Mercury Inventory for New Zealand: 2020

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 2020. 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, 2012 and 2016

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, published in 2019, 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. Bracketed results are mean of the range.

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
1. Extraction and use of fuels/energy sources	332.3 – 2,672.3 (1503)	318.8–2334.7 (1327)	7.4 – 83.3 (45.3)	2.0 – 17.3 (10.1)	-	4.1 – 236.6 (120.4)
2. Primary (virgin) metal production	448.7 – 566.6 (507.8)	25.18 – 84.05 (54.7)	8.71	59.79 – 118.66 (89.3)	1.42	353.7
3. Production of other minerals and materials	194 – 210.9 (202.4)	1.42 – 2.94 (2.2)	-	192 – 206.7 (199.3)	0.94	-
4. Intentional use in industrial processes	-	-	-	-	-	-
5. Consumer products with intentional use	106.3 – 209.1 (157.9)	1.36 – 11.24 (6.3)	0.16 – 1.66 (0.91)	1.0 – 10 (5.5)	26.76	77.0 – 159.4 (118.3)
6. Other intentional products/processes	50.9	1.1	6.93	-	29.1	13.8
7. Production of recycled metals	20.0	-	-	-	20	-
8. Waste incineration	12.1 – 14.6 (13.4)	11.2 – 13.7 (12.5)	-	-	-	0.88
9. Waste deposit/landfill and wastewater treatment	3,764.5 – 9,740 (6,754)	34.5	157.7 – 3,145.4 (1,652)	62.9 – 1258 (660.7)	-	94.4 – 1887 (991)
10. Crematoria and cemeteries	32.7 – 130.9 (81.8)	22.1 – 88.3 (55.2)	-	10.6 – 42.6 (26.6)	-	-
Totals	**4,962– 13,615 (9,291)**	**414.2 – 2,569 (1,494)**	**182.3– 3,247 (1,715)**	**357.7 – 1,623.8 (992)**	**78.2**	**514.4 – 2,681 (1,598)**

(Note: Landfill reservoir (3,415 kg) is not included in outputs here so total outputs will not equal total inputs. Also the totals in the table may not exactly equal the sum of displayed data, due to rounding.)

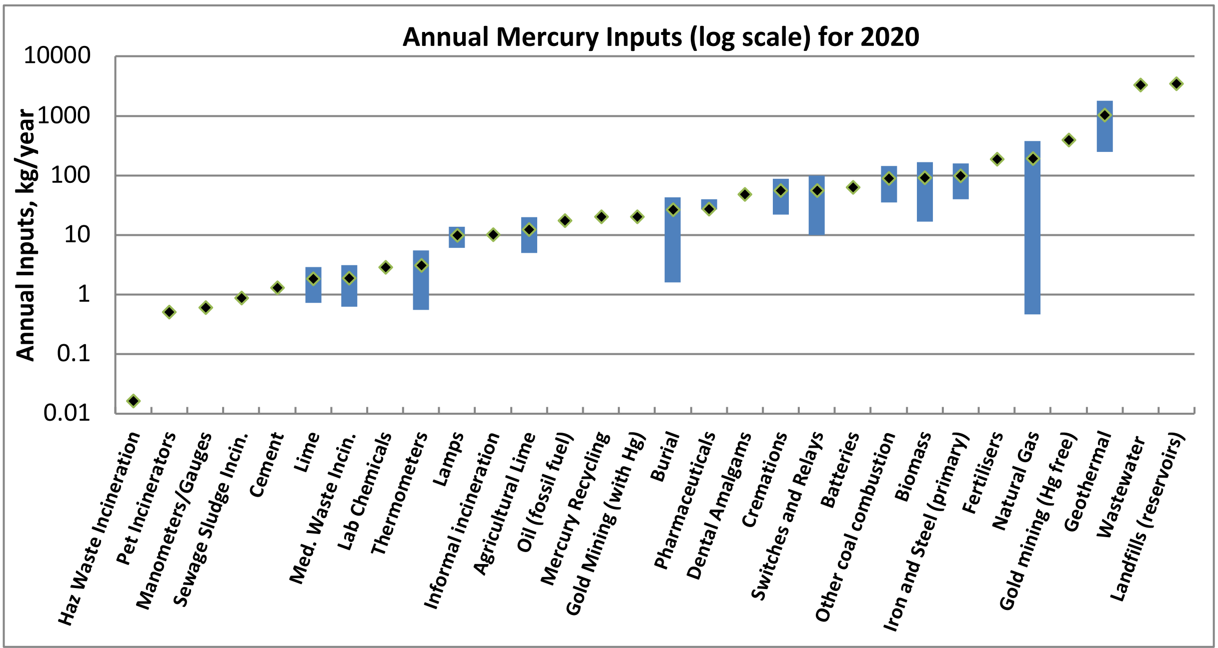
By far the greatest quantities in the inputs column are for category 9, waste disposal. However, most of the mercury in the solid waste stream is placed into long-term storage (ie. controlled landfill), rather than being mobilised into the environment. This was assigned to a 'Reservoir' output category, 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 the extraction and use of fuels and other energy sources, with the dominant contributor here being geothermal energy.

The next highest input category 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. Mercury accompanies the gold during the refining process and where the ore is pyrite it is removed as a waste product at the end.

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), wastewater treatment and disposal, the extraction and utilisation of geothermal energy and gold and silver mining. 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 2016

The estimated total input of mercury for New Zealand for 2020 is 9,291 kg which is significantly less than the 28,632 kg estimated for 2016. Most of the difference can be attributed to a five-fold reduction in the default UNEP Toolkit input factor for solid waste disposal which is one of the largest activities assessed. Other significant reductions have occurred with release estimates for gold and silver mining (not involving mercury amalgamation) as a result of improved data for mercury concentrations in ore. Mercury containing lights also show release reduction as high discharge mercury and sodium street lamps and compact fluorescent lamps continue to be replaced by LED equivalents. Releases from natural gas production are down by 15% reflecting a downward trend in gas production since 2017.

On the other hand some sources have seen significant increases in their mercury estimates. The estimated releases from coal burning at the Huntly Power station have increased four-fold from 2016 as a result of impaired hydro generation and natural gas shortages in 2020 requiring much greater thermal coal generation. Releases from phosphate fertiliser application have doubled since 2016 due to estimation improvements rather than an increase in application rates. Releases from biomass combustion have increased by 33%, again as a result of improvements in estimation.

Other changes are simply due to the normal year to year variations in commercial or industrial activity or simply relate to changes in the population. For example wastewater generation and cremations are proportional to population size.

COVID-19 did have some influence on commercial and industrial activity in 2020 although its effect was not as great as might have been anticipated and varied according to sector. Fuel refining was adversely affected, particularly aviation fuel, which led to mercury release reductions.

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 , crematoria, waste disposal and waste incineration.
- The outputs to water are totally dominated by waste disposal, especially wastewater discharges. Extraction and use of fuels and primary metal production are the next most significant contributors.
- The outputs to land are dominated by waste disposal and production of minerals with mercury impurities.
- The outputs to products are comprised largely of consumer products with intentional use of mercury, other intentional product/process use and production of recycled metals.
- The outputs to waste feature waste disposal and primary metal production as the largest sources with other notable contributions from consumer products and fuel/energy use.

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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: 2020

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 2020. 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, 2012 and 2016 (MfE, 2008, MfE, 2013 and MfE 2018).

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.

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.

While the 2008 and 2012 New Zealand mercury inventories provided background information for the government leading up to the decision to sign the Convention, the 2016 inventory and the current work are intended to provide updates of that information. They 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 December 2019. 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 January 2017
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. Wherever possible local output factors have been determined, with use of Toolkit default factors reserved for situations where this was not feasible or practicable.

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. Revised versions of the Toolkit (v1.2 and v1.4 were published in 2013 (UNEP, 2013) and 2017 (UNEP 2017) and were used for the preparation of the 2012 and 2016 inventories for New Zealand. The most recent version (v1.5) was published in December 2019 (UNEP, 2019). This version of the Toolkit was used for the current work. Changes to input factors made in this revision which are relevant for New Zealand were as follows:

- For Section 4.3 (Gold extraction and processing not involving mercury amalgamation) the default input factor has been changed from 15g Hg /tonne to 5.5 g Hg /tonne (although it should be noted local input factors are used to estimate this source).
- For Sections 11.1 and 11.2 (Solid waste disposal) the default input factor has been changed from 5g Hg/tonne to 1 g Hg /tonne.
- For Section 7.3 (Light sources with mercury) the default input factor for double ended fluorescent tubes has been changed from 25 mg Hg / item to 8 mg Hg / item.
- For Section 7.3 (Light sources with mercury) for single ended compact fluorescent lamps the default input factor has been changed from 10 mg hg / item to 2.7 mg Hg / item.
- For Section 7.3 (Light sources with mercury) for high pressure mercury vapour lamps the default input factor has been changed from 30 mg Hg / item to 40 mg Hg/item.

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 those previously prepared 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

[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.

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

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 2020 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, 2019). 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. One of the Rankine units has since been decommissioned permanently but three units were in full operation in 2020.

The amount of coal burnt in any particular year at Huntly power station is dependent on a number of factors including the amount of electricity that can be provided by hydro generation. In 2020 New Zealand had a spell of warm dry autumn weather which extended into the winter months resulting in annual hydro generation dropping by 5.2%. In addition the HVDC Cook Strait cable underwent refurbishment in 2020 resulting in a requirement for

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.

higher thermal electricity generation in the North Island. Coal consumption at Huntly in 2020 was 19.5 (PJ)[3] which is significantly higher than the 4.8 PJ/annum consumed in 2016. (MBIE, 2021)[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 total coal consumption by Huntly Power Station in 2020 was 898,500 tonnes, compared to 223,242 tonnes in 2016 and 1,270,000 tonnes in 2012 (E LaFace, Genesis Energy, pers comm, 2022).

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 and 2016. As shown, there has been a marked increase in both inputs and outputs from 2016 figures due to the increase 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)
Huntly Power Station, 2020	898,500	0.02 -0.19	18.0 – 170.7 (94.3)	16.2 – 153.6 (84.9)	1.8 – 17.1 (9.45)

(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).

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

New Zealand produces three types of coal – bituminous, sub-bituminous and lignite. Bituminous coal has the highest energy value and is mined solely on the South Island's West Coast. Of New Zealand's total production of bituminous coal in 2020 (1,128,917 tonnes) almost all was exported (1,107,741 tonnes) to be used as coking coal in the world's steel blast furnaces (MBIE 2021).

Lignite has the lowest energy of the three coal types and is mined chiefly at two Southland coal fields – Waimumu and Ashers (NZ Petroleum and Minerals 2022) and is used in the lower South Island. New Zealand produced 297,690 tonnes of lignite in 2020 (MBIE 2021)

Sub-bituminous coal is intermediate in energy quality and is mined at several opencast mines in both the North Island and the South Island. Two mines in the Waikato at Rotowaro and Maramarua produced 746,936 tonnes of sub-bituminous coal (NZ Petroleum and Minerals 2022) which is about 54% of New Zealand's total production in 2020 which was 1,392,075 tonnes (MBIE 2021). The remaining production was mined at 10 sites in the South Island. In addition to domestic coal production, New Zealand also imports significant quantities. In 2020 New Zealand imported 1,079,332 tonnes of coal, mostly sub-bituminous from Indonesia (MBIE 2021).

Total national coal consumption in 2020 was 2,585,940 tonnes (MBIE 2021). About half of this coal was used for electricity generation and primary steel manufacturing with food manufacturing being another large coal consumer, particularly in the South Island where there is no access to reticulated natural gas. The distribution of domestic coal consumption across MBIE's sector descriptions was as follows:

Electricity generation (Huntly)	801,646[5]
Use in co-generation plants	309,833 tonnes
Other transformation (steel manufacture)	416,579 tonnes
Industrial use, agriculture, forestry and fishing	1,000,409 tonnes
Commercial/institutional use	26,490 tonnes
Residential use	13,157 tonnes
Production losses	17,826 tonnes

The figure for total coal consumption (2,585,940 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	801,646 tonnes
Steel manufacturing	782,240 tonnes[6]
Cement and lime manufacturing	107,520 tonnes[7].

5 There is a discrepancy of 96,854 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. This is consistent with the approach used in the previous inventory.

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).

Subtracting the sum of the three sectors considered elsewhere (1,691,406 tonnes) from New Zealand's total coal consumption gives an amended quantity of 894,534 tonnes for Other Coal Use in 2020. million tonnes. As mentioned earlier this coal is produced in different parts of the country. It has been assigned the following approximate distribution, which assumes all imported coal is used for electricity and steel production and which allows a direct estimation of remaining Waikato coal quantities. The coal remainder is then distributed to the South Island coal fields based on coal production data for 2020 for the South Island. (NZ Petroleum and Minerals, 2022).

Waikato coal	202,430 tonnes
South Island coal[7]	470,631 tonnes
Southland lignite	221,473 tonnes

Coal mercury content

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. The most recent estimate is that there are about 160 coal-fired boilers in New Zealand ranging in size from 1 to 43 MW (CRL Energy, 2011). The reduction in coal consumption in this category compared to previous inventories may reflect the decommissioning or conversion of some coal fired boilers to alternative fuels (such as biomass). 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.

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

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
Waikato Coal, 2020	202,430	0.04 – 0.20	8.1 – 40.5	7.7 – 38.5	0.4 – 2.0
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
South Island Coal, 2020	470,631	0.03 – 0.10	14.1 – 47.0	13.4 – 44.7	0.7 – 2.4
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
Southland Lignite, 2020	221,473	0.06 – 0.25	13.3 – 55.4	12.6 – 52.6	0.7 – 2.8
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)**
Totals, 2020	**894,534**		**35.5 – 142.9 (89.2)**	**33.7 – 135.8 (84.8)**	**1.8 – 7.2 (4.5)**

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 16 productive oil fields in New Zealand, although the majority of production is accounted for by eight of these; Maui, Pohokura, Tui, Maari, Mangahewa, Kupe, Cheal and Turangi (MBIE, 2021). The combined production is a mixture of crude oil, natural gas liquids, condensates and naphtha, with a total production in 2020 of 963,860 tonnes. This is about 40% lower than the 2016 production of 1,584,650 tonnes and 48% 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 3.28 kg in 2020.

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 0.656 kg/year.

Virtually all of New Zealand's indigenous oil production is exported (MBIE, 2021). Hence, the remainder of the 3.28 kg of mercury inputs noted above (ie. 2.62kg) 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 2020 was 3,942,100 tonnes (MBIE, 2021), which is significantly lower than the 5,529,950 tonnes reported for 2016. This reduction in feedstock quantity is a direct consequence of the reduced demand for transport fuels resulting from the COVID-19 lock downs in 2020. 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 13.4 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 (7.91 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, 2021), 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 7.91 kg/year. However in 2020, 40.8 % of New Zealand's domestic petroleum consumption came 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 11.14 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	-
Extraction 2020	963,860	0.0034	0.66[a]			0.66	
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
Refining 2020	3,942,100	0.0034	13.4	3.35	0.1		2.0
Use, 2012	-	-	14.42	14.4	-	-	-
Use, 2016	-	-	14.5	14.5	-	-	-
Use 2020			11.14	11.14			
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**
Totals, 2020	**-**	**-**	**17.3[b]**	**14.5**	**0.1**	**0.66**	**2.0**

Notes: a a further 5.04 kg was removed through oil exports in 2012, 5.39 kg in 2016 and 3.06 kg in 2020

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 16 fields as noted previously for oil (MBIE, 2021). About 95% of the gas production comes from the Maui, Pohokura, Kapuni, Mangahewa, Kupe and Turangi fields, and the total gas production in 2020 from all fields was 4,737 million cubic metres (Mm^3), with an energy content of 190 PJ. This is 15% down on the 5,557 million cubic metres (Mm^3), or 221 PJ, produced in 2016 and reflects a significant downward trend in New Zealand's gas production since 2017. The net gas production is only about 95% 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 2020 gas volumes gives a total mercury input of between 0.47and 379 kg, with a mid-range value of 190 kg for 2020.

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)	-
Gas Extraction and Use, 2020	4,737	0.1 - 80	0.47 – 379 (189.7)	0.09 - 76 (37.9)	0.09 – 76 (37.9)	0.28 – 227.4 (113.8)	

Note: a: The releases in product were reported separately in 2012 but for 2016 and 2020 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.

As shown in the previous sections, accurate statistical information is available for national annual consumption of coal, natural gas and petroleum products. Such statistics are not available for biomass (essentially wood waste) because the tonnages used are either not recorded or are recorded indirectly such as in the form tonnes of steam raised per hour. In addition, wood waste can vary significantly in it is composition and moisture content– off cuts, shavings, saw dust, bark etc. which will affect its energy content. Previous mercury inventories have used the boiler rating (MW) of industrial wood burning heat plant listed in the Heat Plant Database (CRL Energy 2011) and derived the total energy consumed by assuming that plant is operated at 70% load for 320 days per year.

Recently MBIE have improved this estimate (MBIE 2017). In 2017 they commissioned the Crown Research Institute Scion to prepare an up to date database of energy raising plant in currently operating wood processing and pulp and paper operations in New Zealand. Scion produced a database with details for 173 wood processing operations. Two approaches were used to derive estimates of fuel use. In the first, the nameplate power rating (MW) of the boiler was combined with estimates of loading (percentage of time the boiler is used in a year), estimates of capacity (the ratio between typical heat demand and the boiler's nameplate capacity to supply heat) and efficiency (assumed to be 0.85 for all boilers, that is 85% of the energy in the fuel is converted to useful heat). In the second approach, annual production levels of wood products and estimates of the energy required to produce each product were used to derive a total fuel use figure. For a reference year of 2016 the first procedure yielded a bioenergy consumption of 40.3 net PJ and the second procedure 39.8 net PJ. Scion have continued to update their database and this is used by MBIE to derive annual industrial energy raised by biomass.

Domestic heating by wood burning also contributes to the total energy attributable to biomass combustion, leading to a combined value of 48.66 PJ reported by MBIE for 2020. (MBIE 2021)

This usage is roughly equivalent to 2.39 million tonnes/year of dry wood.

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

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)
Biomass usage, 2020	2,390,000	0.007 – 0.07	16.7 – 167 (92.0)	16.7 – 167 (92.0)

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).

Currently New Zealand has an installed geothermal electric power generation capacity of 1,005 MW from 19 geothermal power plants. The five largest plants at Wairakei (181 MW), Te Mihi (166 MW), Nga Awa Purua (140 MW), Mokai (110 MW) and Kawerau (100 MW) produce about 70% of this power (NS Energy, 2021). In 2020 New Zealand's total electricity generation from geothermal power was reported to be 7834 Gigawatt-hours, about 6% higher than the 7411 Gigawatt-hours reported for 2016 (MBIE, 2021)

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.

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 2020 was < 7.2 kg (T Baldwin, Contact Energy, pers comm, 2022).

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 4.2% of geothermal use, on an energy basis, (MBIE, 2021). 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
Geothermal power, 2020	7,834	0.03 – 0.22	235 – 1723	227.8 – 1715.8	7.2
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	-
Direct use, 2020	based on 4.2% of the above		9.8 – 72	9.8 - 72	-
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**
Totals, 2020	**-**	**-**	**244.8 – 1795 (1020)**	**237.6 – 1787.8 (1013)**	**7.2**

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 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Coal – large power plants	18 – 170.7 (94.3)	16.2 – 153.6 (84.9)	-	1.8 – 17.1 (9.45)	-	-
Other coal combustion	35.5 – 142.9 (89.2)	33.7 – 135.8 (84.8)	-	-	-	1.8 – 7.2 (4.5)
Oil extraction, refining and use	17.26	14.5	0.1	0.66	-	2.0
Gas extraction, refining and use	0.47 – 379.4 (189.7)	0.09 – 76 (37.9)	0.09 - 76 (37.9.1)	-	-	0.28 – 227.4 (113.8)
Other fossil fuels	-	-	-	-	-	-
Biomass fuel	16.7 - 167 (92.0)	16.7 – 167 (92.0)	-	-	-	-
Geothermal power	244.8 – 1,795 (1,020)	237.6 – 1,787.8 (1,013)	7.2	-	-	-
Totals	**332 – 2,672.3 (1503)**	**318.8 – 2,334.7 (1327)**	**7.4 – 83.3 (45.4)**	**2.46 –17.76 (10.1)**	**-**	**4.1 – 236.6 (120.3)**

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, 2019). 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, 2019). 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 and the Correnso underground gold mine.

In 2020 144,500 ounces of gold and 6,200 ounces of silver were produced from the McRaes' operation, while Waihi produced 19,800 ounces of gold and 38,600 ounces of silver. Waihi production in 2020 was about 15% of that achieved in 2016 because processing was shut from March to October as the development of the Martha Underground mine progressed. (Oceana Gold, 2020).

In order to produce the quantities of gold and silver in 2020 a total of 5,418,740 tonnes of ore was processed at McRaes' and 137,415 tonnes at Waihi's processing plants (G Lee and K Watson, Oceana Gold, pers comm). The average mercury concentration in Waihi ore for samples collected in 2019 and 2021 was 0.259 g/ tonne (K Watson, Oceana Gold Corporation, pers comm).

Mercury concentrations for McRaes ore are inferred from analysis of iron in pyrite mineral after the ore has been crushed, ground and concentrated in a series of floatation cells. This assumes a constant gold to mercury ratio and gold to pyrite ratio in the pyrite mineral being separated by floatation. Because the mercury is amalgamated to the gold in pyrite, it is tightly bound to the gold and is not lost in the concentration process. Mercury also forms a stable complex with cyanide which is similarly absorbed to carbon in the so-called carbon-in-leach enrichment system. This means that mercury follows gold to the refining stage and it is only here that separation occurs. The separated mercury is collected and is sent off-site to a waste management company. The amount of mercury generated at refining matches the estimate of the mercury present at the concentrated ore stage (G Lee Oceana Gold, pers comm)

The amount of concentrated ore processed in 2020 at McRaes was 126,307 tonnes and the average derived mercury concentration for the concentrate was 2.8 g/tonne (G. Lee OceanaGold, pers comm)

The reported mercury concentrations in ore combined with ore quantities for 2020 have been used to generate mercury releases separately for the McRaes and Waihi operations. The Toolkit default factors for estimating the output distributions of 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 have been used for Waihi but replaced by a factor of 1.0 (100%) for releases to waste for McRaes.

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 and 2016. It is now considered that mercury input estimates for both the 2012 and 2016 Inventories were too high as a result of the McRaes mercury in ore estimate being applied to the total weight of ore handled rather than the weight of concentrated ore produced after floatation treatment.

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	Waste	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)
Gold/silver production, 2020	0.126 (McRaes) 0.137 (Waihi)	2.8 (McRaes) 0.26 (Waihi)	389.25	1.42	0.71	353.7	32.0	1.42

(The figures shown in brackets for 2016 are based on a mid-range ore factor of 0.75 g/tonne rather than the mean value of the range shown).

Certainty assessment

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

Input estimates: MEDIUM -HIGH (because they are based on recent analytical data)

Output estimates: MEDIUM (because the waste output, the largest category, is based on company data)

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[8] 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 2020 calendar year was 601,490 tonnes and the mill used 782,240 tonnes of Waikato and Indonesian coal[9], and 62,526 tonnes of lime (D Bryson, New Zealand Steel, pers. comm, 2022). A further 35,921 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 2020 (D Bryson, New Zealand Steel, pers comm, 2022).

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 land as the baghouse dusts go to a controlled landfill at the NZ Steel site.

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.

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

9 52% of the coal was from Indonesia.

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	Land
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
Waikato Coal, 2020	782,240	0.05 – 0.20	39.1 - 156	19.6 – 78.0	19.6 – 78.0
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
Limestone, 2020	62,526	0.005 – 0.02	0.31 – 1.25	0.16 – 0.63	0.16 – 0.63
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)**
Total, 2020			**39.4 – 157.3 (98.6)**	**19.76 – 78.63 (49.3)**	**19.76 – 78.63 (49.3)**

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).

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 dominated by the use of ore in gold and silver production, which is largely separated from the product as a waste stream.

Table 4-5: Summary of inputs and outputs for the primary metal production category for 2020

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	389.3	1.42	0.71	32.03	1.42	353.7
Aluminium	-	-	-	-	-	-
Ferrous metals	39.4 – 157.3 (98.6)	19.76 – 78.63 (49.3)		19.76 – 78.63 (49.3)	-	
Totals	**448.7 – 566.6 (507.8)**	**25.18 – 84.05 (54.7)**	**8.71**	**59.79 – 118.66 (89.3)**	**1.42**	**353.7**

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

Currently New Zealand has only one cement manufacturer - Golden Bay Cement in Whangarei. Historically the cement kiln has been fired on coal supplemented by waste wood, but the recent introduction of tyre derived fuel from granulated waste tyres has enabled the company to reduce its coal use by 15% (Fletcher Building, 2021).

Total cement production for 2020 was 802,121 tonnes. (C.Ehlers, Northland Regional Council pers comm, 2022). The primary raw ingredient for cement manufacturing 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. The average mercury emission rate for testing carried out in 2020 was 0.92 kg/year (C.Ehlers, Northland Regional Council pers comm, 2022). 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 802,121 tonnes gives mercury inputs of from 3.2 to 401 kg/year. The bottom of this range is about four times 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 controls[10], with output distribution factors of 0.7 (70%) to air and 0.3 (30%) to product. Applying these to the air

[10] 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.

emission rate of 0.92 kg/year, gives an estimated release in product of 0.39 kg/year, and a total production input of 1.31 kg/year.

The mercury input and output estimates for cement production are shown in Table 5-2. The 2012 estimates were much higher than for 2016 and 2020 because the emissions from the now closed Holcim Westport plant were much higher than at Golden Bay Cement.

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
Cement production, 2020	802,121	1.31	0.92	0.39

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[11]. The other 5 kilns are located in Te Kuiti, Otorohanga (2), and Te Kumi, all in the Waikato region, and Dunback, in Otago. Currently the industry has been consolidated into two separate companies (MfE, 2021). Data is not available for the total burnt lime production in New Zealand in 2020. However it is possible to derive a production figure from the carbon dioxide emission figures that burnt lime manufacturers must declare annually to New Zealand’s Emission Trading Scheme. This calculation takes the form: total carbon dioxide emissions (tonnes) = 0.748 x (tonnes calcium oxide produced). Data given in the most recent New Zealand Greenhouse Gas Inventory report for 2019 gives a greenhouse gas

[11] 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.

emission from lime production of 108,000 tonnes CO2. (MfE 2021). This allows an estimate of actual lime production of 144,385 tonnes in 2019 (MfE, 2021). This is significantly lower than the 245,700 tonnes produced in 2015 used for the previous inventory.

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 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[12] 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 and the carbon dioxide emissions described above are for the calcination process only. 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)
Lime production, 2020	144,385	5 - 20	0.72 – 2.89 (1.81)	0.50 – 2.02 (1.26)	0.22 – 0.867 (0.54)

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.

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12 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.

The phosphate rock is imported from numerous other countries and contains varying amounts of mercury. In previous inventories the amount of mercury introduced to New Zealand from phosphate rock has been estimated by converting import quantities into weight of superphosphate equivalent and then using the mean and range of superphosphate analytical results available to derive a range for mercury inputs. For example measurements in 2015 and 2016 conducted on 65 monthly samples had values in the range < 0.05 - 2.7 mg/kg superphosphate with a mean of 0.09 mg/kg superphosphate (G Sneath, Fertiliser Association, pers comm, 2017). The latter concentration figure was used for the upper limit[13] in the input and output estimates, along with a lower level of 0.05 mg/kg to give a mercury input range of 54.8 – 98.6 kg/year for 2016.

Using the same approach for mercury analytical data available from 2019 – 2021, the 136 analyses conducted on superphosphate samples gave a range of 0.02 – 0.2 mg mercury/kg product with a mean result of 0.1 mg mercury/kg product (G Sneath, Fertiliser Association, pers comm, 2022). The total New Zealand imports of phosphate rock in 2022 were 471,978 tonnes according to HSC import codes 2510.10.00.00 and 2510.20.00.00 (import data obtained from Statistics New Zealand, 2022). Deriving a superphosphate mercury content range of 0.02 – 0.1 mg mercury/kg product as before and applying it to the phosphate rock quantity imported converted to its equivalent as superphosphate gives an annual mercury input range of 18.7 – 93.3 kg/year for 2020.

However according to the Fertiliser Association of New Zealand, superphosphate is not the only phosphate product which is applied in New Zealand. Other products include Sulphur Super and Di-ammonium Phosphate (DAP). Superphosphate and Sulphur Super now comprise the majority of phosphate fertiliser applications with DAP holding the 40% of market share remaining (G Sneath, Fertiliser Association, pers comm, 2022). It should be noted that these results are based on the phosphorous content of the fertiliser. New Zealand fertiliser application records are recorded on the basis of the amount of phosphorous applied rather than the weight of the fertiliser itself because they vary in their phosphorous content. For example superphosphate is 9% phosphorous and DAP is 20% phosphorous. In 2020 149,000 tonnes of phosphorous in fertiliser were applied in New Zealand (G Sneath, Fertiliser Association, pers comm, 2022).

Mercury analysis results are now available for DAP from 2019- 2021. For 30 samples these showed a range of 0.1- 1.1 mg mercury /kg product. Expressing the mercury analytical results available for both superphosphate and DAP in terms of mg mercury per kg phosphorous for each product gives values of 0.56 mg mercury/kg P for superphosphate and 2.3 mg mercury/kg P for DAP (G Sneath, Fertiliser Association, pers comm, 2022). These results were derived on the basis that where results are expressed as "not-detected" a concentration of half the detection limit has been applied. This convention has been used elsewhere in this Inventory.

Applying the two mercury contents to the total phosphorous applied in 2020 (149,000 tonnes) based on 40% for DAP and 60% for superphosphate gives an annual total of 187 kg mercury. As with previous inventories the mercury is assumed to be discharged to land.

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 2020 was 986,870 tonnes (NZ Petroleum and Minerals, 2022 (b)). This is similar to the quantity reported for 2016. The Fertiliser Association have noted that lime use in agriculture has steadily declined since a peak in use in 2002 (Fertiliser Association, 2022).

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13 The use of the mean value instead of the maximum was adopted for the 2012 inventory because the analytical data is highly skewed towards the mean, and the same approach has been taken here for the sake of consistency.

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)
Phosphate fertiliser, 2020	149,000 (as P)	1.255 (as P)	187	187
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)
Agricultural lime, 2020	986,870	0.005 – 0.02	4.93 – 19.73 (12.3)	4.93 – 19.73 (12.3)

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 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 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Cement	1.31	0.92	-	-	0.39	-
Pulp and paper	-	-	-	-	-	-
Lime	0.72 – 2.89 (1.81)	0.50 – 2.02 (1.26)	-	-	0.22 – 0.867 (0.54)	-
Phosphate fertiliser	187		-	187	-	-
Agricultural lime	4.93 – 19.73 (12.3)	-	-	4.93 – 19.73 (12. 3)	-	-
Totals	**194.0 – 210.9 (202.4)**	**1.42 – 2.94 (2.2)**	**-**	**192 – 206.7 (199.3)**	**0.61 – 1.26 (0.94)**	**-**

6 Intentional use of mercury in industrial processes

This category covers mercury releases from several industrial chemical processes (UNEP, 2019), 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[14]

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.

In 2021 the Minister for the Environment, Hon David Parker, recommended to Cabinet that the National Emission Standards for Air Quality be amended to specifically prohibit the use of mercury in chlor alkali, acetaldehyde, vinyl chloride monomer, sodium or potassium methylate or ethylate and polyurethane production (Office of the Minister for the Environment, 2021).

14 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, 2019). 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 2020. However, this only indicates the total value of the imports, which was $655,442 in 2020. In addition, the data cover all types of thermometers, including those not containing mercury, such as alcohol-filled thermometers.

As an alternative approach, 9 suppliers of medical and veterinary equipment and laboratory equipment were contacted including those companies which reported sales for the 2016 Inventory. Responses were obtained from 8 of these. Sales of mercury thermometers in 2020 totalled 1107 units from one supplier.

Mercury thermometers are listed as non-electronic measuring devices which cannot be manufactured, imported or exported after 2020 as required by The Minamata Convention. An exception is made if the thermometers are installed in large-scale equipment or used for high precision measurement where no suitable mercury-free alternative is available (MfE, 2020)

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, 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)
Annual sales, 2020	1,107	0.5 - 5	0.554 – 5.54 (3.04)	0.055 – 0.554 (0.305)	0.166 – 1.66 (0.91)	0.332 – 3.32 (1.83)

Certainty assessment

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

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, 2019).

Mercury containing switches and relays are products which cannot be manufactured, imported or exported after 2020 as required by The Minamata Convention. Exceptions include very high accuracy capacitance and loss measurement bridges and high frequency radio frequency switches and relays in monitoring and control instruments with a maximum mercury content of 20 mg per bridge, switch or relay (MfE, 2020).

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 and 2016 Inventories 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)
Annual usage, 2020	5.0 x 10^6	0.002 – 0.02	10 – 100 (55.3)	1.0 – 10 (5.50)	1.0 – 10 (5.50)	8.0 – 80.0 (44.2)

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, 2019). 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). Auckland Transport's design code for street lighting specifies: "all new or replacement luminaries must be LED luminaries" (Auckland Transport, 2022)

LFLs and CFLs

Import data for fluorescent lamps and tubes was obtained from Statistics New Zealand for 2020 (HS Code: 8539.31.00.00). This indicated total annual imports of LFLs and CFLs of 2,069,383 million units per year.

The Energy Efficiency & Conservation Authority (EECA) collects sales data for all regulated appliances (EECA, 2022). From 1 April 2020 – 31 March 2021 there were 942,946 CFLs and 832,389 LFLs sold in New Zealand. This sales data has been used in estimating the mercury inputs, rather than the bulk import information noted above. Since peaking in 2014 with sales figures of 2.72 million, annual CFL light sales have declined steadily as they are replaced with LED lamps. Sales for 2021 are 10% below those for 2020.

With regard to mercury content it is expected that most New Zealand products sold will comply with Australian requirements (M Hammond-Blain, EECA, pers comm, 2022). Under Australian regulations maximum mercury levels for CFL lights are 5 mg for lights 30 Watts and over and 2.5 mg for lights under 30 Watts. The Toolkit's most recent revision (UNEP, 2019) recommended a default input factor of 2.7 mg mercury per CFL and this has been adopted.

From 2017 Australian regulations required LFL lights to have a mercury content below 5 mg. The previous inventory used a range from 1.1 – 5 mg mercury per LFL which is lower than the current Toolkit default factor of 8 mg mercury / LFL but is more appropriate for the New Zealand market.

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 2020 of about 58,000 high-intensity discharge lamps, and about 210,000 'other' lamps, many of which are ultra violet lights with or without a filament. As can be seen in Table 7-4 the high intensity discharge lamp types (mercury vapour, sodium and metal halide) show a steep decline in numbers from 2012 to 2020 which is consistent with the comments given above regarding the increasing use of LEDs for street lighting. Ultra violet light numbers show a reverse of this trend with numbers increasing significantly.

The mercury content for these depends on the lamp type and varies from 5 to 40 mg/lamp (UNEP, 2019). In accordance with recent Toolkit recommendations, the input factor for high pressure mercury vapour lights has been increased from 30 mg per item to 40 mg per item. (UNEP, 2019).

Input and output estimates

The estimates for the total mercury inputs for all 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 2020 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. This waste stream was first covered in the 2012 Inventory Report where it was estimated that these exports contained about 3 kg of mercury. Tonnages of lamps handled for export have remained at stable levels over the intervening years. However for 2020 and 2021 COVID-19 lockdowns reduced the amounts submitted for recycling by 60% (O. Filva, Interwaste, pers comm, 2022). Consequently for this Inventory the estimate of the amount exported has been adjusted to 1.2kg.

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
Fluorescent Tubes (LFLs), 2020	1.1 - 5	832	0.92 – 4.2
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
Compact Fluorescent Lamps (CFLs), 2020	2.7	943	2.55
High Pressure Mercury Vapour, 2012	30	50	1.5
High Pressure Mercury Vapour, 2016	30	35	1.1
High Pressure Mercury Vapour, 2020	40	15	0.61
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
High Pressure Sodium Lamps (HPS), 2020	10 - 30	16	0.16 – 0.48
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
UV lamps for tanning, 2020	5 - 25	210	1.1 – 5.3
Metal halide lamps, 2012	25	500	12.5
Metal halide lamps, 2016	25	106	1.6 – 5.3
Metal halide lamps, 2020	25	27	0.68

The mercury input and output estimates for mercury lamps are shown in Table 7-5: Input and output estimates for mercury lamps7.5.

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)
All lamps (see details above), 2020	6.0 – 13.8 (9.83)	0.30 – 0.69 (0.50)	5.71 – 13.1 (9.3)

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

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 primary batteries, that is batteries which are not rechargeable (UNEP, 2019).

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 such as the cylindrical AA and AAA and rectangular 9V types comprised 89% of battery use. The remaining 11% were made up of rechargeable batteries (2%) and button cell batteries (9%).

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.

Of the cylindrical and rectangular battery types, manganese and zinc carbon batteries are now acknowledged to be mercury free globally. On the other hand alkaline manganese batteries may contain mercury. Similarly zinc air, silver oxide and alkaline button cells may contain mercury although many such batteries available for sale in New Zealand are now labelled as mercury free.

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 remained under review. EU Regulation 2017/852 similarly prohibited export, import and manufacturing of batteries that contain more than 0.0005% of mercury by weight after 31 December 2018 (UNEP, 2019).

UNEP conducted a major investigation of mercury in batteries for its 2019 Toolkit update (UNEP, 2019). Some of the major findings of significance for New Zealand are as follows. Surveys of the largest battery suppliers showed that, as of June 2019, Duracell, Energizer, Varta and Panasonic supplied only mercury free micro alkaline, silver oxide and zinc air batteries. With regard to manufacturing in the United States cylindrical batteries have been mercury free since the 1990s and alkaline, silver oxide and zinc air button batteries have ben mercury free since 2012. UNEP assume that China and India still have considerable markets of mercury added button cells (UNEP, 2019).

Data from Statistics New Zealand show that in 2020 the EU, USA, Australia and Japan provided 77% of our zinc air button imports and 86% of our silver oxide button batteries. China produced 96% of our alkaline button batteries and a conglomerate of countries held major shares of the manganese alkaline battery import market: Singapore and Malaysia (42%), China (30%) and the European Union, USA and Australia (17%).

Energizer button cell batteries are believed to hold about 50-60% of the market in this country and all of this brand now contain no added mercury. (Roger Spice, Energizer NZ Ltd, pers comm.) For the previous inventory it was assumed that the overall distribution for all brands for sale in New Zealand is 75% mercury free and this approach has also been adopted here

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[15]. For the outputs it was assumed that all of the batteries were disposed to waste. A recent report by Consumer NZ discussed the used battery disposal options for households (Consumer NZ, 2019). The options available were either disposal at the local council run hazardous waste collection facility at transfer stations or landfills or depositing with a battery recycling scheme. In the former case batteries are typically treated by encapsulation in concrete and then transferred to landfill. For the latter, battery recycling was estimated to cover only 0.2% of annual battery sales[16] and the batteries are currently being stored by the recyclers because there are no local companies capable of recycling batteries in New Zealand. The input and output calculations are shown in Table 7-7. The figures shown in brackets are the mean of the reported ranges.

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15 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.

16 For button batteries such as zinc air the recycling rate may be higher because many audiology companies collect hearing aid batteries and provide specific disposal containers for their customers.

Table 7-6: Estimated mercury inputs for batteries

Type	Size, cm^3	Mercury content g/kg	Number of batteries	Weight per battery, g	Total weight of batteries, kg	Mercury inputs, kg
Mercury oxide button, 2012	<300	320	98,126	1	98	31.4
Mercury oxide button, 2016	<300	320	2.543	1	2.5	0.81
Mercury oxide button, 2020	<300	320	14,287	1	14.3	4.57
Silver oxide button, 2012	all	3.4 – 10	653,266	1	653	2.2 – 6.5
Silver oxide button, 2016	all	1	815,320	1	815	0.82
Silver oxide button, 2020	all	1	305,051	1	305	0.31
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
Zinc air button, 2020	all	3	3,975,291	1	3,975	11.9
Alkaline button, 2016[a]	all	1.25	6,828,996	1	6,829	8.54
Alkaline button, 2020[a]	all	1.25	8,474,609	1	8,475	10.6
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
Alkaline MnO_2, 2020	<300	0.063	47,043,112	12	564,516	35.6

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
Batteries, 2020	59,812,360	0 - 320	62.99	62.99

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

As discussed in Section 6.1, in 2021 the Minister for the Environment, Hon David Parker, recommended to Cabinet that the National Emission Standards for Air Quality be amended to specifically prohibit the use of mercury in polyurethane production (Office of the Minister for the Environment, 2021). For the 2012 and 2016 Inventory reports it was estimated that sales of mercury catalyst were occurring from a single importer with a total quantity of 200 grams. With the impending ban and the small quantities previously involved it has been assumed that releases from this source are insignificant.

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 (MPI, 2022), and a search of this database in early June 2022 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[17]. 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, 2020) 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 showed that there are currently only 2 mercury-containing human pharmaceutical products registered for use in New Zealand (as opposed to the 4 noted in the 2016 Inventory Report). One of these contains phenylmercuric nitrate, and the other phenylmercuric acetate. Only one of these products was sold in New Zealand in 2020 for a total input of 0.021 kg of mercury (A Lal, Teva Pharma (NZ) Ltd, pers comm).

A survey of Thiomersal use by local manufacturers and distributors of veterinary medicines was conducted on the Ministry's behalf by Animal and Plant Health New Zealand. Information was requested for the 2020 calendar year on the amounts of Thiomersal raw material imported for further formulation and the amounts of Thiomersal in ready to use animal products that were imported. Respondents to the survey indicated that a total of 50 kg of Thiomersal raw material and 3.965 kg of Thiomersal in animal formulations were imported. The survey was not able to provide any conclusive information on the amounts of Thiomersal in animal products that were exported.

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

The total import quantity of 53.965 kg for Thiomersal in animal products contains 26.741 kg mercury. Combined with the 0.021 kg in human pharmaceuticals, the total mercury input for pharmaceuticals for human and veterinary use is consequently 26.762 kg.

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 2020

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.

Table 7-8: Summary of inputs and outputs for consumer products with intentional use of mercury for 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Thermometers with mercury	0.554 – 5.54 (3.04)	0.055 – 0.554 (0.305)	0.160 – 1.66 (0.91)	-	-	0.332 – 3.32 (1.83)
Switches, contacts and relays	10 – 100 (55)	1.0 – 10 (5.5)	-	1.0 - 10 (5.5)	-	8.0 – 80 (44)
Lamps	6.01 – 13.8 (9.83)	0.30 – 0.69 (0.50)	-	-	-	5.71 – 13.1 (9.3)
Batteries	62.99	-	-	-	-	62.99
Polyurethane with mercury catalyst		-	-	-		-
Biocides/pesticides	-	-	-	-	-	-
Paints	-	-	-	-	-	-
Pharmaceuticals	26.76	-	-	-	26.76	-
Cosmetics	-	-	-	-	-	-
Totals	**106.31 – 209.1 (157.9)**	**1.36 – 11.24 (6.3)**	**0.16- 1.66 (0.91)**	**1.0 – 10 (5.5)**	**26.76**	**77.0- 159.4 (118.3)**

8 Other intentional product/process uses

This category covers mercury uses in a range of other intentional products and uses (UNEP, 2019). 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 which are used in restorative dentistry. Mercury typically comprises about 45 to 50% of these amalgams. The amount of amalgam used to fill a cavity depends on its size. Amalgam capsules are sold in different weights with the amount of mercury present corresponding to 400 mg, 600 mg, 800 mg and 1200mg. These amalgams are still used in New Zealand, although non-mercury alternatives are readily available.

An online search for dental supply companies revealed 20 operating in New Zealand but only two of these sold mercury amalgam restorative products in 2020. Product sales numbers from these companies combined with the amount of mercury in each sale item allowed the calculation of a total mercury input of 47.5 kg for 2020.

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. 5.025 million) of between 251 and 1,005 kg/year. However, the information obtained from amalgam suppliers indicate that a more appropriate figure would be 47.5kg/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
Dental amalgam, 2020	47.5	100%	47.5	0.95	6.65	28.50	11.40

Note. For the 2012 and 2016 Inventory Reports the total weight of amalgam sold was combined with the average concentration of mercury to give an annual mercury input. For the 2020 estimates the concentration of mercury in individual products was assigned to specific product numbers and summed, hence the use of 100% for mercury content.

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, 2019). Electronic models have by and large superceded mercury sphygmomanometers.

Four medical equipment suppliers were contacted including the two firms selling sphygmomanometers in 2016. One firm estimated that they had sold about 8 units in 2020 with the remainder reporting that no mercury containing devices were sold in 2020 and that they would not be selling any in the future.

Input and output estimates

The Toolkit indicates that each sphygmomanometer contains 75g of mercury on average. Consequently the annual mercury inputs will be 0.6 kg mercury allocated to the product output 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 2019).

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 2020 inventory the survey has been limited to current sales by laboratory supply companies. Five laboratory supply companies were contacted for details of 2020 sales of mercury and mercury containing products. A total of 1.5 kg elemental mercury and 1.34 kg of mercury containing compounds expressed as mercury were sold in 2020. which gives a total mercury contribution of 2.84kg

Input and output estimates

The Toolkit does not provide any specific output factors for this category 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, 2016	4.77	0.24	0.48	4.05
Annual sales, 2020	2.84	0.14	0.28	2.42

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, 2019). These products are prohibited by legislation in New Zealand. (Office of the Minister for the Environment, 2020)

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 2020

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 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Dental mercury amalgam fillings	47.5	0.95	6.65	-	28.5	11.4
Manometers and gauges	0.6	-	-	-	0.6	-
Laboratory chemicals and equipment	2.84	0.14	0.28	-	-	2.42
Mercury use in religious rituals and folklore	-	-	-	-	-	-
Miscellaneous product uses, mercury metal, other sources	-	-	-	-	-	-
Totals	**50.94**	**1.09**	**6.93**	**-**	**29.1**	**13.82**

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, 2019). 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 however this company closed down in 2016.

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 2020 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 similar to those used in the 2016 Inventory Report which used a figure of 20 kg per year, with the assumption again that this will be for use in small-scale gold mining.

Certainty assessment

Activity data: LOW (because no recent data is available)

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)

The closure of New Zealand's only secondary steel mill, Pacific Steel Ltd in South Auckland, in 2015 means that there are no mercury inputs to New Zealand from this source category.

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 2020

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, 2019). 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. In 2019 Dow AgroSciences became Corteva Agriscience after the merger between Dupont and Dow Chemicals in 2017.

The incinerator 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 incinerator was out of service for most of 2020, but did operate at the end of the year for 138 hours to process liquid wastes (T Gellen, Corteva Agriscience, pers comm, 2022).

No emission testing for mercury was conducted in 2020. An emission rate of < 1.1 mg/hour for mercury was measured for liquid wastes in 2016. Combining this rate with the 138 hours operated in 2020 gives an estimated annual emission of < 0.15g. As with previous updates it is assumed that all of the mercury is 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 one 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. There were no changes to the amount of waste burnt in 2020 compared to 2016 so the original estimate of 78 tonnes of medical waste incinerated annually still applies (B. Woolhouse, Grey Hospital, pers comm, 2022). The incinerator 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 2020 (mean 1.87 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 at Tahuna 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 4,500 tonnes of wastewater solids per year. For the 2020 calendar year 4664 tonnes of solids were incinerated. This material was comprised of 33.8% dry solids (C. McGaw, Dunedin City Council, 2022). Consequently on a dry basis, 1,576.4 of waste water solids were incinerated.

The previous inventory used a mercury composition of 0.56 mg/kg for Dunedin (Green Island) biosolids. On this basis multiplying dry sludge processed by mercury concentration gives an annual mercury input to the incinerator of 0.88 kg/year. The incinerator off-gases are tested annually for mercury, and the average mercury emission result for testing conducted in November 2019 indicates emissions of 0.73 kg/year (K2 Environmental, 2020). 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 does not 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 latest New Zealand dioxin inventory for 2020 (MfE, 2022) estimated that the quantity of domestic wastes burned annually in New Zealand was about 10,085 tonnes/year.

There is no data available on the mercury content of New Zealand municipal solid wastes. For the 2012 and 2016 inventories Toolkit default factors of 1 – 10 g/tonne. Were applied. For the most recent Toolkit revision issued in 2019 a range of 0.2 – 4 g/tonne of waste with an intermediate value specified as 1g/ tonne of waste is now recommended. As is discussed more fully in Section 11.1, the intermediate factor is seen as most appropriate for New Zealand.

Applying this to the annual waste quantities indicates an annual mercury input of 10.1 kg/yr. For the output calculations, it is assumed that all of the mercury is discharged to air.

Certainty assessment

Activity data: LOW (because it was based on a limited amount of 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, 2022) lists some other incineration sources in New Zealand, including 13 school incinerators, and 28 pet incinerators.

The estimated waste throughput for the school incinerators was only 13 tonnes/year, in total. The wastes burned in these units would have a similar composition to that burned in backyard rubbish fires, and would only add a further 0.1% 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 510 tonnes/year, in 2020. 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 0.51 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

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 2020

Category	**Mercury Inputs, kg/year**	**Mercury Outputs, kg/yr**				
		Air	**Water**	**Land**	**Product**	**Waste**
Municipal waste incineration	-	-	-	-	-	-
Hazardous waste incineration	0.00015	0.00015	-	-	-	-
Medical waste incineration	0.62 – 3.12 (1.87)	0.62 – 3.12 (1.87)	-	-	-	-
Sewage sludge incineration	0.88	-	-	-	-	0.88
Informal waste incineration	10.1	10.1	-	-	-	-
Other (pet incinerators)	0.51	0.51	-	-	-	-
Totals	**12.1 – 14.6 (13.4)**	**11.23 – 13.73 (12.5)**	**-**	**-**	**-**	**0.88**

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, 2019). 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. Information on tonnages of waste deposited in Class 1 landfills is available from data collected through the Waste Disposal Levy scheme. From July 2019 to June 2020 3,352,322 tonnes were recorded, with 3,547,485 tonnes listed for July 2020 to June 2021 (MfE, 2021). Averaging these quantities gives an estimated total quantity of 3,449,904 tonnes of waste for 2020. The Ministry for the Environment comment that there was a slight decrease of waste to class 1 landfills in 2019 and 2020 with the decrease in 2020 likely due to COVID-19. However longer term trends suggest that the rate of disposal is increasing for many sites around the country. Over time there has been a change in waste composition with inert waste (such as plastics) increasing, food waste decreasing and wood waste increasing.

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, 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. For previous inventories default factors of 1 – 10 g/tonne of waste were recommended for estimating inputs. The most recent Toolkit revision issued in 2019 provides a revised range of 0.2 – 4 g/tonne of waste with an intermediate value specified as 1g/ tonne of waste. The low end input factor is expected to be relevant for a situation where substantial parts of waste products with high mercury concentrations (thermometers, batteries, dental amalgam wastes, switches etc.) have been sorted out of the waste for separate treatment. The high end input factor is expected to be relevant for situations where no such sorting takes place (UNEP, 2019). Some sorting of high mercury concentration products is likely to occur in New Zealand but there are still significant quantities of materials such as button batteries and LFL and CFL lights which are sent to landfill. Consequently, the intermediate input factor is seen as most appropriate for New Zealand.

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 remain unchanged and have been applied here.

The mercury input and output calculations for controlled landfill are shown in Table 11-2 for 2012, 2016 and 2020.

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)
Landfilling of wastes, 2020	3.45×10^6	1	3,450	34.5	0.345	3,415

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 3 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, 2019).

The Ministry for the Environment commissioned a major review of the wastewater sector in New Zealand in 2020 (Beca, GHD and Boffa Miskell, 2020). The report indicated that there were 318 active municipal wastewater treatment plants in New Zealand servicing 79% of the population. The remaining 21%, who live largely in rural areas, must treat their own household wastewater flows using an on-site wastewater management system (OWMS) such as a septic tank. An OWMS discharges treated wastewater effluent to a land application on the property such as a drainage field. Water NZ estimate there are about 270,000 OWMS in New Zealand (Water NZ, 2020).

The total volume of wastewater produced annually in New Zealand will be the sum of wastewater treated in wastewater treatment plants per annum and the volume of water discharged from OWMS annually.

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: “2020-2021 Combined WWTP Data.xlsx” (Water NZ, 2022). Averaging data for 2019-2020 and 2020-2021 from the spreadsheet gives a total estimated volume of 497,162,000 m^3/year handled by New Zealand wastewater treatment plants in 2020.

Similar records are not kept for OWMS. For the purposes of this inventory people using OWMS are assumed to discharge wastewater at the same rate as individuals who are connected to a wastewater treatment plant. At June 2020 New Zealand’s estimated population was 5,025,000 (Stats NZ, 2020) so the 21% of individuals not connected to a treatment plant number 1,055,250. Consequently OWMS are estimated to have discharged 132,117,300 m^3/year and therefore New Zealand’s total wastewater production for 2020 was 629,279,000 m^3.

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[18], 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.

18 The toolkit refers to the land disposal route as “sector specific” wastes.

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 – 5,550 (2,913.8)	138.7 – 2,775 (1,456.9)	55.5 – 1110 (582.8)	83.25 – 1,665 (874.1)
Municipal WWTP, 2020	629 x 10^9	0.5 - 10	314.5 – 6,290 (3304)	157.3 – 3,145 (1652)	62.9 – 1,258 (661)	94.4 – 1,887 (991)

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)

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. In June 2022 there was one current permit listed for export of mercury-containing wastes (EPA, 2022) which was for the export of *miscellaneous mercury bearing waste including crushed lamps and fluorescent* tubes. This category was covered in Section 7.4. In addition, there are two current permits for imports of mercury metal wastes and mercury lamps, both from New Caledonia, by Waste Management (NZ) Ltd

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 2020.

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 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Waste	Reservoir
Controlled landfills	3450	34.5	0.35	-	-	3415
Diffuse dumping	-	-	-	-	-	-
Informal - industrial wastes	-	-	-	-	-	-
Informal - general waste	-	-	-	-	-	-
Wastewater treatment	314.5 – 6,290 (3302)	-	157.3 – 3,145 (1,652)	62.9 – 1,258 (660.5)	94.4 - 1887 (991)	-
Totals	**3764.5 – 9740 (6753.6)**	**34.5**	**157.7 – 3145.4 (1652.2)**	**62.9 – 1,258 (660.7)**	**94.4 – 1887 (991)**	**3,415**

12 Crematoria and cemeteries

This category covers mercury releases from cremation and burial of human bodies (UNEP, 2019). The various sub-categories and the primary release pathways are summarised in Table 12-1.

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

Mercury releases from crematoria and cemeteries arise mainly from 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, 2022) show that for 2020 there were 32712 registered deaths with 22073 estimated cremations or 67% of the total. As might be expected the total is only slightly up on the 31,333 deaths reported in 2016, for which 64% were cremated[19].

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)	-
Cremation, 2020	22,073	1 - 4	22.1 – 88.3 (55.2)	22.1 – 88.3 (55.2)	
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)
Cemeteries, 2020	10,639	1 - 4	10.6 – 42.6 (26.6)		10.6 – 42.6 (26.6)

19 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 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Crematoria	22.1 – 88.3 (55.2)	22.1 – 88.3 (55.2)	-	-	-	-
Cemeteries	10.6 – 42.6(26.6)	-	-	10.6 – 42.6 (26.6)	-	-
Totals	**32.7 – 130.9 (81.8)**	**22.1 – 88,3 (55.2)**	**-**	**10.6 – 42.6 (26.6)**	**-**	**-**

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, 2020

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
1. Extraction and use of fuels/energy sources	332.3 – 2,672.3 (1503)	318.8–2334.7 (1327)	7.4 – 83.3 (45.3)	2.0 – 17.3 (10.1)	-	4.1 – 236.6 (120)
2. Primary (virgin) metal production	448.7 – 566.6 (507.8)	25.18 – 84.05 (54.7)	8.71	58.79 – 118.66 (89.3)	1.42	353.7
3. Production of other minerals and materials	194 – 210.9 (202.4)	1.42 – 2.94 (2.2)	-	192 – 206.7 (199.3)	0.94	-
4. Intentional use in industrial processes	-	-	-	-	-	-
5. Consumer products with intentional use	106.3 – 209.1 (157.9)	1.36 – 11.24 (6.3)	0.16 – 1.66 (0.91)	1.0 – 10 (5.5)	26.76	77.0 – 159.4 (118.3)
6. Other intentional products/processes	50.9	1.1	6.93	-	29.1	13.8
7. Production of recycled metals	20.0	-	-	-	20	-
8. Waste incineration	12.1 – 14.6 (13.4)	11.2 – 13.7 (12.5)	-	-	-	0.88
9. Waste deposit/landfill and wastewater treatment	3,764.5 – 9,740 (6,754)	34.5	157.7 – 3,145.4 (1,652)	62.9 – 1258 (660.7)	-	94.4 – 1887 (991)
10. Crematoria and cemeteries	32.7 – 130.9 (81.8)	22.1 – 88.3 (55.2)	-	10.6 – 42.6 (26.6)	-	-
Totals	**4,962– 13,615 (9,291)**	**414.2 – 2,569.1 (1,494)**	**182.3– 3,247.4 (1,715)**	**357.7 – 1,623.8 (992)**	**78.2**	**514.4 – 2681 (1,598)**

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 (3,415 kg) 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). This explains why the sum of inputs is greater than the sum of outputs.

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

The next highest input is 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.

Below that, the most notable source categories are production of other minerals and materials 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.

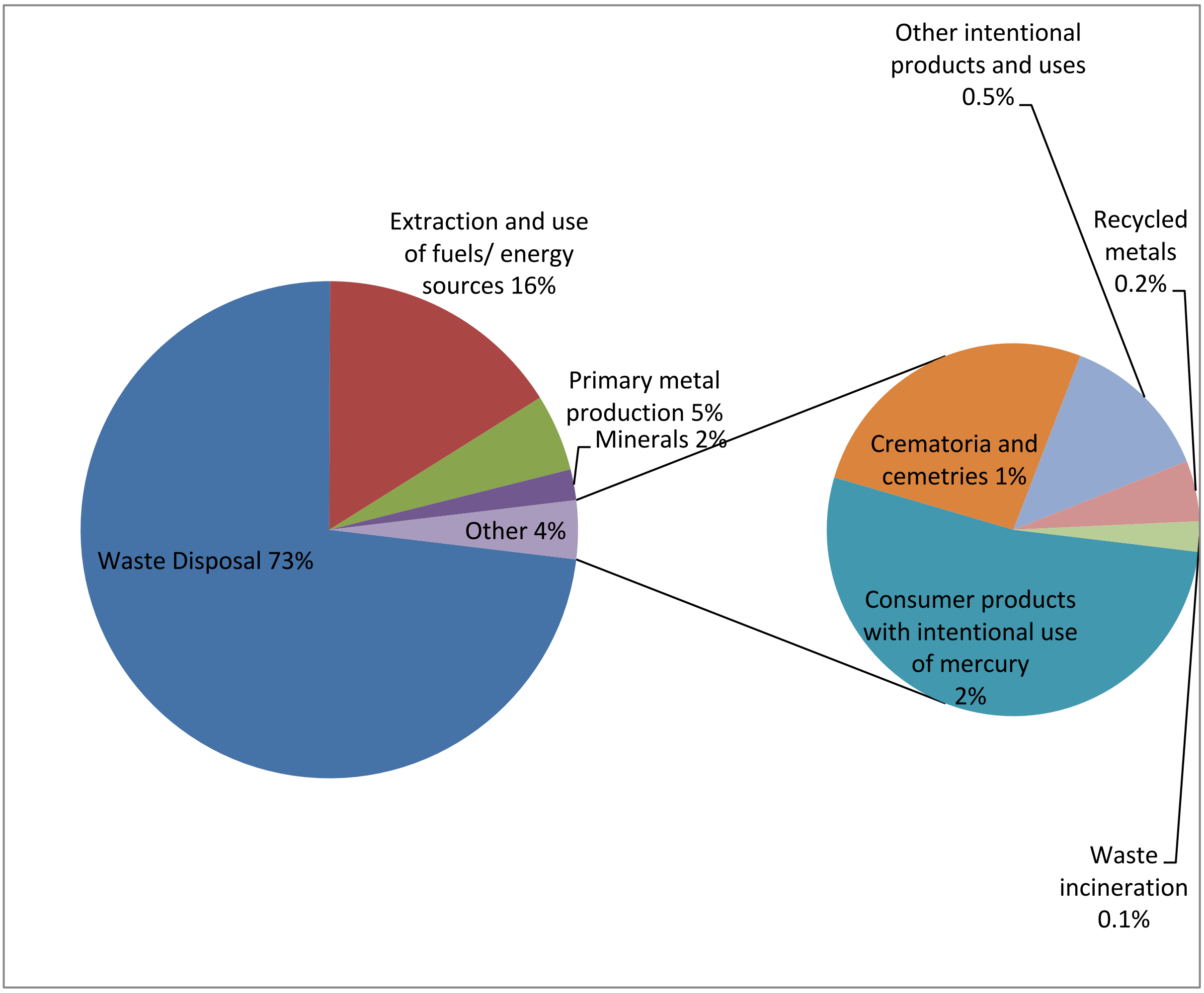


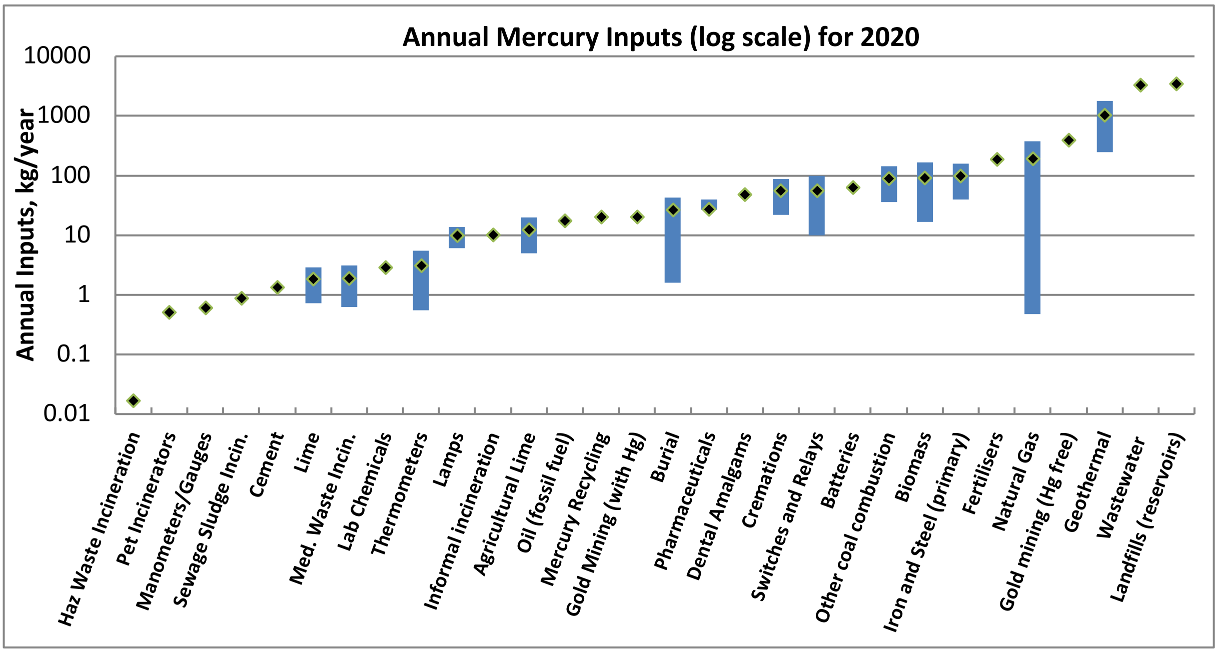
Figure 14-1: High level graphical summary of mercury inputs

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 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), wastewater treatment and disposal, the extraction and utilisation of geothermal energy and gold and silver mining. 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.

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



14.3 Changes in mercury inputs since 2016

The estimated total input of mercury for New Zealand for 2020 is 9,291 kg which is significantly less than the 28,632 kg estimated for 2016. Most of the difference can be attributed to a five-fold reduction in the default UNEP Toolkit input factor for solid waste disposal which is one of the largest activities assessed. Other significant reductions have occurred with release estimates for gold and silver mining (not involving mercury amalgamation) as a result of improved data for mercury concentrations in ore. Releases of mercury from mercury containing lights are also significantly down as high discharge mercury and sodium street lamps and compact fluorescent lamps continue to be replaced by LED equivalents. Releases from natural gas production are down by 15% reflecting a downward trend in gas production since 2017.

On the other hand some sources have seen significant increases in their mercury estimates. The estimated releases from coal burning at the Huntly Power station have increased four-fold compared to 2016 as a result of impaired hydro generation and natural gas shortages in 2020 requiring much greater thermal coal electricity generation. Releases from phosphate fertiliser application have doubled compared to 2016 due to estimation improvements rather than an increase in application rates. Releases from biomass combustion have increased by 33%, again as a result in improvements in estimation.

Other changes are simply due to the normal year to year variations in commercial or industrial activity or simply relate to changes in the population. For example wastewater generation and cremations are proportional to population size.

COVID-19 did have some influence on commercial and industrial activity in 2020 although its effect was not as great as might have been anticipated and varied according to sector. Fuel refining was adversely affected, particularly aviation fuel, which led to mercury release reductions.

14.4 Summary of mercury outputs

The five charts given below provide summaries of the relative contributions (above 0.1%) 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, crematoria, waste disposal and waste incineration.
- The outputs to water are totally dominated by waste disposal, especially wastewater discharges. Extraction and use of fuels and primary metal production are the next most significant contributors.
- The outputs to land are dominated by waste disposal and production of minerals with mercury impurities.
- The outputs to products are comprised largely of consumer products with intentional use of mercury other intentional product/process use and production of recycled metals.
- The outputs to waste feature waste disposal and primary metal production as the largest sources with other notable contributions from consumer products and fuel/energy use.

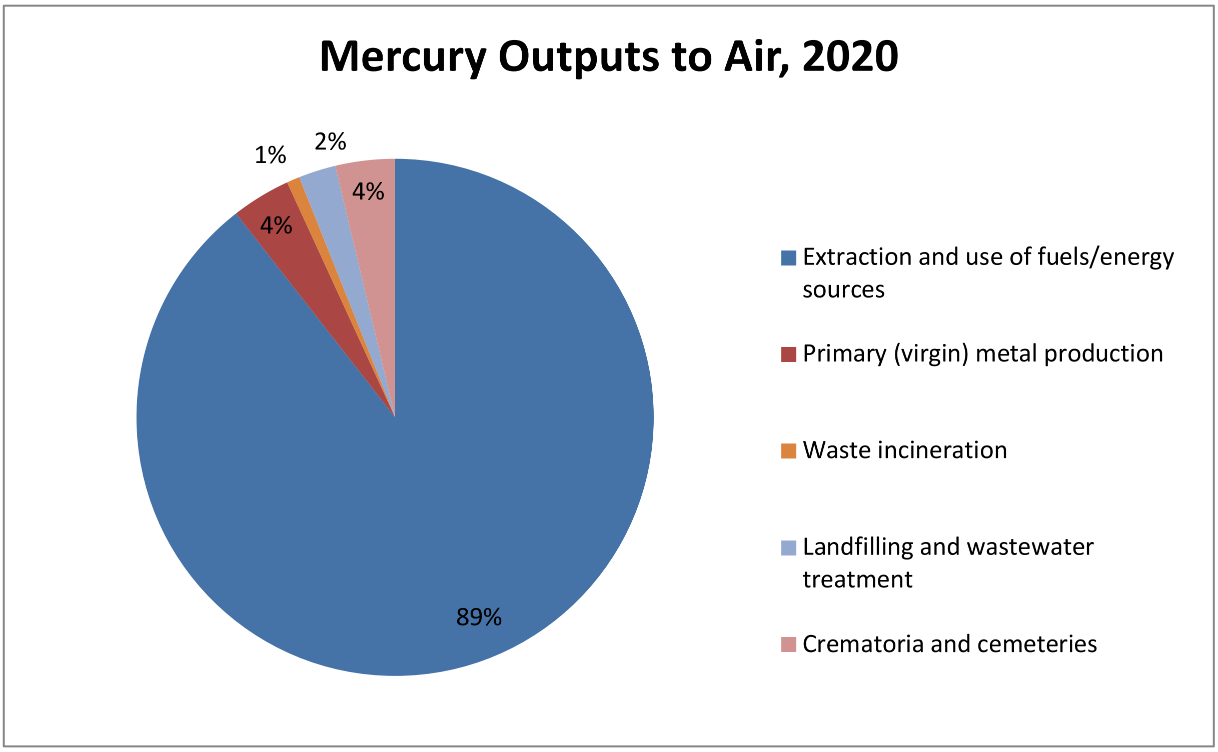


Figure 14-3: Relative mercury outputs to air, by source category

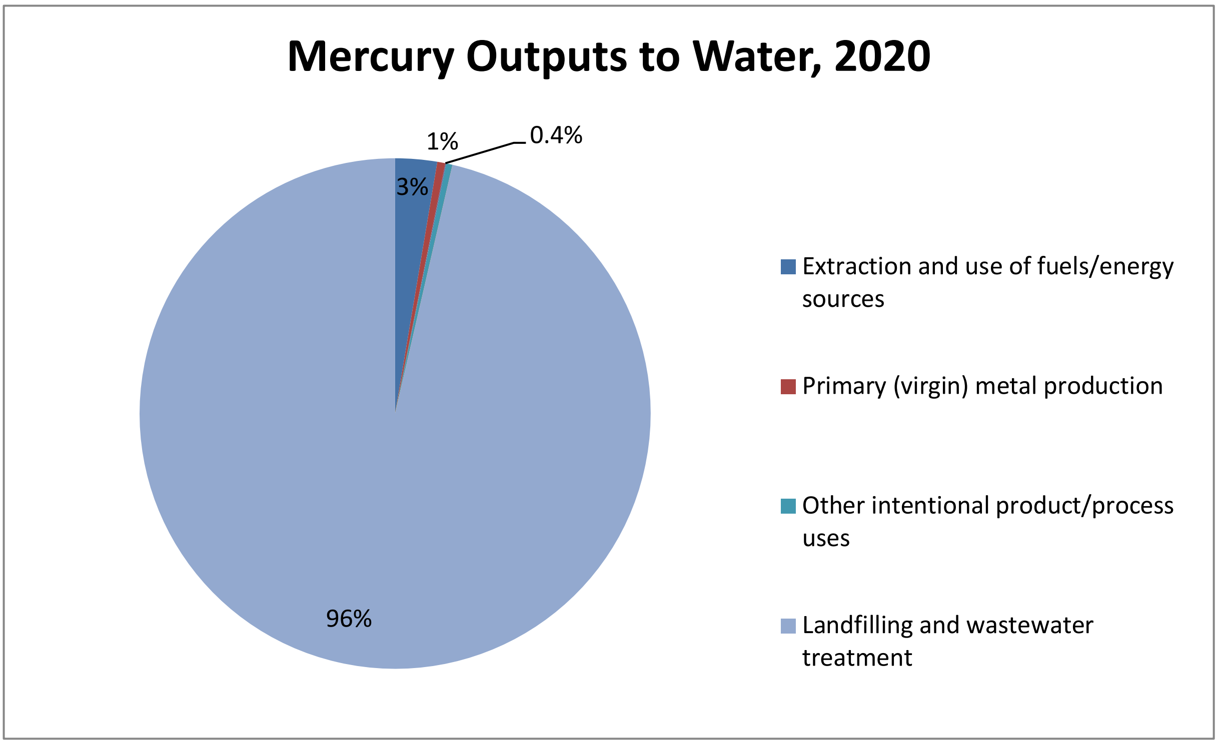


Figure 14-4: Relative mercury outputs to water, by source category

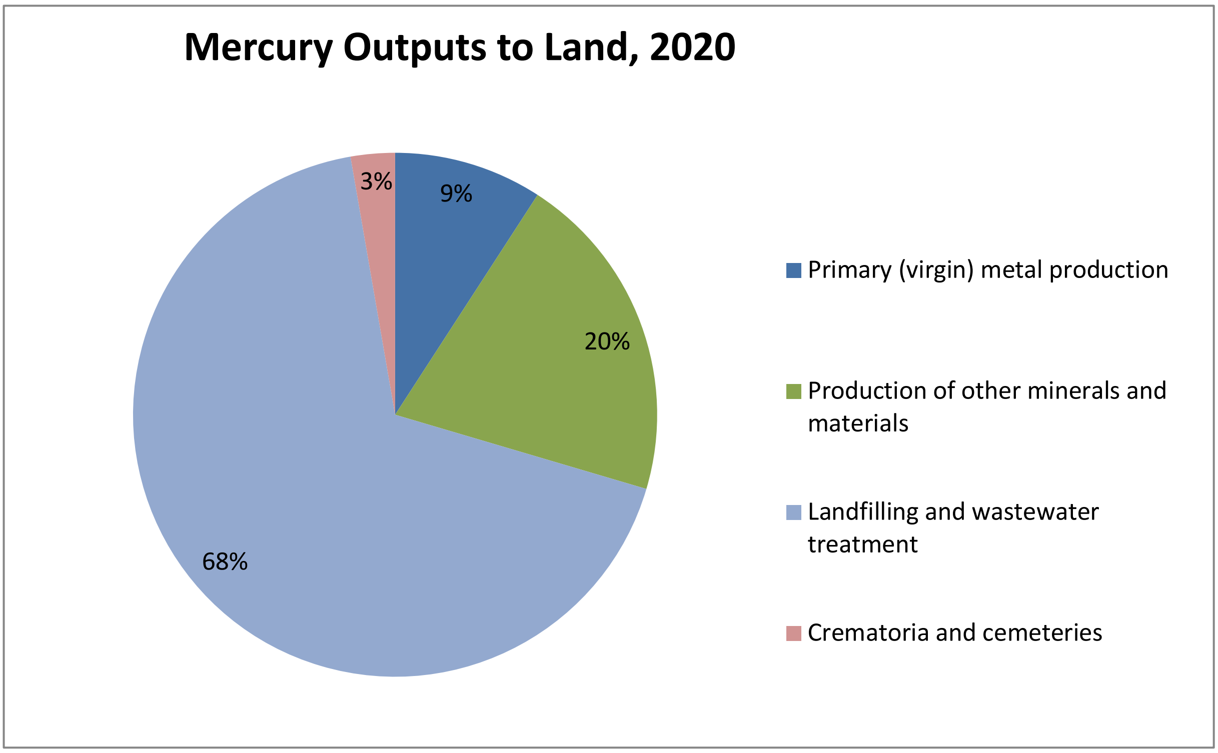


Figure 14-4: Relative mercury outputs to land, by source category

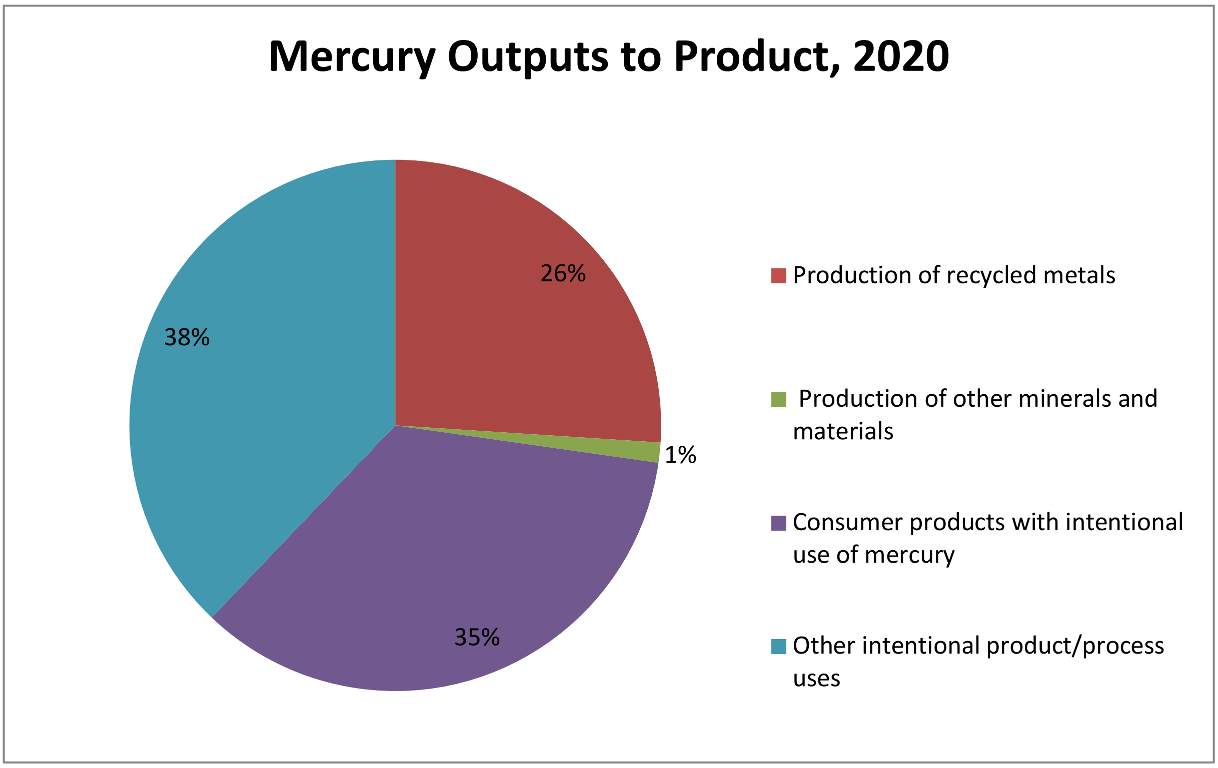


Figure 14-5: Relative mercury outputs to products, by source category

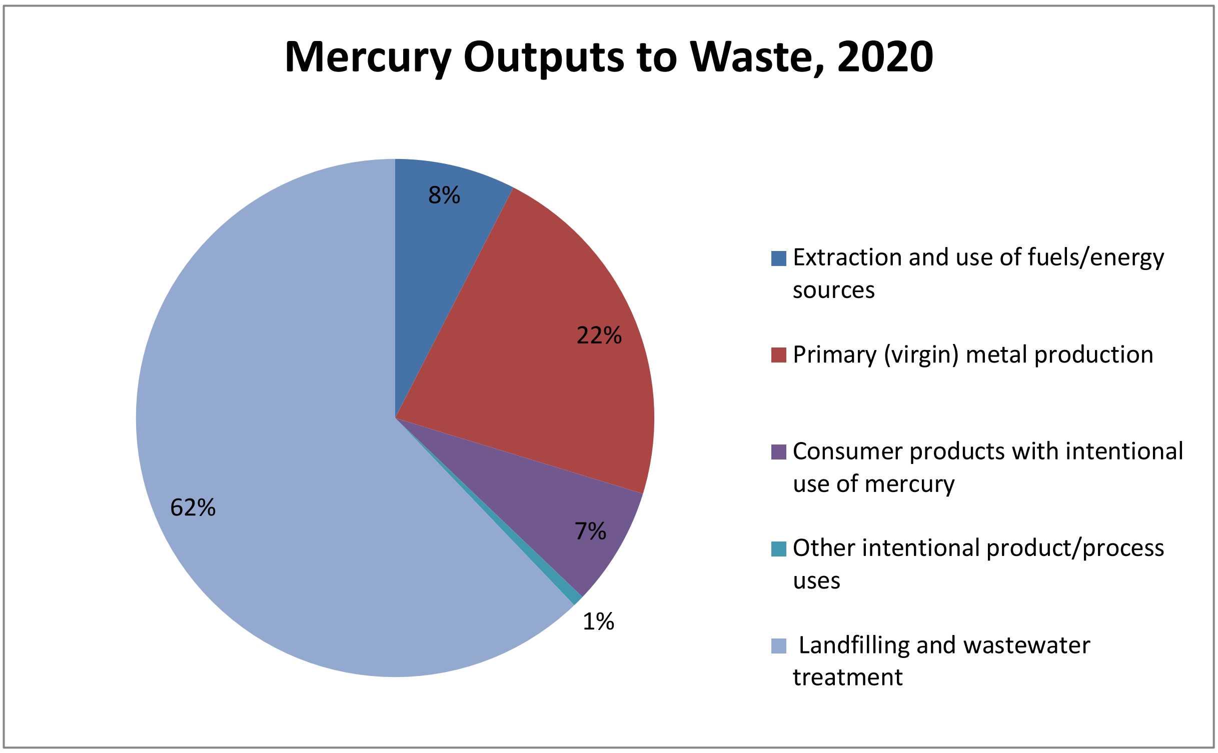


Figure 14-6: Relative mercury outputs to waste, by source category

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	18 – 170.7 (94.3)	16.2 – 153.6 (84.9)	-	1.8 – 17.1 (9.45)	-	-
Other coal combustion	35.5 – 142.9 (89.2)	33.7 – 135.8 (84.8)	-	-	-	1.8 – 7.2 (4.5)
Oil extraction, refining and use	17.26	14.5	0.1	0.66	-	2.0
Gas extraction, refining and use	0.47 – 379.4 (189.7)	0.09 – 76 (37.9)	0.09 – 76 (37.9)	-	-	0.28 – 227.4 (113.8)
Biomass fuel	167.7 – 167 (92.0)	167.7 – 167 (92.0)	-	-	-	-
Geothermal power	244.8 – 1,795 (1,020)	237.6 – 1,787.8 (1,013)	7.2	-	-	-
Gold & silver production, with mercury	20	4	8	8	-	-
Gold & silver production, without mercury	389.3	1.42	0.71	32.03	1.42	353.7
Ferrous metals production (iron & steel)	39.4 – 157.3 (98.6)	19.76 – 78.63 (49.3)	-	19.76 – 78.63 (49.3)	-	-
Cement production	1.31	0.92	-	-	0.39	-
Lime production	0.72 – 2.89 (1.81)	0.50 – 2.02 (1.26)	-	-	0.22 – 0.867 (0.54)	-
Phosphate fertiliser	187	-	-	187	-	-
Agricultural lime application	4.93 – 19.73 (12.3)	-	-	4.93 – 19.73 (12.3)	-	-
Thermometers with mercury	0.554 – 5.54 (3.05)	0.055 – 0.554 (0.305)	0.16 – 1.66 (0.91)	-	-	0.332 – 3.32 (1.83)
Electrical switches, contacts and relays with mercury	10 – 100 (55)	1.0 – 10 (5.5)	-	1.0 - 10 (5.5)	-	8.0 – 80 (44)
Light sources - lamps	6.01 – 13.8 (9.83)	0.30 – 0.69 (0.50)	-	-	-	5.71 – 13.1 (9.3)
Light sources - LCDs	0	-	-	-	-	-
Batteries containing mercury	62.99	-	-	-	-	62.99

Category	Mercury Inputs, kg/year	Mercury Outputs, kg/yr				
		Air	Water	Land	Product	Waste
Polyurethane with mercury catalyst	0	-	-	-	0	-
Pharmaceuticals for human and veterinary uses	26.76	-	-	-	26.76	-
Dental mercury amalgam fillings	47.5	0.95	6.65	-	28.5	11.4
Manometers and gauges	0.60	-	-	-	0.60	-
Laboratory chemicals and equipment	2.84	0.14	0.28	-	-	2.42
Recycled mercury	20	-	-	-	20	-
Secondary ferrous metals (iron and steel)	0	0	-	-	-	0
Hazardous waste incineration	0.00015	0.00015	-	-	-	-
Medical waste incineration	0.62 – 3.12 (1.87)	0.62 – 3.12 (1.87)	-	-	-	-
Sewage sludge incineration	0.88	-	-	-	-	0.88
Informal waste incineration	10.1	10.1	-	-	-	-
Other (pet incinerators)	0.51	0.51	-	-	-	-
Controlled landfills/deposits	3450	34.5	0.35	-	-	-
Wastewater treatment systems	314.5 – 6,290 (3,304)	-	157.3 – 3,145 (1,652)	62.9 – 1,258 (661)	-	94.4 – 1,887 (991)
Crematoria	22.1 – 88.3 (55.2)	22.1 – 88.3 (55.2)	-	-	-	-
Cemeteries	10.6 – 42.6 (26.6)	-	-	10.6 – 42.6 (26.6)	-	-
Totals, all sources	**4,962 – 13,615 (9,291)**	**414 – 2569 (1,494)**	**182 – 3,247 (1,715)**	**358 – 1624 (992)**	**78.2**	**514 – 2681 (1598)**

(* Landfill reservoir (3,415 kg) is not included in outputs here so total outputs will not equal total inputs. Also the totals in the table may not exactly equal the sum of displayed data, due to rounding)

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