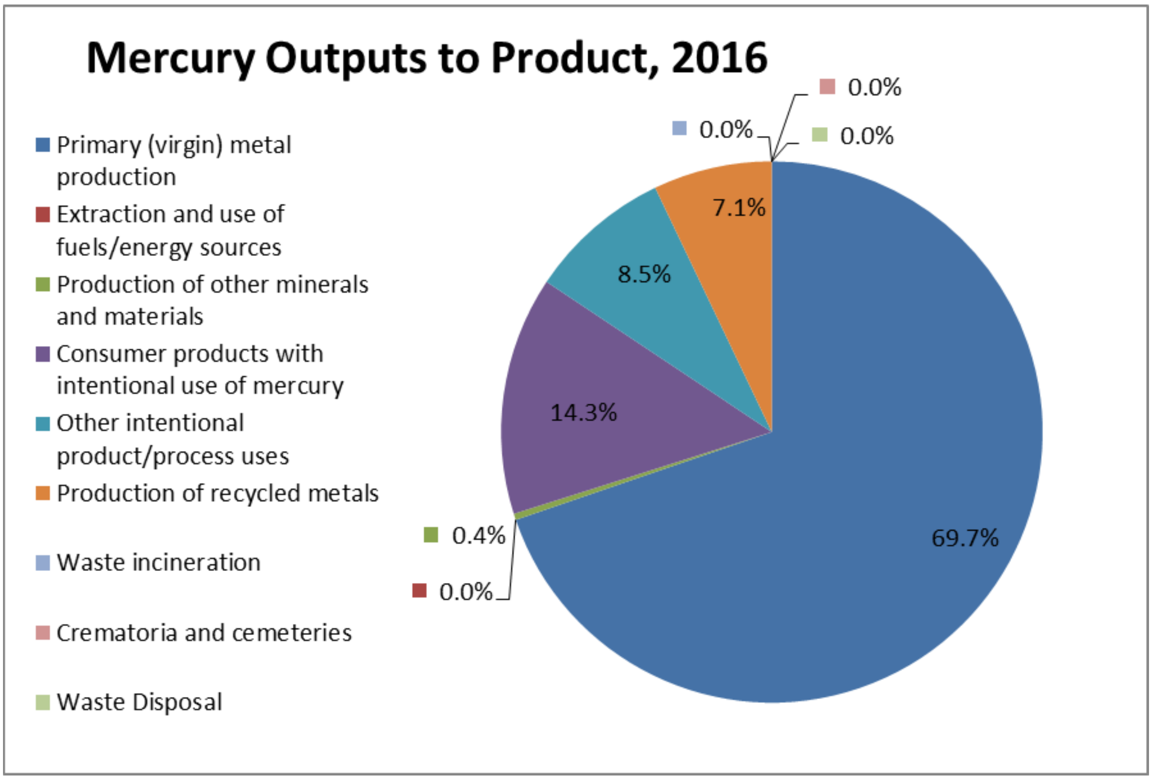


Figure 14-6: Relative mercury outputs to products, by source category

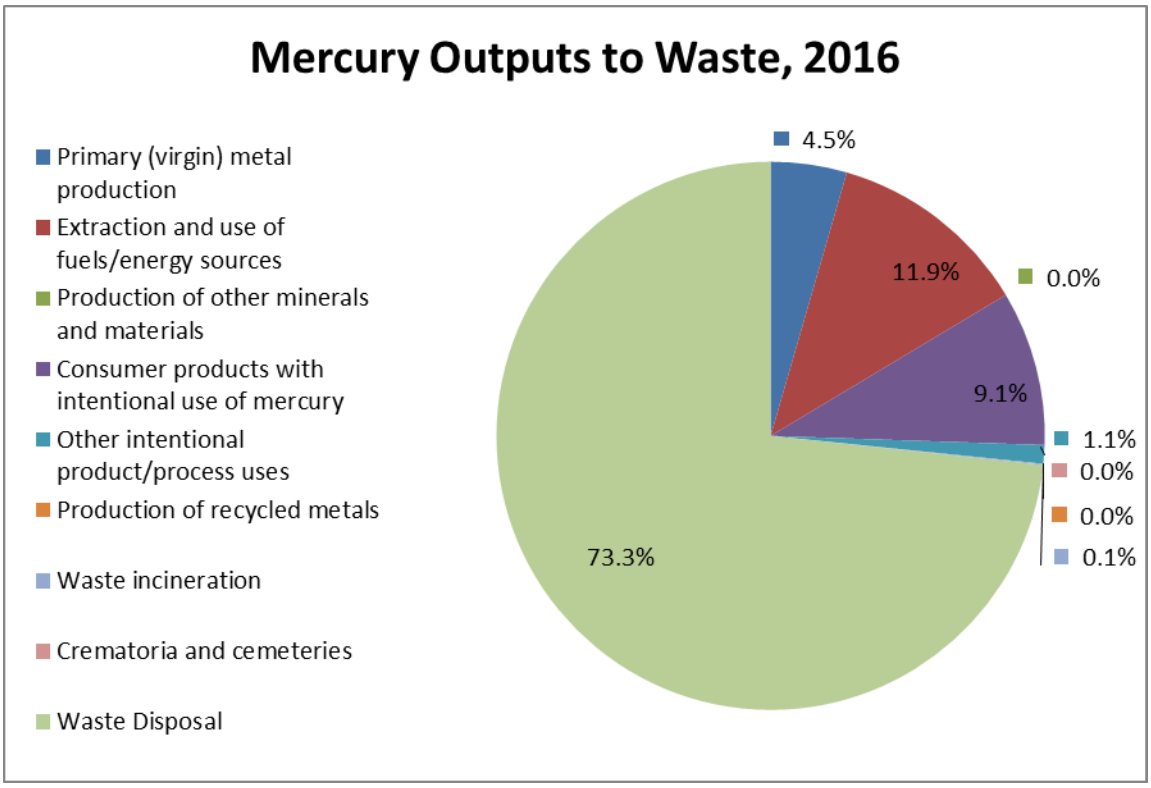


Figure 14-7: Relative mercury outputs to waste, by source category

Table 14-2: Detailed listing of mercury inputs and outputs*

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Coal – large power plants	4.47 – 42.42 (23.44)	4.02– 38.17 (21.10)	-	0.45 – 4.24 (2.34)	-	-
Other coal combustion	47.0 – 187.1 (117.1)	44.6 – 177.8 (111.2)	-	-	-	2.35 – 9.21 (5.78)
Oil extraction, refining and use	23.2	19.1	0.19	1.08	-	2.82
Gas extraction, refining and use	0.56 – 444.6 (222.6)	0.11 – 88.9 (44.52)	0.11 – 88.9 (44.52)	-	-	0.34 – 266.8 (133.6)
Biomass fuel	12.6 – 126 (69.3)	12.6 – 126 (69.3)	-	-	-	-
Geothermal power	230.5 – 1,692.4 (961.5)	221.9 – 1683.8 (952.9)	8.6	-	-	-
Gold & silver production, with mercury	20	4	8	8	-	-
Gold & silver production, without mercury	1,508 – 13,114 (4,918)	60.3 – 525 (196.7)	30.2 – 263 (98.4)	1,357 – 11,803 (4,426)	60.3 – 525 (197)	-
Ferrous metals production (iron & steel)	42.71 - 171.2 (106.9)	21.4 – 85.6 (53.5)	-	-	-	21.4 – 85.6 (53.5)
Cement production	0.47	0.33	-	-	0.14	-
Lime production	1.23 – 4.91 (3.07)	0.86 – 3.44 (2.15)	-	-	0.37 – 1.47 (0.92)	-
Phosphate fertiliser	54.8 – 98.6 (76.7)	-	-	54.8 – 98.6 (76.7)	-	-
Agricultural lime application	4.88 – 19.51 (12.20)	-	-	4.88 – 19.51 (12.20)	-	-
Thermometers with mercury	1.91 – 19.05 (10.5)	0.19 – 1.91 (1.1)	0.57 – 5.72 (3.1)	-	-	1.14 – 11.4 (6.3)
Electrical switches, contacts and relays with mercury	9.4 - 94 (51.7)	0.94 – 9.4 (5.17)	-	0.94 – 9.4 (5.17)	-	7.5 – 75.2 (41.36)
Light sources - lamps	8.16 – 26.5 (17.3)	0.41 – 1.33 (0.87)	-	-	-	7.75 – 25.18 (16.47)
Light sources - LCDs	0	-	-	-	-	-

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Batteries containing mercury	44.77	-	-	-	-	44.77
Polyurethane with mercury catalyst	0.2	-	-	-	0.2	-
Pharmaceuticals for human and veterinary uses	40	-	-	-	40	-
Dental mercury amalgam fillings	37.3	0.75	5.22	-	22.38	8.95
Manometers and gauges	1.84	-	-	-	1.84	-
Laboratory chemicals and equipment	4.77	0.24	0.48	-	-	4.05
Recycled mercury	20	-	-	-	20	-
Secondary ferrous metals (iron and steel)	0	0	-	-	-	0
Hazardous waste incineration	0.0098	0.0098	-	-	-	-
Medical waste incineration	0.62 – 3.12 (1.87)	1.6 – 8 (4.8)	-	-	-	-
Sewage sludge incineration	0.8	-	-	-	-	0.8
Informal waste incineration	18.1 – 180.9 (99.5)	18.1 – 180.9 (99.5)	-	-	-	-
Other (pet incinerators)	0.26	0.26	-	-	-	-
Controlled landfills/deposits	3,410 – 34,100 (18,755)	34 – 341 (187.6)	0.34 – 3.4 (1.88)	-	-	-
Wastewater treatment systems	277.5 – 5550 (2,913.8)	-	138.7 – 2,775 (1,456.9)	55.5 – 1110 (582.8)	-	83.25 – 1,665 (874.1)
Crematoria	20.1 – 80.5 (50.3)	20.1 – 80.5 (50.3)	-	-	-	-
Cemeteries	11.2 – 44.8 (28.0)	-	-	11.2 – 44.8 (28.0)	-	-
Totals, all sources	**5,857 – 56,192 (28,632)**	**465 – 3,370 (1,822)**	**192 – 3,158 (1,627)**	**1,494 – 13,098 (5,142)**	**145 – 610 (282)**	**185 – 2,200 (1,192)**

(* The totals in the table may not exactly equal the sum of displayed data, due to rounding)

15 List of References

EPA, 2017. http://www.epa.govt.nz/search-databases/Pages/applications-search.aspx accessed on 10 May 2017. Environmental Protection Authority, Wellington.

EPA, 2017a. Waste Imports, Export, Transit Permits (http://www.epa.govt.nz/hazardous-substances/import-export/permit-holders/Pages/default.aspx, Environmental Protection Authority, Wellington, current at 1 May 2017.

Farrar, WP, Edwards, JF and Willard, D, 1994. Pathology in a Dog Associated with Elevated Tissue Mercury Concentrations. J Vet. Diagnostic Investigations, v6, p511 – 514.

Genesis Energy, 2017. https://www.genesisenergy.co.nz/huntly-power-station-plant-description accessed 5 May 2017.

Holcim, 2016. Media Statement; Holcim New Zealand Shipping Changes, Holcim New Zealand, 14 June 2016.

IPWEA 2016. Street Lighting and Smart Controls (SLSC) Roadmap. Report prepared for Department of the Environment and Energy, Australian Government, by Strategic Lighting Partners and Next Energy through the Institute of Public Works Engineering Australia.

Li, Z, 2002. Mineralogy and Trace Elements of the Cretaceous Greymouth Coals and their Combustion Products, PhD Thesis, University of Canterbury, Christchurch.

MBIE, 2016. Energy in New Zealand 2016 (for the 2015 calendar year) and web-based data tables for 2016. Wellington, Ministry of Business, Innovation and Employment.

MBIE, 2016a. Mining Production Statistics, obtained from the Petroleum and Minerals website, Ministry of Business, Innovation and Employment, Wellington, http://www.nzpam.govt.nz/cms/minerals/facts-and-figures.

MfE, 2002. A Guide to the Management of Cleanfills. Ministry for the Environment, Wellington.

MfE, 2008a. Mercury Inventory for New Zealand, 2008. Ministry for the Environment, Wellington.

MfE, 2011.New Zealand Inventory of Dioxin Emissions to Air, Land, and Water, and Reservoir Sources: 2011. Ministry for the Environment, Wellington.

MfE, 2017. New Zealand's Greenhouse Gas Inventory 1990–2015. Ministry for the Environment, Wellington.

MfE, 2017. See: http://www.mfe.govt.nz/issues/waste/waste-disposal-levy/index.html and http://www.mfe.govt.nz/issues/waste/progress-and-outcomes/waste-disposal-levy.html

MoH, 2010. Our Oral Health; Key Findings of the 2009 New Zealand Oral Health Survey. Ministry of Health, Wellington.

MoH, 2016. Immunisation Handbook 2014, 3rd edition, December 2016. Ministry of Health, Wellington.

Newcombe, VC, 2008. Mercury Use in the Goldmining Industry: A retrospective examination of elemental mercury use in the gold mining industry of the West Coast of New Zealand in the period 1984 – 1988. MPhil (science) thesis, Massey University, Wellington.

NZIC, 1998a. Steel Making, in Chemical Processes in New Zealand, 2nd Edition, volume 2. NZ Institute of Chemistry, Auckland.

NZIC, 1998b. The Manufacture of Sulfuric Acid and Superphosphate, in Chemical Processes in New Zealand, 2nd Edition, volume 1. NZ Institute of Chemistry, Auckland.

NZFMRA, 2013. Fertiliser guidelines obtained from the Fertiliser Association web site (www.fertiliser.org.nz), May 2013.

NZGA, 2017. New Zealand Geothermal Association web site http://www.nzgeothermal.org.nz/elec_geo.html, accessed May 2017.

Oceana Gold, 2017. Annual Information for the year ended December 31, 2016. Oceana Gold Corporation, Melbourne, 31 March 2017.

Penumarthy, L, Oehme, FW and Hayes, RH, 1980. Lead, Cadmium and Mercury Tissue Residues in Healthy Swine, Cattle, Dogs and Horses from the Midwestern United States. Arch. Environ. Contam. Toxicol. V9 p193 – 206.

PSL, 2017. Pacific Steel limited web site http://www.pacificsteel.co.nz/about/our-history/, accessed May 2017.

Tonkin and Taylor 2013. Assessment of Appropriate Disposal Options for Household (Dry Cell) Batteries (T and T ref. 29540). Report prepared for Auckland Council by Tonkin and Taylor Ltd.

UNEP, 2013. Toolkit for Identification and Quantification of Mercury Releases, 2nd edition, version 1.2, April 2013. United Nations Environment Programme, Geneva.

UNEP, 2017. Toolkit for Identification and Quantification of Mercury Releases, 2nd edition, version 1.4, January 2017. United Nations Environment Programme, Geneva.

Water NZ, 2017. National wastewater treatment plant database; www.waternz.org.nz/WWTPInventory, Water New Zealand, accessed May 2017.