Overview of Mercury Material Flow in Japan (FY2019)

1. Background and Objective

The Minamata Convention on Mercury (hereinafter referred to as the "Convention") entered into force on 16 August 2017. On the same day, the "Act on Preventing Environmental Pollution of Mercury (Act No.42 of 2015; hereinafter referred to as the "Act") entered into force almost on a full scale.

The Convention requires to implement comprehensive mercury control measures throughout the lifecycle of mercury, including imports and exports, use in products, emissions and releases to the environment and disposal. In this regard, a mercury material flow could serve as a basic reference to develop and implement appropriate measures and to verify the effects thereof in the future. For this reason, the Ministry of the Environment, Japan (MOEJ) published "Mercury Material Flow in Japan (FY2010)"[1] in 2013, the material flow[2] for FY2014 in 2016, and the material flow[3] for FY 2016 in 2020.

The target year of this material flow is FY2019 to verify the progress of domestic measures before and after the enforcement of the Act, taking into account the availability of statistical and other information.

The methodology to develop a material flow will be further reviewed, as necessary, in line with the best available information for its improvement. It is expected that the knowledge and experience gained through the process of developing the material flow will be useful for other countries in developing their own material flows and for the Secretariat of the Minamata Convention in preparing guidance documents and reports; therefore, we will provide support and contribution by utilizing such knowledge and experience.

2. Executive Summary[4]

The overview of the mercury material flow in Japan (FY2019) is shown in Figure 1 and Figure 2. The primary results of the flow are, (1) 80 tons of input came from raw materials and fuels for domestic use (of which 70 tons is from imported raw materials and fuels, 3.8 tons from domestically-produced raw materials and fuels, 0.93 tons from imported mercury or mercury alloys, 0.12 tons from imported mercury-added products and 4.8 tons from imported waste containing mercury), (2) 30 tons moved outside of the country (29 tons of mercury exported, 0.80 tons of mercury in exported mercury-added products, 0.33 tons of mercury contained in other exported products/waste), (3)15 tons emitted/released into the environment (14 tons of atmospheric emission, 0.28 tons of release to public waters and 0.53 tons of release to land), and (4) 14 tons landfilled for final disposal.

The input to each process and the output from the process are as follows.

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[1] The MOEJ press release (21st March, 2013): "Mercury Material Flow and Mercury Emission Inventory in Japan" https://www.env.go.jp/press/16475.html

[2] Results of Mercury Material Flow for Mercury (FY2014) https://www.env.go.jp/chemi/tmms/materialflow/materialflow_2014.pdf

[3] Overview of Mercury Material Flow in Japan (FY2016) https://www.env.go.jp/content/000073050.pdf

[4] Each total value has two significant digits and is rounded to the nearest whole number. Due to rounding off, some of the figures may differ from the totals in parentheses. Although the unit of mercury material flow should be ton/year, "ton" is used in this document for simplicity.

- Mercury input to the processing/industrial use of raw materials and fuels is 74 tons (mercury in imported raw materials and fuels: 70 tons, mercury in domestically produced raw materials and fuels: 3.8 tons, input from waste incineration facilities: 0.57 tons). Mercury output from the processes is 57 tons (input to the mercury recovery process: 37 tons[5], atmospheric emissions: 9.9 tons, release to waters: 0.097 tons, release to land: 0.41 tons, final disposal: 9.4 tons).
- Mercury input to the mercury recovery process is 87 tons (input from industrial use of raw materials and fuels: 37 tons, input from societal use of mercury: 16 tons, input from waste incineration facilities: 1.2 tons, mercury in imported wastes: 4.8 tons, mercury stock at the beginning of the fiscal year (FY): 28 tons[6]). Mercury output from the processes is 72 tons (production of mercury compounds and sales of mercury: 7.5 tons or more, mercury exports: 29 tons, mercury stock at the end of the FY: 36 tons[6], atmospheric emissions: 0.0021 tons, releases to waters: 0.000015 tons, final disposal: 0.0070 tons).
- Mercury input to societal use of mercury is 8.9 tons or more (purchase: 7.8 tons or more (amounts of mercury shipped for refinery/sales), imported mercury and mercury alloys: 0.93 tons, mercury in imported mercury-added products is 0.12 tons), and mercury output from those uses is 26 tons (mercury in exported mercury-added products: 0.80 tons, atmospheric emissions: 0.061 tons, input to mercury recovery: 16 tons, input to waste incineration facilities: 10 tons). In addition, the amount of mercury used for manufacturing mercury-added products is 3.5 tons.
- Mercury input to the waste incineration and other processes (including sewage treatment) is 10 tons (from societal use of mercury: 10 tons, from sewer: 0.43 tons[7]), and mercury output from the processes is 11 tons (input to industrial use of raw materials and fuels: 0.57 tons, input to the mercury recovery process: 1.2 tons, atmospheric emissions: 4.4 tons, release to waters: 0.17 tons, release to land: 0.12 tons, final disposal: 4.2 tons).
- Mercury input to other processes is 0.013 tons or more (mercury storage anticipated disposal), and output (atmospheric emissions) from such processes is 0.074 tons (cremation).

Prior to publication, the results of this material flow were confirmed by related business organizations. Some of the values, such as mercury content, are referenced to the results of past interview surveys, but the results of estimation using these values were also confirmed. On the next page, Figures 1 and 2 show the overview of the mercury material flow in Japan based on FY 2019 and the detailed version, respectively.

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[5] Of the 37 tons (figure for the recovery side), the amount of 31 tons is sludge from non-ferrous metal smelting facilities and the amount of 6.0 tons is sludge and liquid waste from other industries. On the other hand, the amount of mercury in sludge from non-ferrous metal smelting facilities on the generation side is 43 tons.

[6] Source: Interviews with mercury recovery businesses in FY2021

[7] The figure is the sum of 0.26 tons of mercury in sludge from sewage treatment and 0.17 tons of mercury released from sewage treatment facilities into public waters.

Mercury Material Flow in Japan (FY2019)

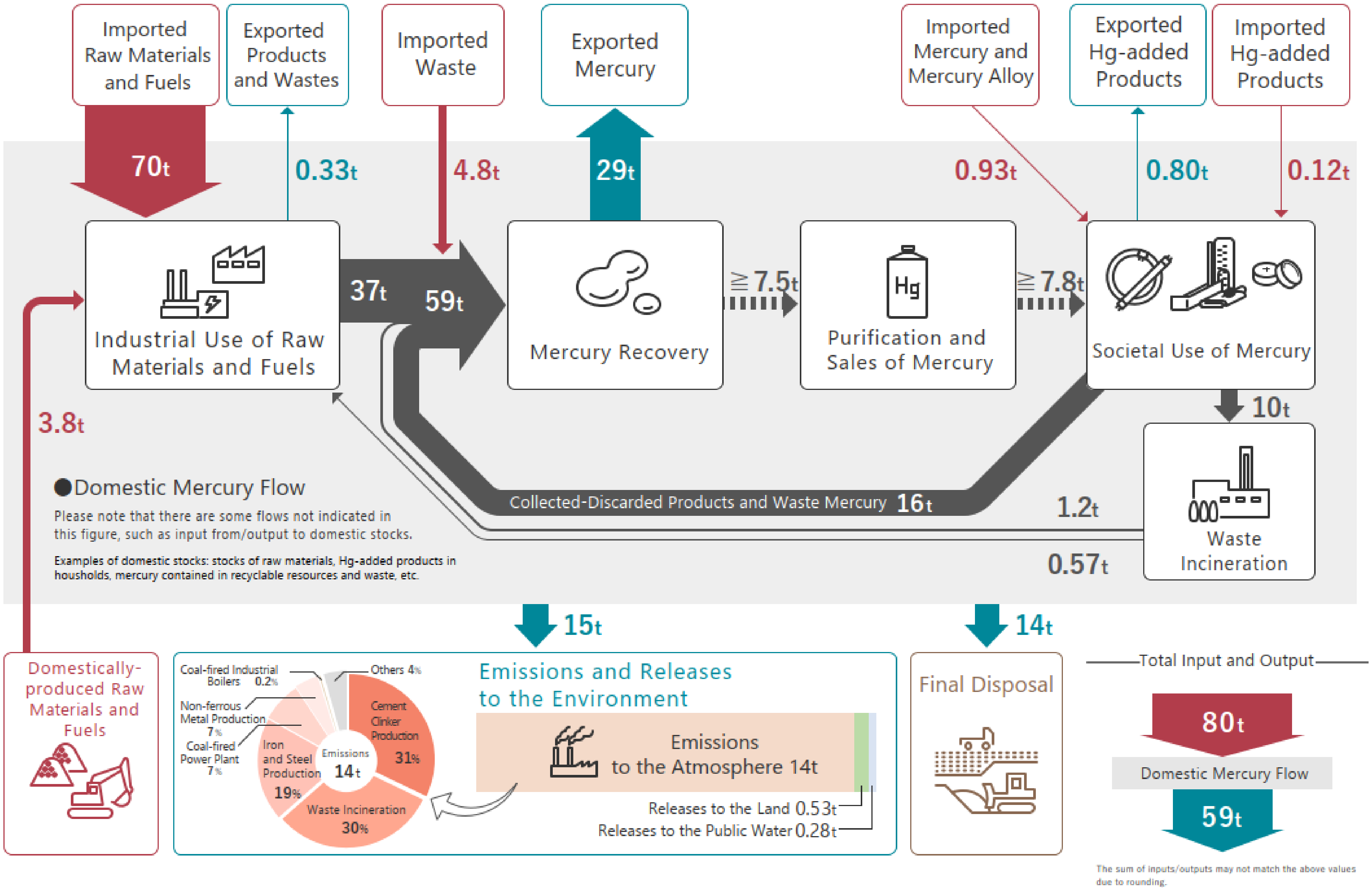
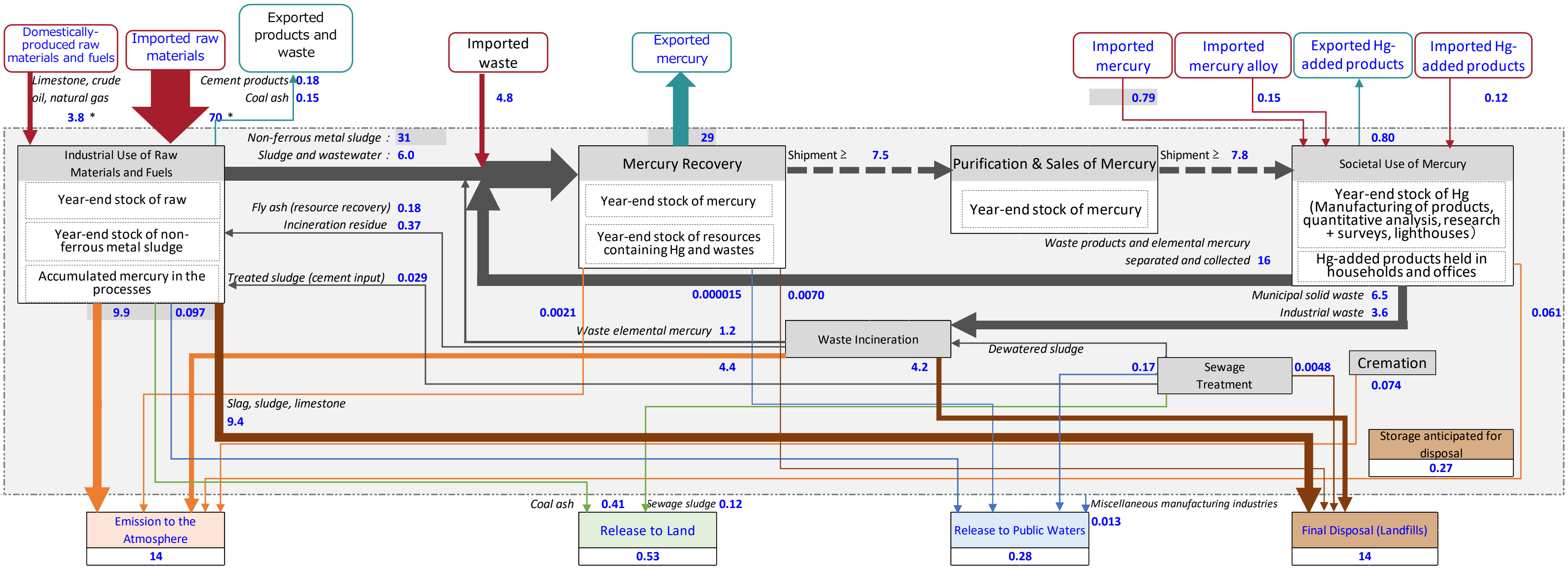


Figure 1 Overview of Mercury Material Flow in Japan (FY2019)



- Mercury flow due to use and recovery
- Mercury emission to the atmosphere
- Mercury release to public waters
- Mercury release to land
- Mercury disposal in landfills

Solid arrows: Mercury flow (thickness is proportional to value)
Dotted arrows: Flows of which amount is not obtained
Number with no shade: Actual or estimated value of FY2019
Number with shade: 3-year average of FY2018-2020
*: Average of the minimum and maximum values of FY2019 due to the gaps of the values among FY2018-2020
・Unit: ton (t-Hg)
・Medium: Italic (e.g. fly ash)
・Box with two-dot chain line: Domestic Mercury Flow
・Box with dot line: Stocks at households and offices

- In this material flow, the mercury flow within Japan's economic zone is defined as the "domestic mercury flow" (the two-dot chain line in the figure); the domestic mercury flow as well as mercury input to the zone and mercury output from the zone to the environment are the subjects of estimation.
- All figures are indicated as the amount of mercury. Significant figures are two-digit, and each figure is rounded off. All figures are expressed in tons (t-Hg). The total amount may not match the sum of the subitems due to rounding off.
- In principle, this material flow uses data for FY2019 (April 2019 - March 2020). It has been prepared using values calculated and estimated based on currently available statistical information, literature, and results of surveys and interviews with business operators and does not cover all usage, releases/emissions, and movement.
- The 14 tons of emissions to the atmosphere in the figure do not include emissions from natural sources.
- The figure represents the amount of mercury in each stage in a single fiscal year of 2019 and does not represent the movement of individual mercury over its lifecycle.
- Mercury-added products held by households and offices are clearly indicated in the flow, but the amount of mercury in these products is not shown.
- Input and output at each stage do not balance because there are mercury in stocks and retained in industrial processes.

Figure 2 Detailed Mercury Material Flow in Japan (FY2019)

3. Words of Caution when referring to the Mercury Material Flow

① "Mercury Material Flow" and "Mercury Emission Inventory"

The material flow represents a flow of an object (material) within a certain period in a coherent system such as an economic zone (within "System boundary" in the conceptual diagram below). When observing the environmental impact of a specific substance in a certain system, an "inventory", which compiles the measurement results of the amount of the substance input from the environment ("Input" in the conceptual diagram below) and the amount released into the environment ("Output" in the conceptual diagram below), is utilized. On the other hand, the "material flow" captures the overall flow of the substance in the system by capturing the input to and output from the system to the environment, along with the flow of substance in each process and the flow of substance between the processes within the system.

In Japan, the "Mercury Emission Inventory[8]" has been developed focusing on atmospheric emissions of mercury in Japan. The material flow is intended to comprehensively capture domestic mercury flows, including emissions obtained in the inventory. In this material flow, the mercury flow within the economic zone of Japan is referred to as "domestic mercury flow", and the estimation in the material flow covers domestic mercury flow, the amount of input from the environment to the economic zone, and the amount of output from the economic zone to the environment.

Inputs to domestic mercury flow include mercury in imported and domestically produced raw materials and fuels. Outputs from domestic mercury flow include exported mercury, emissions and releases to the environment and final disposal (landfill).

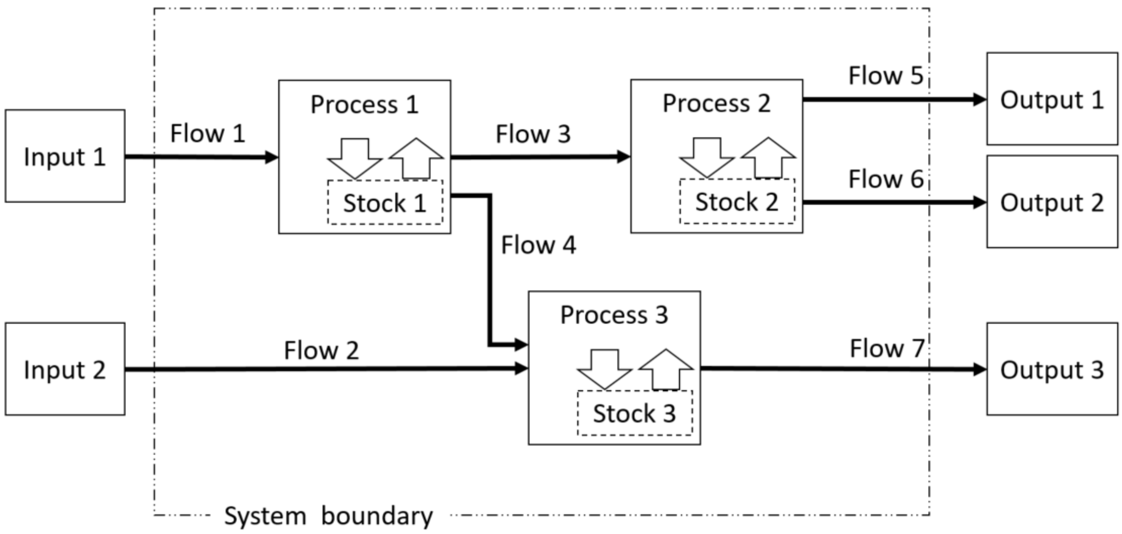


Figure 3 Conceptual diagram of material flow

8 As of March, 2024, the estimation results for FY 2010, FY 2014 - FY 2020 have been published on the MOEJ website shown below. Details of the updated results are published in the MOEJ's "Survey Report on Measures to Control Mercury Emissions". https://www.env.go.jp/air/suigin/invertory.html

② Limitations of the Mercury Material Flow

1) The material flow was developed using data for 2019 fiscal year (April 2019 to March 2020). However, calculated/estimated values based on the best available statistics, literatures and interview surveys with business operators do not necessarily cover all the usage, emission or movement of mercury. Raw data for FY2019 are used whenever available, and if such data are not available or significantly fluctuate by year, numerical values of the nearest year to FY2019 or the average values over several years are used for the calculation/estimation (see attachment for details).
2) Mercury-added products and waste/mercury-containing recyclable resources held in households and offices are expressed as "products held in households and offices" (at the end of FY/ the beginning of FY) in "Societal use of mercury" of the material flow, but the estimated amounts of mercury in those products are treated as reference values because the quantities of the products are difficult to identify, with some exceptions.
3) There are some parts where the input and output in each process do not balance. This is possibly because there are unknown values as described in 1) and 2). These parts need further elaboration.

③ Entry Method of Numerical Values

All the numerical values in the mercury material flow are corresponding values in metric tons of mercury (t-Hg). The significant figures are two digits, and each figure is rounded off. Although the unit of the materials flow should be the amount of mercury moved from one sector to the other per year, "t-Hg" is used in this document for simplicity.
In each table, "0" is used when reported or estimated as "zero", and "N/A" is used when reported as unknown. When the data is not reported nor available, it is marked as "-".

For mercury releases to waters, the following notation was used.

- In the case where it was confirmed that the process does not generate wastewater: "0 t-Hg (no effluent)"
- In the case where it was confirmed that the process generates wastewater and that mercury concentration is below the low limit of quantification: "0 t-Hg (with effluent)" or "0 t-Hg (with effluent in some facilities)"

④ Definition of Terms

The following terms were added to the FY2019 material flow that were not previously available.

Term	Definition
Societal use of mercury	Manufacture and use of mercury-added products (manufacture of mercury-added products, use and disposal of mercury-added products held in households and offices), use of mercury (metrological analysis and research/investigation, ensuring safety of navigation routes).
Quantitative analysis	For measurement and analysis of mass/volume/area, and environment

Term	Definition
	(e.g., for inspection and analysis of products, for measurement using mercury as a medium (use in mercury injection method measuring devices (porosimeters), for replacing mercury contained in measuring instruments).
Research/investigation	Mercury is used for research and investigation purposes that do not fall under the above “Quantitative analysis” (e.g., for operating research vessels, for chemical analysis).
Mercury in research equipment	Mercury filled in research equipment over several fiscal years (e.g., in research vessels, J-PARC facilities, radioactivity measuring instruments).
Mercury in lighthouse (rotating device)	Mercury filled in a mercury bath type rotating device for rotating lens of lighthouse.
Mercury-containing recyclable resources	Mercury, mercury compounds or materials containing mercury or mercury compounds that meet the requirements for mercury content, and for which disposal operations are carried out that result in resource recovery, recycling, recovery use, direct reuse, or alternative use are conducted (excluding waste under the Waste Management and Public Cleansing Law and radioactive materials and materials contaminated thereby) and that are useful.
Mercury refining/sales	Refining: Increasing purity of mercury Sales: Delivery to others (including wholesale)
Storage anticipated for disposal	A municipality purchases mercury equivalent to the amount of mercury assumed to have been contained in mercury-added products as municipal solid waste generated within its jurisdiction and stores it for future environmentally sound disposal.

Attachment

Mercury Material Flow in Japan

(2019 Fiscal Year)

Estimation method

CONTENTS

1. FLOW FOR INPUT OF RAW MATERIALS AND FUELS

1.1 Mercury Content in Imported Raw Materials and Fuels

According to the Trade Statistics by the Ministry of Finance, the Resource and Energy Statistics by the Agency for Natural Resources and Energy, the Statistics of Production by the Ministry of Economy, Trade and Industry, and interviews with Japan Mining Industry Association and Japan Paper Association in FY2021, imports of raw materials and fuels (coal, crude oil, naphtha, iron ore, non-ferrous metal ore, natural gas, limestone, wood pellets, Palm Kernel Shell (PKS) and wood chips for pulp) are shown in Table 1.1.1. As imports of raw materials and fuels other than non-ferrous metal ores have been almost stable from FY2018 to FY2020, the material flow uses the data for FY2019. For non-ferrous metal ores, a three-year average from FY2018 to FY2020 is adopted to be consistent with the mercury material flow (amount of mercury recovered) at non-ferrous metal smelting facilities.

The total amount of mercury in imported raw materials and fuels is estimated as 70 t-Hg. For mercury in raw materials and fuels, the amount of mercury is estimated by multiplying the amount of imports by the mercury concentration. The mercury concentration of imported natural gas was determined to be 0.014 mg/t or less based on the results of the interview survey with relevant domestic businesses (0.01 μg/Nm^3 or less) in FY 2020, assuming that the density of imported natural gas is 0.7 kg/Nm^3.

Table 1.1.1 Mercury content in imported raw materials and fuels (FY2019)

Raw material and fuel		Import		Hg concentration	Hg content in raw materials and fuels	
		Amount	Unit		(kg-Hg)	(t-Hg)
Coal	Anthracite	5,413	10^3 t	0.0390 (g/t)	6,465	6.5
	Bituminous coal	152,228				
	Other coals	7,379				
	Briquette, oval briquette, etc.	29				
	Lignite	15				
	Peat	97				
	Coke, etc.	600				
Crude oil	Crude oil (refining use)	173,212	ML	2.6 (mg/kL)	450	0.45
Naphtha		17,919	10^3 t	0.001 (g/t)	18	0.018
Iron ore (incl. concentrate)	Iron ore (uncondensed)	104,485	10^3 t	0.0329 (g/t)	3,872	3.9
	Iron ore (condensed)	13,320				
	Burned iron sulfide	0.026				
Non-ferrous metal ore Note	Copper, lead, zinc concentrate, gold ore	551	10^4 t	—	—	59
Natural gas	Liquified Natural Gas	76,498	10^3 t	0.014 or less (mg/t)	1.07 or less	0.0011 or less
Limestone		551	10^3 t	0.022 (g/t)	12	0.012
Wood pellet		1,733	10^3 t	0.044 (g/t)	76	0.076

Raw material and fuel	Import		Hg concentration	Hg content in raw materials and fuels	
	Amount	Unit		(kg-Hg)	(t-Hg)
PKS	2,795	10^3 t	0.0090 (g/t)	25	0.025
Wood chips for pulp	10,236	10^3 t	0.007 - 0.07 (g/t)	72 - 717	0.072 - 0.72
Total				—	70

Note: The non-ferrous metal ore imports and the amount of mercury in the ores are averaged over three years from FY2018 to FY2020 in order to be consistent with the mercury flow (mercury recovery) at the non-ferrous metal smelting facilities.

[Source]

Imported amount of coal: the amount of dry coal was calculated by using figures from the Trade Statistics by the Ministry of Finance (wet coal) with a ratio of 95.85 million tons of dry coal to 108.54 million tons of wet coal for coal consumption in the Survey of Electric Power Statistics.

Imports of iron ore, natural gas, limestone: Trade Statistics (the Ministry of Finance, Japan)

Crude oil and naphtha imports: Resource and Energy Statistics (the Agency for Natural Resources and Energy)

Mercury concentration in coal: The interview survey with the Federation of Electric Power Companies of Japan (FY2021) (based on dry coal)

Mercury concentration in crude oil: Measurement results by member companies of Petroleum Association of Japan (2009-2010)

Mercury concentration in naphtha: S&P Global Platts, “Specifications Guide; Asia Pacific & Middle East Refined Oil Products (Last update: August 2023)”

Mercury concentration in iron ore: Arithmetic mean of ore lumps used in blast furnaces in Japan shown in 3.34, on page70 of “National Institute for Environmental Studies Report (2010)” (concentration units ppb used as weight basis)

Amount of imported non-ferrous metal ore: The interview survey with Japan Mining Industry Association (FY2021)

Amount of mercury in non-ferrous metal ore: Calculated by non-ferrous metal ore input and amount of mercury in the input based on the interview survey with Japan Mining Industry Association (FY2021).

Mercury concentration in natural gas: Calculated to be 0.014 mg/t or less, assuming that the density of liquefied natural gas is 0.7 kg/Nm^3 based on the results of the interview survey in FY 2020 (0.01 µg/Nm^3 or less) with relevant domestic companies.

Mercury concentration in limestone: Implementation of measures to control the emission of mercury to the atmosphere based on the Minamata Convention on Mercury (First Report) Reference Material 2, “Results of Survey on Actual Conditions of Mercury Emission”, page 92, https://www.env.go.jp/press/102627.html

Amount of imported wood pellets: The Trade Statistics by the Ministry of Finance, (HS code 440131000 (wood pellets))

Amount of imported PKS: The Trade Statistics by the Ministry of Finance, (total of HS code 230660 (oil-cake and other solid residue of palm nuts or kernels) and HS code 140490200 (gampi and nuts (including their shells, whether or not ground), and hard seeds).

Mercury concentration in wood pellets: According to the wood pellet quality standard set by Japanese Wood Pellet Association, the moisture content is 10% or less on arrival basis and the mercury concentration is 0.1 mg/kg on anhydrous basis. However, the mercury concentration in woody biomass fed to biomass-fired boilers in Japan is used in this report. Among the fuels in the Air Pollution Control Act notification data for woody biomass, wood waste and recycled wood were considered as construction wood waste, and the average mercury concentrations in these and other woody biomass are used to calculate the mercury concentration of woody biomass supplied to biomass-fired boilers in Japan by multiplying the ratio of construction wood waste to the total fuel procurement volume nationwide, which was obtained from surveys of fuel wood supply and demand trends conducted by Japan Woody Bioenergy Association (https:// jwba.or.jp/project-report/fuelwood-demand-survey/).

Mercury concentration in PKS: Taketoshi Kusakabe and Masaki Takaoka. (2021). “Current Status of Mercury Abatement Technologies”, Journal of the Japan Society of Material Cycles and Waste Management.

Amount of imported wood chips for pulp: Amount of wood input (from the FY2021 interview survey with Japan Paper Association) multiplied by the ratio of the amount of wood consumption (28,204,846 m^3) to the amount of imported wood consumption (19,495,107 m^3) (in the Annual Statistics on Production of Paper/Printing/Plastic products/Rubber products by the Ministry of Economy, Trade and Industry).

Mercury concentration in wood chips for pulp: UNEP toolkit Level 2

1.2 Mercury Content in Domestically Produced Raw Materials and Fuels

According to the Statistics of Production by the Ministry of Economy, Trade and Industry, and the survey on woody biomass energy use trend by the Forestry Agency, the amounts of domestic production of raw materials and fuels (limestone, crude oil and natural gas, woody biomass, wood chips for pulp) are as shown in Table 1.2.1. Since domestic production of raw materials and fuels has been stable during FY2018-2020, the material flows uses the data for FY2019.

The amount of mercury contained in domestically produced raw materials and fuels is 3.7 - 4.0 t-Hg was estimated; the average value of 3.8 t-Hg is used for the material flow. The amount of mercury in limestone is estimated by multiplying the amount of production by the mercury concentration. The amount of mercury in crude oil and natural gas is obtained through the interview survey with domestic businesses conducted in FY2021. The amount of mercury in woody biomass and wood chips for pulp was estimated by multiplying the amount of production with mercury concentration.

Table 1.2.1 Mercury content in domestically produced raw materials and fuels (FY2019)

Raw material/fuel	Raw material/fuel production		Hg concentration	Hg content in domestic raw material/fuel production	
	Amount	Unit		(kg-Hg)	(t-Hg)
Limestone	137,506	10^3t	0.022 (g/t)	3,025	3.0
Crude oil	524	ML	N/A	138	0.14
Natural gas	2,466,946	10^3S m^3	N/A	81	0.081
Woody biomass	9,573	10^3t	0.44 (g/t)	421	0.42
Wood chips for pulp	4,573	10^3t	0.007 - 0.07 (g/t)	32 - 320	0.032 - 0.32
Total				3, 697 - 3,985	3.7 - 4.0

[Source]

Production volume of limestone, crude oil, and natural gas: Statistics of Production (Resources, Ceramics, Building materials) by the Ministry of Economy, Trade and Industry

Mercury concentration in limestone: Implementation of measures to control the emission of mercury into the atmosphere based on the Minamata Convention on Mercury (First Report) Reference Material 2, "Results of Survey on Actual Conditions of Mercury Emission", page 92, https: //www.env.go.jp/press/102627.html

Mercury in crude oil and natural gas domestically produced: Interviews with domestic businesses in FY2021.

Production volume of woody biomass: Estimated by subtracting wood pellet imports from domestic inputs (from the "Survey on Woody Biomass Energy Use Trend (FY2019)", the Forestry Agency).

Mercury concentration in woody biomass: According to the wood pellet quality standard set by Japanese Wood Pellet Association, the moisture content is 10% or less on arrival basis and the mercury concentration is 0.1 mg/kg on anhydrous basis. However, the mercury concentration in woody biomass fed to biomass-fired boilers in Japan is used in this report. Among the fuels in the Air Pollution Control Act notification data for woody biomass, wood waste and recycled wood were considered as construction waste, and the average mercury concentrations in these and other woody biomass are used to calculate the mercury concentration of woody biomass supplied to biomass-fired boilers in Japan by multiplying the ratio of construction wood waste to the total fuel procurement volume nationwide, which was obtained from the surveys of fuel wood supply and demand trends conducted by Japan Woody Bioenergy Association (https:// jwba.or.jp/project-report/fuelwood-demand-survey/).

Production volume of wood chips for pulp: Estimated by subtracting wood pellet imports from domestic inputs (from the FY2021 interview survey with Japan Paper Association)

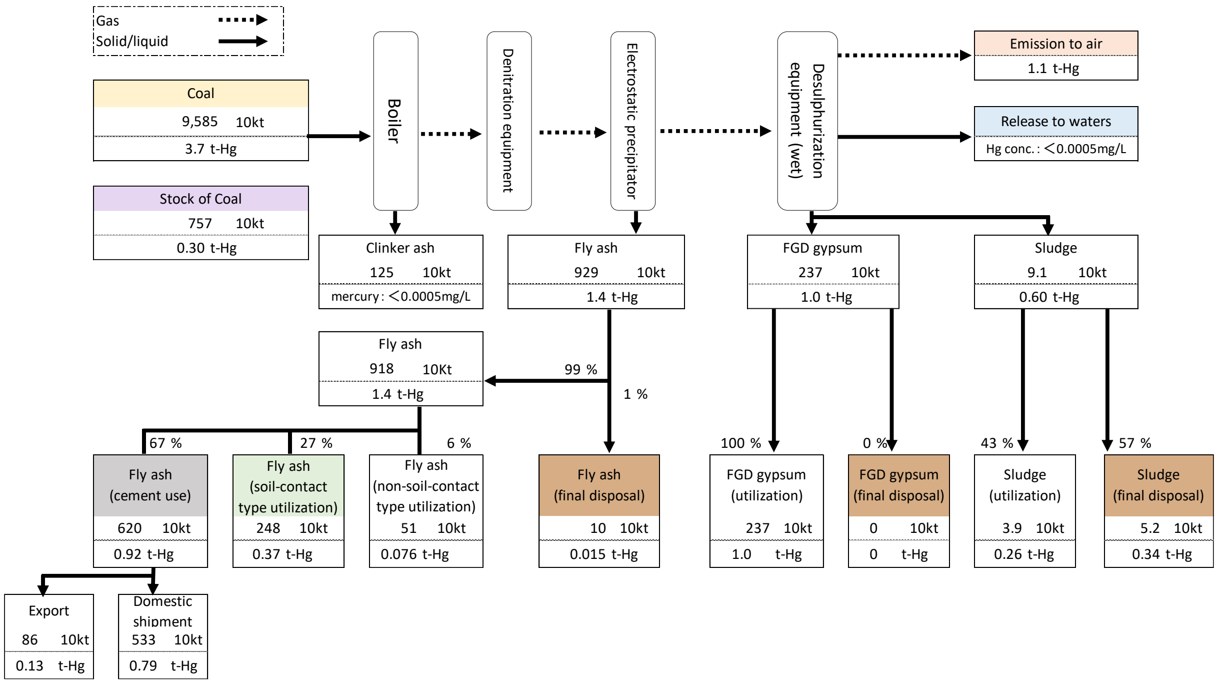
Mercury concentration in wood chips for pulp: UNEP toolkit Level 2

2. FLOW FOR PROCESSING/INDUSTRIAL USE OF RAW MATERIALS AND FUELS

This section describes the mercury flow associated with processing/industrial use of raw materials and fuels by each industry. The figures show the input in light yellow, material/fuel stock in light purple, atmospheric emission in light orange, release to waters in light blue, release to land in light green, final disposal in brown, and cement applications in gray.

2.1 Coal-Fired Power Plants

The mercury flow in coal-fired power plants is shown in Figure 2.1.1.



Flow: Prepared based on the interview survey with the Federation of Electric Power Companies of Japan (FEPC)

Values in the flow: Data extrapolated based on information obtained from the interview survey with the FEPC in FY2021, using data in the Electricity Survey Statistics by the Agency for Natural Resources and Energy. The amount of atmospheric emissions are from the "Mercury Emission Inventory (for FY2019)".

Exported amount of coal ash: The MOEJ website, Status of import/export of waste, etc., (2) About export confirmation and import permission of wastes under the Waste Disposal and Public Cleansing Law (2019) https://www.env.go.jp/recycle/yugai/index4.html

Figure 2.1.1 Mercury flow in coal-fired power plants (FY2019)

1) Mercury in coal consumed

According to the Electricity Survey Statistics by the Agency for Natural Resources and Energy, domestic coal consumption for coal-fired power generation is as shown in Table 2.1.1. Amount of mercury in the coal consumed for coal-fired generation is estimated by multiplying the coal consumption amount by the mercury concentration in coal (0.0390 g/ton) obtained from the interview survey with the Federation of Electric Power Companies of Japan (FEPC).

Table 2.1.1 [Coal-fired power generation] Mercury in coal consumption in electric power industries (FY2019)

Coal consumption (10^4 t)	Hg concentration in coal (g/ton)	Hg content in coal consumed (t-Hg)
9,585	0.0390	3.7

[Source]
Amount of coal consumption: Dry coal amount in the Electricity Survey Statistics by the Agency for Natural Resources and Energy
Mercury concentration in coal: The interview survey with the FEPC in FY2021 (based on dry coal)

Table 2.1.2 shows mercury content in coal stock.

Table 2.1.2 [Coal-fired power generation] Mercury in year-end coal stock
(End of FY2019: March 2020)

Coal Stock (10^4t)	Hg concentration in coal (g/t)	Hg content in coal stock (t-Hg)
757	0.0390	0.30

[Source]
Amount of coal stock: The FEPC responded that the amount of wet coal consumed in FY2021 was 6,0121,000 tons; the amount of dry coal was estimated by multiplying the ratio of dry coal to wet coal in the Electricity Survey Statistics by the Agency for Natural Resources and Energy. The ratio of coal consumption (the FEPC data: the Electricity Survey Statistics data = 6,845 : 9,585 = 100 : 140) was used for the extrapolation.
Mercury concentration in coal: the Interview survey with the FEPC in FY2021 (based on dry coal).

2) Mercury in coal ash utilized or disposed of

Table 2.1.3 and Table 2.1.4 summarize the amount of coal ash (fly ash, clinker ash) generated, utilized, and finally disposed of by coal-fired power plants of the FEPC members, based on the data obtained from the interview survey with the FEPC in FY2021. The amount of coal ash generated from businesses covered by the Electricity Survey Statistics is extrapolated by using the coal consumption of the FEPC members and the ratio of 100 : 140 (68.45 million tons[9]: 95.85 million tons) of the coal consumption by the FEPC members to that by the Electricity Survey Statistics as shown in 1) above.

Mercury in fly ash is estimated as 1.4 t-Hg by multiplying the extrapolated amount of coal ash generation by the mercury concentration obtained from the interview survey with the FEPC in FY2021. The amount of mercury in clinker ash could not be calculated because the leachate test results showed that the mercury concentration of clinker ash was below the lower limit of quantification (< 0.0005 mg/l).

Table 2.1.3 [Coal-fired power generation] Mercury amount in fly ash utilized or disposed of (FY2019)

	Fly ash generation/utilization/final disposal		Hg concentration in fly ash (mg/kg)	Hg content in fly ash (t-Hg)
	FEPC data (10^4 t)	Extrapolated value (10^4 t)		
Generation	663	929	0.149	1.4
Utilization	656	918		1.4
Final disposal	7.4	10		0.015

[9] The FEPC responded that the amount of wet coal was 77.52 million tons in the FY2021 interview; the amount of dry coal was estimated by using the ratio of dry coal to wet coal in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.

[Source]
Amount of generation, utilization, and disposal of fly ash: The interview survey with the FEPC in FY2021. Note that the ratio of coal consumption (the FEPC data: the Electricity Survey Statistics data = 6,845 : 9,585 = 100 : 140) is used for extrapolation.
Mercury concentration in fly ash: The interview survey with the FEPC in FY2021.

Table 2.1.4 [Coal-fired power generation] Mercury in clinker ash utilized or disposed of (FY2019)

		Clinker ash generation/utilization/final disposal		Hg concentration in clinker ash (mg/kg)	Hg content in clinker ash (t-Hg)
		FEPC data (10^4 t)	Extrapolated value (10^4 t)		
Generation		89	125	Below LLOQ (Note)	N/A
	Utilization	85	119		N/A
	Final disposal	4.3	6.0		N/A

Note: The lower limit of quantification in the leachate test is 0.0005 mg/L.
[Source]
Amount of generation, utilization, and final disposal of clinker ash: The interview survey with the FEPC in FY2021. Note that the ratio of coal consumption (the FEPC data: the Electricity Survey Statistics data = 6,845 : 9,585 = 100 : 140) is used for extrapolation.
Mercury concentration in clinker ash: The interview survey with the FEPC in FY2021.

The "Coal Ash Nationwide Fact-finding Report (Results for FY2019)" summarizes the amount of coal ash generated from the "electricity business" and "general industries (manufacturing industry, etc.)" and its status of utilization. According to this report, the amount of utilized coal ash generated from the electricity business and its breakdown are shown in Table 2.1.5 (unit of amount is shown as thousand tons based on the report). Table 2.1.6 shows the amount of mercury that transfers from the coal ash utilized when it is mixed with the soil or spread directly on the soil (Shaded items in the table. In the material flow, shown as "soil-contact type utilization"). Fly ash used as a raw material in cement manufacturing facilities is separately estimated in Section 2.4. Hence among "cement production" category, "cement materials" and "cement admixture" excluding "concrete admixture" are regarded as "cement use". Items other than "soil contact-type utilization" and "cement use" are regarded as "non-soil-contact type utilization". The composition ratio for each type of utilization is; 67.5% for "cement use", 27.0% for "soil-contact type utilization" and 5.6% for "non-soil-contact type utilization".
In Table 2.1.6, mercury in fly ash utilized is estimated by multiplying the amount of fly ash utilized of 9,180 thousand tons obtained through the extrapolation as shown in Table 2.1.3 by respective utilization ratio, and then multiplying it by the mercury concentration. Since the utilization ratio of fly ash and clinker ash differs for each purpose of use, no distinction is made between fly ash and clinker ash in the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". Since the composition ratio in Table 2.1.5 is not exclusive to fly ash, the amount of mercury allocated to each purpose of utilization in Table 2.1.6 may be either underestimated or overestimated. However, the total value of 1.4 t-Hg of mercury in fly ash utilized is not affected by errors in the composition ratio.

Table 2.1.5 Amount of utilization of coal ash generated from electricity business (FY2019)

Category	Purpose of use Note1	Amount of utilization (10^3 t)	Ratio (%)
Cement-relarted	Cement material	5,607	66.69
	Cement admixture	66	0.79
	Concrete admixture	97	1.15
	Subtotal	5,770	68.63
Civil engineering	Soil improvement material	49	0.58
	Construction material	259	3.08
	Electric construction material	82	0.98
	Soil stabilizer	259	3.08
	Asphalt filler	3	0.04
	Coal mine filling	276	3.28
	Subtotal	928	11.04
Construction	Building interior board	236	2.81
	Artificial lightweight aggregate	84	1.00
	Concrete secondary product	38	0.45
	Subtotal	358	4.26
Agriculture, forestry, and fisheries	Fertilizer (incl. snow melting agent)	27	0.32
	Fish reef	0	0.00
	Soil improvement material	83	0.99
	Subtotal	110	1.31
Others	Sewage treatment agent	0	0.00
	Iron and steel production	12	0.14
	Others Note2	1,229	14.62
	Subtotal	1,241	14.76
Total		8,407	100

Note 1: The shaded items (either mixing with soil or direct spreading over soil) are categorized into "soil-contact type utilization". Other purposes except for "soil-contact type utilization" are categorized into "non-soil-contact type utilization". "Cement material" and "cement admixture" used as raw materials in cement production facilities are regarded as "cement use" and are not included in "non-soil-contact type utilization".

Note 2: Almost all of the "Others" in the table refers to "land reclamation" (sea reclamation, etc.) and hence are classified as "soil-contact type utilization".

Note 3: In regard to the utilized coal ash, no distinction is made between fly ash and clinker ash in the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)".

Source: "Coal Ash Nationwide Fact-finding Report (Results for FY2019)", March 2021, Japan Coal Energy Center
https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf

Table 2.1.6 [Coal-fired power generation] Mercury content in fly ash utilized (FY2019)

Purpose	Composition rate (%)	Fly ash utilized (10^4 t)	Hg concentration in fly ash (mg/kg)	Hg content in fly ash utilized (t-Hg)
Cement use	67.5	620	0.149	0.92
Soil-contact type	27.0	248		0.37
Non-soil-contact type	5.6	51		0.076
Total	100	918		1.4

Note: The "Coal Ash Nationwide Fact-finding Report" does not distinguish between fly ash and clinker ash, and the breakdown of fly ash and clinker ash in the composition ratio of each purpose of use is unknown. The amount of mercury allocation to each recycling application may be underestimated or overestimated. However, the total value of 1.4 t-Hg is not affected by errors in the composition ratio.

Source for composition rates by purpose: "Coal Ash Nationwide Fact-finding Report (Results for FY2019)" (March 2021, Japan Coal Energy Center) https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf

Source for mercury concentration in fly ash: The interview survey with the FEPC in FY2021

3) Mercury in flue gas desulfurization gypsum utilized or disposed of

Table 2.1.7 shows the amount of FGD (flue gas desulfurization) gypsum generated, utilized, and disposed of by coal-fired power plants of the FEPC members according to the interview survey with the FEPC in FY2021. It needs to be noted that the amount of FGD gypsum generated from businesses covered by the Electricity Survey Statistics is extrapolated using the ratio of 100 : 140 (the ratio of coal consumption from data obtained from the FEPC and the Electricity Survey Statistics data as shown in 2) above).

The amount of mercury in FGD gypsum is estimated by multiplying the mercury concentration (0.428 mg/kg) obtained from the interview survey with the FEPC by the extrapolated amount of generation, utilization, and final disposal.

Table 2.1.7 [Coal-fired power generation] Mercury in FGD* gypsum utilized and disposed of (FY2019)

FGD gypsum	Generation, utilization, and final disposal of FGD gypsum		Hg concentration in FGD gypsum (mg/kg)	Hg content in FGD gypsum (t-Hg)
	FEPC data (10^4 t)	Extrapolated value (10^4 t)		
Generation	169	237	0.428	1.0
Utilization	169	237		1.0
Final disposal	0	0		0

* FGD stands for flue gas desulfurization.

[Source]

Amount of generation, utilization, and final disposal of FGD gypsum: The interview survey with the FEPC in FY2021. Note that the ratio of coal consumption (the FEPC data: the Electricity Survey Statistics data = 6,845 : 9,585 = 100 : 140) is used for extrapolation.

Mercury concentration in FGD gypsum: The interview survey with the FEPC in FY2021.

4) Mercury in sludge utilized or disposed

Table 2.1.8 shows the amount of sludge generated utilized and finally disposed by the coal-fired power plants of the FEPC members according to the interview survey with the FEPC in FY2021. It needs to be noted that

that the amount of sludge generated from businesses covered by the Electricity Survey Statistics is extrapolated using the ratio as shown in 2) above).

The amount of mercury in the sludge is estimated by multiplying the mercury concentration (6.60 mg/kg) obtained from the interview survey with the FEPC by the extrapolated amount of generation, utilization, and final disposal.

Table 2.1.8 [Coal-fired power generation] Mercury in sludge utilized and disposed (FY2019)

		Generation, utilization, and final disposal of sludge		Hg concentration in sludge (mg/kg)	Hg content in sludge (t-Hg)
		FEPC data (10^4 t)	Extrapolated value (10^4 t)		
Generation		6.5	9.1	6.60	0.60
	Utilization	2.8	3.9		0.26
	Final disposal	3.7	5.2		0.34

[Source]

Amount of generation, utilization, and final disposal of sludge: The interview survey with the FEPC in FY2021. Note that the ratio of coal consumption (the FEPC data: the Electricity Survey Statistics data = 6,845 : 9,585 = 100 : 140) is used for extrapolation.

Mercury concentration in sludge: The interview survey with the FEPC in FY2021.

5) Mercury in exported coal ash

According to the MOEJ's website (Status of import/export of waste, etc., (2) About export confirmation and import permission of wastes under the Waste Disposal and Public Cleansing Law (2019)), the amount of exported coal ash in FY2019 was 1,028 thousand tons. It should be noted that this amount does not distinguish between two sources, "coal-fired power plants" and "coal-fired industrial boilers"; therefore, the amount of exported coal ash generated by coal-fired power plants is calculated to be 861 thousand tons based on the ratio of the amount of coal ash generated (for cement) between coal-fired power plants (6,196 thousand tons) and coal-fired industrial boilers (1,200 thousand tons) as presented in the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". Also, the amount of mercury in the exported coal ash was estimated to be 0.13 t-Hg by multiplying the exported amount by the mercury concentration in the coal ash.

Table 2.1.9 [Coal-fired power generation] Mercury in exported coal ash (FY 2019)

Exported coal ash (10^3t)	Hg concentration in coal ash (mg/kg)	Hg content in exported coal ash (t-Hg)
861	0.149	0.13

[Source]

Exported coal ash: Estimated using the ratio of coal-fired power plants and coal-fired industrial boilers, to the exported coal ash volume as indicated on the MOEJ's website, status of import/export of waste, etc., (2) About export confirmation and import permission of wastes under the Waste Disposal and Public Cleansing Law (2019). https://www.env.go.jp/recycle/yugai/index4.html

Mercury concentration in coal ash: The interview survey with the FEPC in FY2021.

6) Atmospheric emission of mercury

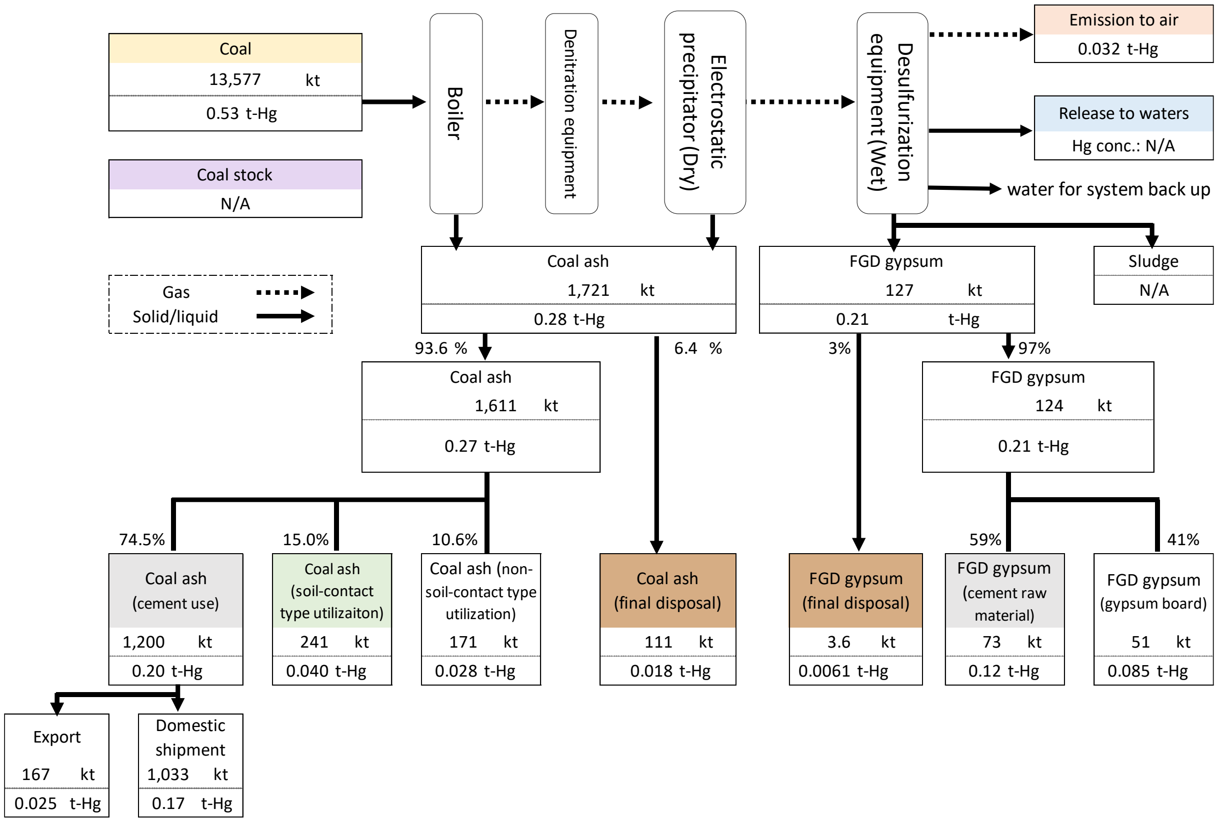
According to the "Mercury Emission Inventory (for FY2019)" (developed in FY2021. For details, see the MOEJ's "Survey Report on Measures to Control Mercury Emissions in FY2021"), atmospheric emission of mercury from coal-fired power plants is estimated to be 1.1 t-Hg based on actual measured data from designated units emitting mercury.

7) Mercury release to public waters

According to the results of the FY2021 interview survey with the FEPC, the amount of mercury in wastewater from coal-fired power plants was mostly below the lower limit of quantification, but since the amount of wastewater was unknown, it was assumed to be "0 (with effluent)".

2.2 Coal-Fired Industrial Boilers

The mercury flow in coal-fired industrial boilers is as shown in Figure 2.2.1.



Flow: Prepared based on the interview survey with Japan Boiler Association

Values in the flow: Estimated by using General Energy Statistics, "Energy Balance Table" (by the Agency for Natural Resources and Energy) and the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)" (by Japan Coal Energy Center (March 2021)). The atmospheric emission is from the "Mercury Emission Inventory (for FY2019)".

Figure 2.2.1 Mercury flow in coal-fired industrial boilers (FY2019)

1) Mercury in residues

Mercury transferred from coal to residues is calculated with the assumption that all the mercury not being released to air is transferred to residues (coal ash, flue gas desulfurization (FGD) gypsum).

Table 2.2.1 [Coal-fired industrial boilers] Mercury in residues (FY2019)

Coal consumption (10^3 t)	Hg concentration in coal (g/t)	Hg content in coal consumed (t-Hg)	Atmospheric emission (t-Hg)	Hg content in residues (t-Hg)
13,577	0.0390	0.53	0.032	0.50

[Source]

Amount of coal consumption: Coal energy conversion for private electricity generation/private steam generation/district heat supply from the Agency for Natural Resources and Energy's General Energy Statistics, "Energy Balance Table" was used as coal consumption (wet coal) for coal-fired industrial boilers, and multiplied by the ratio of wet coal to dry coal consumption in the Agency's the Electricity Survey Statistics to estimate coal consumption (dry coal) for coal-fired industrial boilers.

Mercury concentration in coal: The interview survey with the FEPC in FY2021.

Amount of atmospheric emission: Results from the "Mercury Emission Inventory (for FY2019)"

Table 2.2.2 shows the distribution of mercury in residues to that of coal ash and FGD gypsum. Mercury transfer ratio (4 : 3) is calculated by using mercury content ratio in residues (coal ash : FGD gypsum = 1 : 3) obtained from the interview survey with the FEPC in FY2021 and multiplying it by generation ratio (coal ash : FGD gypsum = 4 : 1) obtained from the "FY 2013 Report on Analysis for the Environmentally Sound Management of Mercury Waste". This is further multiplied by the amount of mercury in residues (0.50 t-Hg) from Table 2.2.1 to calculate the mercury content in coal ash and FGD gypsum.

Table 2.2.2 [Coal-fired industrial boilers] Mercury in coal ash and FGD* gypsum

	Hg concentration (mg/kg) Note 1	Generation ratio Note 2	Mercury transfer ratio Note 3	Hg content (t-Hg)
Coal ash	0.149	4	4	0.28
FGD gypsum	0.428	1	3	0.21

* FGD stands for flue gas desulfurization.

Note 1: Mercury concentration in the residues obtained from the interview survey with the FEPC in FY2021. The mercury concentration value of fly ash is used as that of coal ash.

Note 2: Generation ratio of residues, based on the "FY2013 Report on Analysis of Environmentally Sound Management of Mercury Waste"(March 2014, the MOEJ) is coal ash : desulfurized gypsum = 4 : 1

Note 3: Mercury transfer ratio is calculated by multiplying mercury content ratio of residues (1 : 3) by generation ratio (4 : 1) = 4 : 3

2) Mercury in coal ash utilized or disposed of

The amount of coal ash generated, utilized, and disposed of from "general industries" (businesses other than electricity businesses that use coal-fired industrial boilers for their own power generation) are obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". The amount of coal ash generated from coal-fired industrial boilers is calculated by using the ratio between the coal consumption in coal-fired industrial boilers identified in the "Mercury Emission Inventory (for FY2019)" and "general industries" obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". In addition, the amount of coal ash utilized and disposed of are estimated by multiplying the amount of coal ash generated by its utilization rate (93.6%), and the disposal rate (6.4%) obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". The amount of generation, utilization and final disposal of coal ash generated from coal-fired industrial boilers is shown in Table 2.2.3.

Table 2.2.3 [Coal-fired industrial boilers] Generation, utilization, and final disposal of coal ash (FY2019)

	Coal consumed (10^3 t)	Coal ash generated (10^3 t)	Coal ash utilized (10^3 t)	Coal ash disposed of (10^3 t)
Coal-fired Industrial boilers	13,577	1,721	1,611	111

[Source]

Figures of coal-fired industrial boilers: Amount of coal ash generated at coal-fired industrial boilers is estimated based on the amount of coal consumption in the "Coal Ash Nationwide Fact-finding Report (Results for FY2019) (February 2021 Japan Coal Energy Center)", https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf, and the ratio of coal consumption in the "Mercury Emission Inventory (for FY2019)". Amounts of utilization and final disposal are estimated by multiplying the amount of coal ash generated by the rate of utilization (93.6%) and the rate of final disposal (6.4%) obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)".

According to the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)", the amount of coal ash utilized that are generated from "general industries" and the breakdown of its use are shown in Table 2.2.4. The report summarized as follows: 74.5% for "cement use", 14.9% for "soil-contact type utilization", 10.6 % for "non-soil-contact type utilization".

The amount of coal ash utilized in Table 2.2.5 is calculated by multiplying the estimated amount of utilized coal ash generated from coal-fired industrial boilers (1,611 thousand tons) in Table 2.2.3 by the ratio of each purpose of utilization. Further, the amount of mercury in coal ash utilized is calculated by multiplying the estimated amount of mercury in the coal ash (0.28 t-Hg) in Table 2.2.2 by the overall utilization ratio (93.6%); the breakdown of the amount of mercury in coal ash utilized is calculated by using the composition ratio in Table 2.2.5.

Table 2.2.4 Amount of utilization and composition ratio of coal ash generated from general industries (FY2019)

Category	Purpose of use Note 1	Amount of utilization (10^3 t)	Ratio (%)
Cement-related	Cement material	2,570	72.19
	Cement admixture	81	2.28
	Concrete admixture	5	0.14
	Subtotal	2,656	74.61
Civil engineering	Soil improvement material	271	7.61
	Construction material	28	0.79
	Electric construction material	0	0
	Soil stabilizer	171	4.80
	Asphalt filler	0	0
	Coal mine filling	10	0.28
	Subtotal	480	13.48
Construction	Building interior board	269	7.56
	Artificial lightweight aggregate	0	0

Category	Purpose of use Note 1	Amount of utilization (10^3 t)	Ratio (%)
	Concrete secondary product	1	0.03
	Subtotal	270	7.58
Agriculture, forestry, and fisheries	Fertilizer (incl. snow melting agent)	3	0.08
	Fish reef	0	0
	Soil improvement material	49	1.38
	Subtotal	52	1.46
Others	Sewage treatment agent	0	0
	Iron and steel production	25	0.70
	Others	77	2.16
	Subtotal	102	2.87
Total		3,560	100

Note: The shaded items (either mixture with soil or direct spreading over soil) are categorized into "soil-contact type utilization". Other purposes except for "soil-contact type utilization" are categorized into "non-soil-contact type utilization". "cement material" and "cement admixture" used as raw materials in cement production facilities are regarded as "cement use" and are not included in "non-soil-contact type utilization".

Source: "Coal Ash Nationwide Fact-finding Report (Results for FY2019)", March 2021, Japan Coal Energy Center https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf

Table 2.2.5 [Coal-fired industrial boilers] Mercury in coal ash utilized (FY2019)

Purpose of use	Composition rate (%)	Coal ash utilized (10^3 t)	Hg content in coal ash utilized	
			(kg-Hg)	(t-Hg)
Cement-related	74.5	1,200	198	0.20
Soil-contact type	14.9	241	40	0.040
Non-soil-contact type	10.6	171	28	0.028
Total	100.0	1,611	266	0.27

Note: The total amount of the utilized coal ash does not match due to rounding off.

Source for composition rate: "Coal Ash Nationwide Fact-finding Report (Results for FY2019)" (March 2021, Japan coal energy center), https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf

3) Mercury in FGD gypsum utilized or disposed of

Amount of generation, utilization, and final disposal of FGD gypsum from "general industries" are obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". The amount of FGD gypsum generated from coal-fired industrial boilers is calculated by using the ratio of the coal consumption by coal-fired industrial boilers in the "Mercury Emission Inventory (for FY2019)" to that by "general industries" in the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". Amount of FGD gypsum utilized and disposed of are estimated by multiplying the amount of FGD gypsum generated by its utilization rate (97%), and the disposal rate (3%) obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". Results are as shown in Table 2.2.6.

Table 2.2.6 [Coal-fired industrial boilers] Generation, utilization, and final disposal of FGD* gypsum (FY2019)

	Coal consumed (10^3 t)	FGD gypsum generated (10^3 t)	FGD gypsum utilized (10^3 t)	FGD gypsum disposed of (10^3 t)
Coal-fired industrial boilers	13,577	127	124	3.6

* FGD stands for flue gas desulfurization.

[Source]

Coal-fired industrial boilers: Amount of FGD gypsum generated in coal-fired industrial boilers is estimated by multiplying the FGD gypsum generated from general industries by the ratio of coal consumption by general industries retrieved from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019) (March 2021, Japan Coal Energy Center) https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf. to that by coal-fired industrial boilers from the "Mercury Emission Inventory (for FY2019)".

Amounts of utilization and final disposal are estimated by multiplying the amount of FGD gypsum generated by its utilization rate (97%) and the disposal rate (3%) obtained from the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)".

Also, according to the report above, 59% of FGD gypsum utilized is used as cement materials and the rest (41%) is used for gypsum boards. Amount of mercury in FGD gypsum utilized and disposed of is estimated as shown in Table 2.2.7 calculated by multiplying the amount of mercury in FGD gypsum (0.21t-Hg) as estimated in Table 2.2.2 by the utilization rate (97%), disposal rate (3%) and ratio of each purpose of utilization (cement raw material: 59%, gypsum: 41%).

Table 2.2.7 [Coal-fired industrial boilers] Mercury in utilized or disposed FGD gypsum (FY2019)

		Amount of generation (10^3 t)	Hg content in FGD gypsum	
			(kg-Hg)	(t-Hg)
Utilization	Cement material	73 (59%)	122	0.12
	Gypsum board	51 (41%)	85	0.085
	Subtotal	124	207	0.21
Final disposal		3.6	6.1	0.0061
Total		127	213	0.21

Source utilization rate: "Coal Ash Nationwide Fact-finding Report (Results for FY2019)" (March 2021, Japan Coal Energy Center), https://www.jcoal.or.jp/ashdb/upload/R01_ashstatistics.pdf

4) Mercury in exported coal ash

According to the MOEJ's website (Status of import/export of waste, etc., (2) About export confirmation and import permission of wastes under the Waste Disposal and Public Cleansing Law (2019)), the amount of exported coal ash in FY2019 was 1,028 thousand tons. It should be noted that this amount does not distinguish between two sources, "coal-fired power plants" and "coal-fired industrial boilers"; therefore, the amount of exported coal ash generated by coal-fired industrial boilers is calculated to be 167 thousand tons based on the ratio of the amount of coal ash generated (for cement) between coal-fired power plants (6,196 thousand tons) and coal-fired industrial boilers (1,200 thousand tons) as indicated in the "Coal Ash Nationwide Fact-finding Report (Results for FY2019)". Also, the amount of mercury in the exported coal ash was estimated to be 0.025 t-Hg by multiplying the exported amount by the mercury concentration in the coal ash.

Table 2.2.8 [Coal-fired industrial boilers] Mercury in exported coal ash (FY 2019)

Exported coal ash (10^3t)	Hg concentration in coal ash (mg/kg)	Hg content in exported coal ash (t-Hg)
167	0.149	0.025

[Source]

Exported coal ash: Estimated using the ratio of coal-fired power plants and coal-fired industrial boilers, to the exported coal ash volume as indicated on the MOEJ's website, status of import/export of waste, etc., (2) About export confirmation and import permission of wastes under the Waste Disposal and Public Cleansing Law (2019). https://www.env.go.jp/recycle/yugai/index4.html

Mercury concentration in coal ash: The interview survey with the FEPC in FY2021.

5) Atmospheric emission of mercury

According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from coal-fired industrial boilers are estimated to be 0.032 t-Hg based on actual measurement data from designated units emitting mercury.

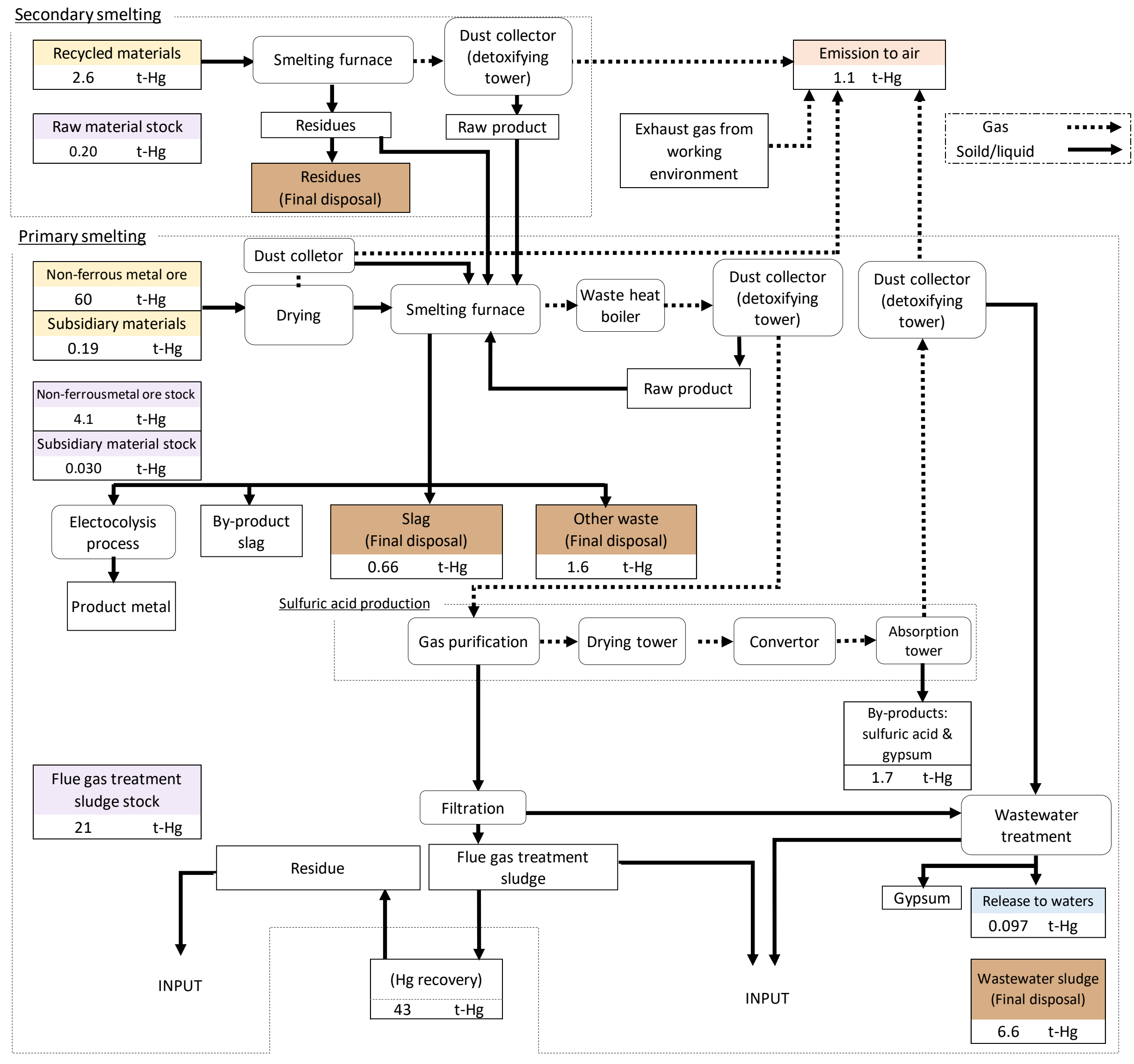
6) Mercury release to public waters

According to the results of the interview survey with Japan Boiler Association in FY2020, there are no examples of research on mercury in wastewater from coal-fired industrial boilers; therefore, the amount of wastewater was unknown, and it was assumed to be "N/A (with effluent)".

2.3 Non-ferrous Metal Smelting Facilities

Figure 2.3.1 shows the mercury flow in non-ferrous metal smelting facilities. When the amount of flue gas treatment sludge from the non-ferrous metal smelting process is small, the sludge may be stored for more than two years and discharged for mercury recovery altogether; therefore, the year of generation and treatment may be different. Since the amount of mercury recovered from flue gas treatment sludge varies greatly by year, a three-year average from FY2018 to FY2020 is adopted for non-ferrous metal smelting facilities.

It should be noted that the production volumes of copper, lead, and zinc from primary smelting facilities provided by Japan Mining Industry Association (JMIA) are equal to the nationwide production volumes; therefore, the values obtained from the interview survey with JMIA are treated as the nationwide values. As for the secondary smelting facilities, relevant data on the JMIA members were obtained from the JMIA interview. On the other hand, the secondary smelting facilities of non-JMIA members are not fully understood; therefore, the estimated values for them are treated as reference.



Flow: Prepared based on the interview survey with Japan Mining Industry Association (JMIA)
Values in the flow: The interview survey with JMIA in FY2021. Atmospheric emissions are from the "Mercury Emission Inventory (for FY 2019)". The "Wastewater sludge (final disposal)", "Slag (final disposal)", "Other waste (final disposal)", and "Wastewater" in the flow include those from primary and secondary non-ferrous metal smelting facilities.

Figure 2.3.1 Mercury flow in non-ferrous metal smelting facilities (FY2019)

1) Mercury in non-ferrous metal ores/raw materials

According to the result of the interview survey with Japan Mining Industry Association (JMIA) in FY2021, the amount of mercury contained in non-ferrous metal ores/raw materials that were input into the non-ferrous metal smelting process is as follows. The three-year average from FY2018 to FY2020 is adopted in the material flow.

Table 2.3.1 [Non-ferrous metal smelting] Mercury in input raw materials

Input material	Hg content in input raw materials (t-Hg)			
	FY2018	FY2019	FY2020	Three-year Average
Non-ferrous metal ores	59	59	61	60
Recycled materials	2.0	2.6	3.4	2.6
Subsidiary materials	0.20	0.22	0.14	0.19

Note: The "input raw materials" are the amounts actually used. According to JMIA, several types (10 types at maximum) of raw material ores are purchased every year by each smelting facility, and the mercury content varies depending on the type of ore. The mercury content is calculated by multiplying the average of the value obtained from analysis for each ore type by the ore input amount.

Source: The results of the interview survey with JMIA in FY2021

Table 2.3.2 [Non-ferrous metal smelting] Mercury in year-end stock of raw materials

Material	Hg content in stock of raw materials (t-Hg)			
	FY2018	FY2019	FY2020	Three-year Average
Non-ferrous metal ores	4.1	4.2	4.0	4.1
Recycled materials	0.17	0.17	0.27	0.20
Subsidiary materials	0.020	0.030	0.040	0.030

Source: The results of the interview survey with JMIA in FY2021

Table 2.3.3 [Non-ferrous metal smelting] Import of non-ferrous metal ores (Reference)

Material	FY2018	FY2019	FY2020	Three-year Average
Import of non-ferrous metal ores (10^4 t)	563	539	553	551

Source: The results of the interview survey with JMIA in FY2021

2) Mercury in residues

According to the results of the interview survey with the JMIA in FY2021, the amount of mercury contained in residues (excluding flue gas treatment sludge) from non-ferrous metal smelting processes is as shown in Table 2.3.4. The amount of mercury in residues was calculated by multiplying measured mercury concentration in residues by the amount of residues generated. The three-year average from FY2018 to FY2020 is adopted in the material flow.

Table 2.3.4 [Non-ferrous metal smelting] Mercury in residues

Residue	Hg content in residues (t-Hg)			
	FY2018	FY2019	FY2020	Three-year average
Wastewater treatment sludge	7.5	7.0	5.4	6.6
Slag	0.29	0.72	0.97	0.66
Other waste [Note1]	0.31	4.0	0.40	1.6

Note 1: For some business entities, other waste includes the amount of flue gas treatment sludge disposed of as addressed in 4) below.
Note 2: Residues include those from primary and secondary non-ferrous metal smelting facilities.
Source: The results of the interview survey with JMIA, FY2021.

3) Mercury in by-products

According to the result of the interview survey with the JMIA in FY2021, mercury content in by-products (sulfuric acid/gypsum) generated from the non-ferrous metal smelting process is shown in Table 2.3.5. The amount of mercury in by-products was calculated by multiplying measured mercury concentration in by-products by the amount of by-product produced. The three-year average from FY2018 to FY2020 is adopted in the material flow. Some of the FGD gypsum generated at non-ferrous metal smelting facilities is used in the finishing process of cement production, but the proportion is unknown. The mercury content in FGD gypsum utilized in cement manufacturing is identified as "less than 1.8 ton-Hg", noting that the maximum amount of 1.8 tons of mercury was transferred via by-products (sulfuric acid and gypsum) in FY2019 (Refer to Table 2.4.3 for details of cement production facilities).

Table 2.3.5 [Non-ferrous metal smelting] Mercury in by-products

By-product	Hg content Note (t-Hg)			
	FY2015	FY2016	FY2017	Three-year Average
Sulfuric acid, gypsum	2.2	1.8	1.3	1.7

Note: If the actual mercury concentration measured is less than the Lower Limit of Quantification (LLOQ), some business entities use 1/2 of the LLOQ for mercury concentration.
Source: The results of the interview survey with JMIA, FY2021

4) Mercury recovered from flue gas treatment sludge

Mercury in flue gas treatment sludge from non-ferrous metal smelting is recovered at outsourced treatment companies. In FY2019, 36 tons of mercury were recovered from the flue gas treatment sludge according to the interview survey with JMIA in FY2021. Given that the amount of sludge varies greatly by year, the three-year average from FY2018 to FY2020 is adopted (43 t-Hg). Considering that the amount outsourced for treatment varies widely by year, the material flow (Figure 1, Figure 2) adopted 31 t-Hg for mercury recovered from flue gas treatment sludge from non-ferrous smelting facilities, the data obtained from treatment companies (For details on mercury recovery, see section 3.1).

5) Mercury in flue gas treatment sludge (stock)

According to the results of the interview survey with JMIA in FY2021, the stock amount of flue gas treatment sludge prior to mercury recovery treatment is shown in Table 2.3.6. The amount of mercury was calculated by multiplying this stock amount by the mercury concentration of the sludge outsourced for treatment (3-year average: 0.052 t-Hg/t), which was estimated based on the results of the interview survey with JMIA in FY2021. The three-year average from FY2018 to FY2020 was adopted for the material flow for non-ferrous metal smelting facilities.

Table 2.3.6 [Non-ferrous metal smelting] Mercury in stock of flue gas treatment sludge

	End of FY2018 (March 2019)	End of FY2019 (March 2020)	End of FY2020 (March 2021)	Three-year Average
Year-end stock of flue gas treatment sludge (t)	426.2	409.0	355.0	396.7
Mercury content in stock of flue gas treatment sludge(t-Hg)	22	21	18	21

[Source]

Amount of year-end stock: The results of the interview survey with JMIA in FY2021

Amount of mercury in the stock: Based on the interview survey with JMIA in FY2021, the mercury concentration in sludge outsourced for treatment was estimated (3-year average: 0.052 t-Hg/t), and the amount of mercury was calculated by multiplying the mercury concentration by the amount of year-end stock.

6) Atmospheric emission of mercury

According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from non-ferrous metal smelting facilities are estimated to be 1.1 t-Hg based on actual measured data from designated units emitting mercury (primary 0.10 t-Hg, secondary 0.97 t-Hg)[10].

7) Mercury release to public waters

According to the interview survey with JMIA in FY2021, the amount of mercury in wastewater from non-ferrous metal smelting facilities is shown in Table 2.3.7. Mercury concentration in the wastewater based on actual measured data was multiplied by volume of the wastewater to estimate the amount of mercury. The three-year average for FY 2018 to FY 2020 was adopted for the material flow.

Table 2.3.7 [Non-ferrous metal smelting] Mercury in wastewater

Residue	Mercury in residues, etc.(t-Hg)			
	FY 2018	FY 2019	FY 2020	Three-year Average
Wastewater Note	0.13	0.080	0.080	0.097

Note 1: Some business entities use 1/2 of the Lower Limit of Quantification (LLOQ) for mercury concentration when the actual measured value is below LLOQ.

Note 2: Wastewater includes wastewater from primary and secondary non-ferrous metal smelting facilities.

Source: The interview survey with JMIA, FY2021

8) Mercury in recycled materials at non-JMIA member facilities (Reference)

For non-JMIA members, the amount of mercury in recycled materials input to the non-ferrous metal smelting process was estimated by multiplying the amount of mercury in recycled materials input used at JMIA member facilities by the ratio of members to non-members of the emission gas flows (FY2019 results) of secondary non-ferrous metal smelting facilities in the data reported under the Air Pollution Control Act. The amount of mercury in recycled materials of the year-end stock was also estimated in the same way. As a result, the amount of mercury in recycled materials input at non-member facilities in

[10] The report indicated 0.63 t-Hg, but the value was revised in June 2023.

FY2019 was estimated to be 4.3 t-Hg, and the amount of mercury in recycled materials of the year-end stock at non-member facilities was estimated to be 0.33 t-Hg. Since these values include uncertainty, they are treated as reference values.

9) Mercury in residues and wastewater generated from non-JMIA member facilities (Reference)

Regarding the amount of mercury in residues and wastewater generated from non-JMIA member facilities, it was assumed that all mercury in the input recycled materials that was not emitted to the atmosphere would be transferred to residues and wastewater. As a result, the amount of mercury in residues and wastewater generated from non-JMIA member facilities was estimated to be 3.7 t-Hg, as shown in Table 2.3.8. Since the value includes uncertainty, it is treated as reference value.

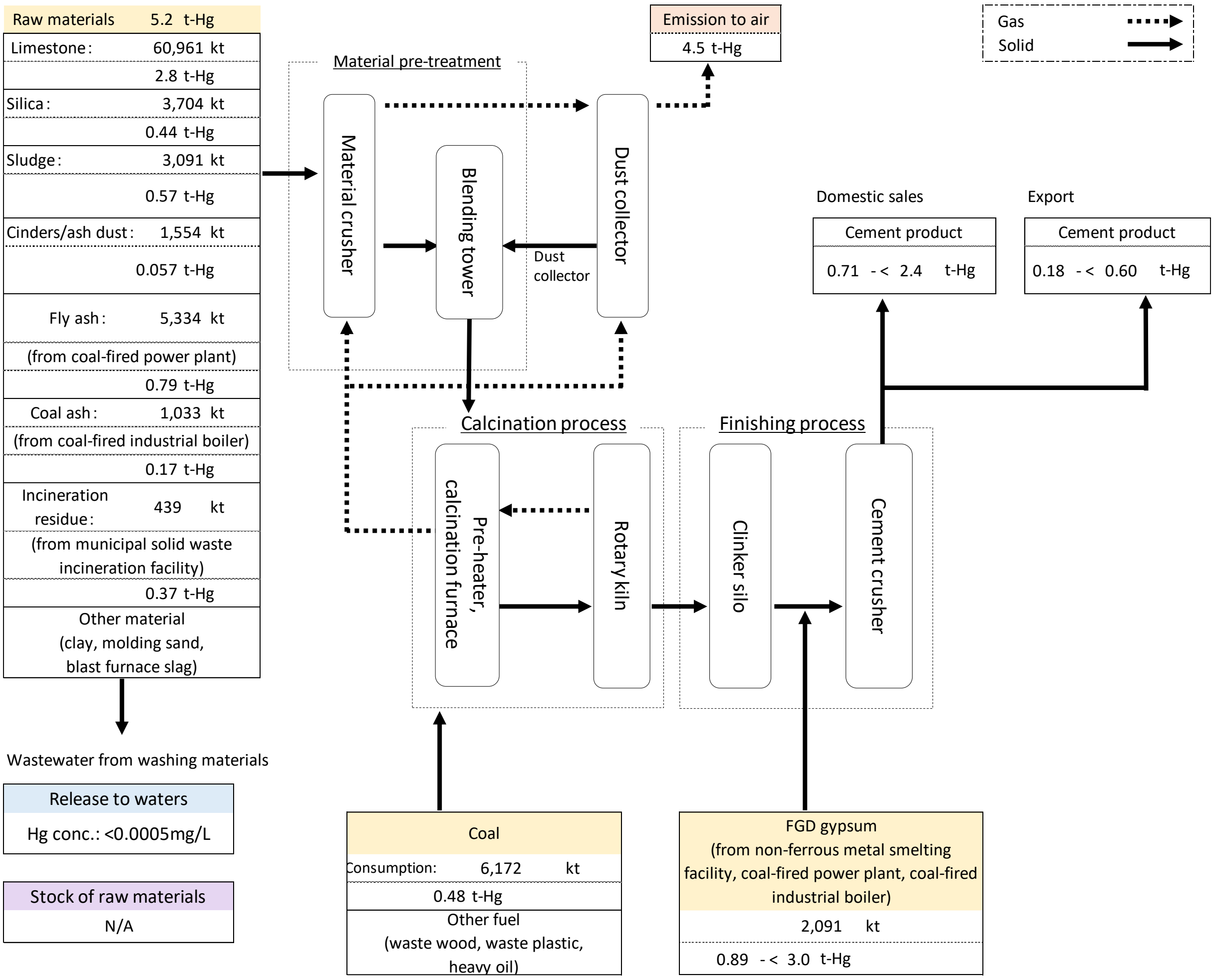
Table 2.3.8 [Non-ferrous metal smelting] Mercury emission to air and mercury in residues and wastewater (from non-JMIA member facilities) (FY 2019)

	(a) Hg in input recycled materials (t-Hg)	(b) Hg emission to air (t-Hg)	Hg in residues and wastewater ((a)-(b)) (t-Hg)
Non-members	4.3	0.60	3.7

Source for mercury emission to air: Estimated by dividing the amount of mercury emissions from secondary non-ferrous metal smelting facilities based on the Mercury Emissions Inventory (for FY2019) proportionally by the flue gas flow from such facilities of JMIA members and non-members (FY2019 results).

2.4 Cement Production Facilities

The mercury flow in cement production facilities is shown in Figure 2.4.1.



Flow: Prepared based on the interview survey with Japan Cement Association (JCA).
Values in the flow: The interview survey with JCA in FY2021, and estimated mercury flow of other industries. Atmospheric emissions are from the "Mercury Emission Inventory (for FY2019)".

Figure 2.4.1 Mercury flow in cement production facilities (FY2019)

1) Mercury in raw/recycled materials

Table 2.4.1 shows the input of raw/recycled materials in the process of cement production obtained from the interview survey with Japan Cement Association (JCA) in FY2021 and estimated mercury flow in other industries. The amount of mercury in raw/recycled materials is estimated by multiplying these inputs by the mercury concentration in the respective raw materials obtained from literatures, interviews with the association and other industries.

Table 2.4.1 [Cement production] Mercury in input raw/recycled materials (FY2019)

Input material	Source	Input (10^3 t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Limestone	-	60,961	0.046	2.8
Silica	-	3,704	0.119	0.44
Sludge	-	3,091	0.183	0.57

Input material	Source	Input (10^3 t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Cinders, soot/dust	-	1,554	0.037	0.057
Fly ash	Coal-fired power plants	5,334	0.149	0.79
Coal ash	Coal-fired industrial boilers	1,033	-	0.17
Incineration residues	Municipal solid waste incineration facilities	439	0.03/5.4	0.37
	Total			5.2

Note: Total amount of mercury and the sum of the individual Hg contents do not match due to rounding off.

[Source]

Input amount of limestone, silica, sludge, cinders, soot/dust: The interview survey with JCA in FY2021 and the mercury flow in other industries as estimated in Section 2.

Input amount of fly ash, coal ash, incineration residues: The mercury flow in other industries as estimated in Section 2.

Mercury concentration in limestone, silica, sludge, cinders, soot/dust: The interview survey with JCA of in FY2018

Mercury concentration in fly ash: The interview survey with the Federation of Electric Power Companies in FY2021

Mercury content in coal ash: Estimated result from Section 2.2

Mercury concentration in incineration residues: Bottom ash 0.03 mg/kg, Fly ash 5.4 mg/kg (2011 Mercury Emissions Investigation Report from Waste Disposal Facilities (March 2012, Towa Technology)). The composition of bottom ash and fly ash is unknown. Based on the existing report (Report on the Environmentally Sound Management of Mercury Waste, March 2014, the MOEJ), estimation was conducted based on the assumption that bottom ash accounts for 85% and fly ash for 15%.

2) Mercury in coal consumed in the calcination process

The amount of mercury in coal consumed in the calcination process of cement production was estimated by multiplying the coal consumption obtained from the interview survey with JCA in FY2021 by the mercury concentration obtained from the interview survey with JCA in FY2018, which is shown in Table 2.4.2.

Table 2.4.2 [Cement production] Mercury in coal consumption at calcination process (FY2019)

Coal consumed (10^3 t)	Hg concentration in coal (mg/kg)	Hg content in coal consumed in the calcination process (t-Hg)
6,172	0.077	0.48

Source for coal consumption and mercury concentration in coal: The interview survey with JCA in FY2021.

3) Mercury in FGD gypsum used in the finishing process

Table 2.4.3 shows the input of FGD gypsum in the finishing process of the cement production obtained from mercury flow in other industries estimated in Section 2. Mercury content in FGD gypsum from non-ferrous metal smelting facilities and coal-fired power plants input to the finishing process are unknown since the amounts of FGD gypsum input to the finishing process are not available. It is assumed that the maximum amount of mercury transferred to by-products (sulfuric acid and gypsum) in non-ferrous metal smelting process is 1.8 t-Hg and that the maximum amount of mercury in utilized FGD gypsum generated at coal-fired power plants is 1.0 t-Hg. Hence the values for these two sources are set to be less than 1.8 t-Hg and 1.0 t-Hg, respectively. The sum of the amounts of mercury from these two sources and additional 0.12 t-Hg of FGD gypsum generated from industrial coal-fired boilers become less than 3.0 t-Hg. The amount of FGD gypsum (2,091 tons) obtained from the interview survey with JCA was multiplied by the mercury concentration of 0.428 mg/kg of FGD gypsum sludge generated from coal-fired power plants, and the result was 0.89 tons. Therefore, the amount of mercury in FGD gypsum input to the cement production facilities was estimated to be between 0.89 and less than 3.0 t-Hg.

Table 2.4.3 [Cement production] Mercury in FGD gypsum input (FY2019)

Input	Source	Input (10^3 t)	Hg concentration (mg/kg)	Hg content (t-Hg)
FGD gypsum	Non-ferrous metal smelting	N/A	N/A	Less than 1.8
	Coal-fired power plant	Less than 2,365	0.428	Less than 1.0
	Coal-fired industrial boiler	73	-	0.12
Total		2,091		0.89 - less than 3.0

Note: Total amount of mercury and the sum of the individual Hg contents do not match due to rounding off.
Source for input of FGD gypsum: The interview survey with JCA in FY2021.
Source for items other than input of FGD gypsum: The mercury flow in other industries as estimated in Section 2

4) Mercury in products

The Cement Handbook (FY2022 edition) reports that domestic sales and exports of cement for FY 2019 are shown in Table 2.4.4. According to the mercury flow in cement production facilities, 0.89 – less than 3.0 t-Hg of mercury in FGD gypsum is expected to be transferred to products in the finishing process, as there is no escape route other than cement products after the input of FGD gypsum. Therefore, by multiplying the ratio of sales volume to export volume, the amount of mercury in domestically sold products was estimated to be 0.71 – less than 2.4 t-Hg and that in exported products was estimated to be 0.18 – less than 0.60 t-Hg.

Table 2.4.4 [Cement production] Mercury in products (FY 2019)

	Products (10^3t)	Hg at the min. value (t-Hg)	Hg at the max. value (t-Hg)
Domestic sales	40,948	0.71	2.4
Export volume	10,532	0.18	0.60
Total	51,480	0.89	3.0

Source for domestic sales and export volume: the Cement Handbook (FY2022 edition) (Japan Cement Association, June 2022)
https://www.jcassoc.or.jp/cement/4pdf/jj3h_06.pdf

5) Atmospheric emission of mercury

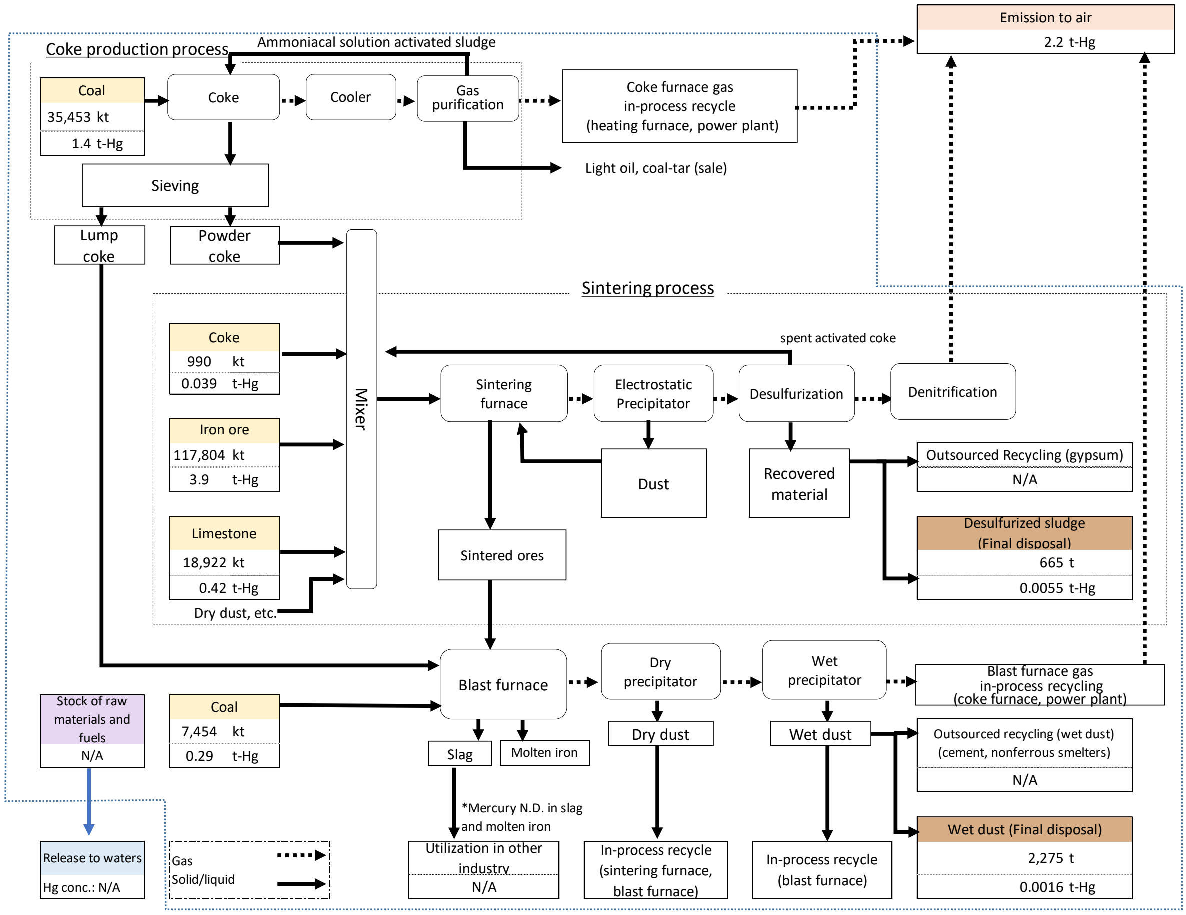
Mercury emissions from cement production facilities are 4.5 t-Hg based on actual measured data from designated units emitting mercury in the “Mercury Emission Inventory (for FY2019)”.

6) Mercury release to public waters

According to the interview survey with JCA in FY 2021, the amount of mercury in wastewater from cement production facilities was assumed to be “0 (with effluent in some facilities)” because some facilities generate wastewater (unknown amount), but all facilities confirmed that the mercury concentration is below the lower limit of quantification.

2.5 Primary Iron Production Facilities

The mercury flow in primary iron production facilities is shown in Figure 2.5.1.



Flow: Prepared based on the interview survey with Japan Iron and Steel Federation (JISF).

Amount of final disposal: The interview survey with the JISF in FY2021

Values in the flow: Estimated based on the interview survey with the JISF in FY2021, General Energy Statistics, "Energy Balance Table" by the Agency for Natural Resources and Energy, and the concentration of mercury in residues ("Mercury Emission Behavior in the Iron and Steel Industry", Masaki Takaoka, Kazuyuki Oshita, 2007). It needs to be noted that only a limited number of data samples were available (n=1 or n=3). Air emissions are from the "Mercury Emission Inventory (for FY 2019)".

Figure 2.5.1 Mercury flow in primary iron production facilities (FY2019)

1) Mercury in raw materials and fuels fed into coke ovens

Table 2.5.1 shows the amount of coal fed into coke ovens and the corresponding mercury content in FY2019. The amount of mercury in coal input is calculated by multiplying the amount of coal input (based on the interview survey with the Japan Iron and Steel Federation (JISF) in FY2021) by the mercury concentration in coal (0.0390 g/t) obtained from the interview survey with the Federation of Electric Power

Companies of Japan (FEPC) in FY2021. Because the amount of coal fed into sintering furnaces is not available, the amount of coal fed into coke ovens and the amount of mercury in the input to coke ovens are regarded as the minimum values for the amount of coal input at the primary iron production facilities and the corresponding mercury content.

Table 2.5.1 [Primary iron production] Mercury in coal fed into coke ovens (FY2019)

Coal input (10^3 t)	Hg concentration in coal (g/t)	Hg content in the coal input (t-Hg)
35,453	0.0390	1.4

[Source]
Coal input: The interview survey with the JISF in FY2021. The response was 40,149 tons of wet coal; the amount of dry coal was estimated by multiplying the ratio of dry coal to wet coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.
Mercury concentration in coal: The interview survey with the FEPC in FY2021.

2) Mercury in raw materials and fuels fed into sintering furnaces

Table 2.5.2 shows the amounts of coal, iron ore, and limestone fed into sintering furnaces, and the amount of mercury in the inputs in FY2019. The amount of mercury in coal input was estimated by assuming that the amount of coal energy conversion of sintered ores in the steel/nonferrous/metal product manufacturing industries in the General Energy Statistics "Energy Balance Table" by the Agency for Natural Resources and Energy was the amount of coal input to the sintering furnaces of primary iron production facilities. For iron ore input, the amount of mercury was estimated by assuming that all imported iron ore is added put into the sintering furnaces of primary iron production facilities. For limestone input, it was assumed that all the limestone for "steel" category in the statistics of Limestone Association of Japan was used in primary iron production facilities.

Table 2.5.2 [Primary iron production] Mercury in raw materials and fuels used in sintering furnaces (FY2019)

Raw material and fuel	Input amount (10^3 t)	Hg concentration (g/t)	Hg content in the input (t-Hg)
Coal	990	0.0390	0.039
Iron Ore	117,804	0.0329	3.9
Limestone	18,922[Note]	0.022	0.42

Note: The "steel" category in Limestone Production and Shipment Trends (Limestone Association of Japan) has been referenced to where there are no separate categories for primary and secondary iron. All limestone is assumed to be input to the primary iron production, as quicklime is input to the secondary iron production.
[Source]
Coal input: Coal energy conversion of sintered ores in the steel/nonferrous/metal product manufacturing industries in the Agency for Natural Resources and Energy's General Energy Statistics, "Energy Balance Table" was used as coal consumption (wet coal) to sintering furnaces at primary iron production facilities. The amount of coal consumption (dry coal) to sintering furnaces in primary iron production facilities was estimated by the coal consumption by the ratio of wet coal to dry coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.
Iron ore input: The interview survey with the JISF in FY2021 (Value for iron ore is the same as imported amount)
Limestone input: Limestone Association of Japan "Limestone Production and Shipment Trends" (June 11, 2021) https://www.limestone.gr.jp/doc/toukei/pdf/toukei2021.pdf

Mercury concentration in coal: the FY 2021 interview survey with the FEPC

Mercury concentration in iron ore: National Institute for Environmental Studies (2010), “FY2009 MOEJ project: Investigation and research work on long-term transport characteristics of persistent substances such as mercury,” page 70, Average concentration of lump ore shown in Table 3.34 (ppb for concentration unit is used on a weight basis).

Mercury concentration in limestone: Implementation of measures to control the emission of mercury into the atmosphere based on the Minamata Convention on Mercury (First Report) Reference Material 2 “Results of Survey on Actual Status of Mercury Emissions”, Page 92, https://www.env.go.jp/press/102627.html

3) Mercury in raw materials and fuels used in blast furnaces

Table 2.5.3 shows the amount of coal input to blast furnaces, and the amount of mercury in the input in FY2019.

Table 2.5.3 [Primary iron production] Mercury in raw materials and fuels used in blast furnaces (FY2019)

Raw material and fuel	Input amount (10^3 t)	Hg concentration (g/t)	Hg content in the input (t-Hg)
Coal	7,454	0.0390	0.29

Coal input: Coal energy conversion of blast furnace pig iron making in the steel/nonferrous/metal product manufacturing industries in the Agency for Natural Resources and Energy's General Energy Statistics “Energy Balance Table” was used as coal consumption (wet coal) to blast furnaces at primary iron production facilities. The amount of coal consumption (dry coal) to blast furnaces in primary iron production facilities was estimated by multiplying the coal consumption by the ratio of wet coal to dry coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.

Mercury concentration in coal: The interview survey with the FEPC in 2021.

4) Mercury in residues disposed of

The amount of residues disposed of from primary iron production facilities obtained from the interview survey with the JISF in FY2021 is multiplied by the mercury concentration in residues obtained from the literature, and the amount of mercury in residues is estimated as shown in Table 2.5.4. It should be noted that the number of data samples in this study is limited (n=1 or n=3).

Table 2.5.4 [Primary iron production] Mercury in residues disposed of (FY2019)

Residue	Amount of final disposal [Note] (t)	Hg concentration in residues (g/t)	Hg content (t-Hg)
Desulfurization sludge	665	8.340	0.0055
Wet dust	2,275	0.716	0.0016

Note: Both types of residues are disposed of in leachate-control type landfills

Source for final disposal amount: The FY2021 interview survey with the JISF.

Mercury concentration in residues: “Mercury Emission Behavior in the Iron and Steel Industry” (Masaki Takaoka, Kazuyuki Oshita, 2007). It needs to be noted that only a limited number of data samples were available (n=1 or n=3).

5) Atmospheric emission of mercury

Table 2.5.5 shows the estimated results of mercury emissions from primary iron production facilities in the “Mercury Emission Inventory (for FY2019)”.

Table 2.5.5 Mercury emission from primary iron production facilities (FY2019)

Source	Mercury Emissions (t-Hg)
Sintering furnace (including pelletizing furnace)	2.1
By-product gas from blast furnace	0.12
By-product gases from coke oven	0.022
Total	2.2

*Mercury emissions from sintering furnaces are estimated by multiplying the emission factor for each type of exhaust gas treatment system based on the results of mercury concentration measurements in the voluntary efforts of the installers of facilities requiring emission control, by the level of activity.

*Atmospheric emissions from by-product gases from blast furnaces and by-product gases from coke ovens are estimated by multiplying the emission factors obtained from the "Mercury emission and behavior in primary ferrous metal production" (Fukuda et al, 2011) by the annual production volume of pig iron and coke.

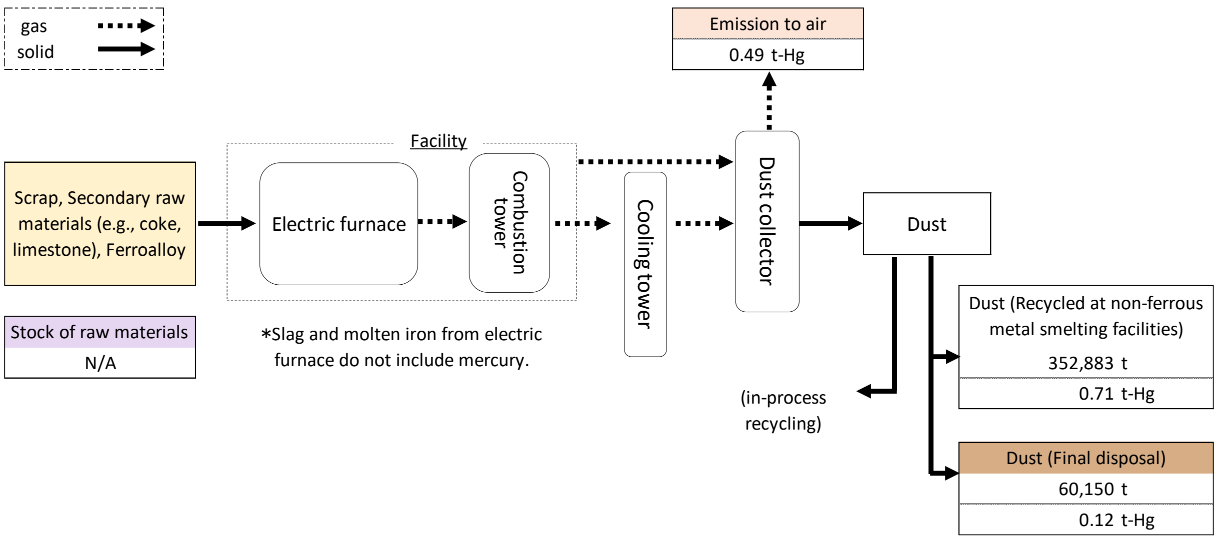
Quoted from the "Mercury Emission Inventory (FY2019)"

6) Mercury release to public waters

According to the interview survey with the JISF in FY2021, they do not have information on the amount of mercury in wastewater, but the wastewater is controlled in compliance with the effluent standards of the Water Pollution Control Law. Therefore, the amount of mercury in wastewater from primary iron production facilities is reported as "N/A (with effluent)".

2.6 Secondary Iron Production Facilities

The mercury flow in secondary iron production facilities is shown in Figure 2.6.1.



Flow: Prepared based on the interview survey with the JISF.

Amount of final disposal: The interview survey with the JISF in FY2021.

Amount of mercury in the flow: Estimated by the interview survey with the JISF in FY2021, existing literatures, and the mercury concentration in residues (result of the independent survey conducted by the JISF obtained from the interview survey with the federation in FY2013). It needs to be noted that only a limited number of mercury concentration data samples (n=19) are used because the independent survey was conducted at limited number of manufacturers. Air emissions are from the "Mercury Emissions Inventory (for FY 2019)".

Figure 2.6.1 Mercury flow in secondary iron production facilities (FY2019)

1) Mercury in residues utilized and disposed of

The amount of residues (precipitator dust) from secondary iron production facilities to be utilized and the amount of mercury in the residues utilized were estimated based on the assumption that "about 15 kg of electric furnace dust is generated per 1 ton of crude steel production" according to domestic research results[11]. The generated amount of precipitator dust was estimated by multiplying the crude steel (electric furnace steel) production volume by 0.015, and the amount of mercury in the precipitator dust to be utilized was calculated by multiplying the precipitator dust amount by the mercury concentration obtained from the literature as shown in Table 2.6.1. The amount of mercury contained in precipitator dust disposed of was calculated by multiplying the total amount of precipitator dust disposed obtained from the JISF interview in FY2021 by the mercury concentration obtained from the literature. It needs to be noted that the data sample size in this literature is limited (n = 19).

Table 2.6.1 [Secondary iron production] Mercury in residues (precipitator dust) (FY2019)

Residue		Generation (t)	Hg concentration in residues (g/t)	Hg content in residues (t-Hg)
Crude steel (electric furnace steel) production (10^3t)		23,526		
Precipitator dust (t)		352,883	2.0	0.71
	Utilization (t)	292,733		0.59
	Final disposal (t)	60,150		0.12

[Source]
Crude steel (electric furnace steel) production: Statistics from the JISF
https://www.jisf.or.jp/data/seisan/documents/2021FY.xls
The amount of precipitator dust generated: Estimated by multiplying crude steel (electric furnace steel) production by 0.015.
The final disposal amount of precipitator dust: The interview survey with the JISF in FY2021.
Note: The dust was disposed of in leachate-control type landfills.
Mercury concentration in residues: The result of the survey conducted by the JISF, which was obtained during the interview in FY 2013. It should be noted that the survey was conducted with some of the Federation members, thus the number of samples was limited (n = 19).

2) Atmospheric Emission of Mercury

Table 2.6.2 shows mercury emissions from secondary iron production facilities summarized in the "Mercury Emission Inventory (for FY2019)".

[11] Tetsuya Nagasaka, Kakenhi project of year 2013-2015, "Development of dust injection technology for EAF steelmaking process" https://kaken.nii.ac.jp/file/KAKENHI-PROJECT-25249105/25249105seika.pdf

Table 2.6.2 Mercury emissions from secondary iron production facilities (FY2019)

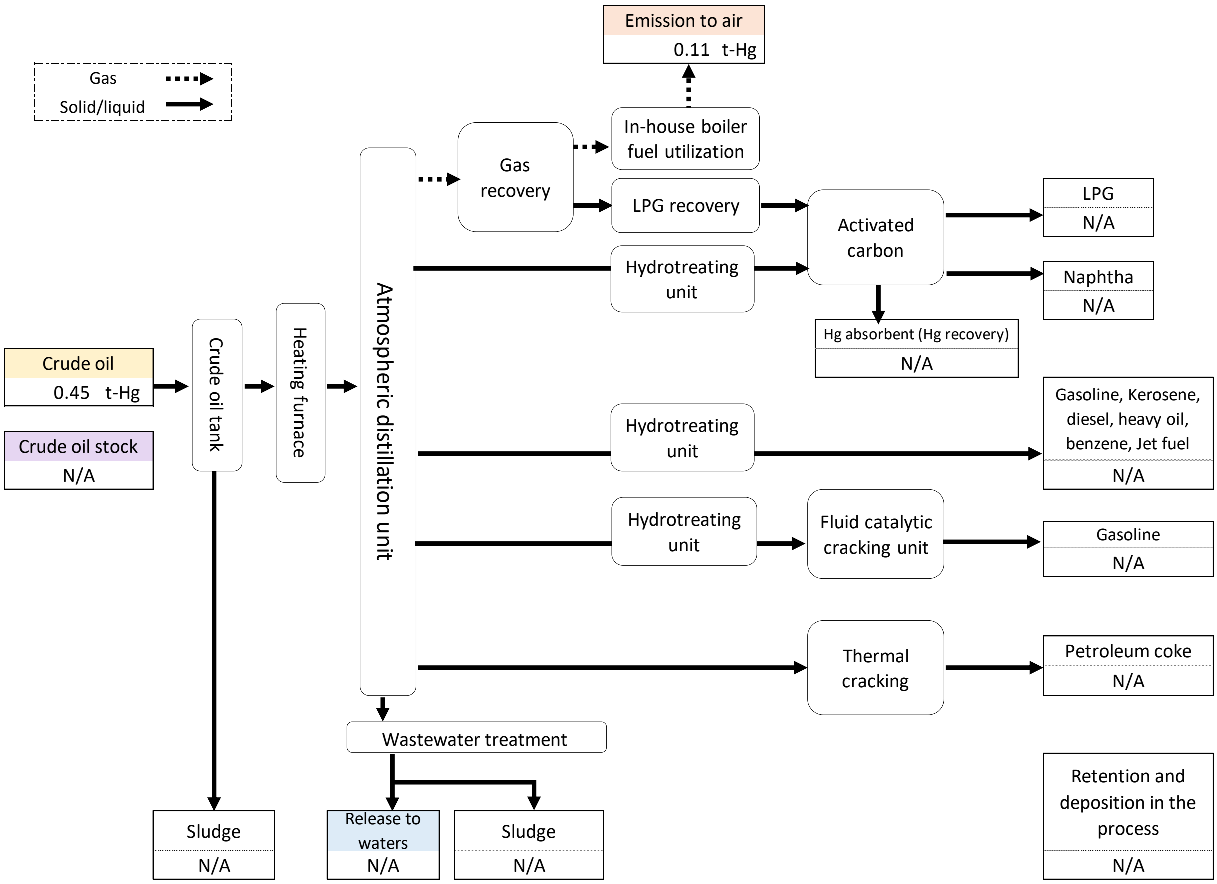
Target facility	Mercury Emissions (t-Hg)
Electric furnace for steel production	0.49

*Emission from electric furnaces for steel production is estimated by multiplying the emission factor for each type of exhaust gas treatment system based on the results of mercury concentration measurements in the voluntary efforts of the installers of facilities requiring emission control, by the level of activity.

Quoted from the "Mercury Emission Inventory (for FY2019)"

2.7 Oil Refining Plants

The mercury flow in oil refining plants is shown in Figure 2.7.1.



Flow: Prepared based on the interview survey with Petroleum Association of Japan in FY2021 and "Heavy metal removal for more advanced refineries" (Ikushima, et al., 2020).

Values in the flow: Estimated based on the FY2021 interview survey with Petroleum Association of Japan. Atmospheric emissions are from the "Mercury Emissions Inventory (for FY 2019)".

Figure 2.7.1 Mercury flow in oil refining plants (FY 2019)

1) Mercury in crude oil input

Based on the interview survey with Petroleum Association of Japan in FY2021, the amount of mercury contained in crude oil input to the oil refining process in FY 2019 is estimated as shown in Table 2.7.1 [Oil refining] Mercury in crude oil input (FY 2019).

Table 2.7.1 [Oil refining] Mercury in crude oil input (FY 2019)

Input	Input amount (kL)	Hg concentration (mg/kL)	Hg in crude oil input (t-Hg)
Crude oil (Refined)	173,701,069	2.6	0.45

[Source]

Input amount: Crude oil processing (excluding lubricant suppliers and other suppliers) from the annual resources and energy statistics (oil) of the Agency for Natural Resources and Energy.

Mercury concentration: Data measured by members of Petroleum Association of Japan (2009-2010)

2) Mercury in products and waste

According to the FY2021 interview survey with Petroleum Association of Japan, the amount of mercury in major oil products, wastes, other process residues and deposits is confirmed to be unknown.

Table 2.7.2 [Oil refining] Mercury transferred to the environmental media and products (FY 2019)

	Amount of Hg transferred (t-Hg)
Atmosphere	0.11
Waters	N/A
Waste	N/A
Products	N/A
Total	0.45

Source for atmospheric emissions: "Mercury Emissions Inventory (for FY 2019)"

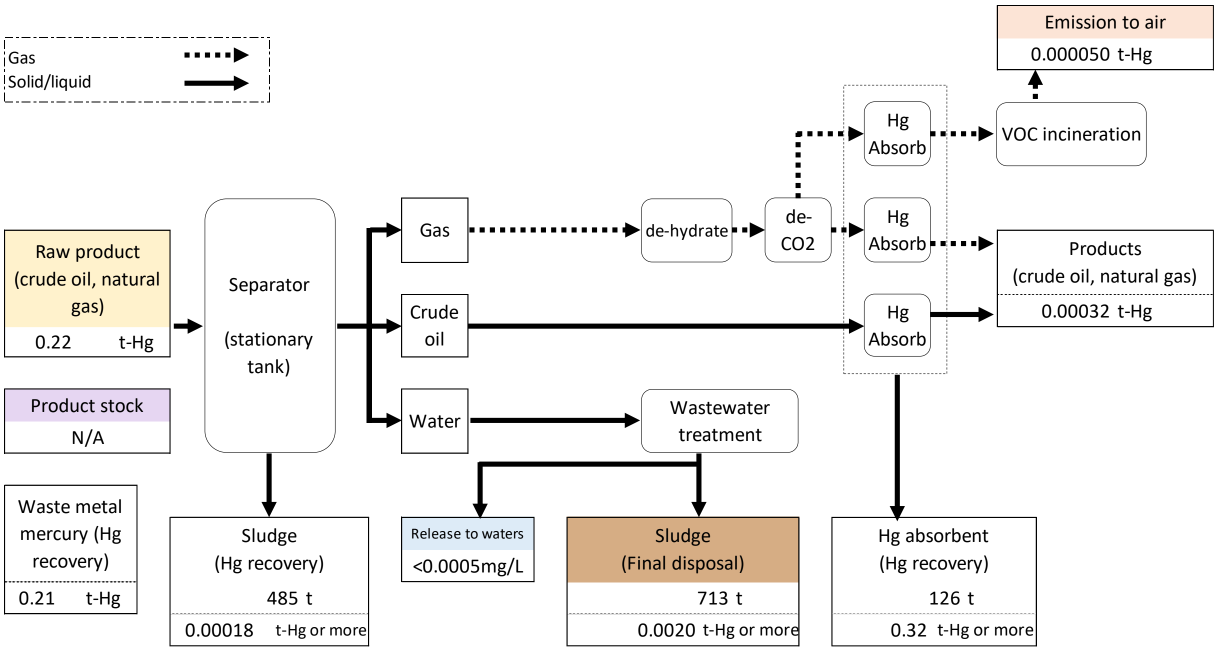
Source for the total value: The interview survey with Petroleum Association of Japan in FY2021. Calculated by multiplying the amount of crude oil input to the oil refining process in FY 2019 by the mercury concentration.

3) Atmospheric emission of mercury

According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from oil refining plants are estimated as 0.11 t-Hg.

2.8 Crude Oil and Natural Gas Production Facilities

The mercury flow in crude oil and natural gas production facilities is shown in Figure 2.8.1. It should be noted that this figure is an example of the flow of a crude oil and natural gas production facility, and all facilities may not be similar.



Flow: Prepared based on the interview survey with Japan Petroleum Development Association
Values in the flow: Interviews with domestic companies in FY2021. Air emissions are from the "Mercury Emission Inventory (for FY 2019)".

Figure 2.8.1 Mercury flow in crude oil and natural gas production facilities (FY2019)

1) Mercury in raw fuels

According to the interviews with domestic companies in FY2021, the amount of mercury in crude oil and natural gas produced in FY2019 is 0.22 t-Hg

2) Mercury in residues

Table 2.8.1 shows the amount of residue generated at crude oil and gas production facilities and the mercury contents therein, obtained from the interviews with domestic companies in FY2021.

Table 2.8.1 [Crude oil and gas production] Mercury in residues generated (FY2019)

Residue	Generation (t)	Hg concentration (g/t)	Hg content (t-Hg)	Treatment method
Separator tank sludge	485	N/A	0.00018 or more	Mercury recovery
Mercury adsorbent	126	N/A	0.32 or more	Mercury recovery
Waste metal mercury	0.21		0.21	Mercury recovery
Wastewater treatment sludge	713	N/A	0.0020 or more	Final disposal

Note: mercury adsorbents are used more than one year.
Source: The interviews with domestic companies in FY2021

3) Mercury in products

Table 2.8.2 shows the amount of mercury in products (crude oil and natural gas) obtained from the interviews with domestic companies in FY2021.

Table 2.8.2 [Crude oil and gas production] Mercury in products (FY2019)

Product	Mercury in products (t-Hg)
Crude oil	0.00022
Natural gas	0.00010
Total	0.00032

Source: The interviews with domestic companies in FY2021

4) Atmospheric emission of mercury

According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from the crude oil and gas production facilities are 50 g-Hg (0.000050 t-Hg) based on the FY2013 interviews of three companies holding crude oil and gas domestic production facilities in Japan, and the same value is estimated for FY2019.

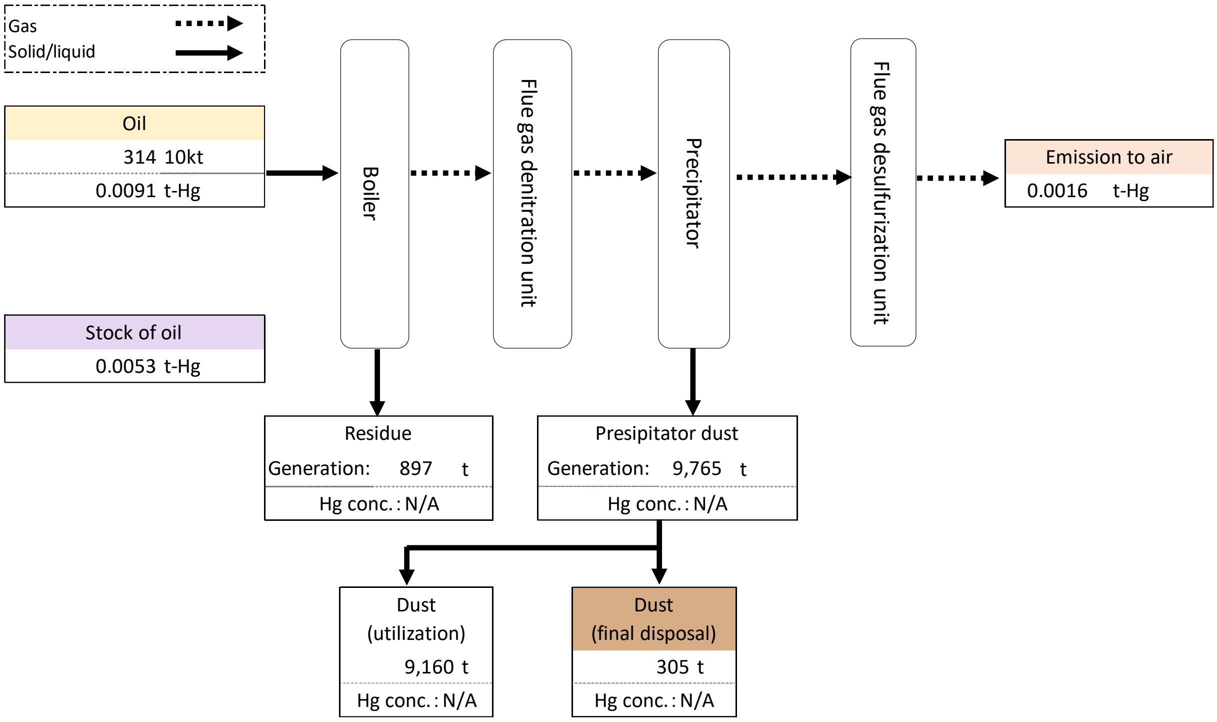
5) Mercury release to public waters

According to the interviews with domestic operators in FY2021, the mercury concentration in wastewater from crude oil and natural gas production facilities is below the lower limit of quantification, and the amount of wastewater is unknown. Therefore, the amount is assumed to be "0 (with effluent)".

2.9 Combustion Facilities using Oil and Other Fuels

(1) Oil-fired Power Plants

The mercury flow in oil-fired power plants is shown in Figure 2.9.1.



Flow: Prepared based on the result of the interview survey with the FEPC in FY2021

Values in the flow: Data extrapolated based on the information obtained from the interview survey with the FEPC in FY2021, using the results of the Electricity Survey Statistics by the Agency for Natural Resources and Energy.

The atmospheric emissions are from the "Mercury Emission Inventory (for FY2019)".

Figure 2.9.1 Mercury flow in oil-fired power plants (FY 2019)

1) Mercury in oil input

Table 2.9.1 shows the amount of mercury in oil input estimated by multiplying the amount of oil input nationwide by the mercury concentration in oil adopted in the Mercury Emission Inventory. The amount of oil input nationwide is extrapolated based on the amount of oil input to oil-fired power plants of the FEPC member companies in FY 2019 obtained from the FY2021 interview survey with the FEPC and the ratio of the electricity generated by the member companies to the national total.

Table 2.9.1 [Oil-fired Power Plants] Mercury in oil input (FY 2019)

Input	Input amount (10^4t)	Hg concentration (mg/t)	Hg in oil input (t-Hg)
Oil	314	2.89	0.0091

Source for the input amount: The amount of oil input was calculated by multiplying 1,873 thousand tons from the FY2021 interview survey with the FEPC by the ratio of the electricity generated by 32 companies generating oil-fired power in Japan and 11 member companies of the FEPC (14 billion kWh : 8.4 billion kWh = 168 : 100) (Source: the Electricity Survey Statistics by the Agency for Natural Resources and Energy).

Source for mercury concentration: "Mercury Emission Inventory (for FY2019)".

2) Mercury in precipitator dust utilized or disposed of

According to the interview survey with the FEPC in FY2021, the amount of precipitator dust generated and the mercury content in the dust from oil-fired power plants are shown in Table 2.9.2. Because mercury concentration of precipitator dust is not available, Hg content in precipitation dust could not estimated.

Table 2.9.2 [Oil-fired Power Plants] Mercury in precipitator dust utilized or disposed of (FY 2019)

	Precipitator dust generation/utilization/final disposal		Hg concentration in precipitator dust (mg/kg)	Hg content in precipitator dust (t-Hg)
	FEPC Data (t)	Extrapolation (t)		
Generation	5,822	9,765	N/A	N/A
Utilization	5,461	9,160		N/A
Final disposal	182	305		N/A

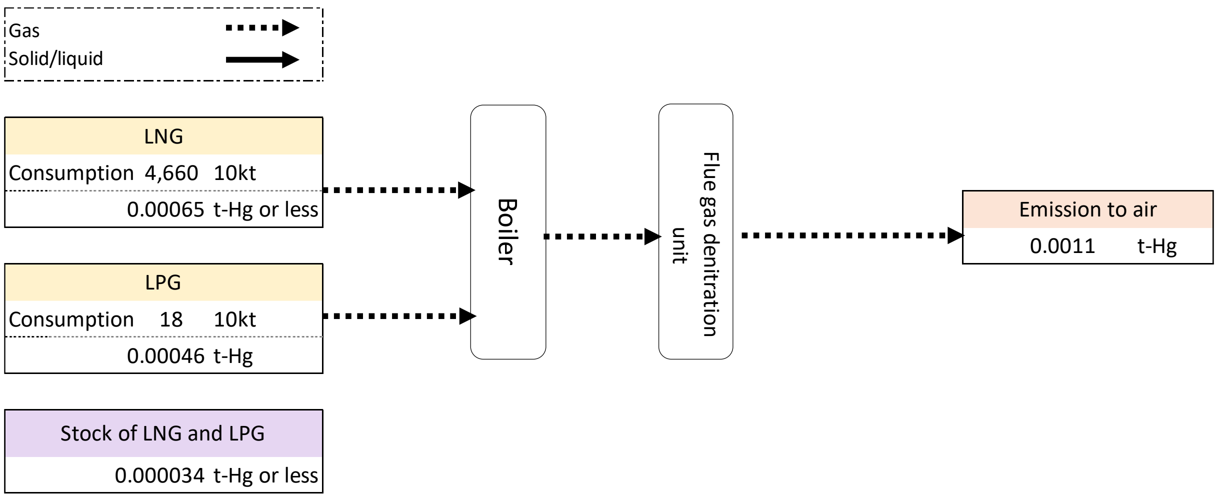
[Source]
Amount of generation, utilization and disposal of precipitation dust: The interview survey with the FEPC in FY2021. Note that the extrapolation uses the ratio of electricity generated by 32 companies generating oil-fired power in Japan and 11 member companies of the FEPC (14 billion kWh : 8.4 billion kWh = 168:100) (Source: the Agency for Natural Resources and Energy's Survey of Electric Power Statistics).

3) Atmospheric emission of mercury

According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from oil-fired power plants are estimated to be 0.0016 t-Hg.

(2) LNG-fired Power Plants

The mercury flow in LNG-fired power plants is shown in Figure 2.9.2.



Flow: Prepared based on the result of the interview survey with the FEPC in FY2021
Values in the flow: Data extrapolated based on the information obtained from the interview survey with the FEPC in FY2021, using data in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.
The atmospheric emissions are from the "Mercury Emission Inventory (for FY2019)".

Figure 2.9.2 Mercury flow in LNG-fired power plants(FY 2019)

1) Mercury in LNG input

Table 2.9.3 shows the amount of mercury in LNG input estimated to be 0.00065 t-Hg or less by multiplying the nationwide amount of LNG input to LNG-fired power plants in FY 2019 by the mercury concentration in LNG obtained from the interview survey with the FEPC. The nationwide amount of LNG input was extrapolated based on the amount of ING input by the FEPC member companies and the ratio of electricity generated by the member companies to the national total.

Note that the amount of LPG input is 0 according to the FY2021 interview survey with the FEPC. However, the Mercury Emission Inventory estimated mercury emissions from LPG-fired power generation using LPG input based on the Electricity Survey Statistics by the Agency for Natural Resources and Energy. Since the emission reduction efficiency is 0, the amount of mercury in the LPG input was added.

Table 2.9.3 [LNG-fired Power Plants] Mercury in LNG/LPG input (FY 2019)

Raw material input	Input amount (10^4t)	Hg concentration in input (mg/t)	Hg in input (t-Hg)
LNG	4,660	0.014 or less	0.00065 or less
LPG	18	2.5	0.00046

Source for the input amount: The nationwide amount of LNG input was calculated by multiplying 42,427 thousand tons of LNG input from the FY2021 interview survey with the FEPC by the ratio of electricity generated by 38 companies generating LNG-fired power in Japan and 11 member companies of the FEPC (353.5 billion kWh : 321.8 billion kWh = 110 : 100) (Source: the Electricity Survey Statistics by the Agency for Natural Resources and Energy).

Source for mercury concentration in LNG: The density of LNG is calculated as 0.7 kg/Nm^3 based on the results of the interview survey with relevant domestic companies in FY2020 (0.01 µg/Nm^3 or less).

Source for mercury concentration in LPG: “Mercury Emission Inventory (for FY2019)”.

2) Atmospheric emission of mercury

According to the “Mercury Emission Inventory (for FY2019)”, mercury emissions from LNG-fired power plants are estimated to be 0.0011 t-Hg.

(3) Industrial Boilers (Oil and Gas)

1) Mercury in Oil and Gas inputs

According to the “Mercury Emission Inventory (for FY2019)”, the amount of mercury in oil and gas inputs to industrial boilers is estimated as shown in Table 2.9.4.

Table 2.9.4 [Industrial Boilers (Oil and Gas)] Mercury in Oil and Gas inputs (FY 2019)

Facility type	Fuel	Consumption	Hg concentration	Hg content (t-Hg)
Industrial boilers (Oil-fired)	Heavy oil	2,854 ML/yr	1 mg/t	0.0044
	Crude oil	3 ML/yr	2.6 mg/kL	
	Naphtha	3 ML/yr	1 mg/t	
	Kerosene	74 ML/yr	1 mg/t	
	Diesel oil	0.7 ML/yr	1 mg/t	
Industrial boilers (Gas-fired)	LNG	597 10^3t/yr	0.014 mg/t	0.00074
	LPG	271 10^3t/yr	2.5 mg/t	
	Natural gas	384 MNm^3/yr	0.01 μg/Nm^3	
	Piped-gas (City gas)	2,759 MNm^3/yr	0.01 μg/Nm^3	
Total amount of mercury input				0.0051

Note: Density of heavy oil is assumed as 0.88, Naphtha as 0.6, Kerosene as 0.8, and Diesel oil as 0.8 for the estimation.

2) Mercury release to public waters and mercury in residues

The amount of mercury released to public waters and in residues from industrial boilers (oil and gas) was estimated as shown in Table 2.9.5, assuming that mercury in fuel inputs not emitted to the atmosphere is either released to public waters or transferred to residues.

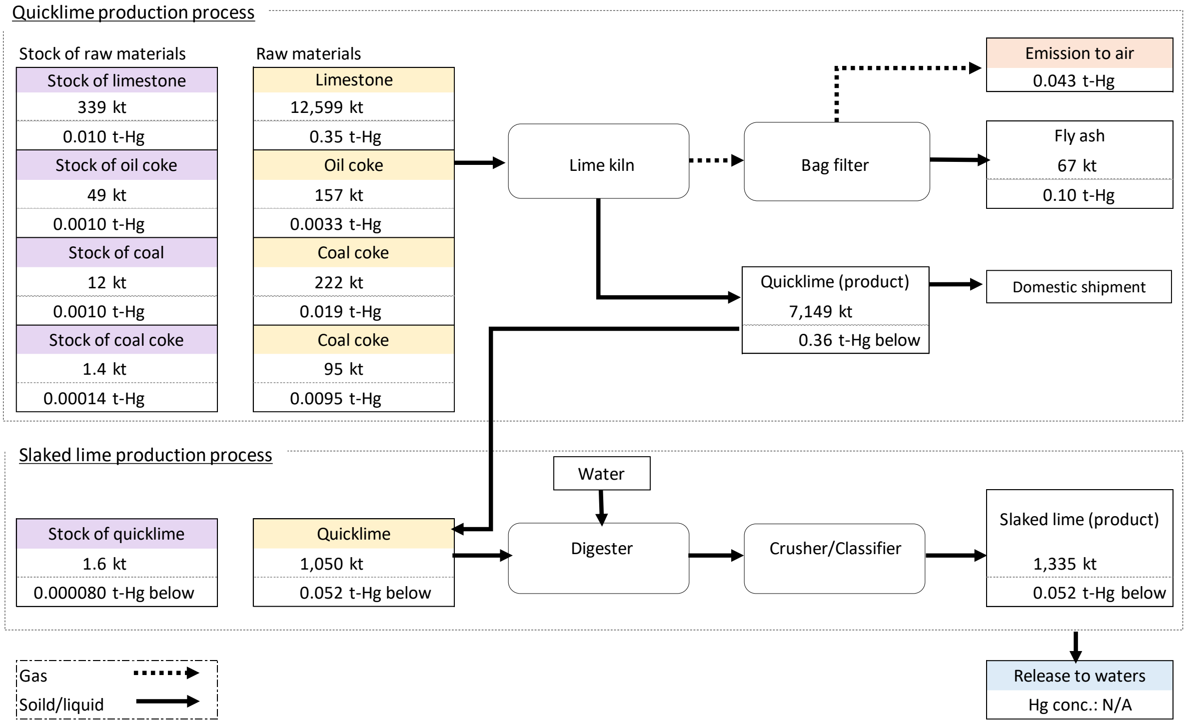
Table 2.9.5 [Industrial Boilers (Oil and Gas)] Mercury air emissions, mercury release to public water bodies, and mercury in residues (FY 2019)

Fuel input	(a) Hg in fuel inputs (t-Hg)	(b) Hg air emissions (t-Hg)	Hg release to public waters/ Hg in residues ((a)-(b)) (t-Hg)
Oil	0.0044	0.0022	0.0022
Gas	0.00074	0.00074	0
Total	0.0051	0.0029	0.0022

Source for mercury in fuel inputs: the amount of mercury indicated Table 2.9.4
Source for mercury emissions: “Mercury Emission Inventory (for FY2019)”.

2.10 Lime Product Production Facilities

The mercury flow in lime product production facilities is shown in Figure 2.10.1.



Flow: Prepared based on the interview survey with Japan Lime Association in FY 2020.
Values in the flow: Nationwide extrapolation based on the FY2021 interview survey with Japan Lime Association member-companies. Air emissions are from the "Mercury Emission Inventory (for FY2019)".

Figure 2.10.1 Mercury flow in lime product production facilities (FY 2019)

(1) Quicklime production

1) Mercury in raw materials and fuels

Based on the results of the interview survey with Japan Lime Association member companies in FY2021, the input amount of raw materials/fuels was estimated by multiplying the input amount of raw materials/fuels used by the interviewed companies by the ratio of the national quicklime production[12] to the production of the interviewed companies. This estimate was then multiplied by the mercury concentration of each raw material/fuel obtained from the interview survey and existing literature to calculate the input amount of mercury in the quicklime production process in FY 2019 and the amount of mercury in stock of raw materials and fuels at the end of the fiscal year as shown in Table 2.10.1 and Table 2.10.2, respectively.

Table 2.10.1 [Quicklime production] Mercury in input raw/recovered materials (FY 2019)

Raw material/fuel	Input amount (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Limestone	12,599	0.028	0.35
Oil coke	157	0.021	0.0033
Coal (dry coal)	222	0.084	0.019

[12] Ministry of Economy, Trade and Industry's Annual Statistics of Production by Chemical Industry ("Quicklime production amount")

Raw material/fuel	Input amount (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Coal coke	95	0.10	0.0095
Total			0.38

[Source]

Input of raw materials and fuels: Extrapolated results by multiplying the ratio of the national product production volume (in Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry) to the product production volume of the interviewed member companies of Japan Lime Association (based on the interview survey with the member companies of the Association in FY2021). Since the coal input of some companies was wet coal, the coal input (dry coal) was calculated by multiplying the ratio of wet coal to dry coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy. Coal includes pulverized coal.

Mercury concentration:

・Limestone, oil coke, and coal: Based on the results of the interview survey with Japan Lime Association member companies in FY2021.

・Coal coke: Implementation of measures to control the emission of mercury into the atmosphere based on the Minamata Convention on Mercury (First Report) Reference Material 2 "Results of Survey on Actual Status of Mercury Emissions", Page 29, https://www.env.go.jp/press/102627.html. Note that the mercury concentration in coal coke (0.10 mg/kg) is used for non-ferrous metal production, which may differ from that used for lime product production.

Table 2.10.2 [Quicklime production] Mercury in year-end stock of raw materials/fuels

(End of FY 2019: March 2020)

Raw materials/fuels	Amount of stock (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Limestone	339	0.028	0.010
Oil coke	49	0.021	0.0010
Coal (dry coal)	12	0.084	0.0010
Coal coke	1.4	0.10	0.00014
Total			0.012

[Source]

Year-end stock: the results of extrapolation, year-end stock at the interviewed companies multiplied by the ratio of the national product production (in the Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry) to the product production of the interviewed member companies of Japan Lime Association (based on the interview survey with the member companies of the Association in FY2021). Since the coal input of some companies was wet coal, the coal input (dry coal) was calculated by multiplying the ratio of wet coal to dry coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy. Coal includes pulverized coal.

Mercury concentration:

・Limestone, oil coke, and coal: Based on the results of the interview survey of Japan Lime Association member companies in FY2021.

・Coal coke: Implementation of measures to control the emission of mercury into the atmosphere based on the Minamata Convention on Mercury (First Report) Reference Material 2 "Results of Survey on Actual Status of Mercury Emissions", Page 29, https://www.env.go.jp/press/102627.html. Note that the mercury concentration in coal coke (0.10 mg/kg) is used for non-ferrous metal production, which may differ from that used for lime product production.

1) Mercury in quicklime products

As shown in Table 2.10.3, the amount of mercury in quicklime products in FY 2019 was estimated by multiplying the amount of quicklime produced nationwide by the mercury concentration in quicklime obtained from the interview survey of Japan Lime Association member companies in FY 2021.

Table 2.10.3 [Quicklime production] Mercury in quicklime products (FY 2019)

Product	Amount produced (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Quicklime	7,149	Less than 0.05	Less than 0.36

Production of quicklime: The Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry
Mercury concentration: Based on the interview survey with Japan Lime Association member companies in FY2021.

2) Mercury in residues

Based on the results of the interview survey with Japan Lime Association member companies in FY2021, the amount of residues generated nationwide was extrapolated by multiplying the amount of residues generated at the interviewed companies by the ratio of the national production to the production volume of quicklime of the interviewed companies. This estimate was then multiplied by the mercury concentration in precipitator dust obtained from the interview survey to calculate the amount of mercury in precipitator dust in FY 2019 as shown in Table 2.10.4.

Table 2.10.4 [Quicklime production] Mercury in residues (FY 2019)

Residue	Residue generated (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Precipitator dust (derived from bug filters)	67	1.56	0.10

[Source]

Amount of residue generated: The results of extrapolation, the amount of residues generated at the interviewed companies multiplied by the ratio of the national product production (in the Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry) to the product production of the interviewed member companies of Japan Lime Association (based on the interview survey with the member companies of the Association in FY2021).
Mercury concentration: Based on the interview survey with Japan Lime Association member companies in FY2021.

3) Atmospheric emission of mercury

Mercury emissions from lime product production facilities are estimated in the “Mercury Emission Inventory (for FY2019)” to be 0.043 t-Hg by multiplying the amount of limestone shipped for lime product production (10,075 thousand tons) by the overall emission factor obtained from the measurement of mercury emissions conducted at two domestic facilities in FY2019.

(1) Slaked lime production

1) Mercury in quicklime input

Based on the results of the interview survey with Japan Lime Association member companies in FY2021, the nationwide input amount of quicklime and the nationwide stock amount at the end of the fiscal year were extrapolated by multiplying those amounts of the interviewed companies by the ratio of the national slaked lime production[13] to that of the interviewed companies. This estimate was then multiplied by the mercury concentration in quicklime obtained from the interview survey to calculate the amount of mercury in quicklime input to the slaked lime production process and the amount of mercury in quicklime stock in FY 2019 as shown in Table 2.10.5 and Table 2.10.6 respectively.

Table 2.10.5 [Slaked lime production] Mercury in quicklime input to slaked lime production process (FY 2019)

	Input amount (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Quicklime	1,050	Less than 0.05	Less than 0.052

[Source]

Input: The result of extrapolation, input of quicklime of the interviewed companies multiplied by the ratio of the national product production (in the Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry) to the product production of the interviewed member companies of Japan Lime Association (from the interview survey with the member companies of the Association in FY2021) .

Mercury concentration: Based on the interview survey with Japan Lime Association member companies in FY2021.

Table 2.10.6 [Slaked lime production] Mercury in year-end stock of quicklime for use in slaked lime production process (End of FY 2019: March 2020)

	Amount of stock (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Quicklime	1.6	Less than 0.05	Less than 0.000080

[Source]

Year-end stock: The result of extrapolation, year-end stock at the interviewed companies multiplied by the ratio of the national product production (in the statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry) to the product production of the interviewed member companies of Japan Lime Association (from the interview survey with the member companies of the Association in FY2021) .

Mercury concentration: Based on the interview survey with Japan Lime Association member companies in FY2021.

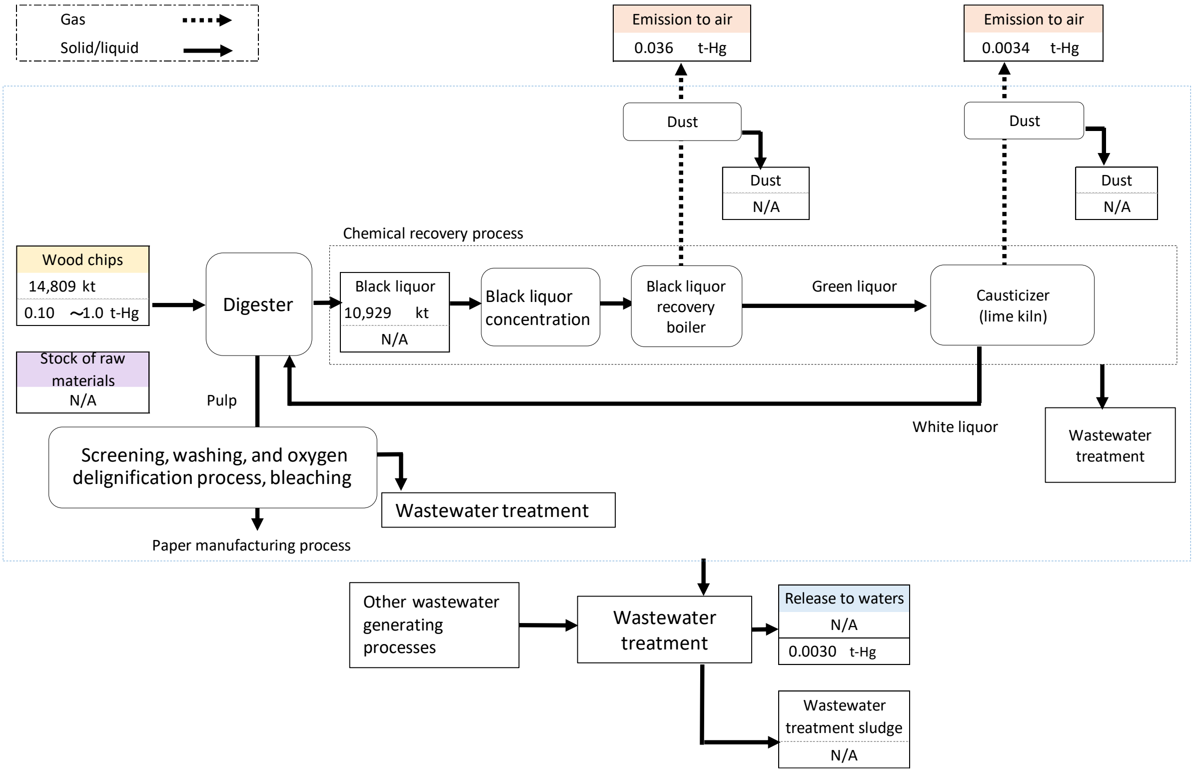
2) Mercury in slaked lime products

According to the Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry, the national production of slaked lime products is 1,335 thousand tons in FY 2019. Since only quicklime and water are used in the slaked lime production process, and it is assumed that all of the mercury in the quicklime is transferred to the products, the amount of mercury in the material flow is less than 0.052 t-Hg.

2.11 Pulp and Paper Production Facilities

The mercury flow in pulp/paper production facilities is shown in Figure 2.11.1.

[13] "Slaked lime production amount" in the Statistics of Production by Chemical Industry by the Ministry of Economy, Trade and Industry



Flow: Prepared based on the interview survey with Japan Paper Association in FY 2021.

Values in the flow: Estimated values based on the results of the interview survey with Japan Paper Association in FY2021 and the mercury concentration in wood chips for pulp as shown in the UNEP Toolkit. The amount of mercury in wastewater is from FY 2019 PRTR data. Air emissions are from the "Mercury Emission Inventory (for FY2019)".

Figure 2.11.1 Mercury flow in pulp and paper production facilities (FY 2019)

1) Mercury in wood chip input

According to the results of the interview survey with Japan Paper Association in FY2021, the amount of wood chip input to the pulp and paper production process in FY 2019 is shown in Table 2.11.1. The UNEP Toolkit (version 1.7) report[14] indicates that the mercury concentration of wood chips in the pulp and paper production is 0.007 - 0.07 g/t. By multiplying the wood chip input by these mercury concentrations, the amount of mercury contained in the input wood chips was estimated to be 0.10 - 1.0 t-Hg.

Table 2.11.1 [Pulp and paper production] Mercury in wood chip input (FY 2019)

Input amount (10^3 BDt)	Hg concentration (g/t)	Hg content (t-Hg)
14,809	0.007 - 0.070	0.10 - 1.0

[Source]

Input amount: The result of the interview survey with Japan Paper Association in FY 2021

Mercury concentration: The report of UNEP Toolkit (Version1.7)

https://wedocs.unep.org/bitstream/handle/20.500.11822/30684/HgTlktRef.pdf?sequence=1&isAllowed=y

2) Mercury in black liquor

[14] UNEP Mercury Inventory Toolkit Level 2 (Version 1.7)
https://wedocs.unep.org/bitstream/handle/20.500.11822/30684/HgTlktRef.pdf?sequence=1&isAllowed=y

According to the results of the interview survey with Japan Paper Association in FY2021, the amount of black liquor supplied to the black liquor recovery boiler in the chemical recovery process is shown in Table 2.11.2. The amount of mercury in the black liquor could not be estimated because the mercury concentration was unknown.

Table 2.11.2 [Pulp and paper production] Mercury in black liquor (FY 2019)

Input amount (10^3 BDt)	Hg concentration (g/t)	Hg content (t-Hg)
10,929	N/A	N/A

Source for input amount: The result of the interview survey with Japan Paper Association in FY 2021

3) Atmospheric emission of mercury

According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from pulp and paper production facilities are estimated to be 0.040 t-Hg.

4) Mercury release to public waters

According to the FY 2019 PRTR data, "Manufacture of pulp, paper and paper products" reported the amount of mercury and its compounds released to public waters as 3 kg-Hg (= 0.0030 t-Hg).

5) Mercury in residues（Reference）

The amount of mercury contained in residues from pulp and paper production facilities was calculated based on the assumption that all of the mercury in the wood chip input (raw materials) that is not emitted to the atmosphere or released to public waters is transferred to the residues (dust and treated wastewater sludge).

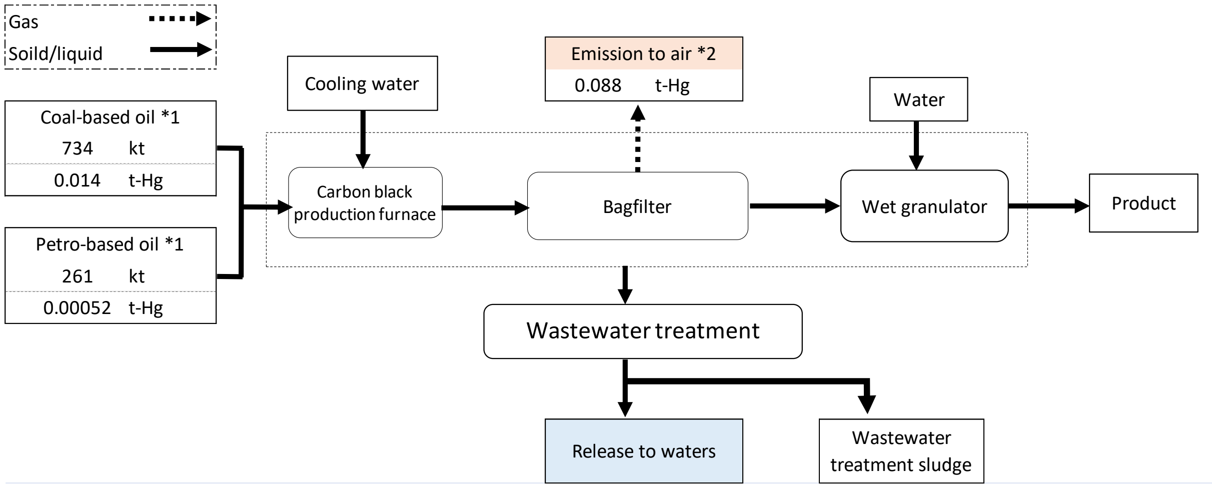
Table 2.11.3 [Pulp and paper production] Mercury in residues (FY 2019) (Reference)

Mercury in wood chip input Note (t-Hg)	Air emissions (t-Hg)	Release to public waters (t-Hg)	Mercury in residues (t-Hg)
0.10 - 1.0	0.040	0.0030	0.061 - 0.99

Note: A minimum of three significant digits is used to estimate the amount of mercury in residues.
[Source]
Amount of mercury in the wood chip input: Calculated by multiplying the results of the interview survey with Japan Paper Association in FY2021 (wood chip input) by the mercury concentration in the wood chips used in pulp and paper production from the UNEP Toolkit (version 1.7).
Air emissions: "Mercury Emission Inventory (for FY2019)".
Release to public waters: The FY 2019 data of PRTR.

2.12 Cabon Black Production Facilities

The mercury flow in carbon black production facilities is shown in Figure 2.12.1.



Flow: Prepared based on the interview survey with Cabon Black Association in FY2021.

*1: Estimated based on the interview survey with Cabon Black Association in FY2022 and FY2023 and results of the survey conducted by the MOEJ in FY 2022.

*2: The air emissions are from the "Mercury Emission Inventory (for FY2019)". The value was estimated by multiplying carbon black production (587,423 t) by the emission factor in the USA (0.15 g/t)[15]. Since the estimated amount of mercury fed into carbon black production furnaces widely differs from the estimated air emissions, further measurement surveys and considerations are planned for refining the estimated air emissions.

Figure 2.12.1 Mercury flow in carbon black production facilities (FY 2019)

1) Mercury in feedstock oil to carbon black production furnaces

The amount of mercury in feedstock oil to carbon black production furnaces in FY 2019 was estimated as shown in Table 2.12.1. The estimate was calculated by multiplying the amount of feedstock oil (amount of feedstock oil used, utilization rate, yield, and domestic production share) estimated from the results of the interview survey with Carbon Black Association and the Association's member companies by the mercury concentration obtained from the measurement survey conducted by the MOEJ in FY2022.

Table 2.12.1 [Carbon black production] Mercury in feedstock oil to furnaces (FY 2019)

Feedstock oil	Input amount (10^3t)	Hg concentration (mg/kg)	Hg content in feedstock oil used (t-Hg)
Coal-based feedstock oil	734	0.020	0.014
Petro-based feedstock oil	261	0.0020	0.00052
		Total	0.015

[Source]

The amount of feedstock oil used: Estimated based on the results of the interview survey (amount of feedstock oil used, utilization rate, yield, and domestic production share) conducted by the MOEJ in FY 2022.

The mercury concentration in the feedstock oil: The measurement survey conducted by the MOEJ in FY2022

2) Atmospheric emission of mercury

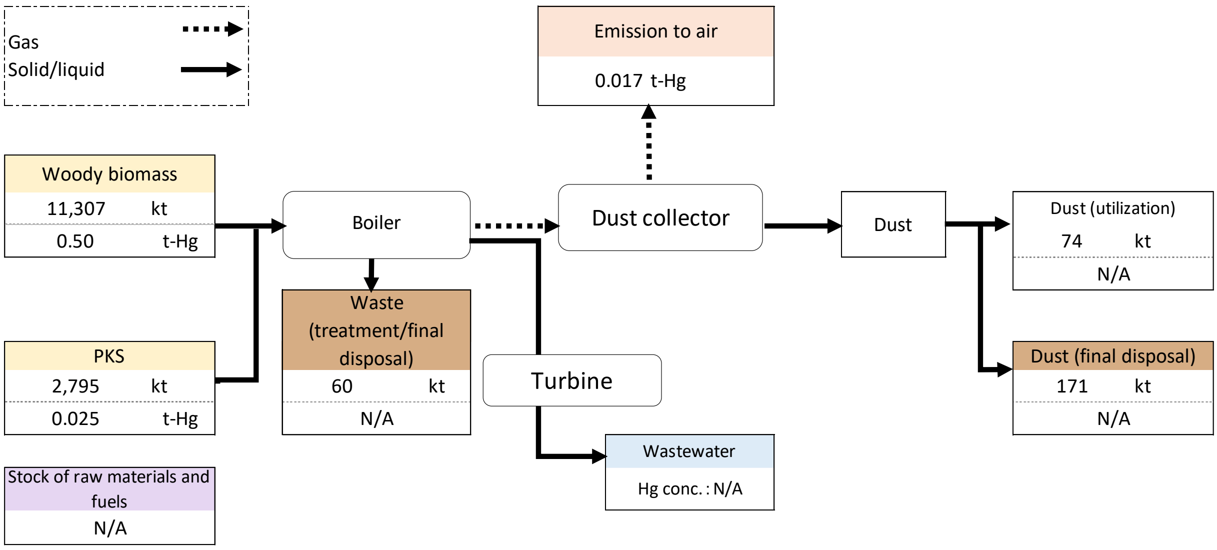
According to the "Mercury Emission Inventory (for FY2019)", mercury emissions from carbon black

[15] US-EPA, Locating and Estimating Air Emission from Sources of Mercury and Mercury Compounds, EPA 454/R-97-012, 1993.

production facilities are estimated to be 0.088 t-Hg. It should be noted that this emission was estimated by multiplying CY 2019 carbon black production (587,423 tons) by the U.S. overall emission factor (0.15 g/t).

2.13 Electricity and Heat Supply Facilities using Biomass Combustion

The mercury flow in electricity and heat supply facilities using biomass combustion is shown in Figure 2.13.1.



Flow: Prepared based on the interview survey conducted as part of the Survey on Measures to Control Mercury Emissions in FY2018 and the interview survey with domestic companies in FY 2021.

Values in the flow: Estimated values based on the results of the interview survey with domestic companies in FY2021,"Survey on Woody Biomass Energy Use Trend" conducted by the Forestry Agency in FY2019, and existing literatures. Atmospheric emissions are from the "Mercury Emissions Inventory (for FY 2019)".

Figure 2.13.1 The mercury flow in electricity and heat supply facilities using biomass combustion (FY 2019)

1) Mercury in input materials

According to the "Survey on Woody Biomass Energy Use Trend (FY2019)" conducted by the Forestry Agency, the amount of woody biomass input to the electricity and heat supply process using biomass combustion in 2019 is shown in Table 2.13.1. Also, according to the Trade Statistics, the imported PKS (oil-cake and other solid residues, resulting from the extraction of palm nuts oil or kernel oil, and gampi as well as nuts (including their shells, whether or not ground), and hard seeds[16]) was 2,795 thousand tons, and it was assumed that all of the imported PKS was input to electricity and heat supply facilities using biomass combustion.

[16] HS code 2306.60.000 and 1404.90.200

Among the fuels in the Air Pollution Control Act notification data for woody biomass, wood waste and recycled wood were considered as construction waste, and the average mercury concentrations in these and other woody biomass are used to calculate the mercury concentration of woody biomass fed to biomass-fired boilers in Japan. The ratio of construction wood waste to the total nationwide fuel procurement volume obtained from the surveys of fuel wood supply and demand trends conducted by Japan Woody Bioenergy Association was applied. The result of the calculation is 0.044 g/t for the mercury concentration of woody biomass fed to the biomass-fired boilers.

In addition, Kusakabe, et al. (2021)[17] reported 0.0090 g/t as the average mercury concentration of PKS. By multiplying the input amount by these mercury concentrations, the amount of mercury in the input woody biomass was estimated to be 0.50 t-Hg, and the amount of mercury in the PKS was estimated to be 0.025 t-Hg.

Table 2.13.1 [Biomass-fired power/heat] Mercury in input woody biomass and PKS (FY 2019)

Input material	Input amount (10^3t)	Hg concentration (g/t)	Hg content in input biomass (t-Hg)
Woody biomass	11,307	0.044	0.50
PKS	2,795	0.0090	0.025

[Source]

Input of woody biomass: Total value of woody biomass (wood chips, wood pellets, fuelwood, wood powder (sawdust), and others) used in workplaces from the Forestry Agency, "Survey on woody biomass energy use trend (2019)". PKS is not included here.

Input of PKS: Trade Statistics, the Ministry of Finance (HS Code 230660000 (oil-cake and other solid residue of palm nuts or kernels)) and 140490200 (gampi and nuts (including their shells, whether or not ground), and hard seeds) and seeds)

Mercury concentration in woody biomass: Among the fuels in the Air Pollution Control Act notification data for woody biomass, wood waste and recycled wood were considered as construction waste, and the average mercury concentrations in these and other woody biomass are used to calculate the mercury concentration of woody biomass fed to biomass-fired boilers in Japan by multiplying the ratio of construction wood waste to the total fuel procurement volume nationwide, which was obtained from the surveys of fuel wood supply and demand trends conducted by Japan Woody Bioenergy Association (https:// jwba.or.jp/project-report/fuelwood-demand-survey/).

Mercury concentration in PKS: Taketoshi Kusakabe and Masaki Takaoka. (2021). "Current Status of Mercury Abatement Technologies", Journal of the Japan Society of Material Cycles and Waste Management.

2) Mercury in incineration residues (cinders)

Based on the results of the interview survey with domestic companies in FY2021, the amount of cinders generated by electricity and heat suppliers using biomass combustion in FY 2019 was estimated by multiplying the amount of cinders generated by the interviewed companies by the ratio of the total domestic woody biomass and PKS input to the woody biomass and PKS input of the interviewed companies. The amount of cinders generated is shown in Table 2.13.2.

[17] Taketoshi Kusakabe and Masaki Takaoka. (2021). "Current Status of Mercury Abatement Technologies", Journal of the Japan Society of Material Cycles and Waste Management.

Table 2.13.2 [Biomass-fired power/heat] Mercury in cinders (FY 2019)

	Generation (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)	Treatment methods
Cinders	60	N/A	N/A	Intermediate treatment/ final disposal

Source for amount of cinders generated: Extrapolation results, by multiplying the amount of cinders generated by the interviewed companies by the ratio of the total domestic woody biomass and PKS input to the woody biomass and PKS input of the interviewed companies, based on the results of the interview survey with domestic companies for FY2021.

3) Mercury in precipitator dust utilized or disposed of

Based on the results of the interview survey with domestic companies in FY2021, the amount of precipitator dust generated, utilized, and finally disposed of by electricity and heat suppliers using biomass combustion is extrapolated by using the ratio of the total domestic woody biomass and PKS input to the woody biomass and PKS input for the interviewed companies, as shown in Table 2.13.3.

Table 2.13.3 [Biomass-fired power/heat] Mercury in precipitator dust utilized or disposed of (FY 2019)

		Precipitator dust (10^3t)	Hg concentration (mg/kg)	Hg content (t-Hg)
Generation		245	N/A	N/A
	Utilization	74		N/A
	Final disposal	171		N/A

Source for the amount of precipitator dust generated, utilized and finally disposed of: Based on the results of the FY2021 interview survey with domestic companies, the result was estimated by multiplying the ratio of the total domestic woody biomass and PKS input to the input volume of woody biomass and PKS of the interviewed companies.

4) Atmospheric emission of mercury

Mercury emissions from electricity and heat supply facilities using biomass combustion are estimated to be 0.017 t-Hg in Japan's Mercury Emission Inventory (for FY 2019). It should be noted, however, that the emission from PKS combustion is not included. This estimate is calculated by multiplying the annual biomass fuel consumption by an emission factor. The biomass fuel consumption is the total value[18]of woody biomass (wood chips, wood pellets, fuelwood, wood powder (sawdust), and others) used in workplaces from the “Survey on Woody Biomass Energy Use Trends (FY2019)” prepared by the Forestry Agency.

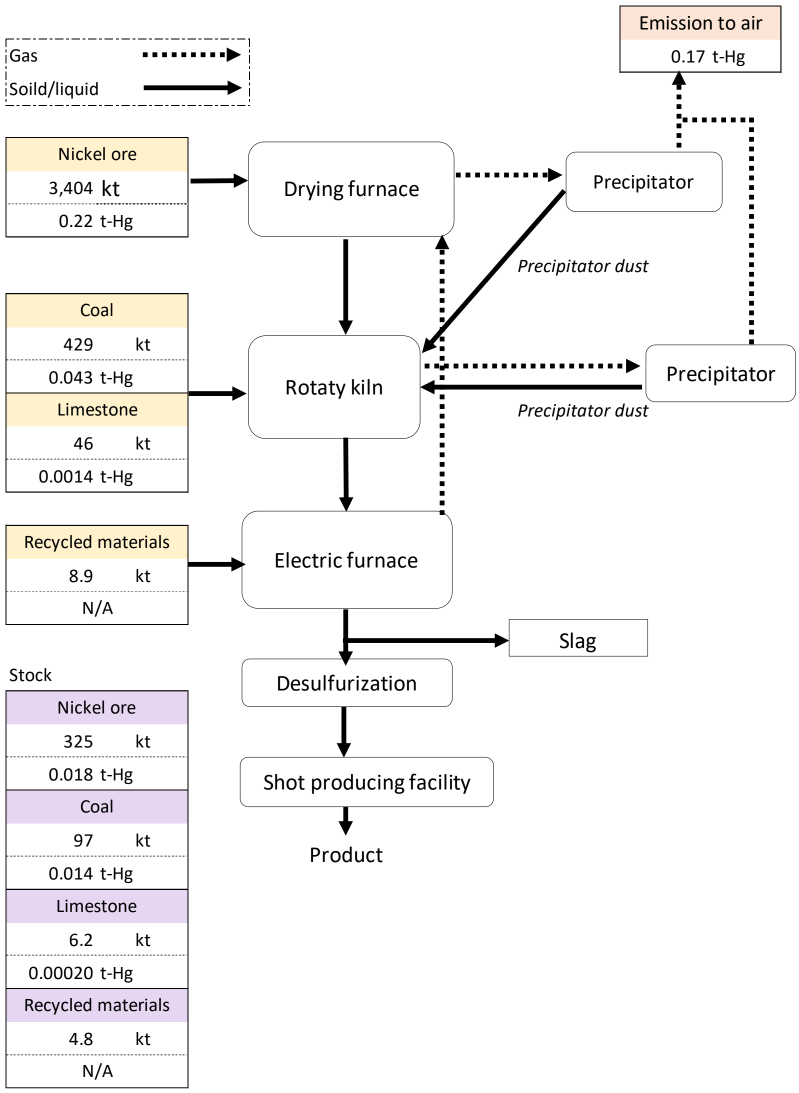
The emission factor is based on the measurement survey on mercury emissions conducted by the MOEJ at two domestic biomass combustion facilities in FY2018.

[18] In order to ensure consistency with the material flow, from FY2020, not only woody biomass consumption but also PKS consumption (HS code 230660000 (oil-cake and other solid residue of palm nuts or kernels) and 140490200 (gampi and nuts (including their shells, whether or not ground), and hard seeds) are included as biomass fuel consumption from the Trade Statistics by the Ministry of Finance.

2.14 Ferroalloy Production Facilities

(1) Ferronickel production facilities

The mercury flow in ferronickel production facilities is as shown in Figure 2.14.1.



Flow: Prepared based on the result of the interview survey with Japan Mining Industry Association (JMIA)

Values in the flow: The interview survey with the JMIA member companies in FY2021. Air emissions are from the "Mercury Emissions Inventory (for FY 2019)".

Figure 2.14.1 Mercury flow in ferronickel production facilities (an example) (FY 2019)

1) Mercury in raw materials

According to the results of the FY2021 interview survey with member companies of the Japan Mining Industry Association (JMIA), the amount of mercury in raw materials used in the ferronickel production process and the amount of mercury in the raw materials in stock in FY 2019 are shown in Table 2.14.1 and Table 2.14.2.

Table 2.14.1 [Ferronickel production]Mercury in input raw materials (FY 2019)

Input of raw material	Input amount (10^3t)	Hg concentration (g/t)	Hg content (t-Hg)
Nickel ore	3,404	0.064	0.22
Coal	429	0.099	0.043
Limestone	46	0.032	0.0014
Recycled materials	8.9	N/A	N/A
Total			0.26

[Source]

Raw materials input: The interview survey with the JMIA member companies in FY2021.

Mercury concentration in nickel ores: Calculated by dividing the sum of mercury in nickel ores estimated on an individual company basis (based on the results of the FY2021 survey of JMIA member companies) by the total amount of nickel ores used.

Mercury concentration in coal: Calculated by dividing the sum of mercury in coal estimated on an individual basis (based on the results of the FY2021 survey of JMIA member companies. If the mercury concentration is unknown, the mercury concentration of the coal identified in the results of the interview survey with the FEPC was used.) by the total amount of coal used. Note that the amount of some companies' coal input was in wet coal; therefore, it was converted to coal input (dry coal) by multiplying the ratio of wet coal to dry coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.

Mercury concentration in limestone: Calculated by dividing the sum of mercury in limestone estimated on an individual basis (If the mercury concentration is unknown, the mercury concentration of limestone identified in the "Implementation of measures to control the emission of mercury to the atmosphere based on the Minamata Convention on Mercury (First Report)" was used.) by the total amount of limestone used.

Table 2.14.2 [Ferronickel production] Mercury in year-end stock of raw materials (FY 2019)

Raw material	Stock amount (10^3t)	Hg concentration (g/t)	Hg content (t-Hg)
Nickel ore	325	0.056	0.018
Coal	97	0.15	0.014
Limestone	6.2	0.032	0.00020
Recycled materials	4.8	N/A	N/A
Total	434		0.033

[Source]

Year-end stock of raw materials: The interview survey with the JMIA member companies in FY2021.

Mercury concentration in nickel ore: Calculated by dividing the sum of mercury in nickel ore estimated on an individual basis (based on the results of the FY2021 survey of the JMIA member companies) by the total amount of nickel ore used.

Mercury concentration in coal: Calculated by dividing the sum of mercury in coal estimated on an individual basis (based on the results of the FY2021 survey of the JMIA member companies. If the mercury concentration is unknown, the mercury concentration of the coal identified in the results of the interview survey with the FEPC was used.) by the total amount of coal used. Note that some companies' coal input was wet coal; therefore, it was converted to coal input (dry coal) by multiplying the ratio of wet coal to dry coal consumption in the Electricity Survey Statistics by the Agency for Natural Resources and Energy.

Mercury concentration in limestone: Calculated by dividing the sum of mercury in limestone estimated on an individual basis (If the mercury concentration is unknown, the mercury concentration of limestone identified in the "Implementation of measures to control the emission of mercury to the atmosphere based on the Minamata Convention on Mercury (First

Report)” was used.) by the total amount of limestone used.

2) Atmospheric emission of mercury

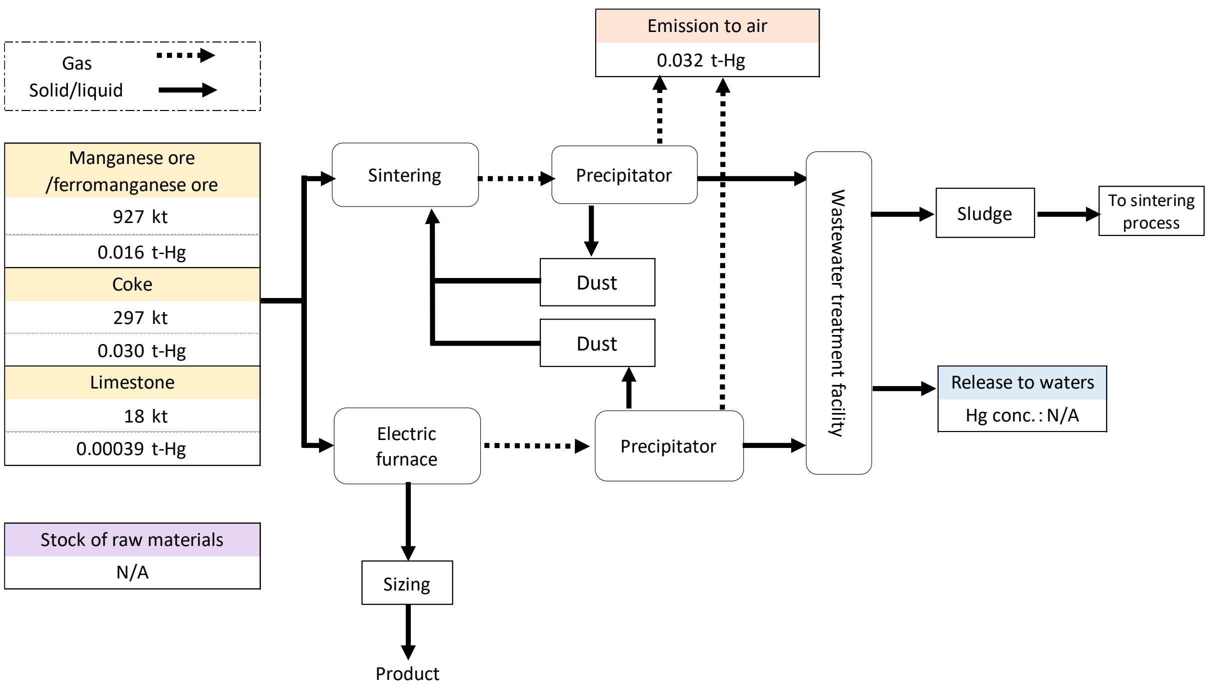
Mercury emissions from ferronickel production facilities were estimated to be 0.17 t-Hg in Japan's Mercury Air Emissions Inventory (for FY 2019) by multiplying the emission factor calculated based on the results of the measurement survey on mercury emissions (FY 2018 and FY 2019) by the national product production (329 thousand tons).

3) Mercury release to public waters

According to the results of the FY2021 interview survey with the JMIA member companies, the amount of mercury in wastewater from ferronickel production facilities was “confirmed to be below the lower limit of quantification”, but the amount of effluent was unknown, so it was “0 (with effluent)”.

(2) Ferromanganese production facilities

The mercury flow in ferromanganese production facilities is as shown in Figure 2.14.2.



Waste: Since all waste is utilized, no solid waste leaves the flow system.

Flow: Prepared based on the “Survey Report on Measures to Control Mercury Emissions in FY2019” conducted by the MOEJ and the result of a FY 2021 interview survey with Japan Ferroalloy Association.

Values in the flow: Estimated based on the interview survey of Japan Ferroalloy Association in FY2021 and existing literatures. Air emissions are from the “Mercury Emission Inventory (for FY 2019)”.

Figure 2.14.2 Mercury flow in ferromanganese production facilities (FY 2019)

1) Mercury in raw materials and fuels

Based on the results of the interview survey with Japan Ferroalloy Association in FY 2021, the amount of mercury contained in raw materials and fuels fed into the ferromanganese production process in FY 2019 is estimated as shown in Table 2.14.3.

Table 2.14.3 [Ferromanganese production] Mercury in raw materials and fuels (FY 2019)

Input of raw materials and fuels	Input amount (10^3t)	Hg concentration (g/t)	Hg content (t-Hg)
Manganese ore/Ferromanganese ore	927	0.017	0.016
Coke	297	0.10	0.030
Limestone	18	0.022	0.00039

[Source]

Input of raw materials and fuels: The result of the FY 2021 interview survey with Japan Ferroalloy Association.

Mercury concentration in manganese ore/ferromanganese ore: The Survey Report on Measures to Control Mercury Emissions (FY2019)

Mercury concentration in coke and limestone: Implementation of measures to control the emission of mercury into the atmosphere based on the Minamata Convention on Mercury (First Report) Reference Material 2 "Results of Survey on Actual Status of Mercury Emissions", Page 29, https://www.env.go.jp/press/102627.html Note that the data on mercury content in coke may differ from the data on coke used for ferromanganese because coke is used for non-ferrous metal production.

2) Atmospheric emission of mercury

Mercury emissions from ferromanganese production facilities were estimated to be 0.032 t-Hg in Japan's Mercury Emission Inventory (for FY 2019) by multiplying the emission factor calculated based on the results of the actual mercury air emissions survey (FY 2018 and FY 2019) by the national product production amount (463 thousand tons).

3) Mercury release to public waters

According to the results of the FY2021 interview survey with Japan Ferroalloy Association, the amount of mercury in wastewater from ferromanganese production facilities was "effluent: 2,480,000m^3 per year in FY2019, and no data is available on mercury concentration in wastewater", so it was "N/A (with effluent)".

3. FLOW FOR MERCURY RECOVERED AND REFINED/SOLD

3.1 Mercury Recovered from Waste and Mercury-Containing Recyclable Resources

Table 3.1.1 shows the amount of mercury recovered from waste and mercury-containing recyclable resources obtained from interview surveys with mercury recovery companies conducted in FY2021 and FY2022. The total amount of mercury recovered is estimated as 58,694 kg-Hg (≒ 59 t-Hg).

Table 3.1.1 Mercury recovered from waste and mercury-containing recyclable resources (FY2019)

Waste/resource type		Mercury recovered (kg-Hg)	Note
(1) Discarded product	Industrial waste	3,860	
	Municipal solid waste	877	
(2) Waste elemental mercury		11,995 (Imported waste: 268)	
(3) Sludge, waste liquid		10,524 (Imported waste: 4,544)	
(4) Non-ferrous metal smelting sludge		31,157	Three-year average (FY2018-FY2020)
(5) Others	Dental amalgam	280	Waste and mercury-containing recyclable resources
	Silver oxide battery	1	Mercury-containing recyclable resources
Total (kg-Hg)		58,694 (Imported waste:4,812)	
Total (t-Hg)		59 (Imported waste: 4.8)	

Note: The portion of the mercury recovered is estimated based on the ratio of the amount treated.

(1) Discarded products (industrial waste and municipal solid waste)

According to the interviews with mercury recovery companies in FY2021 and FY2022, amounts of discarded products treated for the purpose of mercury recovery and the amount of mercury recovered are as shown in Table 3.1.2. The total amount of mercury recovered from discarded products is 4,737 kg-Hg (≒ 4.7 t-Hg).

Table 3.1.2 Treatment of and mercury recovery from discarded mercury-added products (FY2019)

Product	Industrial waste		Municipal solid waste	
	Waste treated (kg)	Hg recovered (kg-Hg)	Waste treated (kg)	Hg recovered (kg-Hg)
Dry cells	2,036,606	40	13,527,345	270
Button batteries	64,795	65	499	0.5
Fluorescent lamps (including shredded portions)	4,814,248	190	4,725,779	180
Backlight (cold cathode fluorescent lamps and external electrode fluorescent lamps)	102,460	3	0	0
HID lamps (mercury lamps)	77,710	3	16	0
Lamps (various mixture)	175,885	20	323,222	36

Product	Industrial waste		Municipal solid waste	
	Waste treated (kg)	Hg recovered (kg-Hg)	Waste treated (kg)	Hg recovered (kg-Hg)
Medical mercury thermometers / industrial mercury thermometers[19]	5,730	570	1,195	97
Medical mercury sphygmomanometers	20,702	1,020	5,906	290
Switches and relays, manometers[20]	8,857	800	0	0
Others (rectifiers, mercury-containing appliances)	22,657	1,150	39	3
Total (kg-Hg)	7,329,650	3,860	18,584,001	877
Total (t-Hg)	7,330	3.9	18,584	0.88

Note: Mercury recovery treatment includes roasting, heat treatment, distillation and extraction of elemental mercury.

Source: The interviews with mercury recovery companies in FY2021 and FY2022 (The portion of the mercury recovered is estimated based on the ratio of the amount treated.)

(2) Waste elemental mercury

Table 3.1.3 shows the amount of mercury recovered from waste elemental mercury and the emission sources thereof obtained from the interviews with mercury recovery companies in FY2021 and FY2022.

Table 3.1.3 Mercury recovered from waste elemental mercury (FY2019)

Type	Source of waste elemental mercury	Hg recovered (kg-Hg)
Waste elemental mercury	Business	8,388
	University/school	979
	Lighthouse	372
	Hospital	229
	Waste incineration facility	1,188
	Others	571
	Imported waste	268
	Total (kg-Hg)	11,995
	Total (t-Hg)	12

Source: The interviews with mercury recovery companies in FY2021 and FY2022.

(3) Sludge, waste liquid

According to the interviews with mercury recovery companies in FY2021 and FY2022, mercury is recovered from sludge and waste liquid among industrial waste other than discarded products. Table 3.1.4 shows the amount of sludge and waste liquid treated and the amount of mercury recovered.

[19] Including glass rod thermometers, mercury filled thermometers and Assmann Type Psychrometers.

[20] Including mercury barometer.

Table 3.1.4 Amount of mercury recovered from sludge and waste liquid (FY2019)

Type	Amount treated (t)	Hg recovered (t-Hg)
Sludge, waste liquid	2,900	11
(Imported sludge and waste liquid)	(891)	(4.5)

Source: The interviews with mercury recovery companies in FY2021 and FY2022

(4) Non-ferrous metal smelting sludge

Table 3.1.5 shows the amount of mercury recovered from sludge generated in the process of non-ferrous metal smelting. The data is obtained from the interviews with mercury recovery companies in FY2021 and FY2022, and from the JMIA (sludge generator). Since the amount of mercury recovered from the sludge varies greatly from year to year, a three-year average of 31t-Hg obtained from the mercury recovery side is used in the material flow.

Table 3.1.5 Mercury recovered from non-ferrous metal smelting sludge

Source	Hg recovered (t-Hg) Note1			
	FY2018	FY2019	FY2020	Three-year average
FY2021 and FY2011 interviews with mercury recovery companies (Recovery side. Only the JMIA members.) Note2	33	12	48	31
The JMIA Note 3 (Generation side. Only the JMIA members.)	42	36	51	43

Note 1: Regarding the difference in the amount of mercury recovered between the generation side and the recovery side, in addition to the differences in the survey targets, there may be a time lag between the discharge and the treatment or counting thereof.
Note 2: Non-JMIA member companies made no treatment contracts between FY2018-2020.
Note 3: The data provided by the JMIA are estimated amount of mercury contained in sludge contracted-out from non-ferrous metal smelting companies.

(5) Others

1) Dental amalgam

Table 3.1.6 shows the amount of dental amalgam treated and mercury recovered obtained from the interviews with mercury recovery companies conducted in FY2021 and FY2022. It needs to be noted that there are two types of dental amalgam; those treated as industrial waste and valuable resources (contract smelting). Mercury is recovered in both cases.

Table 3.1.6 Mercury recovered from dental amalgam (FY2019)

Type	Classification	Amount treated (kg)	Hg recovered	
			(kg-Hg)	(t-Hg)
Dental amalgam	Industrial waste	268	130	0.13
	Valuables (Contracted smelting)	221	150	0.15
	Total	489	280	0.28

Source: The survey with mercury recovery companies in FY2021 and FY2022.

2) Silver oxide batteries

Table 3.1.7 shows the amount of silver oxide batteries treated and mercury recovered thereof obtained from the interviews with mercury recovery companies conducted in FY2021 and FY2022. Amount of silver oxide batteries treated as industrial waste and mercury recovered from this operation is included in Table 3.1.4 “Button batteries”.

Table 3.1.7 Treatment of and mercury recovery from silver oxide batteries treated as recyclable resources (FY2019)

Type	Classification	Amount treated (kg)	Hg recovered	
			(kg-Hg)	(t-Hg)
Silver oxide battery	Valuables (Contracted smelting)	827	1	0.001

Source: The interviews with mercury recovery companies in FY2021 and FY2022.

3.2 Mercury Refined and Sold

The reporting requirement, “Report on the Storage of Mercury or Mercury Compounds According to the Mercury Pollution Prevention Act” (hereinafter referred to as the “Report on the Storage of Mercury”[21]), started in August 2017. Since the reporting is required for those who store mercury or mercury compounds equal to or more than 30 kg, estimated amounts of stock and transfer based on the reporting have been regarded as the minimum amount. According to the reports submitted on FY 2019, the amount of mercury recovered from waste and mercury-containing recyclable resources and shipped to the domestic market was 6.8 t-Hg or more. In addition, according to the results of the FY2021 interview survey with domestic companies, the amount of mercury used in the domestic production of inorganic chemicals (mercury sulfide and mercury compounds) was 0.69 t-Hg or more. Based on these results, the amount of mercury transferred from the mercury recovery process to the mercury refining and marketing process was estimated to be 7.5 t-Hg or more. Also, according to the “Report on the Storage of Mercury” under the Mercury Pollution Prevention Act, the amount of mercury that was subsequently refined and shipped for the manufacture of mercury-added products, inorganic pigment production, metrological analysis and research/investigation was 7.1 t-Hg or more. Assuming that the amount of above-mentioned of inorganic chemicals produced was sold as is, the amount of mercury transferred from the mercury refining/ sales process to the mercury use process in society was estimated to be 7.8 t-Hg or more. Besides, the amount of mercury used in research studies and quantitative analysis and sent to refining as mercury-containing recyclable resources and returned to the original users was 2.5 t-Hg or more.

[21] The target substances in this reporting system are mercury, mercury (I) chloride, mercury (II) oxide, mercury (II) sulfate, mercury (II) nitrate and mercury (II) nitrate hydrate, mercury sulfide and those mixtures with a concentration of 95% or more, and cinnabar. In this section, only reports on mercury are used.

3.3 Export of Mercury

According to the Trade Statistics by the Ministry of Finance, the amount of mercury export from Japan (FY2018-FY2020) is as shown in Table 3.3.1. Considering that the export volume varies widely by fiscal year, a three-year average is adopted in the material flow.

Table 3.3.1 Export of mercury (FY2018 - FY2020)

Item	FY2018	FY2019	FY2020	Three-year average
Mercury export (kg-Hg)	39,075	24,974	22,091	28,713

Source: The Trade Statistics, the Ministry of Finance

4. FLOW FOR SOCIETAL USE OF MERCURY

4.1 Import of Mercury

(1) Import of mercury

Mercury imports from FY2018 to FY2020 are shown in Table 4.1.1 according to the Trade Statistics by the Ministry of Finance. Because the statistics do not show the breakdown of mercury compounds, the mercury compounds are not included in "import of mercury" in this material flow. Considering that the import volume varies widely by fiscal year, a three-year average is adopted in the material flow.

Table 4.1.1 Import of mercury (FY2018-FY2020)

Item	FY2018	FY2019	FY2020	Three-year average
Mercury import (kg-Hg)	0	8	2,348	785

Source: The Trade Statistics, the Ministry of Finance

(2) Import of mercury alloys

According to the interview survey with Japan Lighting Manufacturers Association (JLMA) in FY2021, the import of mercury alloys used for manufacturing lamps (FY2018-FY2020, mercury equivalent) is shown in Table 4.1.2. For the material flow, 145 kg-Hg (≒ 0.15 t-Hg), which is the actual value for FY2019, is adopted.

Table 4.1.2 Import of mercury alloys (Mercury equivalent) (FY2018 to FY2020)

Item	FY2018	FY2019	FY2020	Three-year average
Mercury alloys import (kg-Hg) (mercury equivalent)	170	145	282	199

Source: The interview survey with JLMA in FY20121

4.2 Societal Use of Mercury (Mercury Utilization)

"Societal use of mercury" covers the production/use of mercury-added products (product manufacture, product use, and product disposal) and the (non-product) use of mercury (metrological analysis, research/investigation, and ensuring safety of navigation routes). Disposal of mercury-added products is described in detail in "Section 3. Flow for Mercury Recovered and Refined/Sold".

4.2.1 Production of Mercury-added products

Table 4.2.1 shows the amount of mercury used for the domestic production of mercury-added products (hereinafter regarded as "Hg content in manufactured products"), and mercury content in imported/exported products, obtained through the interviews with industry organizations and business entities in FY2021. Total amount of mercury used in domestically manufactured products is estimated as 3.5 t-Hg, mercury content in imported products is estimated as 0.12 t-Hg and mercury content in exported products is estimated as 0.80 t-Hg. The values in the table below are obtained through the interviews with the business entities and do not cover the entire domestic market.

Table 4.2.1 Mercury in domestically produced, imported, and exported products (FY2019)

Product		Hg used for domestic production (t-Hg)	Year Note1	Hg in imported products (t-Hg)	Hg in exported products (t-Hg)	Year Note1
Button batteries	Alkaline button batteries	0	2019CY	N/A	0	2019CY
	Silver-oxide batteries	0.060	2019CY	0	0.059	2019CY
	Zinc-air batteries	0.010	2019CY	0	0.0070	2019CY
Mercury-added dry-cell batteries		0	2019CY	N/A	0	2019CY
Switches and relays		0.29	2019FY	N/A	0.11	2019FY
Lamps	Fluorescent lamps Note2	0.44	2019FY	0.069	0.0033	2019FY
	HID lamps	0.22	2019FY	0.049	0.11	2019FY
Industrial measuring devices	Glass Hg thermometers	0.071	2019FY	0.0033	0	2019FY
	Vacuum gauges	0.015	2019FY	N/A	N/A	2019FY
Medical measuring devices	Mercury thermometers	0	2019FY	0	0	2019FY
	Sphygmomanometers	1.7	2019CY	0	0.51	2019CY
Mercury for dental use		0	2019FY	0	0	2019FY
Pharmaceuticals	Vaccine preservative	0.00034	2019FY	0	0	2019FY
	Merbromin related products	0	2019FY	0	0	2019FY
Inorganic chemicals	Mercuric sulphide	0.68	2019FY	N/A	0	
	Mercury compounds	0.015	2019FY	N/A	0	
Total		3.5		0.12	0.80	

Note 1: 2019FY denotes Fiscal year 2019 and 2019CY denotes Calendar year 2019.
Note 2: Fluorescent lamps include cold cathode fluorescent lamps (CCFL)
Note 3: The figures in the table show the amount obtained from the interviews with manufacturers and importers/exporters of mercury-added products and business associations in FY2021, and do not necessarily reflect the amount in the entire market.
Source: Information obtained through the interviews with manufacturers/importers and other business entities, FY2021.

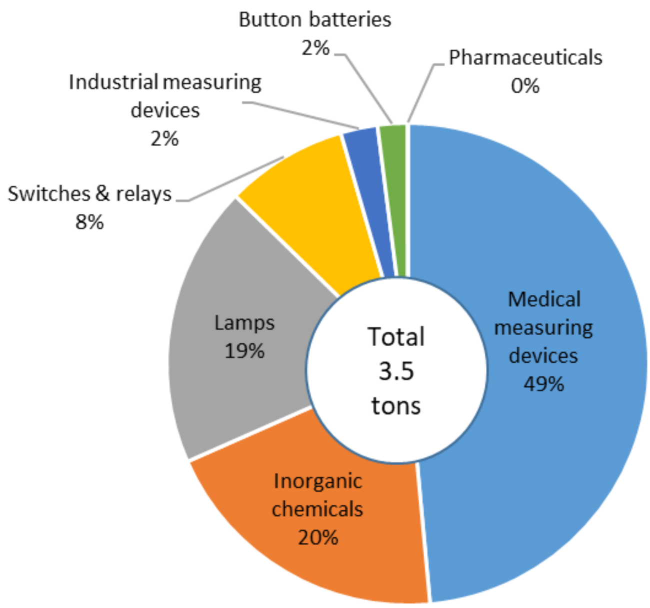
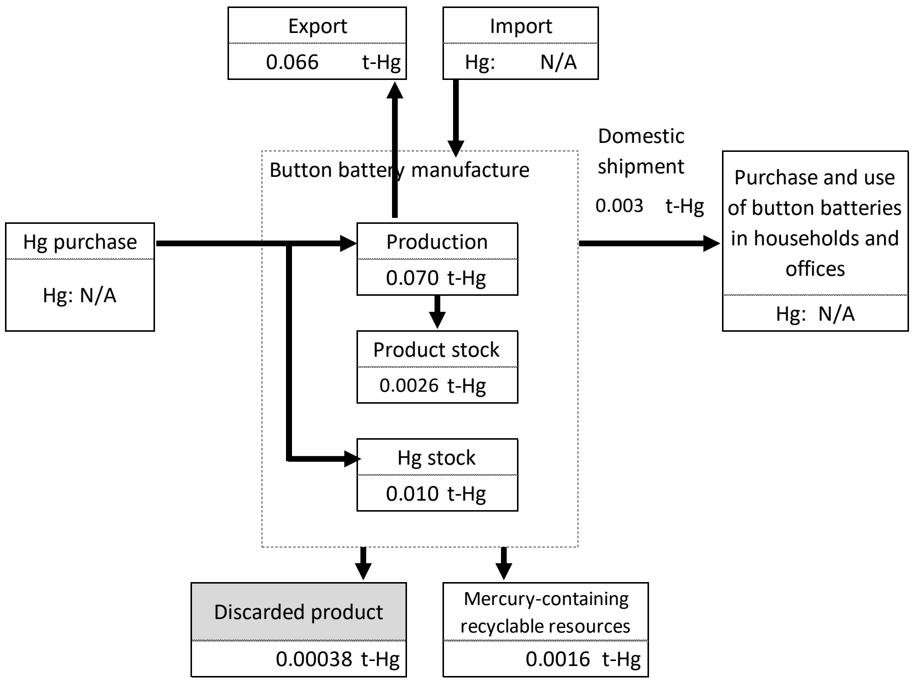


Figure 4.2.1 Mercury used for the domestic production of mercury-added products (FY2019)

(1) Button batteries

The mercury flow in manufacturing button batteries is shown in Figure 4.2.2.



Note: There are no processes that generate air emissions and wastewater.
Values in the flow: The interview survey with Battery Association of Japan (BAJ) in FY 2021. The amounts of mercury in discarded products and mercury-containing recyclable resources are figures from the manufacturing process.

Figure 4.2.2 Mercury flow in manufacturing button batteries (CY2019)

Table 4.2.2 shows the amount of mercury used for the domestic production of button batteries by Battery Association of Japan (BAJ) member companies and mercury contained in import/export of button batteries obtained through the interview survey with BAJ in FY2021.

It is identified that 0 t-Hg of mercury was contained in alkaline manganese batteries imported by BAJ member companies. Besides this amount, it is assumed that there are certain amounts of mercury-added batteries imported by non-BAJ member companies, and some mercury-added batteries are incorporated in and imported with assembled products. Hence, the total picture is unknown. Therefore, the amount of mercury in the imported alkaline button batteries is determined to be "N/A" in Table 4.2.1.

Table 4.2.2 Mercury in domestically manufactured and imported/exported button batteries (CY2019, Only BAJ member companies)

Battery type	Hg in manufactured products (t-Hg)	Hg in imported products (t-Hg)	Hg in exported products (t-Hg)
Alkaline manganese	0	0	0
Silver oxide	0.060	0	0.059
Air zinc	0.010	0	0.0070
Total	0.070	0	0.066

Source: The interview survey with BAJ in FY2021

The amount of mercury in button batteries shipped within Japan (Hg in products shipped domestically) and the amount of mercury in stock of button batteries at the end of the calendar year (Hg in year-end stock products) are shown in Table 4.2.3.

Table 4.2.3 Mercury in button batteries shipped domestically and in year-end stock (CY 2019, BAJ member companies only)

Battery type	Hg in products shipped domestically (t-Hg)	Hg in year-end stock products (t-Hg)
Alkaline manganese	0	0
Silver oxide	0	0.0024
Air zinc	0.003	0.0002
Total	0.003	0.0026

Source: The interview survey with BAJ in FY2021

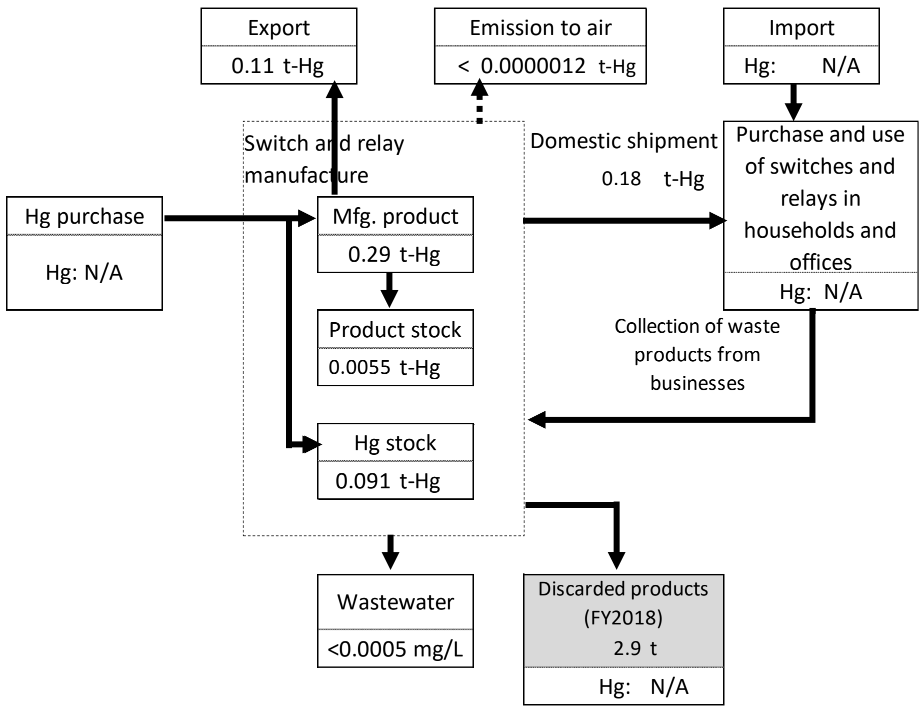
In addition, according to the results of the interview survey with BAJ in FY 2021, the amount of elemental mercury used in the domestic production of button batteries by BAJ member companies in CY 2019 was 0.010 t-Hg at the end of the fiscal year.

(2) Dry-cell batteries

Domestically manufactured dry-cell batteries are all mercury free. Hence, the amount of mercury in dry-cell batteries that are domestically manufactured and exported is 0. Due to a lack of data, the amount of mercury-added dry-cell batteries import was indicated as "N/A". Further, it has been known, through the "FY2019 Survey on mercury-added products (the MOEJ)", that some mercury-added dry-cell batteries are incorporated in and imported with assembled products, but this amount remains unknown. Hence it has been indicated as "N/A" in Table 4.2.1.

(3) Switches and relays

The mercury flow in manufacturing switches and relays is shown in Figure 4.2.3.



Values in the flow: The interview survey with domestic manufacturers of switches and relays in FY 2021 and "Mercury Emission Inventory (for FY 2019)".

Figure 4.2.3 Mercury flow in manufacturing switches and relays (FY2019)

Table 4.2.4 shows mercury used for the domestic production of switches and relays and mercury content in switches and relays exported, which was calculated by multiplying the amount of mercury per product by the numbers of switches and relays manufactured in Japan and exported respectively, as obtained through the interview survey with domestic manufacturers of switches and relays in FY2021. There are single units for the use in the manufacture of assembled products, and there is a possibility that switches and relays are imported in a state where they have already been incorporated into products. However, since those volumes of distribution are unknown, it has been deemed to be "N/A" in Table 4.2.1.

Table 4.2.4 Mercury in domestically manufactured and exported switches and relays (FY2019)

Switch/relay type	Manufacture		Export	
	Production (units)	Hg in manufactured products (t-Hg)	Export (units)	Hg in exported product (t-Hg)
Over current relays [Note1]	9,354	0.14	1,946	0.029
Seismoscopes [Note2]	482,721	0.14	267,457	0.080
Total		0.29		0.11

Note 1: 15g of mercury is used in one "over current relay".
Note 2: 0.3g of mercury is used in one seismoscope.
Source: The interviews with manufacturers of switches and relays in FY2021

The amount of mercury in switches and relays shipped within Japan and the amount of mercury in products stocked at the end of the year are shown in Table 4.2.5.

Table 4.2.5 Mercury in switches and relays shipped domestically and in year-end stock (FY 2019)

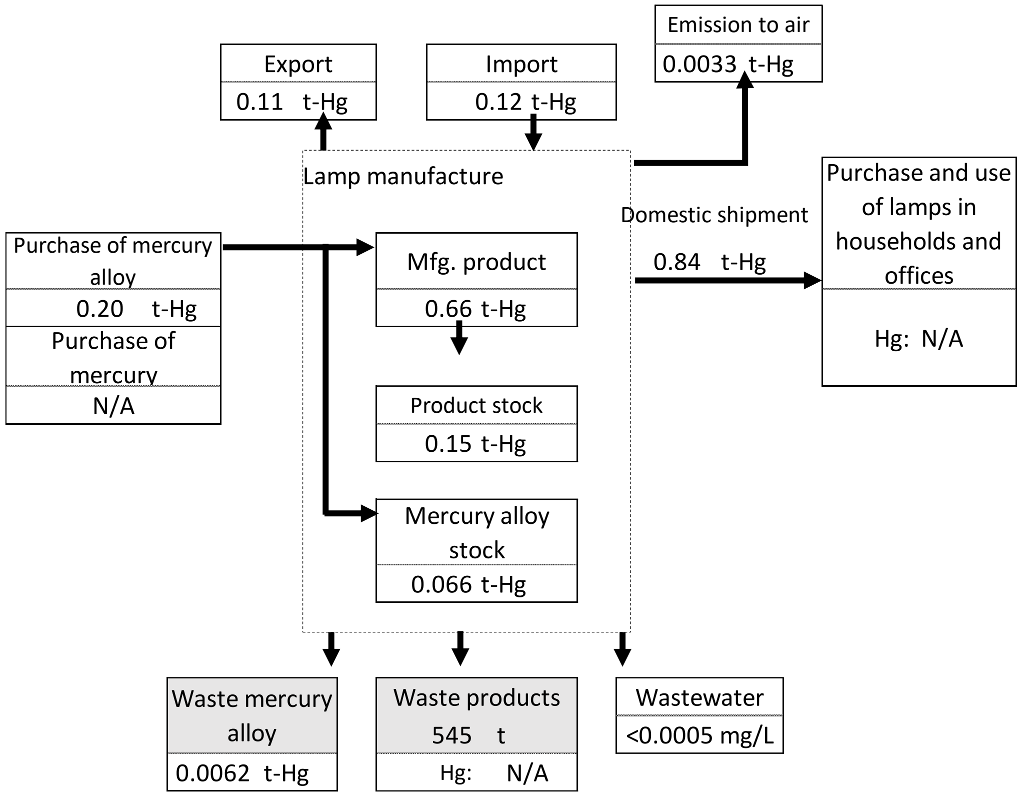
Switch/relay type	Domestic shipment		Year-end stock	
	Shipped products (units)	Hg in products (t-Hg)	Products in stock (units)	Hg in products (t-Hg)
Over current relays	7,277	0.11	134	0.0020
Seismoscopes	230,539	0.069	11,773	0.0035
Total		0.18		0.0055

Source: The interview survey with manufacturers of switches and relays in FY2021

In addition, according to the results of the interview survey with manufacturers of switch and relay in FY 2021, the stock of elemental mercury used in the domestic manufacture of switches and relays at the end of FY 2019 was 0.091 t-Hg.

(4) Lamps

The mercury flow in manufacturing lamps is shown in Figure 4.2.4.



Values in the flow: The interview survey with JLMA in FY 2021 and "Mercury Emission Inventory (for FY 2019)".

Figure 4.2.4 Mercury flow in manufacturing lamps (FY2019)

Table 4.2.6 and Table 4.2.7 show mercury content in domestically manufactured lamps and in imported/exported mercury-added lamps respectively, according to the interview survey with Japan Lighting Manufacturers Association (JLMA) in FY2021.

Table 4.2.6 Mercury in domestically manufactured lamps (FY2019)

Type	Average Hg content (mg-Hg/unit)	Lamp production (10^3 units)	Hg content in products (t-Hg)
Fluorescent lamps Note	4.9	90,150	0.44
HID lamps	63.1	3,417	0.22
Total			0.66

Note: "Fluorescent lamps" include cold cathode fluorescent lamps (back light)
Source for lamp production and Hg content per unit: The interview survey with JLMA in FY2021

Table 4.2.7 Mercury in imported and exported lamps (FY2019)

Type	Import		Export	
	Imported lamp (10^3 units)	Hg content in products (t-Hg)	Exported lamp (1,000 units)	Hg content in products (t-Hg)
Fluorescent lamps	13,957	0.069	681	0.003
HID lamps	781	0.049	1,722	0.11

Type	Import		Export	
	Imported lamp (10^3 units)	Hg content in products (t-Hg)	Exported lamp (1,000 units)	Hg content in products (t-Hg)
Total		0.20		0.11

Source for imported/exported lamps: The interview survey with JLMA in FY2021
Hg amount in manufactured products: Estimated by multiplying imported/exported amounts with the average mercury content shown in Table 4.2.6.

Similarly, the amount of mercury in lamps shipped within Japan and the amount of mercury in lamps in stock at the end of the year are shown in Table 4.2.8.

Table 4.2.8 Mercury in lamps shipped domestically and in year-end stock (FY 2019)

Type	Domestic shipment		Stock	
	Shipped products (10^3 units)	Hg content in products (t-Hg)	Products in stock (units)	Hg content in products (t-Hg)
Fluorescent lamps	99,070	0.49	18,126	0.089
HID lamps	5,665	0.36	989	0.062
Total		0.84		0.15

Source for product shipment/stock amount: the interview survey with JLMA in FY 2021.
Mercury in products: Estimated by multiplying the shipped/stocked volume by the average mercury content shown in Table 4.2.6.

In addition, according to the results of the interview survey with the JLMA in FY2021, the year-end stock of mercury alloys used for domestic lamp production in FY 2019 was 0.066 t-Hg.

(5) Industrial measuring devices

Based on the interviews with several business associations in FY2021, the amount of mercury in domestically manufactured industrial measuring devices (amount of mercury used for manufacturing industrial measuring devices) was estimated by multiplying the mercury content per unit by the number of manufactured devices (see Table 4.2.9). The amount of mercury in imported/exported of these measuring devices are estimated similarly (see Table 4.2.10). Note that the interview survey with Japan Association of Meteorological Instruments Engineering in FY 2016 confirmed that there were no member companies manufacturing Fortan mercury barometers as of October 2016; therefore, they were excluded from the estimates for FY 2019.

Table 4.2.9 Mercury in domestically manufactured industrial measuring devices (FY2019)

Type	Mercury content per unit (g-Hg/unit)	Devices manufactured (units)	Hg content in manufactured devices (t-Hg)
Glass mercury thermometers [Note1]	3.7	19,244	0.071
Macleod vacuum gauges	135	26	0.0035
U-shape vacuum gauge [Note2]	50	227	0.011
Total			0.086

Note 1: "Glass mercury thermometers" include float-type hydrometers containing glass thermometers.

Note 2: The mercury content in "U-shape vacuum gauge" varies by model. Since only the smallest model (average Hg content was 50g-Hg/unit) was sold in FY 2019, the average Hg content in the device for FY2019 is 50g-Hg/unit.
Note 3: The total mercury content does not match the sum of mercury content for each product type due to rounding off.
Sources:
Average mercury content and number of devices manufactured: The interviews with entities shown below conducted in FY2021
Glass mercury thermometers: Japanese Cooperative Kumiai for Glass Measuring Instruments Industry
Vacuum gauges: Japan Scientific Instruments Association

Table 4.2.10 Mercury in imported and exported industrial measuring devices (FY2019)

Type	Import		Export	
	Imported devices (units)	Hg in imported devices (t-Hg)	Exported devices (units)	Hg in exported devices (t-Hg)
Glass mercury thermometers Note	901	0.0033	0	0
Vacuum gauges	0	0	0	0
Total		0.0033		0

Note: As float-type hydrometers are not imported/exported, the values only include glass mercury thermometers
Sources:
Number of devices imported/exported: The interviews with entities shown below conducted in FY2021
Glass mercury thermometers: Japanese Cooperative Kumiai for Glass Measuring Instruments Industry
Vacuum gauges: Japan Scientific Instruments Association
Amount of mercury in devices: Estimated by multiplying the number of devices imported by the average of mercury content per unit indicated in Table 4.2.9.

According to the interview survey with Japanese Cooperative Kumiai for Glass Measuring Instruments Industry in FY2021, waste elemental mercury generated from the manufacturing processes of glass mercury thermometers and float-type hydrometers is collected from the office of Japanese Cooperative Kumiai every two to three years and sent to industrial waste treaters. Based on this information, assuming that waste generated in FY2020 (waste elemental mercury 207 kg and waste devices 302 kg) was for three years, waste discharged in FY2019 was estimated by multiplying the 1/3 of the waste generated in FY2020 by mercury concentration in waste provided by the Japanese Cooperative Kumiai to be 0.081 t-Hg.

Table 4.2.11 Waste discharged from manufacturing processes of glass mercury thermometers (FY2019)

Type	Waste discharged (kg)	Hg concentration in waste (g-Hg/kg)	Hg content in waste (t-Hg)
Waste elemental mercury	69	-	0.069
Waste products (glass mercury thermometers)	101	120	0.012
Total			0.081

Source: The interview survey with Japanese Cooperative Kumiai for Glass Measuring Instruments Industry in FY2021

(6) Medical measuring devices

The amount of mercury in domestically manufactured medical measuring devices (amount of mercury used for manufacturing medical measuring devices) is estimated by multiplying mercury content per device (obtained from interviews with domestic manufacturers and importers and the Japan Federation of Medical

Devices Associations in FY2021) with the number of devices manufactured (shown in the Statistics of Production by Pharmaceutical Industry (see Table 4.2.12). The amount of mercury in imported and exported products (see Table 4.2.13) are estimated similarly. According to the interview survey with Japanese Cooperative Kumiai for Glass Measuring Instrument Industry in FY2013, it was confirmed that mercury thermometers are not manufactured domestically; therefore, their domestic production and export figures are set to be "0" for FY 2019.

Table 4.2.12 Mercury in domestically manufactured medical measuring devices (CY2019)

Type	Mercury content per unit (g-Hg/unit)	Devices manufactured (unit)	Hg content in manufactured devices (t-Hg)
Sphygmomanometers	41	40,875	1.7
Mercury thermometers	1.2	0	0
		Total	1.7

[Source]
Average mercury content per unit of sphygmomanometer: The interview survey with Japan Federation of Medical Devices Associations in FY2021.
Number of mercury sphygmomanometers devices manufactured: The Statistics of Production by Pharmaceutical Industry (2019)
Average mercury content per unit of mercury thermometer: The interviews with importers in FY2019

Table 4.2.13 Mercury in imported and exported medical measuring devices (CY2019)

Type	Import		Export	
	Devices imported (units)	Hg in imported devices (t-Hg)	Devices exported (units)	Hg in exported devices (t-Hg)
Sphygmomanometers	0	0	12,316	0.51
Mercury thermometers	0	0	0	0
Total		0		0.51

[Source]
Import/export of mercury sphygmomanometers: The Statistics of Production by Pharmaceutical Industry (2019)
Import of mercury thermometers: The interview survey with Japanese Cooperative Kumiai for Glass Measuring Instruments Industry in FY2021
Export of mercury thermometers: Since mercury thermometers are not manufactured domestically, their domestic production and export figures are "0" for FY 2019.
Mercury contents in devices: Estimated by multiplying the mercury content per unit indicated in Table 4.2.12 by the number of units exported.

Also, the mercury content in year-end stock of mercury sphygmomanometers was estimated by multiplying the year-end stock of mercury sphygmomanometers as reported in the Statistics of Production by Pharmaceutical Industry (2019) by the mercury content per unit shown in Table 4.2.12, which was 0.056 t-Hg.

(7) Dental mercury

According to the interview survey with Japan Dental Materials Manufacturers Association in FY2013, the manufacture and import of dental mercury in Japan have ceased since February 2014. Hence, the manufacture/import amount of dental mercury in FY2019 is set to be 0.

(8) Pharmaceuticals

1) Vaccine containing thimerosal

Table 4.2.14 shows the amount of mercury used for the domestic production of vaccine containing thimerosal (Hg content in manufactured products) and that contained in imported and exported vaccine, according to Japanese Association of Vaccine Industries in FY2021.

Table 4.2.14 Mercury in vaccine containing thimerosal (FY2019)

Product	Hg content in manufactured products (g-Hg)	Hg content in imported products Note (g-Hg)	Hg content in exported products (g-Hg)
Vaccine containing thimerosal	345	0	0

Source: The interview survey with Japanese Association of Vaccine Industries in FY 2021

Also, based on the interview survey with the Japanese Association of Vaccine Industries in FY2021, the amount of mercury in discharged waste (discarded raw materials/products) was estimated by multiplying the amount of waste (discharged waste) by mercury per kg of waste in FY 2019, as shown in Table 4.2.15.

Table 4.2.15 Mercury in discarded materials and products (FY 2019)

Product	Discharged waste (kg)	Hg content per kg of waste (g)	Hg in waste raw materials and products (g-Hg)
Vaccine containing thimerosal	8.737	495.5 - 980	4,329 - 8,562
Vaccine containing thimerosal	19,352.6	0.0002 - 0.025	3.9 - 484
Waste liquid containing thimerosal	344.2	0.0080	2.8
Waste liquid generated during production processes	15,900	0.0002 - 0.0005	3.2 - 8.0
Total			4,339 - 9,057

Source for discharged waste and mercury content per kg of waste: The interview survey with Japanese Association of Vaccine Industries, FY 2021

2) Products containing mercurochrome

According to the interview survey with domestic companies in FY 2018, the production of the products containing mercurochrome was terminated as of August 2016, and the stock of merbromin (solution) was treated in December 2017. Domestic production and import/export volume of mercurochrome-related products (adhesive plasters) in FY 2019 was set at 0.

(9) Inorganic chemicals

1) Mercuric sulfide

Table 4.2.16 shows the amount of mercury used for domestic production of mercuric sulfide for pigment use obtained from the interview survey with manufacturers in FY2021. Its exported amount is zero. Imported amount of mercuric sulfide remains unknown, and Table 4.2.1 shows “N/A”.

Table 4.2.16 Mercury used for domestic production of mercuric sulfide (FY2019)

Product	Mercury used	
	(kg-Hg)	(t-Hg)
Mercuric sulfide (pigment use)	676	0.68

Source: The interview survey with manufacturers of mercuric sulfide, FY 2021

2) Mercury compounds

Table 4.2.17 shows mercury used for the domestic production of mercury compounds obtained from the interview survey with domestic producers in FY2021. Its exported amount is zero. The amount of imported mercury compounds are unknown and Table 4.2.1 shows "N/A".

Table 4.2.17 Mercury used for domestic production of mercury compounds (FY2019)

Product	Mercury used	
	(kg-Hg)	(t-Hg)
Mercury compounds Note	15	0.015

Note: Mercury compounds include mercuric sulfide (II), mercury acetate (II), mercury nitrate (I), and others. Mercuric sulfide produced as reagents is included in this category.

Source: The interview survey with domestic producers of mercury compounds in FY2021

4.2.2 Mercury Utilization

Since the Reports on the Storage of Mercury provide data on the amount of mercury stored, purchased, used, and disposed of by storage purpose (metrological analysis, research/investigation, storage anticipated for disposal), these data were used to estimate the mercury flows for metrological analysis, research/investigation and storage anticipated for disposal. It should be noted that since the data were reported by entities storing at least 30 kg of mercury or mercury compounds, the estimated amounts of stocks and transfers based on the reports were considered to be minimum values.

(1) Metrological analysis and research/investigation

According to the Reports on the Storage of Mercury for FY 2019, the amount of mercury in stock at the beginning of the year was 2.1 t-Hg or more, the amount purchased was 3.3 t-Hg or more, the amount used was 3.2 t-Hg or more, the amount disposed of was 0.0015 t-Hg or more, and the amount in stock at the end of the year was 2.2 t-Hg or more, for metrological analysis (for use in metrological analysis such as mass, volume, area and environment (e.g., for inspection and analysis of products, for measurement applications using mercury as a medium (including use in mercury injection method measuring instruments (porosimeters) and replacement of mercury injected into measuring instruments)) and for research/investigation (e.g., for use in research vessel operation, for chemical analysis). Regarding the mercury contained in research equipment (mercury in use) that cannot be identified in the Reports on the Storage of Mercury, the interviews with major organizations conducting research and surveys in FY2021 revealed that 20.52 t-Hg of mercury was stored in research equipment.

(2) Ensuring safety of navigation routes (Lighthouse)

In FY2021 the interview survey with the Japan Coast Guard was conducted to identify the situation about mercury used to replenish the mercury tanks for rotating lighthouse lenses and the storage of less than 30 kg of mercury that could not be identified in the Report on the Storage of Mercury. As a result, at the end of FY 2019, the number of lighthouses using mercury was 50, the amount of mercury in the lighthouses (rotating equipment) was 3.9 t-Hg, the amount discarded was 0.48 t-Hg, and the stock was 3.3 t-Hg.

4.3 Mercury-Added Products Held in Households and Offices (Reference)

For fluorescent lamps, HID lamps, and silver oxide batteries, the Weibull cumulative distribution function was used to estimate the amount of mercury in mercury-added products held in households and offices by multiplying the amounts[22] of mercury per unit of product for each year by the numbers of products assumed not to have yet reached the end of their lifetime among the sales volume[23] of products shipped by the end of FY 2019. Product lifetime was assumed to be 5.9 years for household fluorescent lamps, 3.6 years for office fluorescent lamps, 3 years for HID lamps for general lighting, 3 years for HID lamps for special purposes, 6 years for automotive HID lamps, and 2 years for silver oxide batteries.

For air zinc batteries, assuming their life span is 2 weeks[24] and that all batteries are replaced every 2 weeks, the batteries would be replaced 26 times per year (52 weeks ÷ 2 weeks), which means that at the end of the fiscal year, 1/26 of the annual shipment would be in use. Therefore, the amount of mercury in air zinc batteries used in hearing aids was at the end of 2019 was estimated to be 0.00012 t-Hg, which is the result of dividing the amount of mercury in domestic shipments of air zinc batteries in FY 2019 (0.003 t-Hg) [25] by 26.

For mercury fever thermometers, mercury non-fever thermometers, and mercury sphygmomanometers, the amounts of mercury in mercury-added products held in households and offices were estimated by referring to the results of the existing surveys on those products held in households and offices. For the amount of mercury in mercury fever thermometers, mercury non-fever thermometers, and mercury sphygmomanometers stored in households, it was estimated based on the results of the "FY 2021 Survey on the Amount of Waste of Mercury-Added Product Stored" conducted by the MOEJ. For the amount of mercury in mercury fever thermometers, mercury non-fever thermometers, and mercury sphygmomanometers stored in hospitals, clinics, educational institutions, and administrative agencies, it was calculated by subtracting the total amount[26] collected for 4 years (FY2016-FY2019) from the results of the survey[27] on the amount stored as of FY2015 (1.4 t-Hg for mercury fever thermometers, 1.6 t-Hg for mercury

22 Fluorescent lamps and HID lamps: The interview survey with Japan Lighting Manufacturers Association
Silver oxide batteries: The interview survey with Battery Association of Japan

23 Product shipment data: The Statistics of Production of Machinery by the Ministry of Economy, Trade and Industry
https://www.meti.go.jp/statistics/tyo/seidou/result/ichiran/nenpo_2007-2020.html

24 https://hochouki.soudan-anshin.com/cont/battery-replacement/

25 The interview survey with Battery Association of Japan

26 The MOEJ. (FY2021). "Report on work to promote mercury recovery from sphygmomanometers, etc., (Re-Tem Corp.)".

27 Niigata Prefecture. (March 2016). "Report on the investigation of the actual status of the storage, etc. of mercury-added products".

non-fever thermometers, and 18 t-Hg for mercury sphygmomanometer).

The amount of mercury in mercury-added products held in households and offices is estimated as follows. For the FY2019 material flow, Table 4.3.1 is treated as the reference value.

Table 4.3.1 Estimated amount of mercury in mercury-added products held in households and offices (Reference) (FY 2019)

Items		Amount of Hg (t-Hg)
Fluorescent lamps	Household use	3.1
	Office use	1.2
HID lamps	General lighting purpose	0.76
	Special purpose	0.51
	Automotive purpose	2.0
Silver oxide batteries	Household and office use	0.00021
Air zinc batteries		0.00012
Mercury fever thermometers	Household use	21.1
	For hospitals, clinics, educational institutions, administrative agencies	1.4
Mercury non-fever thermometers	Household use	27.3
	For hospitals, clinics, educational institutions, administrative agencies	1.6
Sphygmomanometers	Household use	66.4
	For hospitals, clinics, educational institutions, administrative agencies	19
Total		144

4.4 Mercury Recovered from Societal Use of Mercury

Based on Section 3.1, the breakdown of the 16 tons of mercury recovered from societal use of mercury is as follows.

Table 4.4.1 Mercury Recovered from Societal Use of Mercury (FY 2019)

Type of use		Hg recovered (t-Hg)
Discarded products	Industrial waste	3.9
	Municipal solid waste	0.88
Waste elemental mercury	Business	8.4
	University/school	0.98
	Lighthouse	0.37
	Hospital	0.23
	Business	0.57

Type of use		Hg recovered (t-Hg)
Others	Dental amalgam	0.28
	Silver oxide battery	0.0010
Total		16

Note: The total mercury recovered differs from the sum of the value in each item in the table due to rounding off.
Source: The interview survey with mercury recovery companies in FY 2021.

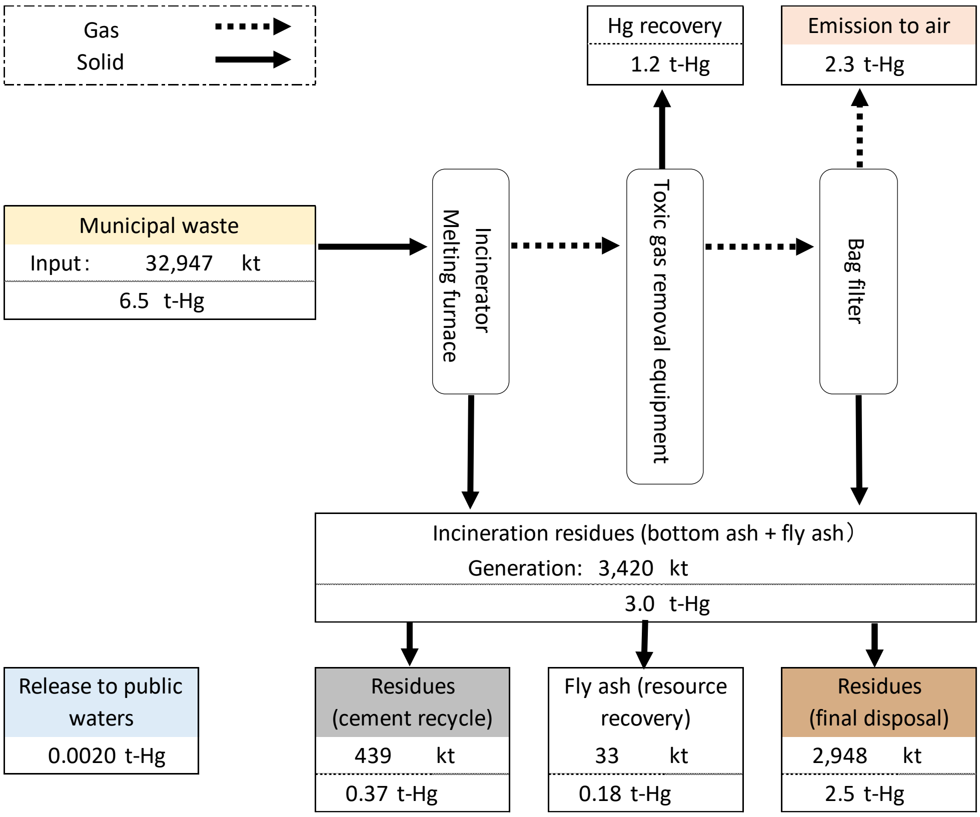
5. FLOW FOR WASTE TREATMENT

5.1 Waste Incineration

The mercury flows for waste incineration are shown below. The figures show the input in light yellow, material/fuel stock in light purple, atmospheric emission in light orange, release to waters in light blue, release to land in light green, final disposal in brown, and cement applications in gray.

(1) Municipal solid waste incineration facilities

The mercury flow in municipal solid waste incineration facilities is shown in Figure 5.1.1.



Flow: Prepared based on the interviews with municipal solid waste treatment companies.
Values in the flow: Estimated result based on the "Results from the Survey on Municipal Solid Waste Management (for FY2019)" by the MOEJ, the interviews with waste treatment companies in FY2021, and PRTR data for FY2019. Air emissions are from the "Mercury Emission Inventory (for FY 2019)".

Figure 5.1.1 Mercury flow in municipal solid waste incineration facilities (FY2019)

1) Mercury in municipal solid waste

Assuming that all of the mercury in municipal solid waste sent to municipal solid waste incineration facilities is transferred to residues (incineration residue, incineration ash), recovered mercury, atmospheric emissions, releases to public waters, the total amount of mercury in the residues was estimated to be the sum of mercury in these residues, which is 6.5 t-Hg.

2) Mercury in incineration residues utilized or disposed of

Table 5.1.1 shows the concentration of mercury in residues generated at municipal solid waste incineration facilities.

Table 5.1.1 [Municipal solid waste incineration] Mercury concentration in incineration residues (bottom ash, fly ash)

Medium	Hg concentration (g/t)
Bottom ash	0.03
Fly ash	5.4
Residues (bottom ash 85%, fly ash 15%) Note	0.84

Note: Although the ratio of bottom ash to fly ash is not identified, estimation was carried out under the assumption that the 85% of residues is bottom ash and 15% is fly ash, based on the "Report on the environmentally sound management of mercury wastes" (the MOEJ, March 2014).
Source for mercury concentration in fly ash and bottom ash: The "Report on the investigation on mercury emissions from waste treatment facilities in FY2011" (the MOEJ, March 2012)

According to the "Results from the Survey on Municipal Solid Waste Management" by the MOEJ, the amount of incineration residues generated at municipal solid waste incineration facilities that were utilized and disposed of in FY2019 are shown in Table 5.1.2. The amount of mercury in incineration residues is calculated by using mercury concentration shown in Table 5.1.1.

Table 5.1.2 [Municipal solid waste incineration] Mercury in incineration residues utilized and disposed of (FY2019)

Medium	Destination	Residues utilized/disposed of (t)	Hg content in residues (t-Hg)
Incineration residues	Conversion to cement material	438,869	0.37
	Final disposal	2,948,006	2.5
Fly ash	Resource recovery Note1	33,243	0.18
	Total	3,420,118	3.0

Note 1: Resource recovery refers to input to non-ferrous metal smelting for metal recovery.
Note 2: The total amount of mercury in residues does not match the sum of mercury amount of each item due to rounding off.
Source for resides utilized and disposed of: The MOEJ, "Results from the Survey on Waste Management" (FY2019) https://www.env.go.jp/recycle/waste_tech/ippan/r1/index.htm

Molten slag generated from municipal solid waste incineration is not included in the material flow for FY2019 since the mercury content is very small.

[Reference] Mercury content in molten slag

National Federation of Industrial Waste Management[28] investigated the amount of molten slag generation from municipal solid waste incineration in FY2006. About 90% of the slag generated was utilized as alternate

[28] "Investigation Report on JIS Compliance of Molten Slag Derived from Industrial Waste (2 weeks 2008)" (March, 2009)

materials such as aggregate of concrete products or asphalt mixture[29]. The amount of slag utilized (recycling) in FY2019 is identified through the investigation on municipal solid waste treatment[30] conducted by the MOEJ. Also, the concentration of mercury in molten slag was measured by the MOEJ[31] in FY2011[32]. According to the data above, the mercury content in utilized molten slag generated from municipal solid waste incineration is shown below.

Table 5.1.3 Mercury in utilized molten slag generated from municipal solid waste incineration (Reference)

Molten slag utilized (FY2019)	Hg concentration in slag	Hg content in slag utilized
540,000 t	Less than 0.01 mg/kg-dry	Less than 5.4 kg-Hg

Note: The average concentration of mercury in soil sampled from 3,020 measuring points was 0.1 ppm according to data[33] published by the National Institute of Advanced Industrial Science and Technology (in 2007 at 3,024 measurement points, (excluding 4 points whose mercury concentration is more than 10 ppm)). The concentration of mercury in molten slag is less than 0.01 ppm (mg/kg-dry), which is less than the mercury concentration in soil.

3) Mercury recovered

According to the interviews with mercury recovery companies in FY2021, the amount of mercury recovered from waste incineration facilities in FY2019 is 1.2 t-Hg. However, the source composition of the mercury between municipal and industrial waste is unknown. In order to avoid duplication in the material flow, the entire amount is attributed to municipal solid waste incineration facilities.

4) Atmospheric emission of mercury

Mercury emission from municipal solid waste incineration facilities is estimated as 2.3 t-Hg based on the measurement of flue gas at designated units emitting mercury in the “Mercury Emission Inventory (for FY2019)”.

5) Mercury release to public waters

According to the PRTR data of FY2019, the amount of mercury and its compounds reported to be released to public waters from “Domestic waste disposal business” is 2 kg-Hg (= 0.0020 t-Hg).

(2) Industrial waste incineration facilities

The mercury flow in industrial waste incineration facilities is shown in Figure 5.1.2

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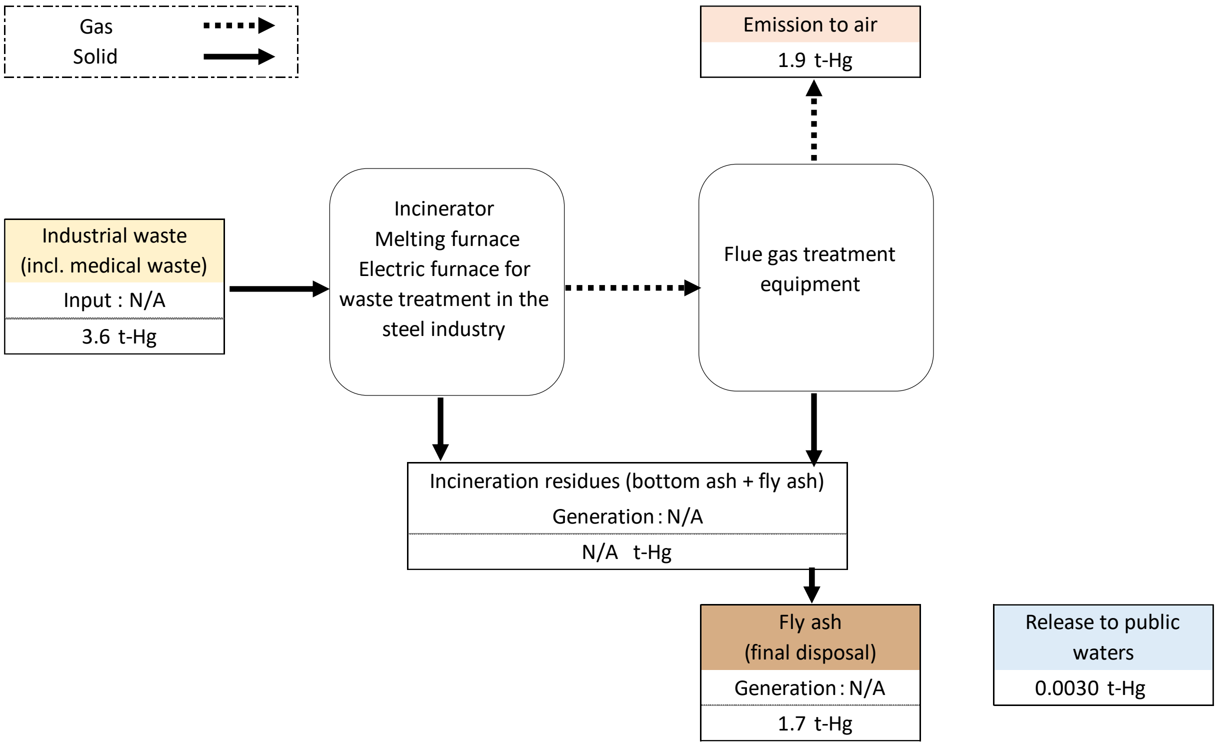
[29] In July 2006, JIS for molten slag as road building material and aggregate for the concrete was developed. JIS A 5032: Molten slag for roads is made by melt-solidification of municipal solid waste, sewage sludge, or their bottom ash
JIS A 5031: Molten slag aggregate for concrete is made by melt-solidification of municipal solid waste, sewage sludge or their bottom ash

[30] “Results from the Survey on Municipal Solid Waste Management (FY2019)”
https://www.env.go.jp/recycle/waste_tech/ippan/r1/index.html

[31] “Report on investigation on emission status of mercury and others from waste treatment facilities and others in FY2011” (March in 2012)

[32] Although JIS A 5032 and JIS A 5031 define the content standard for mercury in molten slag as “total mercury 15 mg/kg or less”, mercury is scarcely detected because heating up to the temperature of 1200°C or higher is conducted in the process.

[33] https://gbank.gsj.jp/geochemmap/data/download.htm



Flow: Since the amount of cinders and fly ash (dust) generated from industrial waste incineration for reuse and final disposal is unknown, it is assumed here that all the cinders and fly ash are for final disposal.
Values in the flow: The amount of mercury in industrial waste is estimated based on existing literature. Releases to public wastes are from PRTR data. Air emissions are from the "Mercury Emission Inventory (for FY2019)".

Figure 5.1.2 Mercury flow in industrial waste incineration facilities (FY2019)

1) Mercury in industrial waste

Assuming that all of the mercury in industrial waste sent to industrial waste incineration facilities is transferred to residues, the total amount of mercury in the residues is the sum of the mercury in fly ash (dust), air emissions, and release to public waters, which is 3.6 t-Hg.

2) Mercury in residues

Emission reduction efficiency in industrial waste incineration facilities is 47.9% according to Kida (2007). Assuming that mercury not emitted to the atmosphere is transferred to wastewaters (from wet scrubbers) and fly ash, the amount of mercury in the residues is estimated as shown in Table 5.1.4 (amount of mercury transferred to residues = mercury emissions x emission reduction efficiency/(1-emission reduction efficiency)). Since the amount of mercury release to public waters, based on PRTR notification, is 0.0030 t-Hg, the amount of mercury in fly ash is estimated to be 1.7 t-Hg.

Table 5.1.4 [Industrial waste incineration] Mercury in residues (FY 2019)

Mercury emission (t-Hg)	Mercury emission reduction efficiency (t-Hg)	Mercury transferred to residues (t-Hg)		
		Total	Mercury release to public waters	Mercury transferred to fly ash
1.9	0.479	1.7	0.0030	1.7

[Source]

Emission reduction efficiency: Akiko Kida, Shinichi Sakai, Yasuhiro Hirai, Hiroshi Moritomi, Masaki Takaoka, Kenji Yasuda. (2007). “Study on the emission inventory of mercury including waste management processes and emission reduction measures”. Chapter 2 Study on mercury emission sources, emission factors and emission inventory.

Air emissions: The Mercury Emission Inventory (for FY2019)

Amount of mercury in residues: Estimated 47.9% of mercury in incinerated materials is assumed to be transferred to residues (fly ash, release to public waters)

Amount of mercury release to waters: PRTR data in FY2019

3) Amount of mercury recovered

According to the interview survey with waste treatment companies in FY2021, the amount of mercury recovered from waste incineration facilities in FY 2019 was 1.2 t-Hg. However, the source composition of the mercury between municipal solid waste and industrial waste is not known. In order to avoid duplication in the material flow, all the mercury was regarded as recovered from municipal solid waste incineration facilities.

4) Atmospheric emission of mercury

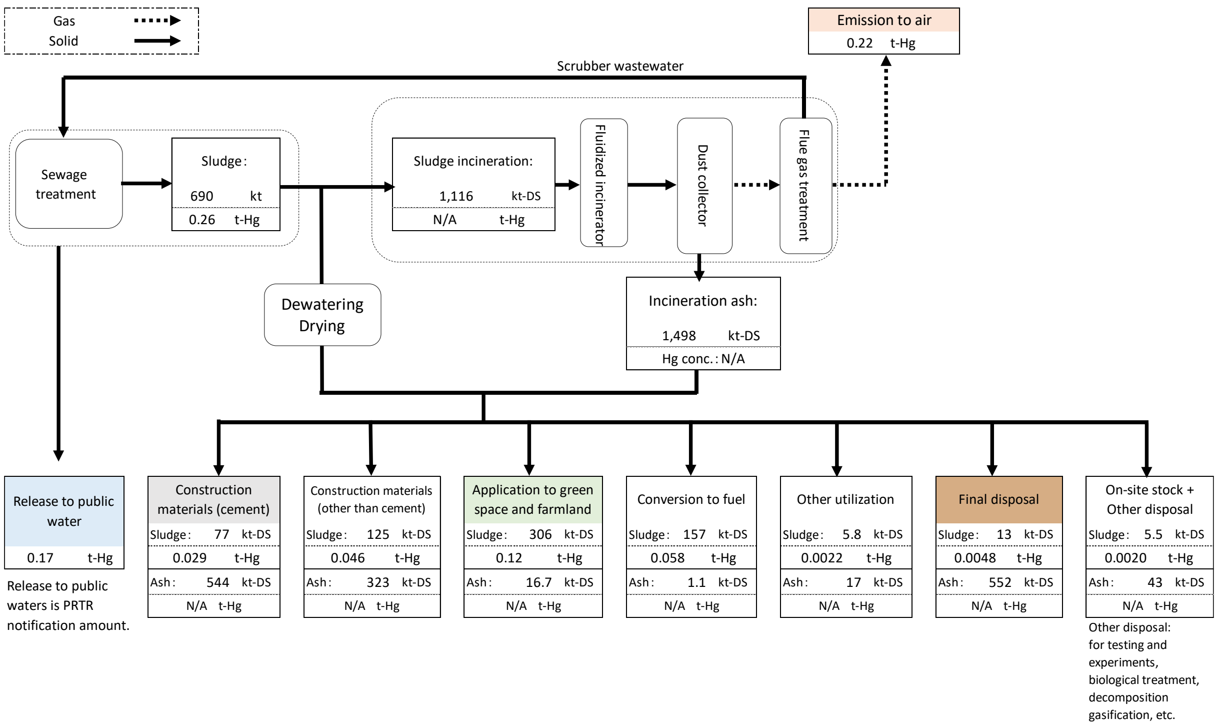
Mercury emission from industrial waste incineration facilities is estimated to be 1.9 t-Hg in the “Mercury Emission Inventory (for FY2019)”.

5) Mercury release to public waters

According to the PRTR data of FY2019, the amount of mercury and its compounds reported to be released to public waters from “Industrial waste disposal business” is 3 kg-Hg (= 0.0030 t-Hg).

(3) Sewage treatment and sewage sludge incineration facilities

The mercury flow in sewage sludge incineration facilities is shown in Figure 5.1.3.



Flow: Prepared based on the interview survey with the Ministry of Land, Infrastructure and Transport, Japan

Values in the flow: Data provided by the Ministry of Land, Infrastructure and Transport, Japan (actual amount in FY2021)
Air emission: Mercury Emission Inventory (for FY2019)
Mercury release to waters: PRTR data in FY2019

Figure 5.1.3 Mercury flow in sewage sludge incineration facilities (FY2019)

1) Sewage sludge generated, disposed of and utilized, and mercury concentration

According to the interview survey with the Ministry of Land, Infrastructure, Transport and Tourism, the amount of sewage sludge generated is calculated by subtracting the amount of incineration ash from the amount of sludge + incineration ash. The mercury content in sewage sludge was estimated by multiplying the mercury concentration by the amount of sewage sludge as shown in Table 5.1.5.

Table 5.1.5 [Sewage treatment/sewage sludge incineration] Mercury in sewage sludge (FY 2019)

Item		(a) Sludge + incineration ash (10^3t-DS)	(b) Incineration ash (10^3t-DS)	Sludge (a)-(b) (10^3t-DS)	Hg concentration in sludge (mg/kg-DS)	Hg content in sludge (t-Hg)
Utilization	Construction materials (used in cement production)	621	544	77	0.37	0.029
	Construction materials (used in other than cement production)	448	323	125	0.37	0.046
	Green farmland	322	17	306	See Table 5.1.6	0.12
	Fuels	159	1.1	157	0.37	0.058
	Others	23	17	5.8	0.37	0.0022
Disposal	Final disposal	565	552	13	0.37	0.0048
	On-site stock and other disposal	48	43	5.5	0.37	0.0020
	Total	2,187	1,498	690		0.26

[Source]
Amount of sewage sludge utilized, incinerated and disposed of: The interview survey with the Ministry of Land, Infrastructure, Transport and Tourism in FY2021.
Mercury concentration in sludge used for green farmland: Average value of mercury concentrations shown in Table 5.1.6

2) Mercury in sewage sludge applied to green space and farmland

The amount of mercury in sewage sludge applied to green space and farmland is estimated as shown in Table 5.1.6 by multiplying the amount of the said sewage sludge (according to the FY2021 interview survey with the Ministry of Land, Infrastructure, Transport and Tourism) by mercury concentration of sludge fertilizer obtained from existing literatures. It needs to be noted that mercury transfer associated with the application of sewage sludge to green space and farmlands is considered as mercury release to land in the material flow.

Table 5.1.6 [Sewage treatment/sewage sludge incineration] Mercury in sewage sludge applied to green space and farmland (FY2019)

Item	Sewage sludge applied to green space and farmland (10^3 t-DS)	Mercury concentration (mg/kg-DS)	Mercury transferred to land (t-Hg)
Compost	253	0.4	0.10
Mechanically dried sludge	20	0.3	0.0060
Carbonized sludge	4.7		0.0014
Dewatered sludge	24	0.4	0.0095
Incineration ash	17	N.D.	0
Others	4.0	0.4	0.0016
Total	322		0.12

Source for sewage sludge utilized at green space and farmland: The interview survey with the Ministry of Land, Infrastructure and Transport, Japan in FY2023

Source for mercury concentration in each item: the Ministry of Agriculture, Forestry and Fisheries, Japan, "Manual on Heavy Metal Management in Sludge Fertilizer" (March 2015). Weighted average of mercury concentration based on on-site inspection conducted from FY2003 to FY2009 (Compost: Concentration in fermented sludge fertilizer is used; Mechanically dried sludge/carbonized sludge: Concentration in burned sludge fertilizer is used; Dewatered sludge and others: Concentration in sewage sludge fertilizer is used.)

3) Atmospheric emission of mercury

Mercury emission from sewage sludge incineration facilities is estimated to be 0.22 t-Hg in the "Mercury Emission Inventory (for FY2019)".

4) Mercury in residues and mercury release to public waters

If the emission reduction efficiency of 47.9% at industrial waste incineration facilities estimated by Kida (2007) could also be applied to sewage sludge incineration facilities, mercury not being emitted to the atmosphere and transferred to residues is estimated to be 0.20 t-Hg[34]. However, since the mercury concentrations in both treated sewage water and bottom ash are N.D.[35], which makes the estimated amount of mercury transferred to residues is 0, this estimated value is treated as a reference value in the material flow. The amount of mercury in effluent to public waters is obtained from PRTR data (0.17 t-Hg).

Table 5.1.7 [Sewage treatment/sewage sludge incineration] Mercury transferred to residues (Reference)

Mercury emission (t-Hg)	Emission Reduction Efficiency	Mercury transferred to residues (t-Hg)
0.22	0.479	0.20

Source for emission reduction efficiency: Akiko Kida, Shinichi Sakai, Yasuhiro Hirai, Hiroshi Moritomi, Masaki Takaoka, Kenji Yasuda (2007), 2006 Research Report on Scientific Research Grants for Waste Management: "Study on the emission inventory of mercury including waste management processes and emission reduction measures" Chapter 2 Study on

[34] Amount of mercury transferred to residues = air emission x emission reduction efficiency/(1 - emission reduction efficiency)

[35] Data provided by the Ministry of Land, Infrastructure, Transport and Tourism

mercury emission sources, emission factors and emission inventory. The emission reduction efficiency at industrial waste incineration facilities in this study is alternatively applied.

5.2 Final Disposal (Landfill)

(1) Final disposal of residues from processing/industrial use of raw materials and fuels, and waste incineration

According to "Section 2. Flow for Processing/Industrial Use of Raw Materials and Fuels", the amount of final disposal of residues generated from processing/industrial use of raw materials/fuels and waste incineration, and mercury therein, are shown in Table 5.2.1. A total of 14 t-Hg was disposed of from eleven industry sectors.

Table 5.2.1 Final disposal of residues from processing/industrial use of raw materials/fuels, and waste incineration (FY2019)

Source	Type of Residue	Residues disposed (t)	Hg content in residues disposed (t-Hg)
Coal-fired power plant	Fly ash	103,619	0.015
	FGD gypsum	0	0
	Sludge	51,809	0.34
Coal-fired industrial boiler	Coal ash	110,874	0.018
	FGD gypsum	3,620	0.0061
Non-ferrous metal smelting facility Note	Wastewater treatment sludge	N/A	6.6
	Slag	N/A	0.66
	Other waste	N/A	1.6
Primary iron production facility	Desulfurization sludge	665	0.0055
	Wet dust	2,275	0.0016
Secondary iron production facility	Precipitator dust	60,150	0.12
Oil and natural gas production facility	Wastewater treatment sludge	713	0.0020
Oil-fired power plant	Fly ash	305	N/A
Biomass combustion facility	Fly ash	171,139	N/A
Municipal solid waste incineration facility	Incineration residues	2,948,006	2.5
Industrial waste incineration facility	Fly ash	N/A	1.7
Sewage treatment facility	Sewage sludge	12,929	0.0048
	Total		14

Note: The amount of residues from non-ferrous metal smelting facilities is a three-year average from FY2018 to FY2020, taking into account the fact that it varies considerable by year.

(2) Landfilling of municipal solid waste (Reference)

Direct landfilling of municipal solid waste is not included in the material flow since the amount of discarded mercury-added products to be landfilled as non-combustible is not available. For reference, in the report on

"Investigation on the situation of mercury waste disposal in FY2019", information on the amount of discarded mercury-added products and their corresponding treatment is available; the amount of mercury contained in mercury-added products that were landfilled in FY2017 is estimated to be 0.017 t-Hg.

Table 5.2.2 Mercury contained in direct landfilling of discarded products (FY2017) (Reference)

Product	Discarded products treated (t)	Hg recovered from 1kg of waste product (kg-Hg)	Hg content in products landfilled (t-Hg)
Fluorescent lamps	262	0.000038	0.010
Dry-cell batteries (excluding button batteries)	280	0.000020	0.0056
Mercury fever thermometers /mercury non-fever thermometers	0.010	0.081	0.00081
Mercury manometers	0.010	0.049	0.00049
Total	542		0.017

Source for discarded products treated: Performance data on waste treatment for FY2017 in the report on "Investigation on the situation of mercury waste disposal in FY2019" by the MOEJ (March 2020). The performance data was collected through the questionnaire survey sent to municipalities and regional affairs associations. Fluorescent lamps treated include those for which municipalities and regional affairs associations chose disposal methods of "crushing/solidifying/landfilling" and "landfilling of fluorescent powder and glass recycling". Other discarded products treated include those for which municipalities and regional affairs associations chose disposal methods of "crushing/solidifying/landfilling".

Source for mercury recovered from 1kg of waste product: Calculated by dividing mercury recovered from municipal solid waste by the amount of municipal solid waste treated in Section 3.1 "Mercury Recovered from Waste and Mercury-containing Recyclable Resources".

(3) Mercury in waste generated from the mercury recovery process

According to the interviews with mercury recovery companies in FY2021, the amount of mercury in waste generated in the process of mercury recovery is 7.0 kg-Hg (≒ 0.0070 t-Hg).

(4) Mercury in waste disposed of

Based on the subsection (1) - (3) above, the amount of mercury in residues (generated from processing/industrial use of raw materials and fuels, waste incineration) landfilled is estimated to be 14 t-Hg, and that in waste (from mercury recovery process) landfilled is estimated to be 0.0070 t-Hg. In the material flow, sum of these values is used (14 t-Hg) for final disposal of waste.

5.3 Others

(1) Mercury storage anticipated for disposal

Table 5.3.1 shows the amount of mercury purchased, used, disposed of, and stocked at the end and the beginning of the fiscal year in FY2019 for municipalities[36] that store mercury anticipated for disposal.

[36] Local governments purchase mercury equivalent to the amount of mercury in mercury-added products discharged from households and offices within their jurisdiction, and the mercury is stored by the local government for future disposal.

Table 5.3.1 Amount of mercury stocks and changes in storage anticipated for disposal (FY 2019)

Storage anticipated for disposal (t-Hg)	FY 2019
Stock at the beginning of FY	0.26 or more
Purchased	0.013 or more
Used	0
Disposed	0
Stock at the end of FY	0.27 or more

Source: Data from the MOEJ

(2) Crematories

1) Atmospheric emission of mercury

Mercury emission from crematories is estimated to be 0.074 t-Hg in the "Mercury Emission Inventory (for FY2019)". The estimate is obtained by multiplying the number of cremations in Japan (1,421 thousand) by an overall emission factor calculated based on actual measurements at crematories.

2) Mercury in cremation ash

The unit transfer of mercury from body to cremation ash is calculated to be 0.38-0.70 mg/body and 0.8-1.52 mg/body according to Takeda (2010). The amount of mercury in cremation ash discharged from crematories in FY 2019 is estimated as shown in Table 5.3.2.

Table 5.3.2 [Cremation] Mercury in cremation ash (FY 2019)

Number of cremations (thousand)	Unit transfer of mercury to cremation ash (mg/body)	Hg content in cremation ash (t-Hg)
1,421	0.38 - 0.70 0.8 - 1.52	0.00054 - 0.0022

[Source]

Number of cremations: the Ministry of Health, Labour and Welfare, "Report on Public Health Administration and Services (FY2019)".

Unit transfer of mercury to cremation ash: Nobuo Takeda (Ritsumeikan University): Health, Labour and Welfare Science Research Grant, Comprehensive Research Project on Health, Safety and Crisis Management Measures, "Study on the Actual Conditions of Emissions of Toxic Chemical Substances at Crematories and Control Measures FY2008-2009 General Research Report" (2010), Chapter 3: Survey of mercury and other heavy metals discharged from crematories. Number of facilities: n = 2.

6. FLOW FOR EMISSIONS AND RELEASES OF MERCURY TO ENVIRONMENT

6.1 Atmospheric Emission of Mercury

Table 6.1.1 shows the estimated results of mercury emissions in the “Mercury Emission Inventory (for FY2019)” (developed in FY2021). The material flow adopted mercury emissions of 14 t-Hg, excluding emissions from natural sources.

Table 6.1.1 Mercury Emission Inventory (for FY2019)

Source category	Emission source			Emission(Note1) (ton-Hg/year)[1] FY2019
Sources listed in Annex D of Minamata Convention	Coal-fired power plants			1.1
	Coal-fired industrial boilers			0.032
	Non-ferrous metals production	Primary		0.10
		Secondary		0.97
	Waste incineration	Municipal solid waste		2.3
		Industrial waste		1.9
		Sewage sludge[2]		0.22
		A facility that recovers mercury from mercury-containing recyclable resources and industrial waste that is obligated to undergo recovery (limited to facilities that include a heating process at the time of recovery) [2]		0.0020
	Cement clinker production			4.5
Other sources	Iron and steel production	Primary iron production	Sintering furnace (including pellet firing furnace)	2.1
			Others (from blast furnace by-product gas, coke oven by-product gas)	0.14
		Secondary iron production	Electric furnace	0.49
	Oil refining			0.11
	Oil and gas production			0.000050
	Combustion of oil and others	Oil-fired power plants		0.0016
		LNG-fired power plants		0.0011
		Oil-fired industrial boilers		0.0022
		Gas-fired industrial boilers		0.00074
	Facilities that use mercury or mercury compounds in production processes[1,3]			N.O.
	Manufacturing facility for products that use mercury[4]	Facilities that do not include a heating process [Includes fluorescent lamp collection and crushing facility]		< 0.000047 [0.0000035]
		Facilities that include a heating process during mercury recovery		0.000015
	Hg-containing products manufacturing	Battery[1,5]		N.E.
		Mercury switch and relay		< 0.0000012
		Lamp[6]		0.0033
		Soaps and cosmetics[1,7]		N.O.

Source category	Emission source		Emission(Note1) (ton-Hg/year)[1] FY2019
		Pesticides and biocides[1,7] (agricultural chemicals)	N.O.
		Sphygmomanometer[1,8]	N.E.
		Hg thermometer[1,7]	N.O.
		Dental amalgam[1,7]	N.O.
		Thimerosal production facility[1,7]	N.O.
		Vermillion production facility	0.0000046
	Others[9]	Limestone production	0.043
		Pulp and paper production (black liquor)	0.040
		Carbon black production	0.088
		Cremation	0.074
		Transportation[10]	0.057
		Electricity/heat supply facilities using biomass combustion	0.017
		Ferroalloy production facility[11]	0.20
Natural sources	Volcano		> 1.4
Total (excluding natural sources)			15.8 (14.4)

Note 1: For sources listed in Annex D of the Convention, emission estimates are based on the results of measurements of mercury concentrations in flue gas which are measured periodically in accordance with the Air Pollution Control Act. The estimation method was to calculate the annual mercury emissions for each target facility and accumulate the values. In the FY2019 inventory, the annual operating hours for the estimation were the values from the facility installation notifications.

Note 2:The period covered by the inventory estimates is FY 2019 (April 2019 - March 2020), and in principle, data from the same period were used for the estimates.

Note 3:Atmospheric emissions by source are expressed using two significant digits, and totals are expressed to one decimal place.

Note 4:For sources with inequality symbols in the emissions, the values with the inequality symbols removed were used to calculate the totals.

1. "N.E." stands for "Not Estimated" (Existence of the emission source is unknown, or emission sources exist but no estimation has been done). "N.O." stands for "Not Occurring" (emission sources do not exist or there is an emission source, but no mercury is emitted to the atmosphere due to the manufacturing process and the structure of the manufacturing facility).
2. Although some facilities do not fall within waste incineration facilities under domestic laws of Japan, they are categorized as waste incineration facilities in the inventory.
3. Mercury is not used in all of the relevant facilities in Japan (the following six types of facilities) (confirmed in FY2012).
   Chlor-alkali production facility, vinyl chloride monomer production facility, polyurethane production facility, sodium methylade production facility, acetaldehyde production facility, vinyl acetate production facility
4. Excludes facilities subject to Annex D of the Convention from intermediate waste treatment facilities.
5. In Japan, mercury is used for the production of button-type batteries only. It has been reported that equipment used in the production process does not allow the emission of mercury to the atmosphere. However, as the detailed flow of the process is not available, it has been treated as N.E.
6. "Lamp" includes fluorescent lamps for general use, cold cathode fluorescent lamps and HID lamps.
7. It has been confirmed that there are no sources of emission for the manufacture of soap and cosmetics and manufacture of pesticides and biocides (FY2012), manufacture of mercury thermometer and manufacture of mercury amalgam for dental use (FY2013), and manufacture of thimerosal (FY2016).
8. It was confirmed in FY2016 that it was difficult to measure the mercury concentration from the outlet due to the structure of the facility, and it was impossible to estimate the amount of discharge.
9. Sources that have not been addressed in past government negotiations but are likely to have mercury emissions into the atmosphere
10. The target is fuel consumption of gasoline and diesel (for business use)
11. The target is ferromanganese and ferronickel production facilities.

Source: "Mercury Emission Inventory (for FY2019)"

6.2 Mercury Releases to Waters

Table 6.2.1 shows estimated mercury releases to waters based on the interviews with business organizations in charge of processing/industrial use of raw materials/fuels, associations of manufacturers of mercury-added products, and individual businesses, as well as data obtained from Japanese PRTR.

Table 6.2.1 Mercury releases to waters (FY2019)

Source	Mercury release (t-Hg)
Processing/industrial use of raw materials and fuels	0.097
Production process of mercury-added products	0
Mercury recovery process Note1	0.000015
PRTR (Notification amount + Estimation of amount not subject to notification due to threshold) Note2	0.18
Total	0.28

Note 1: Release from the mercury recovery process also includes mercury release from the treatment of wastewater from mines.
Note 2: In order to avoid double-counting of mercury release from processing/industrial usage of raw materials/fuels (non-ferrous metal smelting process), the value of “non-ferrous metal production” is excluded from the PRTR data.

(1) Mercury release to waters from processing/industrial use of raw materials and fuels

Table 6.2.1 shows mercury release to waters from processing/industrial use of raw materials/fuels, according to the results of the interviews for the Section 2 “Flow for Processing/Industrial Use”. The total amount of release to waters is 0.097 t-Hg in the material flow. Wastewater in this section includes that from flue gas treatment facilities as well as that generated from offices.

Table 6.2.2 Mercury releases to waters from processing/industrial use of raw materials (FY2019)

Release source	Mercury content in wastewater (t-Hg)	Source (remarks)
Coal-fired power plants	0 (with effluent)	Interview survey with the Federation of Electric Power Companies (Wastewater from flue gas desulfurization facility: Below LLOQ Note, Unknown wastewater volume)
Coal-fired industrial boilers	N/A (with effluent)	Interview survey with Japan Boiler Association
Non-ferrous metal smelting	0.097	Interview survey with Japan Mining Industry Association (Three-year average of data from FY2018 to FY2020)
Cement production	0 (with effluent in some facilities)	Interview survey with Cement Association of Japan (Some facilities discharge wastewater, but all discharges are below LLOQ Note, Unknown wastewater volume)
Primary iron production	N/A (with effluent)	Interview survey with the Japan Iron and Steel Federation (Process managed based on the effluent standard in the Water Pollution Control Law)
Secondary iron production	0 (no effluent)	Interview survey with Japan Iron and Steel Federation (Wastewater does not occur due to dry-type flue gas treatment)
Oil refining plants	N/A	Interview survey with Petroleum Association of

Release source	Mercury content in wastewater (t-Hg)	Source (remarks)
		Japan
Oil and natural gas production	0 (with effluent)	Interview survey with domestic companies (Below LLOQ[Note], Unknown wastewater volume)
Combustion facilities using oil and other fuels	N/A	Interview survey with the Federation of Electric Power Companies of Japan
Lime product production facilities	N/A (with effluent)	Interview survey with member companies of Japan Lime Association
Carbon black production facilities	N/A (with effluent)	Interview survey with Carbon Black Association
Electricity/heat supply facilities using biomass combustion	N/A (with effluent)	Interview survey with Biomass Power Association
Ferronickel production facility	0 (with effluent)	Interview survey with member companies of Japan Mining Industry Association (Below LLOQ[Note], Unknown wastewater volume)
Ferroalloy production facility	N/A (with effluent)	Interview survey with Japan Ferroalloy Association
Total	0.097	

Note: The Lower Limit of Quantification (LLOQ) is 0.0005 mg/L

(2) Mercury release to waters from manufacturing processes of mercury-added products

Table 6.2.3 shows mercury release to waters in manufacturing processes of mercury-added products. According to the interviews with business organizations and others in FY2021, the amount of release is "0" for all the manufacturing processes.

Table 6.2.3 Mercury releases to waters from manufacturing processes of mercury-added products (FY2019)

Product	Mercury release (kg-Hg)	Interviewee
Button batteries	0 (no effluent)	Battery Association of Japan
Switches and relays	0 (no effluent)	Manufacturers (Below LLOQ[Note], Unknown wastewater volume)
Lamps	0 (with effluent in some facilities)	Japan Lighting Manufacturers Association (Some facilities discharge wastewater, but all discharges are below LLOQ[Note], Unknown wastewater volume)
Industrial measuring devices	0 (no effluent)	Japanese Cooperative Kumiai for Glass Measuring Instruments Industry, Japan Pressure Gauge and Thermometer Manufacturers' Association, Japan Scientific Instrument Association
Medical measuring devices	0 (no effluent)	The Japan Federation of Medical Devices Association
Medicines	0 (no effluent)	Japanese Association of Vaccine Industries, Manufacturers
Inorganic chemicals	0 (no effluent)	Manufacturers
Total	0	

Note: The Lower Limit of Quantification (LLOQ) is 0.0005 mg/L

Source: The interviews in FY2021 with organizations/companies shown in the column of “Interviewee”.

(3) Mercury release from the mercury recovery process to public water bodies

According to the FY2021 interview survey with mercury recovery companies, the amount of mercury released from the mercury recovery process into public water bodies is 0.015 kg-Hg (= 0.000015 t-Hg).

(4) Mercury release to public waters (PRTR data)

Table 6.2.4 shows the reported data on mercury release to public waters and the estimated release outside notification in reference to the PRTR data in FY2019. In the material flow, in order to avoid double-counting with “mercury releases to waters from processing/industrial use of raw materials/fuels”, the total amount under the PRTR notification excluding “non-ferrous metal production” with estimated amount (for estimation for portion under the cutoff amount for notification), which amounts to 0.18 t-Hg, is adopted.

Table 6.2.4 Mercury release to public waters (FY2019, PRTR data)

Industry code	Industry type	Reported data on release to waters (kg/year)	Estimated release outside notification (release below cutoff threshold requiring notification) (kg/year)	Industrial category in the material flow
500	Metal mining	0	Not estimated	-
700	Crude oil and natural gas mining	0	Not estimated	Crude oil and natural gas production
1200	Manufacture of food	No notification	1	-
1800	Manufacture of pulp, paper and paper products	3	Not estimated	Pulp/paper production
1900	Publishing, printing and allied industries	No notification	0	-
2000	Manufacture of chemical and allied products	0	0	-
2100	Manufacture of petroleum and coal products	0	Not estimated	Oil refining, carbon black production
2200	Manufacture of plastic products	No notification	0	-
2300	Manufacture of rubber products	No notification	Not estimated	-
2500	Manufacture of ceramic, stone and clay products	0	0	Cement production, lime product production facilities
2600	Steel industry	0	0	Primary/Secondary iron production, ferroalloy production facilities
2700	Manufacture of non-ferrous metals and products [Note2]	~~16~~	0	Non-ferrous metal smelting, ferronickel production facilities
2800	Manufacture of fabricated metal products	No notification	0	-
2900	Manufacture of general-purpose machinery	No notification	Not estimated	Manufacture of mercury-added products (batteries, lamps)
3000	Manufacture of electrical	No notification	0	-

Industry code	Industry type	Reported data on release to waters (kg/year)	Estimated release outside notification (release below cutoff threshold requiring notification) (kg/year)	Industrial category in the material flow
	machinery, equipment and supplies			
3200	Manufacture of precision instruments and machinery	No notification	Not estimated	Manufacture of mercury-added products (industrial measuring devices, medical measuring devices)
3400	Miscellaneous manufacturing industries	No notification	0	Manufacture of mercury-added products (Pharmaceuticals, inorganic chemicals)
3500	Electric industry	0	Not estimated	Coal-fired power plants, oil-fired power plants, LNG-fired power plants, electricity/heat supply facilities using biomass combustion
3700	Heat supply industry	No notification	Not estimated	-
3830	Sewage industry	166	Not estimated	Sewage treatment and sewage sludge incineration facilities (Refer to PRTR for water release from sewage treatment)
4400	Warehousing business	No notification	0	-
8620	Product inspection industry	No notification	1	-
8630	Measurement certification industry	0	0	-
8716	Municipal solid waste treatment service	2	Not estimated	Municipal solid waste incineration
8722	Industrial waste disposal business (including special controlled industrial waste disposal business)	3	Not estimated	Industrial waste incineration
8800	Medical and other health services	No notification	2	-
9140	Higher education institution	No notification	0	-
9210	Natural science research institution	0	1	-
	Subtotal	174	5	
	Total	179		

Note 1: "0 kg/year" indicates a value of less than 0.5 kg.

Note 2: In order to avoid double counting of the released amount from processing/industrial usage of raw material (non-ferrous metal smelting process), the value of "non-ferrous metal production" is excluded.

Source: PRTR Information Square, FY2019 data (published on March 19, 2021), https://www.env.go.jp/chemi/prtr/result/past_gaiyoR01.html

6.3 Mercury Release to Land

Among residues generated from the processing/industrial use of raw materials and fuels and waste incineration, “mercury release to land” refers to the amount of mercury released to land from the portion that either comes in direct contact with soil or gets mixed, or is utilized by directly spreading over the land.

As shown in the Section 2 “Flow for processing/industrial use of raw materials and fuels”, Table 6.3.1 shows the amount of residues utilized that falls within the definition mentioned above and mercury content therein. The total amount of mercury released to land is estimated as 0.53 t-Hg.

Table 6.3.1 Mercury release to land from processing/industrial use of raw materials and fuels, and waste incineration (FY2019)

Source	Residue type	Utilization purpose	Residue utilized (10^3 t)	Hg content in residue utiliezed (t-Hg)
Coal-fired power plants	Fly ash	Soil-contact type	2,476	0.37
Coal-fired industrial boilers	Coal ash	Soil-contact type	241	0.040
Sewage treatment facilities	Sewage sludge	Compost use at green farms	306	0.12
		Total		0.53

Note: For fly ash generated from coal-fired power plants, it is possible to underestimate or overestimate the amount of mercury in the residues utilized.