

NATIONAL INVENTORY OF MERCURY RELEASES IN SINGAPORE

National Environment Agency (NEA)

Dec 2022

This inventory was established in accordance with the guidelines stipulated in the UN Environment's "Toolkit for identification and quantification of mercury releases" (UNEP Toolkit), Inventory Level 1 (version 1.5, November 2019).

Executive Summary

Mercury is a chemical of global concern due to its long-range atmospheric transport, persistence, ability to bioaccumulate in ecosystems and negative effect on human health and the environment.

The Minamata Convention on Mercury was adopted in 2013 in response to the need for global action to protect human health and the environment from the adverse impact of mercury.

Singapore ratified the Minamata Convention on Mercury on 22 September 2017 and the Convention came into force for Singapore on 21 Dec 2017, 90 days after the deposition of the instrument of accession. As a Party, Singapore has developed an inventory of mercury emissions from relevant sources.

This inventory was developed based on available data in 2021. In the absence of 2021 data, the previous years' data was used, and the year was stated in the relevant sections of this report.

This mercury release inventory was derived with the use of mercury emissions data collected from source emission tests and available sampling results from wastewater treatment. In absence of monitoring data, the "Toolkit for identification and quantification of mercury releases" (UNEP Toolkit) was used to derive the estimated mercury releases. The UNEP Toolkit uses pre-determined factors to calculate the mercury releases, derived from data on mercury inputs and releases from the relevant mercury source types from available literature and other relevant data sources.

The UNEP Toolkit has estimated a portion of mercury will be released to land and air through illegal dumping or disposal by open fire. As illegal dumping and disposal by open fire are prohibited in Singapore, there will not be any such releases to the land and air. Any releases to land and air that the UNEP toolkit estimated is due to illegal dumping or burning of products containing mercury will be accounted for as disposal of general waste.

In addition, Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. Furthermore, all wastewater will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer (e.g. industries located in certain parts of Jurong Island) will discharge trade effluent into the watercourse after treatment to meet the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations. The release of mercury from the various sources that are sent for incineration or wastewater treatment will be accounted for under waste incineration and wastewater system/treatment respectively.

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Lastly, as incineration ash is disposed of at a controlled landfill, waste streams have not been included in the report.

In Singapore, there are no domestic production and processing activities that use mercury. Controls are in place banning the import of several consumer products containing mercury, such as batteries containing more than 0.0005% by weight of mercury and mercury thermometers. Mercury could potentially be released to the environment from the incineration of waste (from other products containing mercury) and combustion of fossil fuels as shown in Table 1 below. However, the concentration of mercury impurities present in our waste and imported fossil fuels is very low because of the stringent regulatory control of mercury.

In addition, pollution control equipment is required at incineration plants and industries so that air emissions comply with the Environmental Protection & Management (Air Impurities) Regulations, which includes limits on mercury emissions. As for wastewater treatment, treated wastewater discharged to the watercourse complies with the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations, which also includes mercury limits.

Table 1: Mercury releases

Source category	Estimated Hg releases, standard estimates, Kg Hg/y				Percent of total releases
	Air	Water	Land	Total releases	
Waste incineration ^{*1}	189.9	0.0	0.0	189.9	33%
Fossil fuel and biomass combustion (excluding coal use)	178.1	0.0	0.0	178.1	31%
Wastewater system/treatment ^{*2}	0.0	106.5	0.0	106.5	18%
Fuel production	45.5	1.8	0.0	47.3	8%
Crematoria and cemeteries	25.4	0.0	5.6	31.0	5%
Use and disposal of other products ^{*3}	16.7	0.0	0.0	16.7	3%
Application, use and disposal of dental amalgam fillings ^{*4}	7.0	0.0	0.0	7.0	1%
Landfilling ^{*5}	2.3	0.0	0.0	2.3	0%
Coal combustion and other coal use	0.5	0.0	0.0	0.5	0%
TOTALS (rounded off)	465	108	6	579	100%

Notes to table above:

^{*1}: Waste in Singapore is collected and sent for incineration. Hence, the release of mercury from the various sources that are sent for incineration will be accounted for under waste incineration.

^{*2}: Wastewater in Singapore will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer will discharge trade effluent into the watercourse after treatment. Hence, the release of mercury from the various sources that are sent for wastewater treatment will be accounted for under wastewater system/treatment.

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- ^{*3}: Mercury may be released to the atmosphere from breakage of light sources during the waste collection process or from wear and tear of polyurethane products.
- ^{*4}: Mercury may be released to the atmosphere during the dental preparations and procedures at dental clinics.
- ^{*5}: The UNEP Toolkit default input factor is based on the mercury content of municipal solid waste (MSW). In Singapore, MSW is incinerated, and the incinerated ash is landfilled together with non-incinerable waste. However, data is not available on the mercury content of waste landfilled in Singapore. We have conservatively used the Toolkit default factor for calculations.

Please refer to the appendices for the details of each source and the assumptions adopted.

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Mercury inventory

This report presents the Singapore's Mercury Inventory which was developed with available data in 2021. In the absence of 2021 data, the previous years' data was used, and the year would be stated in the relevant sections of this report.

This mercury release inventory was derived from mercury emissions data collected from source emission tests and available sampling results from wastewater treatment. In the absence of monitoring data, the "Toolkit for identification and quantification of mercury releases" (UNEP Toolkit) that is made available by the Chemicals Branch of the United Nations Environment Programme (UN Environment Chemicals) at their website below would be used:

<http://web.unep.org/chemicalsandwaste/what-we-do/technology-and-metals/mercury/toolkit-identification-and-quantification-mercury-releases>

The UNEP Toolkit uses pre-determined factors to calculate the mercury releases, derived from data on mercury inputs and releases from the relevant mercury source types from available literature and other relevant data sources.

A Summary of sources present in Singapore

Singapore is a major oil refinery hub, and the industrial landscape has expanded to other sectors such as manufacturing, aerospace, pharmaceutical and electronics.

As a city state, Singapore has limited resources and many of the products used in Singapore are imported from other countries. There are no mining activities carried out in Singapore nor domestic production of metals and raw materials. As a party to the Minamata Convention on Mercury, Singapore regulates the use of Mercury. There are no domestic production and processing activities with intentional mercury use.

Mercury release sources present in Singapore are shown below. Only relevant source types identified to be present are included in this report.

- (A) Energy consumption
- Coal combustion in large power plants
 - Combustion/use of petroleum coke and heavy oil
 - Combustion/use of diesel, gasoil, petroleum, kerosene, liquefied petroleum gas (LPG) and other light to medium distillates
 - Use of raw or pre-cleaned natural gas
 - Use of pipeline gas (consumer quality)

- Biomass fired power and heat production
- (B) Fuel production
 - Oil refining
- (C) Use and disposal of products with mercury content
 - Dental amalgam fillings (“silver” fillings)
 - Electrical switches and relays with mercury
 - Light sources with mercury
 - Batteries with mercury
 - Polyurethane (PU, PUR) produced with mercury catalyst
 - Laboratory chemicals
 - Other laboratory and medical equipment with mercury
- (D) Waste incineration
 - Incineration of municipal/general waste
 - Incineration of hazardous waste
 - Incineration of medical waste
 - Sewage sludge incineration
- (E) Landfilling and wastewater treatment
 - Controlled landfills
 - Wastewater system/treatment
- (F) Crematoria and cemeteries
 - Crematoria
 - Cemeteries

Minor mercury release source types (i.e., infra-red detection semiconductors) were not included in this report.

B Summary of mercury emission and releases

The key mercury releases present in Singapore are releases to air and water.

The UNEP Toolkit has estimated a portion of mercury will be released to land and air through illegal dumping or disposal by open fire. As illegal dumping and disposal by open fire are prohibited in Singapore, there will not be any such releases to the land and air. Any releases to land and air that the UNEP toolkit estimated is due to illegal dumping or burning of products containing mercury will be accounted for as disposal of general waste.

In addition, Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. Furthermore, all wastewater will be discharged into the public sewerage system, where available. Only industries that does

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not have access to public sewer (e.g. industries located in certain parts of Jurong Island) will discharge trade effluent into the watercourse after treatment to meet the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations. The release of mercury from the various sources that are sent for incineration or wastewater treatment will be accounted for under waste incineration and wastewater system/treatment respectively.

Lastly, as incineration ash is disposed of at a controlled landfill, waste streams have not been included in the report.

Table 2 below provides a summary of key mercury releases from all source categories present. Figures in blue font were obtained from Source Emission Tests (SET). As these data are empirical data collected on-site, it will be representative of the actual releases. The mercury estimates for the rest of the source categories are based on default input factors in the UNEP Toolkit where information on actual mercury release is not available. For sewage sludge incineration and wastewater system/treatment, sampling results collected by the Public Utilities Board (PUB) are used.

Mercury estimates for the source categories in green font are based on population data, electrification rate and/or dental personnel density in Singapore. The electrification rate was mentioned in the toolkit as a possible factor that indicates the level of development in the country and prevalence of products containing mercury.

Table 2: Summary of mercury releases

Source category	Estimated Hg releases, standard estimates, Kg Hg/y		
	Air	Water	Land
Energy consumption			
Coal combustion in large power plants	0.5	0.0	0.0
Combustion/use of petroleum coke and heavy oil	7.1	0.0	0.0
Combustion/use of diesel, gasoil, petroleum, kerosene	2.8	0.0	0.0
Use of raw or pre-cleaned natural gas	159.1	0.0	0.0
Use of pipeline gas (consumer quality)	0.0	0.0	0.0
Biomass fired power and heat production	9.1	0.0	0.0
Fuel production			
Oil refining	45.5	1.8	0.0
Use and disposal of products with mercury content			
Dental amalgam fillings ("silver" fillings) ¹	7.0	0.0	0.0
Electrical switches and relays with mercury	0.0	0.0	0.0
Light sources with mercury ²	0.3	0.0	0.0
Batteries with mercury	0.0	0.0	0.0
Polyurethane (PU, PUR) produced with mercury catalyst ³	16.4	0.0	0.0
Laboratory chemicals	0.0	0.0	0.0
Other laboratory and medical equipment with mercury	0.0	0.0	0.0

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Waste incineration			
Incineration of municipal/general waste ^{*4}	134.2	0.0	0.0
Incineration of hazardous waste	11.8	0.0	0.0
Incineration of medical waste	7.6	0.0	0.0
Sewage sludge incineration	36.3	0.0	0.0
Landfilling and wastewater treatment			
Controlled landfills ^{*5}	2.3	0.0	0.0
Wastewater system/treatment ^{*6}	0.0	106.5	0.0
Crematoria and cemeteries			
Crematoria	25.4	0.0	0.0
Cemeteries	0.0	0.0	5.6
TOTAL	465.4	108.3	5.6

Notes to table above:

- *1: Mercury may be released to the atmosphere during the dental preparations and procedures at dental clinics.
- *2: Mercury may be released to the atmosphere from breakage of light sources during the waste collection process.
- *3: Mercury may be released to the atmosphere from wear and tear of polyurethane products.
- *4: Waste in Singapore is collected and sent for incineration. Hence, the release of mercury from the various sources that are sent for incineration will be accounted for under waste incineration.
- *5: The UNEP Toolkit default input factor is based on the mercury content of municipal solid waste (MSW). In Singapore, MSW is incinerated, and the incinerated ash is landfilled together with non-incinerable waste. However, data is not available on the mercury content of waste landfilled in Singapore. We have conservatively used the Toolkit default factor for calculations.
- *6: Wastewater in Singapore will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer will discharge trade effluent into the watercourse after treatment. Hence, the release of mercury from the various sources that are sent for wastewater treatment will be accounted for under wastewater system/treatment.

In Singapore, there are no domestic production and processing activities that use mercury. Controls are in place banning the import of several consumer products containing mercury, such as batteries containing more than 0.0005% by weight of mercury and mercury thermometers. Mercury could potentially be released to the environment from the incineration of waste (from other products containing mercury) and combustion of fossil fuels. However, the concentration of mercury impurities present in our waste and imported fossil fuels is very low because of the stringent regulatory control of mercury.

In addition, pollution control equipment is required at incineration plants and industries so that air emissions comply with the Environmental Protection & Management (Air Impurities) Regulations, which includes limits on mercury emissions. As for wastewater treatment, treated wastewater discharged to the watercourse complies with the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations, which also includes mercury limits.

Appendices

1 Derivation of estimated mercury release

This section describes how the estimated mercury release was derived using the data collected.

1.1 Formula used for source emission test data

Mercury emissions data for the following sources is collected through the source emission tests.

- Coal combustion in power plant
- Incineration of municipal/general waste
- Incineration of hazardous waste
- Incineration of medical waste

As incineration ash is disposed of at a controlled landfill, this waste stream will not be included in the report. Only mercury release to air is estimated for these sources and it is derived using the following formula.

Formula

Estimated annual mercury release *air* for industrial chimney stack #1 =

$$\text{emission results (mg/Nm}^3\text{)} \times \text{air flow rate (Nm}^3\text{/h)} \times \text{operating hours (h/yr)} \times \text{unit conversion rate (kg/mg)}$$

Estimated annual mercury release *air* =

Summation of estimated annual mercury release *air* for stacks #1, #2, #3,

Data Source

- Emission results is obtained from Source Emission Test (SET) report
- Air flow rate is obtained from SET report
- Operating hours is 24 h/day x 365 day/yr = 8,760 h/yr (assuming the facility is operating on a 24/7 basis)
- Conversion rate is 0.000001 kg/mg

1.2 Formula used for activity rate data

For the remaining sources, mercury emissions data is either not applicable or not available at the time of compilation of this report. The UNEP Toolkit was used to derive the estimated mercury releases.

The UNEP Toolkit provides default input and mercury releases distribution factors for calculation of the mercury releases and the following formula are used. Actual sampling data is used for computation where available.

General formula

(1) Estimated mercury input =

Activity rate (mass or volume or number of mercury containing substances/yr) x
default mercury input factor (kg Hg/mass or volume or number of mercury containing substances)

(2) Estimated annual mercury release_{air, water, land} =

estimated mercury input (kg Hg/yr) x
distribution factor_{air, water, land}

Formula for mercury in products

(with the exception of light sources and batteries which use the general formula)

(1a) Mercury input factor for dental amalgam =

default mercury input factor (kg Hg/number of inhabitants/yr) x
 $\frac{\text{Singapore's dental personnel density}}{\text{Denmark's dental personnel density}}$

Note: The default mercury input factor is based on a Danish study. Hence, the dental personnel density is compared against Denmark.

(1b) Mercury input factor for other mercury in products =

default mercury input factor (kg Hg/number of inhabitants/yr) x
 $\frac{\text{Singapore's electrification rate}}{100\% \text{ electrification rate}}$

(2) Estimated mercury input =

Activity rate (number of inhabitants) x
mercury input factor (kg Hg/number of inhabitants/yr)

(3) Estimated annual mercury release_{air, water, land} =

estimated mercury input (kg Hg/yr) x distribution factor_{air, water, land}

Data Source

- Activity rate is from publicly available data or data collected by NEA as detailed in Section 2
- Default mercury input factor is obtained from UNEP toolkit except for sewage sludge incineration and wastewater system/treatment which is based on sampling results collected by PUB
- Dental personnel density is obtained from UNEP toolkit /WHO databases
- Electrification data is obtained from International Energy Agency (IEA)
- Distribution factor is from Table 1-1 as per guidance under UNEP toolkit and the assumptions detailed in Section 1.3

1.3 Assumptions and factors used

The UNEP Toolkit has estimated a portion of mercury will be released to land and air through illegal dumping or disposal by open fire. As illegal dumping and disposal by open fire are prohibited in Singapore, there will not be any such releases to the land and air. Any releases to land and air that the UNEP toolkit estimated is due to illegal dumping or burning of products containing mercury will be accounted for as disposal of general waste.

In addition, Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. Furthermore, all wastewater will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer (e.g. industries located in certain parts of Jurong Island) will discharge trade effluent into the watercourse after treatment to meet the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations. The release of mercury from the various sources that are sent for incineration or wastewater treatment will be accounted for under waste incineration and wastewater system/treatment respectively.

Lastly, as incineration ash is disposed of at a controlled landfill, waste streams have not been included in the report.

The factors used in this report are tabulated in Table 1-1 below for reference.

Table 1-1: Input and distribution factors used

Source category	Mercury input		Mercury releases distribution factor		
	Factor	Unit	Air	Water	Land
Energy consumption					
Combustion/use of petroleum coke and heavy oil	0.0000200	kg Hg / tonne of oil product combusted	1.00	0.00	0.00
Combustion/use of diesel, gasoil, petroleum, kerosene, LPG and other light to medium distillates	0.0000020	kg Hg / tonne of oil product combusted	1.00	0.00	0.00
Use of raw or pre-cleaned natural gas	0.0000001	kg Hg / Nm ³ of gas used	1.00	0.00	0.00
Use of pipeline gas (consumer quality)	0.00000000022	kg Hg / Nm ³ of gas used	1.00	0.00	0.00
Biomass fired power and heat production	0.0000300	kg Hg / tonne of biomass combusted	1.00	0.00	0.00
Fuel production					
Oil refining	0.0000034	kg Hg / tonne of crude oil refined	0.25	0.01	0.0
Waste incineration					
Sewage sludge incineration	0.0006000	kg Hg / tonne of sewage sludge incinerated	0.90	0.00	0.00
Landfilling and wastewater treatment					
Controlled landfills	0.0010000	kg Hg / tonne of waste landfilled	0.01	0.00	0.00
Wastewater system/treatment	0.00000035	kg Hg / m ³ of wastewater treated	0.00	0.50	0.00

Source category	Mercury input		Mercury releases distribution factor		
	Factor	Unit	Air	Water	Land
Use and disposal of products with mercury content					
Dental amalgam fillings ("silver" fillings) ^{*1}	0.0000639	Kg Hg / inhabitant/yr	0.02	0.00	0.00
Electrical switches and relays with mercury ^{*2}	0.0001399	Kg Hg / inhabitant/yr	0.00	0.00	0.00
Light sources with mercury	0.0000080	Kg Hg / Number of hot cathode linear/straight fluorescent lamp sold	0.05	0.00	0.00
	0.0000027	Kg Hg / Number of hot cathode compact fluorescent lamp sold			
	0.0000250	Kg Hg / Number of hot cathode circular fluorescent lamp sold			
Batteries with mercury	12.0000000	Kg Hg/tonne of zinc-air batteries sold	0.00	0.00	0.00
	5.0000000	Kg Hg/tonne of alkaline batteries sold			
	4.0000000	Kg Hg/tonne silver oxide batteries sold			
Polyurethane (PU, PUR) produced with mercury catalyst ^{*2}	0.0000300	Kg Hg / inhabitant/yr	0.10	0.00	0.00

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Source category	Mercury input		Mercury releases distribution factor		
	Factor	Unit	Air	Water	Land
Laboratory chemicals ^{*2}	0.0000100	Kg Hg / inhabitant/yr	0.00	0.00	0.00
Other laboratory and medical equipment with mercury ^{*2}	0.0000400	Kg Hg / inhabitant/yr	0.00	0.00	0.00
Crematoria and cemeteries					
Crematoria	0.0012774	kg Hg / corpse cremated	1.00	0.00	0.00
Cemeteries	0.0012774	kg Hg / corpse buried	0.00	0.00	1.00

Notes to table above:

*1: The UNEP toolkit recommended to use the higher end of the default input factor (i.e. 0.0002 kg mercury consumed per inhabitant per year based on a Danish study), multiplied with the country's estimated dental personnel density (i.e. 0.2648) and divided by the dental personnel density of Denmark (i.e. 0.8292). Hence the input factor used is 0.0002 kg mercury consumed per inhabitant per year x $\frac{\text{Singapore's dental personnel density}}{\text{Denmark's dental personnel density}} = 0.0000639$ kg mercury consumed per inhabitant per year.

*2: As Singapore's electrification rate is 100%, a factor of 1 was applied apart from the default input factors.

2 Data and inventory

This section describes the sources categories present in Singapore and estimated mercury release for the respective sources. Please refer to Section 1 to understand how the estimated mercury release was derived using the data collected.

2.1 Energy consumption and fuel production

This category covers mercury releases from energy consumption and fuel production.

The sub-categories are as follows:

- (A) Energy consumption
 - Coal combustion in large power plants
 - Coal-fired industrial boilers
 - Combustion/use of petroleum coke and heavy oil
 - Combustion/use of diesel, gasoil, petroleum, kerosene
 - Use of raw or pre-cleaned natural gas
 - Use of pipeline gas (consumer quality)
 - Biomass fired power and heat production
 - Charcoal combustion

- (B) Fuel production
 - Oil extraction
 - Oil refining
 - Extraction and processing of natural gas

Industries in Singapore do not use coal to fire their boilers. The facilities also do not carry out combustion of charcoal, oil extraction and extraction and processing of natural gas.

2.1.1 Coal combustion in large power plants

Singapore has a coal-burning utility plant which burns low-sulphur coal as well as other materials such as wood chips and natural gas. Mercury emissions data for coal combustion in this power plant is collected through the SET.

The estimated annual mercury release is derived from the multiplication of the emission results (mg/Nm^3) with the air flow rate (Nm^3/h) and operating hours (h/yr). It is conservatively assumed that the facility is operating every day for 24 hours a day in the calculation of the mercury release.

All incineration ashes are disposed of at the offshore Semakau Landfill. The Semakau landfill is specially designed and constructed with

impermeable linings and leachate treatment systems. As Semakau Landfill is a controlled landfill, waste streams have not been included in the report.

2.1.2 Combustion of natural gas

Natural gas is used by several sectors in Singapore and the consumption data for 2020 (Energy Market Authority, 2021) is tabulated in Table 2-1-1 below. As the 2021 data is not available at the time of compilation of this inventory, the 2020 data is used instead.

It is conservatively assumed that the industrial and transport related sectors in Singapore use raw or pre-cleaned natural gas while commerce, services and household sectors use pipeline gas. The UNEP Toolkit was used to estimate the annual mercury input and mercury releases based on aggregated activity rate as detailed in Section 1.2.

Table 2-1-1: Natural gas consumption by sectors in 2020

Sector	Annual Consumption (TJ/yr)	Annual Consumption (Nm ³ /yr) ^{*1}
Raw or pre-cleaned natural gas (estimated at 0.1 kg of mercury present in 1 million Nm ³ of gas)		
Industrial-related	61,945.01	1,585,792,256
Transport-related	82.32	2,107,392
Others	127.02	3,251,712
Total		1,591,151,360
Pipeline gas (estimated at 0.00022 kg of mercury present in 1 million Nm ³ of gas)		
Commerce and Services-related	3,246.08	83,099,571
Households	3,191.00	81,689,600
Total		164,789,171

Note to table above:

*1: The annual fuel consumption of natural gas in Nm³/yr is derived based on a conversion rate of 25,600 Nm³ per TJ (International Energy Agency, 2004)

A sample derivation of the mercury release from combustion of raw or pre-cleaned natural gas is below.

Example

$$\begin{aligned}
 (1) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (volume of gas used/yr)} \times \text{default mercury input factor} \\
 & \text{(kg Hg/volume of gas used)} \\
 & = 1,591,151,360 \text{ Nm}^3/\text{yr} \times 0.0000001 \text{ kg Hg/Nm}^3 \text{ of gas used} \\
 & = 159.12 \text{ kg Hg/yr}
 \end{aligned}$$

$$\begin{aligned}
 (2) \quad & \text{Estimated annual mercury release}_{air} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{air} \\
 & = 159.12 \text{ kg Hg/yr} \times 1.00 \\
 & = 159.1 \text{ kg Hg/yr}
 \end{aligned}$$

2.1.3 Combustion of other fuels

The industries in Singapore use several types of fuel. Based on data collected by NEA from the companies, the fuel consumption in 2018 is listed in Table 2-1-2 below. The estimated mercury release did not account for the presence of pollution control equipment in place to control the release of mercury into the environment. The UNEP Toolkit was used to estimate the annual mercury input and mercury releases based on aggregated activity rate as detailed in Section 1.2.

Table 2-1-2: Fuel consumption in 2018

Source Category	Annual Fuel Consumption (tonne/yr)
Combustion/use of diesel, gasoil, petroleum, kerosene, LPG and other light to medium distillate	1,416,321.56
Combustion/use of petroleum coke and heavy oil	352,526.73
Biomass fired power and heat production	302,827.45

A sample derivation of the mercury release from combustion/use of diesel, gasoil, petroleum, kerosene, LPG and other light to medium distillate is below.

Example

$$\begin{aligned}
 (1) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (tonne of oil product combusted/yr)} \times \text{default} \\
 & \text{mercury input factor (kg Hg/tonne of oil product combusted)} \\
 & = 1,416,321.56 \text{ tonne/yr} \times 0.000002 \text{ kg Hg/tonne of oil product} \\
 & \text{combusted} \\
 & = 2.83 \text{ kg Hg/yr} \\
 \\
 (2) \quad & \text{Estimated annual mercury release}_{air} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{air} \\
 & = 2.83 \text{ kg Hg/yr} \times 1.00 \\
 & = 2.8 \text{ kg Hg/yr}
 \end{aligned}$$

2.1.4 Oil refining

Based on data collected by NEA from the companies, the total amount of crude oil refined per day in 2021 is estimated at 1,082,000 barrels. It is conservatively assumed that the facility is operating every day in the calculation of the mercury release. No data is available on the mercury content of the refinery inputs. The Toolkit default factor has been used for the calculations as detailed in Section 1.2.

A sample derivation of the mercury release from oil refining is below.

$$\begin{aligned}
 (1) \quad & \text{Activity rate} = \\
 & \text{Daily activity rate (barrel of crude oil refined/day)} \\
 & \div \text{unit conversion for barrel (barrel/tonne)} \times \text{unit conversion for day (day/yr)} \\
 & = 1,082,000 \text{ barrel of crude oil refined/day} \div 7.37 \text{ barrel/tonne}^1 \times 365 \text{ day/yr} \\
 & = 53,586,160.11 \text{ tonne of crude oil refined/yr} \\
 \\
 (2) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (tonne of crude oil refined/yr)} \\
 & \times \text{default mercury input factor (kg Hg/ tonne of crude oil refined)} \\
 & = 53,586,160.1 \text{ tonne/yr} \times 0.0000034 \text{ kg Hg / tonne of crude oil refined} \\
 & = 182.19 \text{ kg Hg/yr} \\
 \\
 (3a) \quad & \text{Estimated annual mercury release}_{\text{air}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{air}} \\
 & = 182.19 \text{ kg Hg/yr} \times 0.25 \\
 & = 45.5 \text{ kg Hg/yr} \\
 \\
 (3b) \quad & \text{Estimated annual mercury release}_{\text{water}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{water}} \\
 & = 182.19 \text{ kg Hg/yr} \times 0.01 \\
 & = 1.8 \text{ kg Hg/yr}
 \end{aligned}$$

As our oil refineries are located in Jurong Island and Pulau Bukom that are not served by public sewers, they would treat the trade effluent before discharging into the watercourse. The estimated mercury released to water is 1.8 kg Hg/yr.

¹ (Joint Oil Data Initiative, 2022)

2.1.5 Actual/Estimated annual mercury releases

The UNEP Toolkit was used to estimate the annual mercury input and mercury releases based on the information data detailed in Sections 2.1.1 to 2.1.4. The results are tabulated in Table 2-1-3 below.

Table 2-1-3: Estimated mercury releases for energy consumption and fuel production

Source ^{*1}	Activity Rate, tonnes/yr	Estimated Annual Hg releases, standard estimates, Kg Hg/yr		
		Air	Water	Land
Coal combustion in large power plants	-	0.5	-	-
Coal-fired industrial boilers	-	-	-	-
Combustion/use of petroleum coke and heavy oil	352,527	7.1	0.0	0.0
Combustion/use of diesel, gasoil, petroleum, kerosene	1,416,322	2.8	0.0	0.0
Use of raw or pre-cleaned natural gas	1,591,151,360	159.1	0.0	0.0
Use of pipeline gas (consumer quality)	164,789,171	0.0	0.0	0.0
Biomass fired power and heat production	302,827	9.1	0.0	0.0
Charcoal combustion	-	-	-	-
Oil extraction	-	-	-	-
Oil refining	53,586,160	45.5	1.8	0.0
Extraction and processing of natural gas	-	-	-	-

Note to the table above:

*1: Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. In addition, all wastewater will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer will discharge trade effluent into the watercourse after treatment. The release of mercury from the various sources that are sent for incineration or wastewater treatment will be accounted for under waste incineration and wastewater system/treatment respectively.

2.2 Domestic production of metals and raw materials

This category covers mercury releases from the domestic production of metals and raw materials with mercury impurities.

The sub-categories are as follows:

- Primary (virgin) metal production
- Cement clinker production
- Pulp and paper production
- Production and processing of other raw materials

In Singapore, there are no facilities carrying out production of metals and raw materials.

2.3 Domestic production and processing with intentional mercury use

This category covers mercury releases from the domestic production and processing with intentional mercury use.

The sub-categories are as follows:

- Chlor-alkali production with mercury technology
- VCM (vinyl-chloride-monomer) production with mercury-dichloride (HgCl_2) as catalyst
- Acetaldehyde production with mercury-sulphate (HgSO_4) as catalyst
- Other production of chemicals and polymers with mercury compounds as catalysts

In Singapore, there are no facilities using mercury or mercury compounds for the processes listed above.

2.4 Waste handling and recycling

This category covers mercury releases from waste handling and recycling.

The sub-categories are as follows:

- (A) Waste incineration
 - Incineration of municipal/general waste
 - Incineration of hazardous waste
 - Incineration of medical waste
 - Sewage sludge incineration
 - Open fire/informal waste burning
- (B) Landfilling
 - Controlled landfills
 - Informal dumping of general waste
- (C) Wastewater treatment
 - Wastewater system/treatment
- (D) Production of recycled metals
 - Production of recycled mercury ("secondary" metal production)
 - Production of recycled ferrous metals (iron and steel) from vehicles

Waste incineration and landfilling

Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. The incineration ash and other non-incinerable wastes are then transported to the offshore Semakau Landfill for final disposal.

Semakau Landfill is bounded by a 7 km long perimeter bund which is lined with an impermeable geomembrane. Monitoring wells are located along the bund and water samples are regularly taken to ensure water quality is not compromised. In addition, solid residues such as sludge from wastewater treatment facilities and fly ash for waste incinerators must be treated to comply with leachate test standards before disposal at Semakau Landfill.

Disposal by open fire and illegal dumping is prohibited under the Environmental Protection and Management (Prohibition on the Use of Open Fires) Order and Environmental Public Health Act 1987 respectively.

Wastewater treatment

Singapore's public sewerage system serves all industrial estates and almost all residences. The Public Utilities Board (PUB) regulates the

sewerage system, as well as the treatment and discharge of industrial wastewater into public sewers.

All wastewater will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer (e.g. industries located in certain parts of Jurong Island) will discharge trade effluent into the watercourse after treatment to meet the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations. Industrial wastewater must be treated to discharge standards stipulated in the Trade Effluent Regulations under the Sewerage and Drainage Act before being discharged into a sewer. The discharge of wastewater into open drains, canals and rivers is regulated by the Environmental Protection and Management Act (EPMA) and the Environmental Protection and Management (Trade Effluent) Regulations.

Production of recycled metals

In Singapore, there are no facilities carrying out the production of recycled metals.

2.4.1 General waste management setup

The UNEP Toolkit requires information on the general waste management setup in Singapore, to determine how mercury is being released via the various pathways (e.g. air, water). NEA estimated that more than 67% of the general waste is landfilled or incinerated and at least 33% of the mercury-added products waste is safely collected and treated separately.

The above inputs will determine the Toolkit default factors used in calculating the distribution of mercury release for consumption of products containing mercury in Section 2.5.

2.4.2 Waste incineration

Mercury emissions data for the following sources is collected through the Source Emission Tests (SET).

- Incineration of municipal/general waste
- Incineration of hazardous waste
- Incineration of medical waste

The estimated annual mercury release is derived from the multiplication of the emission results (mg/Nm^3) with the air flow rate (Nm^3/h) and operating hours (h/yr). It is conservatively assumed that the facility is operating every day for 24 hours a day in the calculation of the mercury release.

Emission levels of mercury is required to comply with the 0.05 mg/Nm³ emission limit for mercury and its compounds under the Environmental Protection & Management Act, Environmental Protection & Management (Air Impurities) Regulations. Mercury emission data is currently not available for one of the facilities carrying out incineration of municipal/general waste. For this facility, the emission was conservatively assumed to be 0.05 mg/Nm³ for this round of reporting. Mercury emission testing would have to be included in their future SETs to improve the accuracy of this report.

A sample derivation of the mercury release from one company with one incinerator is below. Thereafter, the estimated annual mercury release is a summation of the releases from all industrial chimney stacks.

Example

*Estimated annual mercury release_{air} for industrial chimney stack #1 =
emission results (mg/Nm³) x air flow rate (Nm³/h) x
operating hours (h/yr) x unit conversion rate (kg/mg)
= 0.0001 mg/Nm³ x 194685 Nm³/h x 8,760 h/yr x 0.000001 kg/mg
= 0.17 kg Hg/yr*

As mercury emissions data is currently not available for sewage sludge incineration, the annual mercury input is computed based on the data collected by PUB on the amount of sewage sludge disposed and mercury concentration present in the sewage sludge. The total amount of sewage sludge incinerated in 2021 is estimated at 67,200 tonnes per year on a dry matter basis with an average mercury concentration of 0.0006 kg/tonne.

A sample derivation of the mercury release from sewage sludge incineration is below.

- (1) *Estimated mercury input =
Activity rate (tonne of sewage sludge incinerated/yr) x average
mercury concentration (kg Hg/ tonne of sewage sludge
incinerated)
= 67,200 tonne/yr x 0.0006 kg Hg / tonne of sewage sludge
incinerated
= 40.32 kg Hg/yr*
- (2) *Estimated annual mercury release_{air} =
estimated mercury input (kg Hg/yr) x distribution factor_{air}
= 40.32 kg Hg/yr x 0.90
= 36.3 kg Hg/yr*

As the incineration ash is disposed of at a controlled landfill, this waste stream has not been included in the report.

2.4.3 Landfilling

There is no data on the mercury content of the waste disposed at Semakau Landfill. Hence, the UNEP Toolkit was used to estimate the annual mercury input and mercury releases as detailed in Section 1.2. Based on the waste disposal information collected by NEA, the total amount of waste landfilled in 2021 is estimated at 232,281 tonnes.

The UNEP Toolkit default input factor is based on the mercury content of municipal solid waste (MSW). In Singapore, MSW is incinerated, and the incinerated ash is landfilled together with non-incinerable waste. However, data is not available on the mercury content of waste landfilled in Singapore. We have conservatively used the Toolkit default factor for calculations.

A sample derivation of the mercury release from landfilling is below.

$$\begin{aligned}
 (1) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (tonne of waste landfilled/yr)} \times \text{default mercury input} \\
 & \text{factor (kg Hg/ tonne of waste landfilled)} \\
 & = 232,280.7 \text{ tonne/yr} \times 0.001 \text{ kg Hg / tonne of waste landfilled} \\
 & = 232.28 \text{ kg Hg/yr} \\
 \\
 (2) \quad & \text{Estimated annual mercury release}_{\text{air}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{air}} \\
 & = 232.28 \text{ kg Hg/yr} \times 0.01 \\
 & = 2.3 \text{ kg Hg/yr}
 \end{aligned}$$

2.4.4 Wastewater treatment

The annual mercury input is computed based on the data collected by PUB on the volume of wastewater treated and mercury concentration present in the wastewater. The volume of wastewater treated is 608.5mil m³ in 2021 with an average mercury concentration of less than 0.00000035 kg/m³.

A sample derivation of the mercury release from wastewater treatment is below.

$$\begin{aligned}
 (1) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (m}^3 \text{ of wastewater treated /yr)} \times \text{average mercury} \\
 & \text{concentration (kg Hg/m}^3 \text{ of wastewater treated)} \\
 & = 608,500,000 \text{ m}^3\text{/yr} \times 0.00000035 \text{ kg Hg/m}^3 \text{ of wastewater} \\
 & \text{treated}
 \end{aligned}$$

$$= 212.98 \text{ kg Hg/yr}$$

$$\begin{aligned} (2) \quad & \text{Estimated annual mercury release}_{\text{water}} = \\ & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{water}} \\ & = 212.98 \text{ kg Hg/yr} \times 0.50 \\ & = 106.5 \text{ kg Hg/yr} \end{aligned}$$

2.4.5 Actual/Estimated annual mercury releases

Mercury emissions data collected from the source emission tests of incineration of municipal/general waste, hazardous waste and medical waste is computed and tabulated in Table 2-4-1 below. As mercury emissions data is currently not available for sewage sludge incineration, landfilling and wastewater treatment, the UNEP Toolkit or sampling result was used to estimate the annual mercury releases based on the information data detailed in Sections 2.4.2 to 2.4.4. The results are similarly tabulated in Table 2-4-1.

Table 2-4-1: Estimated mercury release for waste incineration, landfilling and wastewater treatment

Source ^{*1}	Activity Rate, tonnes/yr	Estimated Annual Hg releases, standard estimates, Kg Hg/yr		
		Air	Water	Land
Incineration of municipal/general waste	-	134.2	-	-
Incineration of hazardous waste	-	11.8	-	-
Incineration of medical waste	-	7.6	-	-
Sewage sludge incineration ^{*2}	67,200	36.3	-	-
Open fire waste burning (on landfills and informally)	-	-	-	-
Controlled landfills	232,281	2.3	0.0	0.0
Informal dumping of general waste	-	-	-	-
Wastewater system/treatment ^{*3}	608,500,000	0	106.5	0

Notes to the table above:

^{*1}: Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. In addition, all wastewater will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer will discharge trade effluent into the watercourse after treatment. The release of mercury from the various sources that are sent for incineration or wastewater treatment will be accounted for under waste incineration and wastewater system/treatment respectively.

^{*2}: The unit of the activity rate for sewage sludge incineration is on a dry matter basis

^{*3}: The unit of the activity rate for wastewater system/treatment is in m³/yr

2.5 General consumption of mercury in products, as metal mercury and as mercury containing substances

Industries in Singapore generally do not use mercury in the manufacturing of their products. Import data is available for some of the product groups and the UNEP Toolkit was used to estimate the mercury release.

UNEP Toolkit was also used to perform calculations for the product groups listed below in Table 2-5-1, where mercury input factors for the various products are multiplied by factors such as population, electrification rate and dental personnel density as shown in Table 2-5-2. The assumption is that population data, electrification rate and/or dental personnel density are possible factors that indicate prevalence of products containing mercury. This is further multiplied by the distribution factor for air, land and water. As all wastewater is treated by the wastewater treatment plants and waste collected is disposed of at incineration plants or landfills, the distribution factor for land and water is always assumed zero.

Table 2-5-1: Data types used as activity rates for dental amalgam and certain other product types

Sub-category	Data types used as activity rates
Dental amalgam fillings ("silver" fillings)	Population, density of dental personnel
Electrical switches and relays with mercury	Population, electrification rate (percent of population with access to electricity)
Polyurethane (PU, PUR) produced with mercury catalyst	Population, electrification rate (percent of population with access to electricity)
Laboratory chemicals	Population, electrification rate (percent of population with access to electricity)
Other laboratory equipment with mercury	Population, electrification rate (percent of population with access to electricity)

Table 2-5-2: Background data for default calculations for dental amalgam and certain other product types

Country	Population in 2021	Dental personnel per 1000 inhabitants	Electrification rate, % of population with access to electricity
Singapore	5,453,566	0.265	100

Except for population data (Singapore Department of Statistics, 2022), the data in Table 2-5-2 is provided as part of the Toolkit. They are based

on authoritative international data sources (i.e., Dental data from WHO and Electrification data from IEA) and is specific to Singapore.

2.5.1 Dental amalgam fillings ("silver" fillings)

Population data and density of dental personnel as detailed in Section 2.5 were used as inputs in the UNEP Toolkit to estimate the mercury release. Mercury controls such as amalgam separators are conservatively not considered in the estimation as there is no readily available information on their application in Singapore.

As illegal dumping is prohibited in Singapore, there would not be any such releases to the land. Any releases to land that the UNEP toolkit estimated is due to illegal dumping will be accounted for as disposal of general waste. Mercury may be released to the atmosphere during the dental preparations and procedures at dental clinics.

A sample derivation of the mercury release from consumption of dental amalgam fillings is below.

$$\begin{aligned}
 (1) \quad & \text{Mercury input factor for dental amalgam} = \\
 & \text{default mercury input factor (kg Hg/number of inhabitants/yr)} \\
 & \times \frac{\text{Singapore's dental personnel density}}{\text{Denmark's dental personnel density}} \\
 & = 0.0002 \text{ kg Hg/number of inhabitants/yr} \times \frac{0.2648}{0.8292} \\
 & = 0.0000639 \text{ kg Hg/number of inhabitant/yr} \\
 \\
 (2) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (number of inhabitants)} \times \text{mercury input factor (kg} \\
 & \text{Hg/number of inhabitants/yr)} \\
 & = 5,453,566 \times 0.00064 \text{ kg Hg/number of inhabitants/yr} \\
 & = 348.48 \text{ kg Hg/yr} \\
 \\
 (3) \quad & \text{Estimated annual mercury release}_{air} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{air} \\
 & = 348.48 \text{ kg Hg/yr} \times 0.02 \\
 & = 7.0 \text{ kg Hg/yr}
 \end{aligned}$$

2.5.2 Thermometers

The mercury release for thermometers is estimated to be zero. The manufacture, import and export of mercury thermometer are not allowed in Singapore, except for those installed in large-scale equipment or those used for high precision measurement, where no suitable mercury-free alternative is available.

Industries in Singapore do not use mercury in the manufacturing of their products and there were no mercury thermometers imported into Singapore in 2021.

2.5.3 Electrical switches and relays with mercury

The mercury release for electrical switches and relays with mercury is estimated to be zero. The manufacture, import and export of the switches and relays are not allowed in Singapore, except for (a) very high accuracy capacitance and loss measurement bridges, and (b) 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. The equipment containing switches or relay (e.g. cars and wall switches in buildings) has a long life-time. It is also likely that switches or relay containing mercury would be present in Singapore for around 15 to 50 years.

As data on the disposal of switches or relay containing mercury is not available, population data and electrification rate as detailed in Section 2.5 were used as inputs in the UNEP Toolkit to estimate the mercury release.

A sample derivation of the mercury release from consumption of electrical switches and relays with mercury is below.

$$\begin{aligned}
 (1) \quad & \text{Mercury input factor} = \\
 & \frac{\text{default mercury input factor (kg Hg/number of inhabitants/yr)} \times \text{Singapore's electrification rate}}{100\% \text{ electrification rate}} \\
 & = 0.0001399 \times \frac{100\%}{100\%} \\
 & = 0.0001399 \text{ kg Hg/number of inhabitants/yr} \\
 \\
 (2) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (number of inhabitants)} \times \text{mercury input factor (kg Hg/number of inhabitants/yr)} \\
 & = 5,453,566 \times 0.0001399 \text{ kg Hg/number of inhabitants/yr} \\
 & = 762.95 \text{ kg Hg/yr} \\
 \\
 (3) \quad & \text{Estimated annual mercury release}_{\text{air, water, land}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \\
 & \times \text{distribution factor}_{\text{air, water, land}} \\
 & = 762.95 \text{ kg Hg/yr} \times 0.00 \\
 & = 0.0 \text{ kg Hg/yr}
 \end{aligned}$$

As illegal dumping is prohibited in Singapore, there would not be any such releases to the land and air. Any releases to land and air that the UNEP

toolkit estimated is due to illegal dumping will be accounted for as disposal of general waste.

2.5.4 Light sources with mercury

The manufacture, import and export of the following light sources are not allowed in Singapore:

- Compact fluorescent lamps with mercury content exceeding 5 mg per lamp
- Triband phosphor linear fluorescent lamps <60 watts with mercury content exceeding 5 mg per lamp
- Other fluorescent lamps with mercury content exceeding 10 mg per lamp
- High pressure mercury vapour (HPMV) lamps for general lighting purposes
- The following cold cathode fluorescent lamps (CCFLs) and external electrode fluorescent lamps (EEFLs) for electronic displays:
 - Short length (≤ 500 mm) with mercury content exceeding 3.5 mg per lamp
 - Medium length (> 500 mm and ≤ 1500 mm) with mercury content exceeding 5 mg per lamp
 - Long length ($> 1,500$ mm) with mercury content exceeding 13 mg per lamp

2021 import data is obtained for the import of light sources that could contain mercury and tabulated in Table 2-5-3 together with their corresponding Harmonised Commodity Description and Coding System Nomenclature (HS) Code. The figures were used as inputs in the UNEP Toolkit to estimate the mercury release.

Table 2-5-3: Import data for light sources

Light Source	HS code	Import quantity (pieces)
Hot cathode linear/straight fluorescent lamp	8539.31.20	292,292
Hot cathode compact fluorescent lamp	8539.31.10	281,380
Hot cathode compact fluorescent lamp with built-in ballast	8539.31.30	40,840
Hot cathode circular fluorescent lamp	8539.31.90	92,901

Mercury may be released to the atmosphere from breakage of light sources during the waste collection process. A sample derivation of the mercury release from consumption of hot cathode linear/straight fluorescent lamp is shown on the next page.

- (1) *Estimated mercury input =*
Activity rate (number of hot cathode linear/straight fluorescent lamp sold/yr) x default mercury input factor (kg Hg/ number of hot cathode linear/straight fluorescent lamp sold)
 $= 292,292 \times 0.000008 \text{ Kg Hg/number of hot cathode linear/straight fluorescent lamp sold}$
 $= 2.34 \text{ kg Hg/yr}$
- (2) *Estimated annual mercury release_{air} =*
estimated mercury input (kg Hg/yr) x distribution factor_{air}
 $= 2.34 \text{ kg Hg/yr} \times 0.05$
 $= 0.1 \text{ kg Hg/yr}$

2.5.5 Batteries with mercury

The mercury release for batteries is estimated to be zero. Import data is available but the HS codes does not differentiate the type of battery such as whether it is a button cell. It is assumed that all batteries are button cells, and all manganese dioxide batteries are alkaline ones. The 2021 import data (excluding re-export data) is obtained for the import of batteries using HS codes (8506.10 to 8506.60) and tabulated in Table 2-5-4.

Singapore has enhanced the control of mercury-added batteries in 2018 where manufacture, import and export of batteries containing more than 0.0005% by weight of mercury per cell are not allowed. However, as primary batteries have a shelf life of around 5 years, we have conservatively used the mercury inputs from the UNEP Toolkit for this round of reporting. The Toolkit default factors extracted and listed in Table 2-5-4 are used for the estimation of mercury releases.

Table 2-5-4: 2021 import data for batteries and their respective estimated mercury content

Battery type	Mercury content in battery (kg Hg /tonne batteries)	Volume imported (tonne/yr)	Mercury Input (kg Hg/yr)
Mercury oxide	320	0	0
Zinc-air	12	23.17	278.04
Alkaline	5	130.49	652.45
Silver oxide	4	2.83	11.32
Total			941.81

A sample derivation of the mercury release from consumption of zinc-air batteries is below.

$$\begin{aligned}
 (1) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (tonne of zinc-air batteries sold/yr)} \times \text{default mercury} \\
 & \text{input factor (kg Hg/ tonne of zinc-air batteries sold)} \\
 & = 23.17 \times 12.0 \text{ Kg Hg / tonne of zinc-air batteries sold} \\
 & = 278.04 \text{ kg Hg/yr} \\
 \\
 (2) \quad & \text{Estimated annual mercury release}_{\text{air, water, land}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{air, water, land}} \\
 & = 278.04 \text{ kg Hg/yr} \times 0.00 \\
 & = 0.0 \text{ kg Hg/yr}
 \end{aligned}$$

In 2021, Singapore introduced an Extended Producer Responsibility (EPR) scheme for e-waste where producers bear the responsibility for the collection and treatment of their products when they reach end-of-life. Consumers are encouraged to dispose batteries (AA, AAA, AAAA, D, C, 9-volt, Button Cell) with battery circumference of no more than 50mm at designated e-waste collection points. As the EPR scheme was only introduced in 2021, we have conservatively assumed that all the mercury inputs are carried over to general waste. Nevertheless, our general waste is collected and disposed of through incineration and subsequent landfilling of incinerable waste (non-incinerable waste will also be landfilled). Mercury emission from our waste incineration plants is tracked through source emission tests. Solid residues such as sludge from wastewater treatment facilities and fly ash for waste incinerators will be treated to comply with leachate test standards before disposal at Semakau Landfill.

2.5.6 Polyurethane (PU, PUR) produced with mercury catalyst

Population data and electrification rate as detailed in Section 2.5 were used as inputs in the UNEP Toolkit to estimate the mercury release.

Mercury may be released to the atmosphere from wear and tear of polyurethane products. A sample derivation of the mercury release from consumption of polyurethane produced with mercury catalyst with mercury is shown below.

$$\begin{aligned}
 (1) \quad & \text{Mercury input factor} = \\
 & \frac{\text{default mercury input factor (kg Hg/number of inhabitants/yr)} \times \\
 & \text{Singapore's electrification rate}}{100\% \text{ electrification rate}} = 0.0000300 \times \frac{100\%}{100\%} \\
 & = 0.0000300 \text{ kg Hg/number of inhabitants/yr}
 \end{aligned}$$

<p>(2) <i>Estimated mercury input =</i> <i>Activity rate (number of inhabitants) x mercury input factor (kg Hg/number of inhabitants/yr)</i> $= 5,453,566 \times 0.0000300 \text{ kg Hg/number of inhabitants/yr}$ $= 163.61 \text{ kg Hg/yr}$</p> <p>(3) <i>Estimated annual mercury release_{air} =</i> <i>estimated mercury input (kg Hg/yr) x distribution factor_{air}</i> $= 163.61 \text{ kg Hg/yr} \times 0.10$ $= 16.4 \text{ kg Hg/yr}$</p>

2.5.7 Paints with mercury preservatives

The mercury release for paints with mercury preservatives is estimated to be zero. Industries in Singapore do not use mercury in the manufacturing of their products and there is no indication of the presence of paints with mercury preservatives in Singapore.

2.5.8 Skin lightening creams and soaps with mercury chemicals

The mercury release for skin lightening creams and soaps with mercury chemicals is estimated to be zero. In Singapore, companies supplying cosmetic products are responsible for ensuring that the product is safe for use and does not contain substances found in Part I of the Third Schedule of the Health Products (Cosmetic Products — ASEAN Cosmetic Directive) Regulations 2007 unless it is in trace amount or technically unavoidable in good manufacturing practice. Mercury and its compounds are included in the list of prohibited substance, except thiomersal and phenylmercuric salts (including borate) which may be used as preservatives in eye make-up and eye make-up remover. Hence, we concluded that skin lightening creams and soaps containing mercury are not allowed to be sold in Singapore.

2.5.9 Medical blood pressure gauges (mercury sphygmomanometers)

The mercury release for mercury sphygmomanometer is estimated to be zero. The manufacture, import and export of mercury sphygmomanometer are not allowed in Singapore, except for those installed in large-scale equipment or those used for high precision measurement, where no suitable mercury-free alternative is available.

There was no non-electronic mercury sphygmomanometer imported in Singapore in 2021 under the HS code 9018.90.90.

2.5.10 Other manometers and gauges with mercury

The mercury release for other manometers and gauges with mercury is estimated to be zero. The manufacture, import and export of the following non-electronic measuring devices are not allowed in Singapore, except for those installed in large-scale equipment or those used for high precision measurement, where no suitable mercury-free alternative is available.

- Barometers
- Hygrometers
- Manometers
- Sphygmomanometer

There were no such mercury-containing measuring devices imported into Singapore in 2021 under the HS code 9025.80.00.

2.5.11 Laboratory chemicals

The mercury release for laboratory chemicals is estimated to be zero. Population data and electrification rate as detailed in Section 2.5 were used as inputs in the UNEP Toolkit to estimate the mercury release.

A sample derivation of the mercury release from consumption of laboratory chemicals is below.

$$\begin{aligned}
 (1) \quad & \text{Mercury input factor} = \\
 & \frac{\text{default mercury input factor (kg Hg/number of inhabitants/yr)} \times \text{Singapore's electrification rate}}{100\% \text{ electrification rate}} \\
 & = 0.0000100 \times \frac{100\%}{100\%} \\
 & = 0.0000100 \text{ kg Hg/number of inhabitants/yr} \\
 (2) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (number of inhabitants)} \times \\
 & \text{mercury input factor (kg Hg/number of inhabitants/yr)} \\
 & = 5,453,566 \times 0.0000100 \text{ kg Hg/number of inhabitants/yr} \\
 & = 54.54 \text{ kg Hg/yr} \\
 (3) \quad & \text{Estimated annual mercury release}_{\text{air, water, land}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \\
 & \times \text{distribution factor}_{\text{air, water, land}} \\
 & = 54.54 \text{ kg Hg/yr} \times 0.00 \\
 & = 0.0 \text{ kg Hg/yr}
 \end{aligned}$$

2.5.12 Other laboratory and medical equipment with mercury

The mercury release for other laboratory and medical equipment with mercury is estimated to be zero. Population data and electrification rate as detailed in Section 2.5 were used as inputs in the UNEP Toolkit to estimate the mercury release.

A sample derivation of the mercury release from consumption of other laboratory and medical equipment with mercury is below.

$$\begin{aligned}
 (1) \quad & \text{Mercury input factor} = \\
 & \frac{\text{default mercury input factor (kg Hg/number of inhabitants/yr)} \times \text{Singapore's electrification rate}}{100\% \text{ electrification rate}} \\
 & = 0.0000400 \times \frac{100\%}{100\%} \\
 & = 0.0000400 \text{ kg Hg/number of inhabitants/yr} \\
 (2) \quad & \text{Estimated mercury input} = \\
 & \text{Activity rate (number of inhabitants)} \times \text{mercury input factor (kg Hg/number of inhabitants/yr)} \\
 & = 5,453,566 \times 0.0000400 \text{ kg Hg/number of inhabitants/yr} \\
 & = 218.14 \text{ kg Hg/yr} \\
 (3) \quad & \text{Estimated annual mercury release}_{\text{air, water, land}} = \\
 & \text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{air, water, land}} \\
 & = 218.14 \text{ kg Hg/yr} \times 0.00 \\
 & = 0.0 \text{ kg Hg/yr}
 \end{aligned}$$

2.5.13 Estimated annual mercury releases

The UNEP Toolkit was used to estimate the annual mercury input and mercury releases based on the information data detailed in Sections 2.5.1 to 2.5.12.

The UNEP Toolkit has estimated a portion of mercury will be released to land and air through illegal dumping or disposal by open fire. As illegal dumping and disposal by open fire are prohibited in Singapore, there will not be any such releases to the land and air. Any releases to land and air that the UNEP toolkit estimated is due to illegal dumping or burning of products containing mercury will be accounted for as disposal of general waste.

In addition, Singapore has a comprehensive waste collection and disposal system where all waste is collected and sent to waste-to-energy plants for incineration. Furthermore, all wastewater will be discharged into the public sewerage system, where available. Only industries that does not have access to public sewer (e.g. industries located in certain parts of Jurong Island) will discharge trade effluent into the watercourse after

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treatment to meet the discharge standards stipulated in the Environmental Protection and Management (Trade Effluent) Regulations. The release of mercury from the various sources that are sent for incineration or wastewater treatment will be accounted for under waste incineration and wastewater system/treatment respectively.

Lastly, as incineration ash is disposed of at a controlled landfill, waste streams have not been included in the report.

The results are tabulated in Table 2-5-5 below. Mercury may be released to the atmosphere during the dental preparations and procedures at dental clinics, from breakage of light sources during the waste collection process and from wear and tear of polyurethane products.

Table 2-5-5: Estimated mercury releases for mercury in products

Source	Activity rate/ Annual consumption /Population	Estimated Annual Hg releases, standard estimates, Kg Hg/yr		
		Air	Water	Land
Dental amalgam fillings ("silver" fillings) ^{*1}	5,453,566 inhabitants 0.265 dental personnel per 1000 inhabitants.	7.0	0.0	0.0
Thermometers	-	-	-	-
Electrical switches and relays with mercury	5,453,566 inhabitants. 100% Electrification rate	0.0	0.0	0.0
Light sources with mercury ^{*2}	707,413 items sold/yr	0.3	0.0	0.0
Batteries with mercury	156 t batteries sold/yr	0.0	0.0	0.0
Polyurethane (PU, PUR) produced with mercury catalyst ^{*3}	5,453,566 inhabitants. 100% Electrification rate	16.4	0.0	0.0
Paints with mercury preservatives	-	-	-	-
Skin lightening creams and soaps with mercury chemicals	-	-	-	-
Other manometers and gauges with mercury	-	-	-	-
Laboratory chemicals	5,453,566 inhabitants. 100% Electrification rate	0.0	0.0	0.0
Other laboratory and medical equipment with mercury	5,453,566 inhabitants. 100% Electrification rate	0.0	0.0	0.0

Note to table above:

^{*1}: Mercury may be released to the atmosphere during the dental preparations and procedures at dental clinics.

^{*2}: Mercury may be released to the atmosphere from breakage of light sources during the waste collection process.

^{*3}: Mercury may be released to the atmosphere from wear and tear of polyurethane products.

2.6 Crematoria and cemeteries

There are 24,220 deaths in 2021, of which 82% and 18% were cremated and buried respectively. (National Environment Agency, 2022).

The UNEP Toolkit was used to estimate the annual mercury input and mercury releases based on the information data detailed above. The results are tabulated in Table 2-6-1 below.

A sample derivation of the mercury release from cremation is below.

$$\begin{aligned}
 (1) \text{ Estimated mercury input} &= \\
 &\text{Activity rate (corpse cremated/yr)} \\
 &\times \text{default mercury input factor (kg Hg/corpse cremated)} \\
 &= 19,860 \times 0.0012774 \text{ kg Hg / corpse cremated} \\
 &= 25.37 \text{ kg Hg/yr} \\
 \\
 (2) \text{ Estimated annual mercury release}_{\text{air}} &= \\
 &\text{estimated mercury input (kg Hg/yr)} \times \text{distribution factor}_{\text{air}} \\
 &= 25.37 \text{ kg Hg/yr} \times 1.00 \\
 &= 25.4 \text{ kg Hg/yr}
 \end{aligned}$$

Table 2-6-1: Estimated mercury releases for crematoria and cemeteries

Source	Activity Rate, number of deaths/yr	Estimated Annual Hg releases, standard estimates, Kg Hg/yr		
		Air	Water	Land
Crematoria	19,860	25.4	0.0	0.0
Cemeteries	4,360	0.0	0.0	5.6

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