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Special Feature

Mercury Emission Control in Japan

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ABSTRACT

The Minamata Convention on Mercury entered into force on August 16, 2017. It requires Parties to the Convention to control and, where feasible, reduce mercury emissions from the listed sources. To implement the Convention, Japan amended the Air Pollution Control Law and added clauses that force operators to control their mercury emissions below emission limit values (ELVs). The ELVs have been established separately for new and existing sources, targeting the source categories listed in the Convention: coal-fired boilers, smelting and roasting processes used in the production of non-ferrous metals (lead, zinc, copper and industrial gold), waste incineration facilities and cement clinker production facilities. The factors used to establish the ELVs include the present state of mercury emissions from the targeted categories as well as the mercury content in fuels and materials, best available techniques (BATs) and best environmental practices (BEPs) to control and reduce mercury emissions and ELVs or equivalent standards to control mercury emissions in other countries. In this regard, extensive data on mercury emissions from flue gas and the mercury content of fuels and materials were collected and analyzed. The established ELVs range from 8 μg/Nm^3 for new coal-fired boilers to 400 μg/Nm^3 for existing secondary smelting processes used in the production of copper, lead and zinc. This paper illustrates the ELVs for the targeted source categories, explaining the rationales and approaches used to set the values. The amended Law is to be enforced on April 1, 2018. From future perspectives, checks of the material flow of mercury, following up on the state of compliance, review of the ELVs and of the measurement and monitoring methods have been noted as important issues.

Key words: Mercury, Minamata Convention, Emission limit value, Best available techniques (BATs), Best environmental practices (BEPs)

1. INTRODUCTION

The Minamata Convention on Mercury (2013, hereinafter called "The Convention") entered into force on August 16, 2017. As of February 1, 2018, 88 countries and regions, including Japan, ratified the Convention, which aims to protect human health and the environment from anthropogenic emissions and releases of elemental mercury and mercury compounds (hereinafter called "mercury"). The entry into force of the Convention, therefore, is a historic step for the international community in tackling mercury pollution in a concerted manner. As the country that experienced Minamata disease, Japan is committed to fulfilling its responsibility under the Convention.

To achieve its objective, the Convention stipulates a number of measures to reduce anthropogenic emissions and releases of mercury. Among the provisions, Article 8 of the Convention requires Parties to control and, where feasible, reduce total mercury emissions to the atmosphere by, for example, setting emission limit values (ELVs). In response to this requirement, Japan amended the Air Pollution Control Law (1967, hereinafter called "APCL"), which is the fundamental basis for protecting the atmosphere in Japan. Then, based on the amended APCL, Japan established ELVs for mercury from the point sources listed in the Convention. A series of considerations on setting ELVs was given by the Central Environment Council (2016), which is the advisory body to the Ministry of the Environment, Government of Japan (MOEJ).

This feature article describes Japan's ELVs on mercury in detail, focusing on the approach and rationale. The article consists of six chapters. Following the introduction section, the second chapter gives a summary of the APCL and its amendment to involve regulation of mercury emissions. The third chapter throws light on the concentration of total mercury in fuels and materials as well as that in flue gas. These data formed the basis for setting ELVs. The fourth chapter illustrates the ELVs for mercury from the targeted sources, giving an explanation on the approach and rationale. The fifth chapter provides future perspectives, followed by the last chapter, conclusions.

2. AMENDMENT OF THE AIR POLLUTION CONTROL LAW

In Japan, the APCL is the central pillar for protecting human health and the ecosystem from air pollution. The APCL was established in 1967 to tackle serious air pollution during a period of high economic growth in Japan and has been amended several times. It controls emissions of air pollutants, such as sulfur oxides and nitrogen oxides, by using regulatory measures, including setting ELVs on stationary and mobile sources and developing total emission control programs for specific areas. The APCL has contributed significantly to improving air quality in Japan.

In regard to ratifying an international treaty in Japan, domestic laws and regulations must be prepared to comply with the requirements of the treaty. Accordingly, amendment of the APCL was discussed to fulfill the stipulations under the Convention. Article 8 of the Convention requires Parties to use the best available techniques (BATs) and best environmental practices (BEPs) in order to control and, where feasible, reduce emissions for new sources by, for example, setting ELVs that are consistent with the application of BATs. For existing sources, the Article stipulates that Parties shall implement one or more of the following measures: a quantified goal, ELVs, use of BATs and BEPs, a multi-pollutant strategy and alternative measures. The argument in the discussion was how to reflect the requirements of the Convention in the amendments to the APCL.

In this regard, the mercury concentrations in the atmosphere were checked. The MOEJ monitors hazardous substances, including mercury, in the atmosphere on an annual basis at over 200 nationwide sites and releases the results. Fig. 1 shows the trend of the mercury concentrations in the atmosphere based on the latest MOEJ release (2017).

In Japan, the guiding criterion of atmospheric mercury concentrations is set at 40 ng/m^3 (yearly average) from the viewpoint of minimizing environmental risks to human health. While mercury had not been regulated under the APCL and other laws, the concentrations of mercury in the atmosphere have been below this criterion since it was established in Fiscal Year (FY) 2003 (from April 1, 2003 to March 31, 2004). In FY 2015, the average and maximum concentrations of atmospheric mercury monitored at 262 sites were 1.9 and 3.7 ng/m^3.

Hence, the amendment was drafted to regulate mercury emissions from flue gas with the aim of reducing global mercury emissions rather than avoiding direct risks to human health by inhalation. In line with this policy approach, clauses for the regulation of mercury in the APCL were drafted separately from others pre-

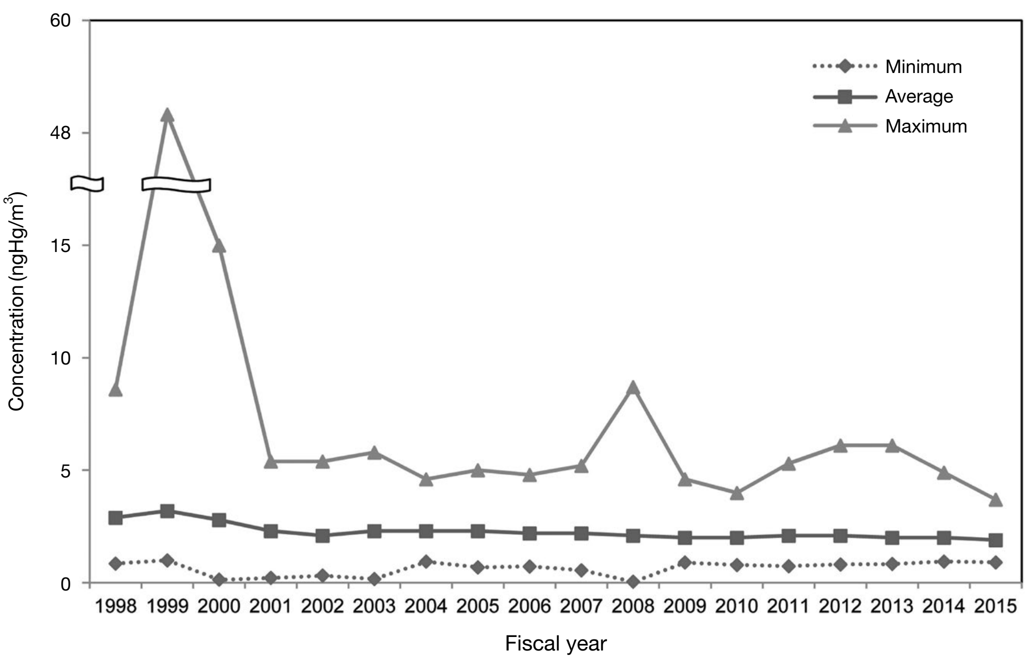

Fig. 1. Trend of total mercury concentrations in the atmosphere.

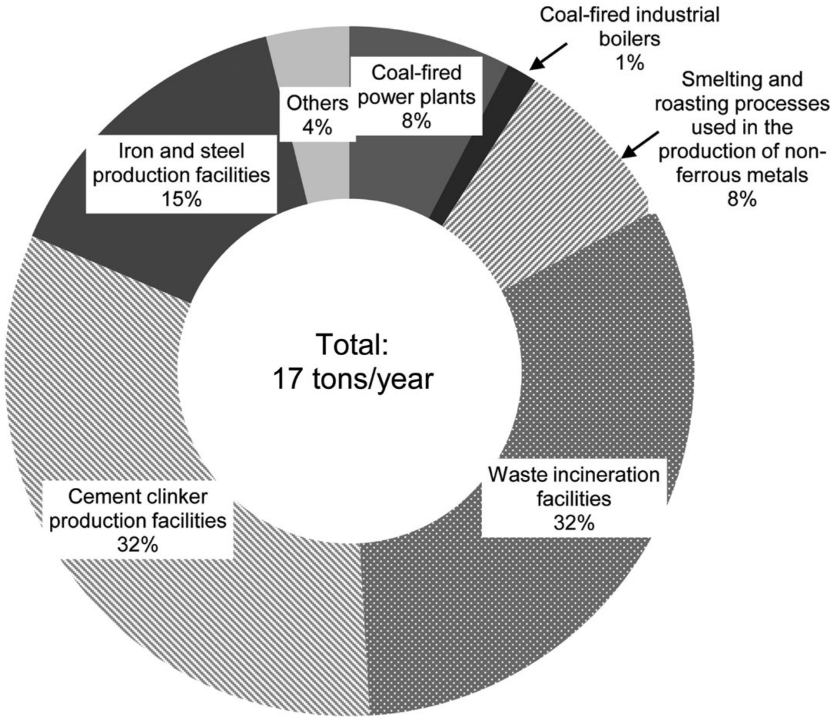

Fig. 2. Mercury emissions by source category in Japan (FY2014).

scribing control of traditional air pollutants. As a countermeasure to reduce mercury emissions, establishment of ELVs for both new and existing sources were proposed.

The next question was which sources should be regulated under the amended APCL. The Convention lists the following point sources that are targeted: coal-fired power plants, coal-fired industrial boilers, smelting and roasting processes used in the production of non-ferrous metals (copper, zinc, lead, industrial gold), waste incineration facilities, and cement clinker production facilities. Fig. 2 illustrates mercury emissions by source category in Japan in FY2014. The total emissions are 17 tons per year. The largest source category is that of the cement clinker production facilities (5.5 tons/year), followed by waste incineration facilities (5.4 tons/year). Artisanal and small-scale gold mining and processing, the largest emission source at the global level, does not exist in Japan. The sum of the emissions from the source categories listed in the Convention accounts for 81% of the total annual emissions. Accordingly, these categories were proposed to be targeted.

As shown in Fig. 2, iron and steel production facilities are the third-largest source category in Japan, while they are not listed in the Convention. Therefore, the proposed amendment of the APCL designated these facilities as “facilities subject to mercury emission control.” This designation urges operators of these facilities to control their emissions by, for example, setting voluntary ELVs.

After a series of discussions on the above points, the amendment of the APCL was finally approved by the National Diet in June 2015. By this amendment, a legal framework to control mercury emissions was created.

3. MONITORING DATA ON MERCURY

Following the amendment of the APCL, the MOEJ started work on setting ELVs for mercury emissions from the targeted sources. To set the ELVs, extensive data were collected and analyzed, including the mercury content in fuels and materials as well as that in the flue gas emitted from the targeted sources. This chapter throws light on the data, which are compiled in the report of the Central Environmental Council (2016).

3.1 Mercury Content in Fuels and Materials

The mercury content in fuels and materials varies depending on the type. The variation of the mercury content significantly affects the concentration of total mercury in the flue gas. In particular, mercury con-

Table 1. Mercury concentrations in fuels and materials.

Source category	Type of fuels and materials	Number of samples	Mercury concentration (mg/kg)
Coal-fired power plants/ Coal-fired industrial boilers	Coal	863	0.001-0.62 (0.038)
	Scrap wood	16	0.004-0.176 (0.049)
	Scrap tire/rubber	10	0.004-0.016 (0.008)
	Scrap plastic	8	<0.001-0.28 (0.079)
	Refuse paper and plastic fuel	15	0.017-0.32 (0.098)
	Pulp and paper mill sludge	10	0.01-0.1 (0.040)
	Sludge	4	0.018-0.19 (0.085)
Smelting and roasting processes used in the production of non-ferrous metals	Copper concentrate	3	0.67-1.8 (1.1)
	Crude ore	12	0.1-112 (41)
	Sulfide ore	4	5.8-13 (8.8)
	Dross	8	5-60 (24)
	Crude zinc oxide	3	0.16-7.3 (3.3)
	Filter dust	3	1-2 (1.4)
	Scrubber sludge	3	5-15.5 (8.5)
	Electronic waste	3	0.006-0.3 (0.135)
	Coke	8	<0.005-0.35 (0.10)
	Silica stone	3	<1-1.8 (0.93)
	Coal	7	<0.1-0.5 (0.19)
Waste incineration facilities	**Industrial waste**		
	Sludge (excluding sewage sludge)	25	<0.005-1 (0.24)
	Sewage sludge	36	<0.02-3.6 (0.793)
	Waste oil	22	<0.0005-0.1 (0.025)
	Acid waste or alkali waste	3	<0.0005-0.014 (0.007)
	Scrap plastic	9	<0.001-0.23 (0.107)
	Scrap metal	4	0.001-0.069 (0.026)
	Scrap paper	3	0.018-0.074 (0.041)
	Scrap wood from demolition	3	<0.01-0.05 (0.033)
	Scrap wood (mixed)	8	<0.01-0.3 (0.071)
	Industrial waste (mixed)	33	<0.001-410 (12.7)
	Municipal waste		
	Municipal waste	10	0.019-0.56 (0.219)
Cement clinker production facilities	Limestone	13	0.009-0.055 (0.022)
	Silica stone	8	0.007-0.17 (0.077)
	Ferrous materials	5	0.02-4.2 (1.110)
	Coal ash	12	0.075-0.4 (0.228)
	Sludge or clay	10	<0.005-1.3 (0.202)
	Construction surplus soil	4	0.32-0.42 (0.375)
	Filter dust	3	0.27-7.8 (3.157)
	Coal	14	0.015-0.91 (0.121)

*The number in parentheses in the Mercury concentration column represents the average of the mercury concentration.

tained in recyclable resources and waste is critical to control mercury emissions in Japan. This is because Japan is attempting to establish a circular economy, which reuses and recycles a variety of waste as much as possible, to overcome the lack of natural resources.

The MOEJ monitored the mercury content in fuels and materials in 2015 as well as the mercury emissions from flue gas. The method used to measure the mercury content in fuels and materials was based mainly on the bottom-sediment measurement method established by the MOEJ (2012). The MOEJ also collected data on mercury content, which operators of sources voluntarily monitored. Table 1 shows the obtained data for the mercury content in fuels and materials that had three or more samples.

As shown in Table 1, the mercury content in coal was relatively low. This is probably because coal-fired power plants in Japan usually use coal with low sulfur for controlling sulfur oxides, where cinnabar (HgS) is one of the states of mercury present in coal. With regard to the types of coal, power plants in Japan mainly use bituminous coal (80% of total), followed by subbituminous coal (7%) and anthracite (5%). In addition, coal-fired boilers burn a mix of secondary fuels such as scraps of material and sludge. The mercury content in these secondary fuels was mostly higher than that in coal, although it was relatively lower than that in the wastes burned in waste incineration facilities.

There are two types of the smelting processes used in the production of non-ferrous metals by the materials entering the processes: primary smelting and secondary smelting. Primary smelting has been defined as those smelting operations using mainly ore and concentrate as materials (the percentage of ore and concentrate in the total weight of materials is 50% or more); secondary smelting, not meaning operations subsequent to primary smelting, uses mainly recyclable resources such as dross and sludge (the percentage of ore and concentrate is less than 50%). From the results of monitoring, crude ore showed a wide range of mercury content. According to the Japan Mining Industry Association (2015), in primary smelting, different concentrates are blended to make the mercury content 1 mgHg/kg for copper concentrate and 10-40 mgHg/kg for zinc and lead concentrates. The recyclable resources used in secondary smelting showed a relatively higher mercury content than waste burned in waste incineration facilities.

The mercury content in waste varies widely and is affected by the extent of mercury mixing. In the monitoring results, mixed industrial waste recorded 410 mg/kg at the maximum, while the minimum was below the detection limit. Scrap paper and wood probably contain mercury because of mercury-containing paint. The mercury content in municipal waste was relatively low. This is partly because used mercury-containing products (e.g., thermometers, batteries, electric lighting) are collected and treated separately in many municipalities in Japan.

Cement clinker production facilities use not only limestone but also various recyclable resources as materials. In Japan, the proportion of recyclable resources tends to be higher than in other countries. In the monitoring results, these recyclable resources showed a higher mercury content than limestone.

3. 2 Measurement of Mercury Emissions from Flue Gas

The MOEJ measured mercury emissions from the targeted sources in 2015. The measurement method (hereinafter called the "MOEJ method") is a modification of the Japanese Industrial Standard (JIS) K0222 Article 4(1) (wet absorption and cold vapor atomic absorption method) for gaseous mercury (1981). The MOEJ method has increased the sampling duration by a factor of five. This provides steady-state results as well as increasing the mercury in the total sample mass above the detection limit. The MOEJ method also measures particle-bound mercury, calculating the sum of gaseous and particle-bound mercury. Furthermore, the MOEJ method applies oxygen corrections to the concentration of mercury emissions from coal-fired boilers, waste incineration facilities and cement clinker production facilities. The oxygen correction is made with the following equation:

$$C = \frac{21 - O_n}{21 - O_s} \times C_s$$

Where:

C = Concentration adjusted to O_n at standard reference condition (μg/Nm^3)
O_n = Oxygen reference value (%)
O_s = Measured oxygen value (%)
C_s = Measured concentration (μg/Nm^3)

The standard reference condition is 273 K, 1 atm. The oxygen reference values for coal-fired boilers, waste incineration facilities and cement clinker production facilities are 6, 10, and 12%, respectively. If the measured oxygen value exceeds 20%, O_s is set at 20%.

In addition to the measurement results of the MOEJ method, facility operators provided results of mercury concentrations which were voluntarily measured mainly based on the JIS method (hereinafter called "other methods"). Table 2 shows the results of mercury emissions from the targeted sources measured by the MOEJ method and other methods.

The Convention classifies coal-fired power plants and coal-fired industrial boilers into different categories. In Japan, however, coal-fired industrial boilers are often used for in-house electricity generation, making it hard to draw a line between them. Hence, coal-fired power plants and coal-fired industrial boilers have been put into one category.

In the measurement results, the concentrations of mercury emissions from coal-fired boilers were lower than those from other sources. This would be because air pollution control systems, which are equipped to control traditional air pollutants, also have the capacity to capture mercury from the combustion of fuels and materials. All 76 facilities surveyed by the MOEJ method installed electrostatic precipitation (ESP) or bag filters. Of these, 32 facilities installed a combination of equipment for desulfurization, denitrification and dust particle removal.

With regard to the units used to measure hourly heat input, the liter of fuel oil equivalent (L_{foe}) is commonly used in Japan. One L_{foe} is equivalent to 1.6 kg of coal. In the measurement survey, almost all the coal-fired boilers for which the hourly heat input exceeded 100,000 L_{foe} used only coal as fuel. The averaged con-

Table 2. Mercury emission level by source category.

Source category	Sub-category		MOEJ method		Other methods	
			Number of samples[a]	Mercury emission level [μg/Nm^3][b]	Number of samples[a]	Mercury emission level [μg/Nm^3][b]
Coal-fired power plants, Coal-fired industrial boilers	Coal-fired power plants, Coal-fired industrial boilers		51 (31)	< 0.1-4.4 (1.2)	517 (65)	< 0.1-13 (1.2)
	Small-scale coal-fired boiler with secondary fuels		87 (44)	< 0.1-16 (1.9)	48 (22)	< 0.1-6.2 (1.3)
Smelting and roasting processes (Primary)	Production of	Copper	28 (10)	< 0.1-1.2 (0.5)	29 (2)	< 0.1-18 (2.4)
		Zinc	20 (4)	< 0.1-39 (9.4)	27 (3)	0.4-150 (26)
Smelting and roasting processes (Secondary)	Production of	Copper	23 (5)	< 0.1-360 (66)	7 (3)	33-710 (370)
		Zinc	49 (12)	< 0.1-1100 (90)	48 (5)	0.5-1600 (280)
		Lead	36 (7)	< 0.1-2300 (290)	10 (3)	1.8-2000 (560)
		Industrial gold	6 (2)	< 0.1-11 (2.0)	1 (1)	430[c]
Waste incineration facilities	Industrial waste incinerator		350 (100)	< 0.1-380 (8.7)	161 (85)	< 0.01-300 (23)
	Municipal waste incinerator		64 (18)	< 0.1-130 (17)	9 (4)	0.5-54 (11.1)
	Sewage sludge incinerator		33 (12)	< 0.02-58 (11)	40 (25)	< 0.01-43 (9.9)
Cement clinker production facilities	Cement kiln		98 (49)	0.9-260 (46)	280 (51)	0.2-220 (39)

[a]The number in parenthesis in the Number of samples column represents the number of facilities.
[b]The number in parenthesis in the Mercury emission level column represents the average of the mercury concentration.
[c]This facility for industrial gold produced copper as well.

centrations of mercury emissions from small-scale coal-fired boilers with secondary fuels were higher than those from other coal-fired boilers.

Regarding the primary smelting processes, approximately 60% of the facilities surveyed by the MOEJ method installed a combination of gas-cleaning equipment that included sulfuric acid plants. Mercury emissions from the facilities for the production of copper were lower than those for the production of zinc. The maximum mercury concentrations from zinc smelting processes were 39 μg/Nm^3 (MOEJ method) and 150 μg/Nm^3 (other methods). These values seem peculiar because the particle-bound mercury concentration of the sample exceeded the gaseous one. In Japan, there is only one primary smelting facility each for the production of lead and of industrial gold. Mercury emissions from these facilities are reportedly below 20 μg/Nm^3.

The mercury emissions from secondary smelting processes vary greatly, owing to the fluctuation of the mercury content of the input materials. With regard to secondary smelting facilities surveyed by the MOEJ method, the maximum concentrations of emissions from copper, zinc and lead smelting processes were 360, 1100 and 2300 μg/Nm^3, respectively. On the other hand, the median concentrations for copper, zinc and lead were 11.3, 15 and 1.6 μg/Nm^3, respectively. Furthermore, 60% or more of the data on mercury emissions from those facilities were below 30 μg/Nm^3. Accordingly, more than half of the facilities seemed to control mercury emissions. All the secondary smelting facilities surveyed by the MOEJ method installed equipment either for dust particle removal (e.g., bag filters) or for gas cleaning.

Waste incineration facilities are classified into industrial waste incinerators, municipal waste incinerators and sewage sludge incinerators. In the measurement survey, there was no considerable difference in the mercury emissions among those incinerators.

In the sub-category of industrial waste incinerators, the maximum concentration surveyed by the MOEJ method was 380 μg/Nm^3. Still, approximately 80% of the measured concentrations were below 10 μg/Nm^3. Many of the industrial waste incinerators installed either bag filters or wet scrubbers or both to control air pollutants. Mercury emissions from medical waste incinerators (number of samples: 23) were < 0.2-49 μg/Nm^3 (average 21 μg/Nm^3), showing no significant difference from other industrial waste incinerators. Mercury emissions from mercury recovery facilities (number of samples: 17) were higher than those from other industrial waste incinerators, with results of 12-200 μg/Nm^3 (average 84 μg/Nm^3).

More than 60% of the mercury emissions from the municipal waste incinerators surveyed by the MOEJ method were below 10 μg/Nm^3. Many of those facilities installed the combination of bag filters with activated carbon or with slaked lime injection in order to control air pollutants. There was no distinct correlation between incineration capacity and mercury emissions or between the years of operation and mercury emissions.

Mercury emissions from sewage sludge incinerators varied less than those from industrial or municipal waste incinerators because the materials burned were relatively homogeneous. Many of those facilities installed bag filters or ESPs in combination with scrubbers. Facilities with larger combustion capacity or with fewer years of operation tended to emit less mercury.

Mercury emissions from the cement clinker production facilities surveyed by the MOEJ method had a maximum of 260 $\mu g/Nm^3$, while 75% of the data were below 50 $\mu g/Nm^3$. All the facilities installed bag filters or ESPs to control air pollutants. The greater the mercury content in the limestone, the greater the mercury emissions measured. Mercury emissions from cement clinker production facilities in Japan are likely to be larger than those in other countries. This is because in Japan, those facilities use a high proportion of recyclable resources, operate without dust shuttling, and circulate cement kiln dust in the kilns.

4. EMISSION LIMIT VALUES ON MERCURY EMISSIONS

This chapter illustrates the ELVs for mercury emissions from the targeted source categories. It has been assumed that the regulation aims at controlling mercury emissions under normal operating conditions, while the emissions vary owing to the mercury content in fuels and materials. Based on this assumption, the ELVs have been established, taking into consideration the following three points. The first point is the present state of mercury emissions from the source categories as well as the mercury content in the fuels and materials, which are described in the previous chapter. The second point is the use of the best available techniques (BATs) and best environmental practices (BEPs) to control and reduce mercury emissions, in accordance with paragraph 4 of Article 8 in the Convention. For this purpose, the draft guidance on BATs/BEPs (UNEP, 2015) has been used as a reference. The third point is consideration of the ELVs or equivalent standards used to control mercury emissions in other countries. For instance, the United States of America and the European Union have established or proposed their ELVs (for example USA Federal Register (2015) and European Commission (2013)). The present state of mercury emissions in Japan was compared to those values. It should be noted that the values of standards differ owing to several factors including the targeted duration (e.g., daily average or yearly average) and the monitoring method.

ELVs have been established separately for new and existing sources, in line with the Convention. New sources can install the latest BATs economically, leading to stricter ELVs than existing sources. However, existing sources are regarded as new ones when the sources are modified by more than 50% of their scale. Facilities for multiple purposes (e.g., coal-fired boilers to incinerate waste as a secondary fuel) are classified according to their main purpose.

Table 3 shows the ELVs for the targeted source categories in connection with the targeted scale and assumed BATs. Operators of the facilities are obliged to control mercury emissions below the ELVs applied. The regulation is to be put in place on April 1, 2018.

Paragraph 2(b) of Article 8 in the Convention allows Parties to establish criteria to identify the sources covered within a source category so long as those criteria for any category include at least 75% of the emissions from the category. In Japan, the sources under the mercury control regulation are already covered by the APCL or other legislation. To identify the targeted capacity of sources for mercury regulation, the same criteria as those for controlling traditional air pollutants are applied. It is estimated that those criteria for each category include more than 98% of the emissions from the category. Using the same criteria will reduce administrative costs and ease the burden on operators.

The unit for an ELV is expressed as micrograms of mercury per cubic meters under standard condition (273 K, 1 atm) or $\mu g/Nm^3$. As in the MOEJ method described in the previous chapter, oxygen corrections are applied to measured values of mercury emissions from coal-fired boilers, waste incineration facilities and cement clinker production facilities.

Coal-fired power plants and coal-fired industrial boilers are classified into one category of “coal-fired boilers.” The ELVs of these facilities are lower than those of others because they are equipped with air pollution control systems that remove not only traditional air pollutants but also mercury from the flue gas. Higher ELVs have been established for small-scale coal-fired boilers with secondary fuels, for which the hourly heat input is below 100,000 L_{foe}, owing to variable mercury content in the fuels. While integrated coal-gasification combined cycle (IGCC) plants are included in coal-fired power plants, there is only one such plant in operation in Japan, providing few data on its mercury emissions. Accordingly, ELVs for IGCC plants have been regarded as one of the issues to be considered in the future.

In the category of smelting and roasting processes

Table 3. Emission limit value by source category.

Source category		Sub category		Targeted capacity	Assumed BATs	Emission limit value ($\mu g/Nm^3$)[a]
Coal-fired power plants, Coal-fired industrial boilers		Coal-fired boilers		Either [heat transfer area of boiler is above 10 m^2] or [hourly heat input capacity is above 50 L_{foe}]	**New**: The combination of equipment for desulfurization, denitrification and dust particle removal is installed. **Existing**: Air pollution control system excluding the above combination is installed.	**New**: 8 (10)[b] **Existing**: 10 (15)[b]
Smelting and roasting processes used in the production of non-ferrous metals	Primary smelting	Furnaces for smelting, roasting, sintering, melting, converting and drying in the production of	Copper and industrial gold	Either [hourly feedstock input capacity is above 0.5 ton], [the grave area is above 0.5 m^2], [the tuyere area is above 0.2 m^2], or [hourly heat input capacity is above 20 L_{foe}][c]	**New and Existing**: In cases where input materials have ordinary mercury impurities, the combination of gas cleaning equipment with sulfuric acid plants is installed. In case where input materials have high mercury impurities, the Boliden Norzink process, etc. is installed in addition to the above combination.	**New**: 15 **Existing**: 30
			Lead and zinc	Same as the above	Same as the above	**New**: 30 **Existing**: 50
	Secondary smelting	Furnaces for smelting, roasting, sintering, melting, converting and drying in the production of	Copper, lead and zinc	Either [hourly feedstock input capacity is above 0.5 ton], [the grave area is above 0.5 m^2], [the tuyere area is above 0.2 m^2], or [hourly heat input capacity is above 20 L_{foe}][c]	In cases where input slag has high mercury impurities, **New and Existing**: The combination of equipment for dust particle removal with high-performance gas cleaning is installed. In other cases, **New**: The combination of equipment for dust particle removal with gas cleaning is installed. **Existing**: Either equipment for dust particle removal or that for gas cleaning is installed.	**New**: 100 **Existing**: 400
			Industrial gold	Same as the above	Same as the above	**New**: 30 **Existing**: 50
Waste incineration facilities		Waste incinerators (excluding the below)		Either [the grave area is above 2 m^2] or [hourly waste input capacity is above 200 kg]	**New**: Either bag filter or wet scrubber is installed in combination with activated carbon injection. **Existing**: Either bag filter or wet scrubber is installed.	**New**: 30 **Existing**: 50
		Waste incinerators to burn high-mercury-content industrial waste or recyclable resources		All facilities are targeted.	**New and Existing**: The combination of bag filter, wet scrubber with chelating agent and activated carbon injection is installed. For new sources, high-performance activated carbon injection is required.	**New**: 50 **Existing**: 100
Cement clinker production facilities		Cement kilns		Either [the grave area is above 1 m^2] or [heat input capacity is above 50 L_{foe}] or [the rated capacity of transformer is above 200 kVA]	**New**: Multiple techniques as BAT in the BAT/BEP guidance are installed. **Existing**: Materials and fuels with low mercury content are selected.	**New**: 50 **Existing**: 80 (140)[d]

[a]A standard oxygen (O_2) content, 6%, 12%, 10% is applied for coal-fired boiler, waste incinerator and cement kiln, respectively.
[b]The number in parentheses is applied to small-scale coal-fired boilers with secondary fuels, which hourly heat input is below 100,000 L_{foe}.
[c]For the smelting and roasting process, more detailed targeted capacity is stipulated by the type of furnace.
[d]The number in parentheses is applied to facilities which have no option but to use local limestone deposits with high mercury content.

used in the production of non-ferrous metals, separate ELVs have been established for primary and secondary smelting. The ELVs for the former have been established lower than those for the latter because of the low mercury content in materials fed into the process. In primary smelting, ELVs for the production of copper and industrial gold have been established lower than those of lead and zinc, reflecting the difference in mercury emissions from the flue gas. In secondary smelting, ELVs for the production of copper, lead and zinc have been established higher than those for industrial gold. The best available techniques for primary and secondary smelting have been assumed corresponding to the level of mercury impurities in the input materials.

Among waste incineration facilities, there is no considerable difference in mercury emissions from industrial waste, municipal waste and sewage sludge incinerators. Hence, the same ELVs have been established for those incinerators. However, different ELVs have been established for waste incinerators that burn industrial waste (or recyclable resources) with high mercury impurities, for example mercury recovery facilities, because of the peculiarity of the sources.

With regard to cement clinker production facilities, the BATs for new facilities have assumed multiple techniques in the draft guidance on BATs/BEPs. Those techniques include careful selection and control of raw materials and fuels, dust shuttling and collecting the dust instead of returning it to the raw feed, and installation of air pollution control devices such as wet scrubbers. The BATs for existing facilities are the selection of materials and fuels with low mercury content. Still, there are cases where facilities have no option but to use local limestone deposits with high mercury content. In those cases, 140 $\mu g/Nm^3$ is used as the ELV for existing facilities instead of 80 $\mu g/Nm^3$.

Operators of the targeted sources are required to periodically monitor gaseous and particle-bound mercury emissions in the flue gas based on the MOEJ method. A sample of the flue gas is collected manually. The required frequency of monitoring for a facility operating throughout the year is three times per year when the flue gas volume is equal to or greater than 40,000 Nm^3/hr and twice per year when it is below 40,000 Nm^3/hr. The procedure to verify compliance with the ELVs is unique. If the monitored value is over the ELV applied, operators are forced to additionally monitor mercury emissions three times or more within 30 days. Out of the four or more monitored values in total, the maximum and minimum values are removed, and the average of the remainder is calculated. Then, compliance is verified if this average is below the applied ELV. If the average is over the ELV applied, local authorities can urge the operators to improve their operation.

5. FUTURE PERSPECTIVES

With the aim of implementing the Convention, Japan has introduced a regulation to reduce mercury emissions. This is a history-making step in the history of the APCL. As the regulation is brand-new, it is important to review progress of the implementation and improve the regulation if necessary. From such future perspectives, the following four points are essential.

First, it should be recognized that the aim of the Convention is to reduce the total amount of mercury emitted and released to the environment. Therefore, it is less meaningful that mercury removed from the flue gas merely shifts to other environmental media such as water and soil. Hence, it is necessary to keep an eye on the material flow of mercury in Japan and check the amount of mercury moving to the environment. If mercury reduction is not achieved, additional measures should be considered.

Second, it is essential to follow the state of compliance with this new regulation. If compliance is not ensured as a whole, it is critical to analyze the cause and consider improvements. In particular, Japan is advancing to a circular economy by recycling and reusing waste. Specifically, secondary smelting and cement clinker production facilities use considerable amounts of recyclable resources with mercury impurities. Accordingly, achievement of both a reduction in mercury emissions and promotion of a circular economy should be pursued.

Third, it is indispensable to review the ELVs themselves. The ELVs have been established based on assumed BATs, which will continuously evolve. Reflection of the evolution into ELVs will be desirable. Furthermore, addition of the IGCC to the targeted sources will be considered if sufficient data on its mercury emissions are obtained.

Lastly, the measurement and monitoring method should be reviewed as well, taking into consideration the progress of the monitoring methodologies and the burden on the operators.

6. CONCLUSIONS

To implement the stipulations of the Convention, Japan amended the APCL and has introduced a new regulation to reduce mercury emissions from the targeted sources. This regulation requires operators to comply with the ELVs for mercury emissions. The ELVs have been established based on the assumed BATs, taking into consideration the mercury content in fuels and materials and current mercury emissions from the sources.

Mercury content in recyclable resources and waste vary widely because they include mercury as impurities. This variation affects the mercury emissions from the sources that use those resources, including secondary smelting processes, waste incinerators and cement clinker production facilities. On the other hand, air pollution control systems to reduce traditional air pollutants contribute to the reduction of mercury emissions as well. These facts have been reflected in the ELVs for mercury emissions.

In response to the entry into force of the Convention, the international community is taking a significant step to control and, where feasible, reduce mercury emissions. As a Party to the Convention, Japan is committed to reducing mercury emissions from the targeted sources. The establishment of the ELVs is the centerpiece to fulfill this commitment.

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