5-1 Development of New Technologies to Suppress Leachate of Heavy Metals from Sewage Sludge Incineration Ash

Eiji Nagatsuka
Technical Development Section, Planning and Coordination Division Bureau of Sewerage
Tokyo Metropolitan Government

Technology 2005 2nd Joint Specialty Conference for Sustainable Management of
Water Quality Systems for the 21st Century

Held in Partnership with Water Environment Federation (WEF); European Water Association (EWA);Japan Sewage Works Association (JSWA); and the California Water Environment Association (CWEA)
August 28–31, 2005 Palace Hotel San Francisco, California, USA
Session No.2 : Metals Removal Technologies

ABSTRACT

Sewage sludge incineration ash ("incineration ash") contains trace amounts of heavy metals, and leachate of arsenic (As) and selenium (Se) that often exceeds the level specified in the Environmental Quality Standards for Soil Contamination of Japan (hereinafter called the "Japanese Standard") is one reason for the flagging rate of incineration ash recycling.

To help expand recycling of incineration ash, the Bureau of Sewerage of the Tokyo Metropolitan Government promoted development of technologies to suppress leachate of heavy metals from incineration ash and methods to reduce heavy metal contents in incineration ash, so as to alleviate the effects of heavy metals generated in the course of application of incineration ash.

1. Adding iron(II) sulfate and sodium thiosulfate to the ash, then heating it to chemically transform it into a form that hinders the leachate of heavy metals (Reagent Addition Method)
2. Adding slaked lime to the incineration ash to create a hydrothermal reaction that causes crystals to form on the surface of the ash that will physically seal the heavy metals. (Hydrothermal Treating Method)
3. Utilizing the fact that heavy metal compounds remain in a gaseous state at the temperature inside the incinerator, to collect the incineration ash with low heavy metal content from the area near the incinerator outlet where the temperature is high. (High-temperature Dust Collection Method)

Each of these methods is introduced below because they have been used successfully to produce incineration ash that meets the requirements of the Japanese Standard by leachate of arsenic and selenium.

INTRODUCTION

In Japan, land for waste disposal is not easy to acquire. Also in Tokyo, the remaining space available for disposal sites is rapidly decreasing. To extend the remaining useable life of disposal sites now in use, the Bureau of Sewerage of the Tokyo Metropolitan Government is making a strong effort to incinerate all sewage sludge for volume reduction as well as to achieve recycling of incineration ash.

Up to now, the Bureau has promoted recycling of incineration ash such as manufacturing of bricks or lightweight fine-grained materials. This, however, requires considerable amounts of energy and costs, making it infeasible as a business.

On the other hand, when sewage sludge incineration ash is to be used for soil as a new recycling application, it is expected that the ash must meet the Japanese Standard in terms of leachate of heavy metals. Japan has already the established standard values for heavy metals, such as cadmium, hexavalent chrome, mercury, selenium, lead, and arsenic.
Of these, arsenic and selenium in incineration ash often exceed the limits, making recycling difficult.

In order to suppress leachate of these heavy metals, three types of technologies as described below are under development.

1. Reagent Addition Method

This method consists of adding reagents to incineration ash to induce a chemical reaction to transform it chemically to make leachate of heavy metals difficult. The reagents used are sodium thiosulfate and iron(II) sulfate, each acting as a reducing agent and a solution-resistant agent. In this method, the oxysalt of arsenic is made insoluble through adsorption of iron hydroxide generated in this condition, and the oxysalt of selenium is first reduced into selenite, then similarly made insoluble through adsorption of iron hydroxide.

Ash treated according to this method, if exposed in the environment, is expected to retain the leachate suppression effect over a long period because readily leachable substances such as calcium ion, etc. are not involved in the leachate suppression principle and the insoluble form is colloidal.

2. Hydrothermal Treating Method

This method consists of containing heavy metals physically by causing crystals to form over the surface of the incineration ash by adding slaked lime to induce a hydrothermal reaction in high-pressure steam.

Ash treated by this method, if exposed in the environment, is expected to retain the leachate suppression effect over a long period because heavy metal salts are contained in the calcium silicate (tobermorite) crystals that are stable against acid rain, etc.

3. High-Temperature Dust Collection Method

This method consists of collecting incineration ash with low heavy metal content in the high-temperature area at the incinerator outlet by utilizing the fact that heavy metal compounds are in the gaseous phase at the temperature inside the incinerator.

This method separates incineration ash with different heavy metal content by performing dust collection at the high-temperature portion at the incinerator outlet and conventional dust collection at the low-temperature portion.

Unlike the reagent addition method in which the heavy metals are transformed into difficult-to-solve substances or the hydrothermal method to seal off the heavy metals with crystals, which require a separate treatment process after recovery of incineration ash, this method enables recovery of incineration ash with low heavy metal content directly from the incinerator.

KEYWORDS
Sewage sludge ash, heavy metals, the environmental standard, resourcizing

METHODOLOGY AND RESULTS

1. Reagent Addition Method

(1) Process used to suppress arsenic and selenium leachate

Suppression of arsenic and selenium leachate from incineration ash was done by adding and mixing iron(II) sulfate and sodium thiosulfate solutions, which was followed by heating (Figure 1). Addition rate of iron(II) sulfate to ash was 1.5-3.0% as $FeSO_4 \cdot 7H_2O$, and that of sodium thiosulfate was 0.5-1.0% as $Na_2S_2O_3 \cdot 5H_2O$. The heating temperature was 150-200°C. The leachate test in Japan (in which the mixture of ash and deionized water at a solution/solid rate of 10 was stirred for six hours, and filtrated and separated to produce the filtrate) proved successful in suppressing leachate of incineration ash, which originally leaches arsenic and selenium at maximum 1 mg/L, to 0.01 mg/L or less as specified in the Japanese Standard.

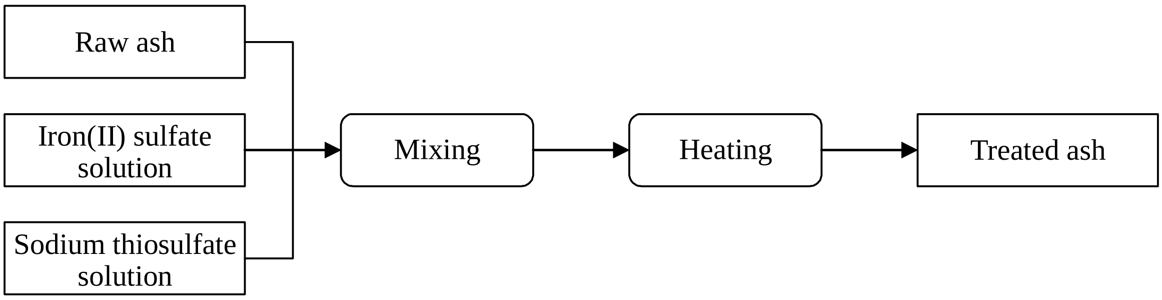


Figure 1 - Process for Arsenic and Selenium Leachate Suppression

(2) Arsenic and selenium leachate suppression mechanism

1) Arsenic

Arsenic in sewage sludge incineration ash leaches as oxyanion of arsenite (As(III)), and arsenate (As(V)). As(III) and As(V) are adsorbed by iron oxyhydroxide which is produced from iron(II) sulfate, and become insoluble.

2) Selenium

Selenium in sewage sludge incineration ash leaches as oxyanion of selenite (Se(IV)) and selenate (Se(VI)). Though Se(IV) is adsorbed and made insoluble by iron oxyhydroxide which is produced from iron(II) sulfate, Se(VI) would not be adsorbed without further treatment. Se(VI) is reduced to Se(IV) by hydrogen sulfide gas which is produced by heating of sodium thiosulfate and water, and it is adsorbed and made insoluble by iron oxyhydroxide.

(3) Outline of demonstration plant

The appearance of a demonstration plant constructed at the K Water Reclamation Center in Tokyo is shown in Figure 2, and an outline of the flow is shown in Figure 3. The main equipment is a double cylindrical kiln about 400mm in diameter and 1600mm in length. Raw ash is put into an inner rotary cylinder, and is indirectly heated by a hot blast supplied between the inner and outer cylinders. In the kiln, ash with added reagents is mixed uniformly, and Se(VI) in ash is reduced by hydrogen sulfide gas produced from heating of water and sodium thiosulfate. The supply of raw ash to the kiln is done in a constant amount by an ash feeder, and the reagents are added during transport from the feeder to the kiln. Treated ash is discharged from the opposite side of the raw ash supplier of the kiln. Soot, gas and water are removed by exhaust gas treatment equipment from the exhaust gas extracted from the kiln before it is released into the atmosphere. This plant has a maximum capacity of 50 kg/h.

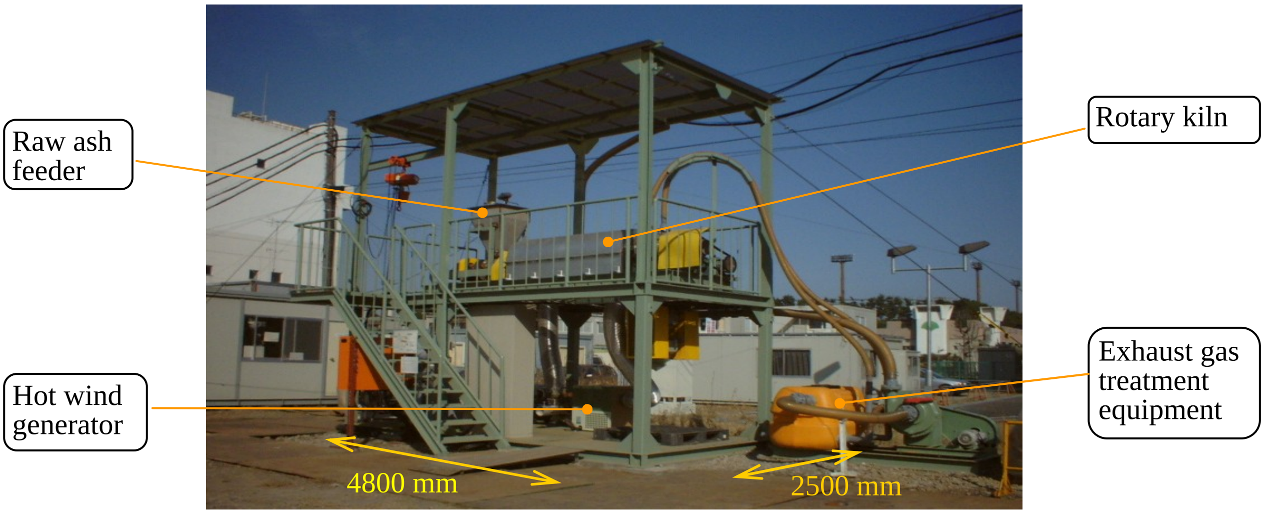


Figure 2 - Appearance of Pilot Plant

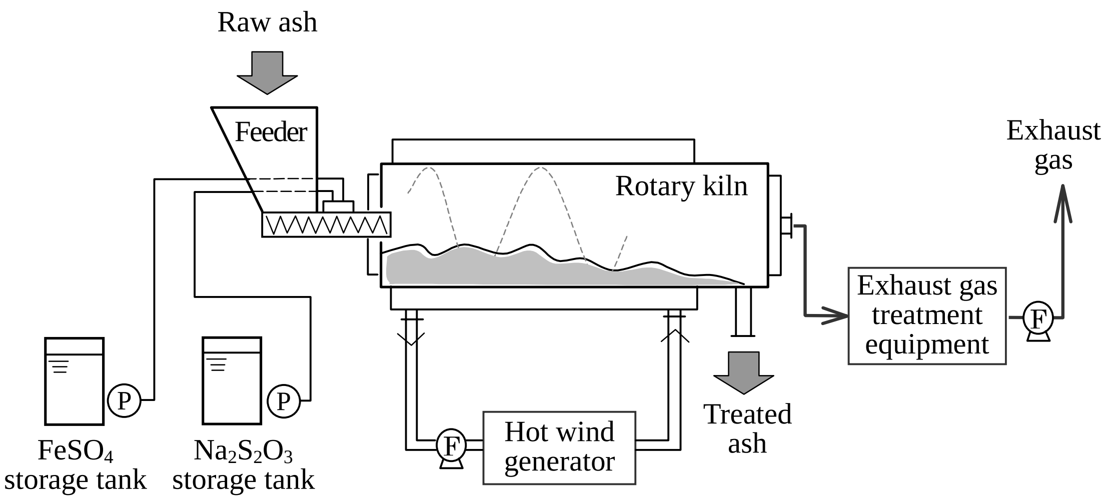


Figure 3 - Schematic Diagram of Treatment of As and Se Leachate at Pilot Plant

(4) Results of demonstration experiments

1) Effect of heating temperature

The results of the leachate test on arsenic and selenium of treated ashes that were heated at different temperature are shown in Table 1. As regards addition of reagents, iron(II) sulfate was added at 3.0%, and sodium thiosulfate was added at 1.5%. At 150-250°C heating temperature, the leachate rate of arsenic and selenium was reduced to 0.01 mg/L or less of the Japanese Standard, proving satisfactory treatment. The optimum temperature was fixed at 200°C. Lower temperatures require longer treatment periods, while higher temperatures lead to higher utilities costs.

Table 1 - Influence of Heating Temperature on As and Se Leachates from Treated Ash

	Heating temperature	As leachate (mg/L)	Se leachate (mg/L)
Raw ash	―	0.49	0.84
Treated ash	150℃	<0.01	0.01
	200℃	<0.01	0.01
	250℃	<0.01	<0.01

2) Effect of addition rate of reagents

The results of the leachate test on arsenic and selenium of treated ashes as a function of addition rate of iron(II) sulfate and sodium thiosulfate are shown in Table 2. The heating temperature was 200°C. The addition rate of iron(II) sulfate was 3.0% and sodium thiosulfate was 1.0%. When each addition rate was reduced by half, the leachate rate of arsenic and selenium was below 0.01 mg/L. When the iron(II) sulfate addition rate was lowered to 1.0% and the sodium thiosulfate addition rate was 0.5%, the arsenic leachate rate exceeded 0.01 mg/L of the Japanese Standard. In the meantime, the leachate rate of arsenic and selenium was below 0.01mg/L when the addition rate of iron(II) sulfate was 2.0% and that of sodium thiosulfate was 0.2%. The adsorption and insolubility of arsenic were estimated to be insufficient if the addition rate of iron(II) sulfate was lowered inadequately. Judging from the effect of arsenic and selenium leachate suppression and economical efficiency, the acceptable addition rates of iron(II) sulfate and sodium thiosulfate should be 1.5-2.0% and approximately 0.5%, respectively.

Table 2 - Influence of Reagent Addition Rate on As and Se Leachates from Treated Ash

	Reagent addition rate		As leachate (mg/L)	Se leachate (mg/L)
	$FeSO_4$	$Na_2S_2O_3$		
Raw ash	―	―	0.38	0.49
Treated ash	3.0%	1.0%	<0.01	<0.01
	1.5%	0.5%	<0.01	<0.01
	1.0%	0.5%	0.02	<0.01
	2.0%	0.2%	<0.01	<0.01

3) Arsenic and selenium leachates under acidic conditions

Though the standard leachate test of Japan is carried out with neutral deionized water, the leachate rates of arsenic and selenium may increase under acid conditions, such as acid rain. Arsenic and selenium form calcium compounds of poor solubility particularly under a high pH condition due to the existence of lime, and their leachate rates decrease. Accordingly, to assume acid rain, a modified TVA leachate test based on the TVA method of Switzerland using saturated carbonated water as a solvent was carried out. The parameters of this test are shown in Table 3.

The results of each of the leachate tests on arsenic and selenium of treated ash, under conditions of an iron(II) sulfate addition rate of 2.0%, a sodium thiosulfate addition rate of 0.2% and a heating temperature of 200°C, are shown in Table 4. The leachate rates of arsenic and selenium were 0.01mg/L or less of the Japanese Standard in either test, and it was proven that treated ash was effective even in an acidic condition.

Table 3 - Parameters of Leachate Test

	Japanese standard method	Modified TVA method
Leachant	Deionized water	Saturated carbonated water
Initial leachant pH	5.8 – 6.3	4
L/S ratio	10	10
pH (during test)	Not under control	Not under control
Test duration	6 hours	24 hours
Stirring condition	Horizontal shaking	Jar test

Table 4: As and Se Leachats Resulting from Different Leachate Tests

	Leachate test	pH (-)	As leachate (mg/L)	Se leachate (mg/L)
Raw ash	Japanese Standard	7.7	0.38	0.49
	Modified TVA	6.0	1.09	0.79
Treated ash	Japanese Standard	6.6	<0.01	<0.01
	Modified TVA	6.0	<0.01	<0.01

4) Leachate of other heavy metals

From sewage sludge incineration ash, only arsenic and selenium leachates exceed the Japanese Standard. Leachate of other heavy metals does not usually exceed the standards. In the case of treated ash, leachate of cadmium, mercury, lead and hexavalent chromium also satisfied the standard.

5) Long-term test of ash recycling materials

A long-term test for effective recycling of treated ash proved satisfactory. A mixture of treated ash and construction waste soil was used as soil for planting. The results indicated no problem for growth of plants or from leachate of heavy metals.

(5) Conclusion

A technology that suppresses leachate of arsenic and selenium from sewage sludge incineration ash was developed. This treatment involves the addition of small amounts of common reagents and heating at moderately high temperatures of 150-200°C, so that the operation cost is low. Leachate of heavy metals such as arsenic and selenium from treated ash is suppressed below the limits set in the Japanese Standard, and the effect continues even under the acidic conditions. Therefore, safety is ensured for leachate of heavy metals even if treated ash is applied in the environment.

2. HYDROTHERMAL TREATING METHOD

(1) Principle of hydrothermal treatment

The hydrothermal reaction develops on the principle illustrated in Fig. 1.

The hydrothermal reaction uses water, high in temperature and pressure, below the critical points (375°C and 22 MPa), featuring high reactivity owing to a large ion product compared to water at normal temperature and pressure. Calcium silicate (tobermorite) is formed by reacting the silica content in incineration ash with calcium in slaked lime under a hydrothermal condition. The tobermorite grows into physically stable and strong crystals, enclosing these heavy metals in the crystal structure. As a result, leachate of arsenic and selenium, can be reduced below the limits in the Japanese Standard.

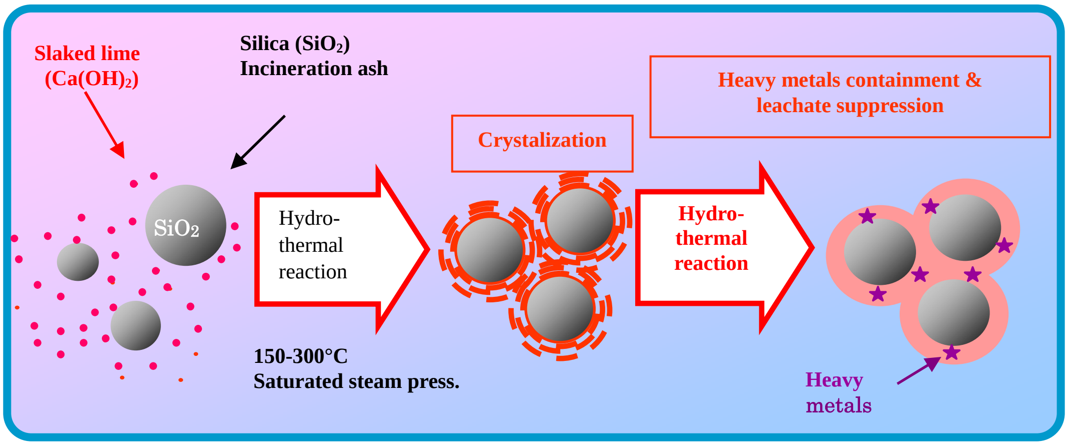


Fig. 1 Principle of Hydrothermal Treatment

(2) Methodology

The test procedures and apparatus are shown in Fig. 2. Incineration ash, slaked lime, an additive (silica source), and water were mixed uniformly and pelletized. Pelletized samples are placed in the pressurizing autoclave. The autoclave is filled with water in the bottom beforehand and adjusted to hydrothermal conditions (temperature and pressure) through heating from the outside. The water addition rate as well as mixing and pelletizing time period was established in such a manner as to produce pellets of 5 mm or less in view of expected applications.

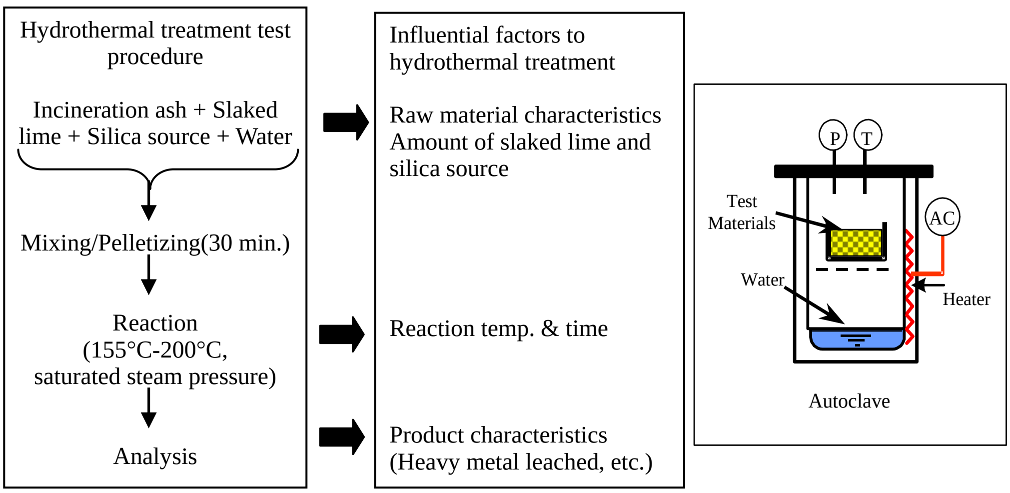
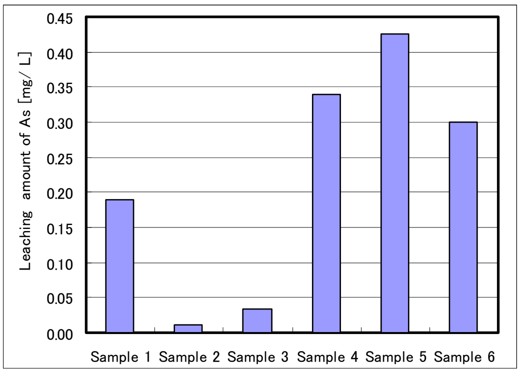


Fig. 2 Test Procedure

(3) Basic property of incineration ash

Fig 3 shows the values of arsenic and selenium leached from the incineration ash used in this experiment obtained in the leachate test method based on the Ministry of Environment Notice No.46, 1991. The highest leachate rate of arsenic and selenium was respectively 0.425 mg/L in Plant B ash (5), and 0.41 mg/L in Plant A ash (3). The leachate rates of other heavy metals, including cadmium, lead, hexavalent chromium and total mercury were below the limits set in the Japanese Standard in all six ash samples.



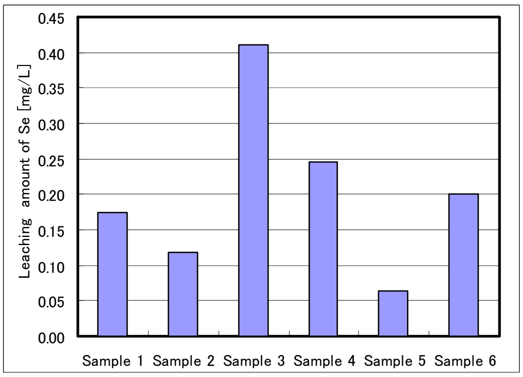


Fig. 3 Arsenic and Selenium Leached from Ash Samples

(Samples 1 to 3 are from Plant A, and 4 to 6 are from Plant B.)

(4) Hydrothermal treatment technology

The study was made on major conditions for tobermorite formation in the hydrothermal treatment; temperature, reaction time length and the addition rate of calcium and silica. Optimum hydrothermal reaction conditions were determined based on the results of tests of six ash samples from different sampling locations and seasons.

Optimum hydrothermal condition: Temp.: 165°C, reaction time: 20 hrs

Addition rates: Calcium (slaked lime) 10%, Silica (fine silica sand) 10%

The arsenic and selenium leachates from six samples under the optimum hydrothermal conditions are shown in Table 1. The leachate rates of all samples were below the Japanese Standard. As shown in Fig. 3, the hydrothermal treatment under optimum condition was effective in suppressing leachate of arsenic and selenium from those ash samples with different leachate rates.

The reliability of treatment under optimum conditions was checked by repeatability tests, confirming that the heavy metal leachate suppression effect was steadily obtained as shown in Table 1.

The results of an availability test on construction waste recycle residue (additive B) and water purifying sludge

Table 1 Test Results under Optimum Hydrothermal Conditions

Sample No.	Metal leachate (mg/L)		Repeatability Test No.
	As	Se	
Sample 1 of A	0.010	0.008	-
Sample 2 of A	< 0.002	0.005	-
Sample 3 of A	0.005	0.002	-
Sample 4 of B	0.002	0.010	Test 1
↓	0.002	0.009	Test 2
↓	0.002	0.004	Test 3
↓	0.002	0.003	Test 4
↓	0.001	0.002	Test 5
Sample 5 of B	< 0.002	0.003	Test 1
↓	< 0.002	0.002	Test 2
↓	< 0.002	0.003	Test 3
Sample 6 of B	0.003	0.003	-
Quality standards	0.01	0.01	

(additive C) are shown in Table 2. Temperature, reaction time and calcium injection were as per the optimum condition. Even with separate addition of additives B or C at 30%, the heavy metal leachate from the hydrothermally treated product cleared the Japanese Standard. This means that treatment of these wastes together with incineration ash would not only reduce incineration ash, but also landfill materials, contributing to alleviation of the environmental load.

Table 2 Test Results in Additive Injection

Additive		Metal leachate (mg/L)	
Injection rate		As	Se
B	30%	0.001	0.001
C	30%	0.003	0.007

(5) Recycling Applications Study

Pelletized or brick-shaped incineration ash used in the hydrothermal treatment method is relatively stronger and more porous than the incineration ash in fine powders, and becomes low-density solidified material. Prospective uses that can exploit such features were studied.
The study included sampling of basic data required for such applications as planting soil as well as a plant growing test.

Table 3 shows the results of the planting feasibility test. The product alone is alkaline, with a relatively low permeability coefficient and a high percentage of solids. Compared to standard soil, the soils mixed with the product contained 10 times the available phosphorus and convertible potassium.

Effective water content varied from product soil to mixed ones, but the variance was small. The product soil, therefore, can be converted to a resource such as planting soil.

Table 3 Characteristics of Planting Soils

Mixing ratio			Hydrothermal product	4	2	1	0
			Standard planting soil	0	2	3	4
Measuring Items	Effective water content		L/m^3	85.1	61.3	75.4	81.2
	Permeability coefficient		cm/sec	9.68×10^{-4}	2.10×10^{-2}	2.02×10^{-2}	4.50×10^{-2}
	3-phase distribution	Solid	%	40.6	29.0	25.0	21.0
		Water	%	16.1	21.8	25.5	26.7
		Air	%	43.3	49.2	49.5	52.3
	Base exchange capacity		mEq/100 g	23.7	14.4	17.6	28.3
	Available nitrogen		Mg/100 g	2.3	1.0	1.4	0.6
	Available phosphoric acid		Mg/100 g	1200	1450	1270	15.4
	Convertible potassium		Mg/100 g	566	240	186	16.9
	Organic carbon content		%	0.2	0.3	0.4	0.8
	pH		-	8.3	7.6	7.5	7.1

The mixed soils were tested for growing a leafy vegetable (komatsuna). It grew better at the mixing rates of standard to product soils of 2 to 2 or 1 to 3. The growth was not so good in the product soil alone when compared to the mixed soils, but it was nearly the same as that of the standard soil alone.

(7) Conclusion

Six ash samples taken from plants at different locations and in different seasons were tested to determine the optimum hydrothermal treatment condition effective for stable suppression of heavy metal leachate. The tests indicated that the optimum conditions were 165°C and 20 hours for reaction, and a 10% calcium source and a 10% silica source for addition.

Repeatability tests conducted to check the reliability of the optimum hydrothermal condition confirmed that the heavy metal leachate constantly fell within the limits set in the Japanese Standard.

A test of growing leafy vegetables revealed that a soil mixture consisting of the hydrothermally treated soil and standard planting soil ensured better growth than standard soil alone.

3. HIGH-TEMPERATURE DUST COLLECTION METHOD

(1) High-temperature Dust Collection Technology

Comparison of the flow between this technology and conventional system is shown in Fig. 1.

Table 1 shows the evaporation temperatures of arsenic and selenium. It is assumed that these substances exist in a gaseous state at the incinerator outlet and do not adhere to incineration ash when the exhaust gas temperature is high (about 800 to 850°C). According to the new technology, a high-temperature cyclone is installed here to collect most (80-85%) of the incineration ash of exhaust gas, which is in a state with less adhesion of arsenic and selenium.

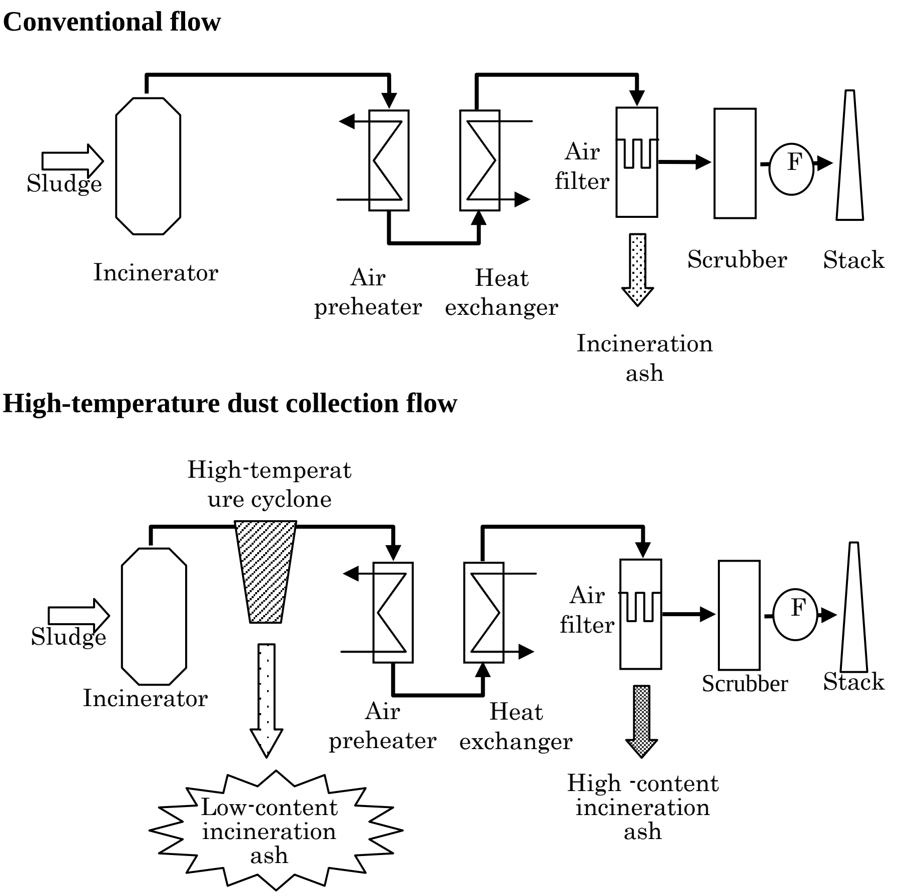


Fig. 1: High-Temperature Dust Collection System Flow

Part of the incineration ash (20 to 15%) that has passed through the high-temperature cyclone is first allowed to have heavy metals volatized in exhaust gas, then collected by an air filter at a moderate temperature (about 200 to 350°C, the temperature level of conventional methods).

Table 1: Arsenic and Selenium Evaporation Temperatures

	Arsenic	Selenium
Evaporation temperature	As:613°C AsO_2:465°C	Se:685°C SeO_2:317°C

The use of high-temperature dust collection technology enables separate recovery of incineration ash with low heavy-metal content (low percentage of leachate) from the high-temperature cyclone and the incineration ash from the air filter with higher heavy metal content.

(2) Outline of the Study

The experimental incinerator incorporating the high-temperature dust collector system was operated at varying dust collection temperatures (incinerator internal temperatures) in the high-temperature cyclone, and the ash recovered from the high-temperature cyclone and the ash from the low-temperature bag filter were analyzed.

In the incinerator experimental facility of S Water Reclamation Center, incineration ash was sampled with a thimble filter from the stack immediately after the incinerator outlet. It was compared with incineration ash collected by the existing dust collector (cyclone + electric dust collector). Table 2 provides an outline of the facility under the study.

Table 2: Outline of Incinerator under Study

		Experimental incinerator	Actual incinerator
Type		fluidized-bed (Bubbling)	Same as left
Maximum treatment capacity		2.4 (t-WET/day)	250(t-WET/day)
Configuration	Sand bed	□400mm	Φ6400mm
	Free board	□600mm	Φ8200mm
	Height	About 7m	About 12m

(3) Study Results

1) Study with the experimental incinerator

The arsenic and selenium content (composition) and the leachate rate under conditions at the varying dust collection temperatures (Condition 1: 780°C, Condition 2: 830°C, Condition 3: 845°C) were compared with the ash from the S Water Reclamation Center ("S ash" in the figure) on the date of sampling of the sludge used in the experiment. They are shown in Figs. 2 and 3. Under both conditions, the arsenic and selenium content in the ash from the high-temperature cyclone was substantially lower than that of the ash from the low-temperature bag filter and that from the S Water Reclamation Center. The effectiveness of the high-temperature dust collection technology was demonstrated.

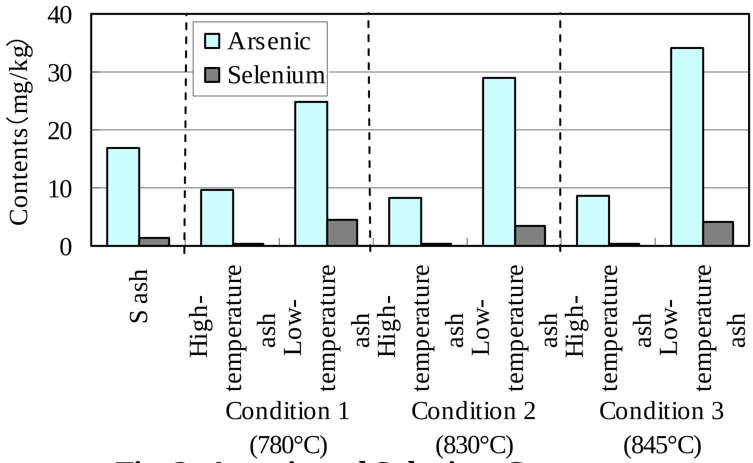


Fig. 2: Arsenic and Selenium Content

Table 3 shows the leachate test results for the ash from the high-temperature cyclone at a dust collection temperature of 845°C. Arsenic, selenium, and other elements proved to be in compliance with the requirements of the Japanese Standard.

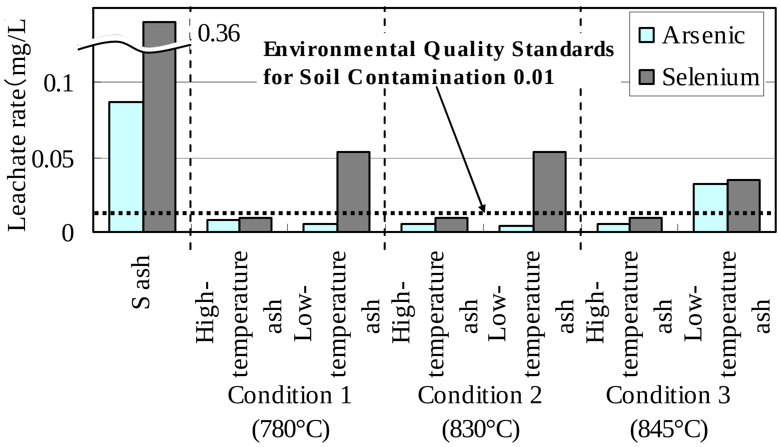


Fig. 3: Arsenic and Selenium Leachate Rate

Table 3: High-Temperature Cyclone Ash Leachate Test Result

Test item	Unit	Leachate test Method based on Ministry of Environment Notice No.46, 1991	Environmental Quality Standards for Soil contamination
		Condition 3 (845 °C)	
As	mg/L	0.005	0.01
Se	mg/L	0.010	0.01
Cd	mg/L	<0.001	0.01
CN	mg/L	<0.01	Not detected
Pb	mg/L	<0.005	0.01
Cr^{6+}	mg/L	<0.01	0.05
T-Hg	mg/L	<0.0002	0.0005
F	mg/L	0.37	0.8
B	mg/L	0.87	1
pH	-	11	-

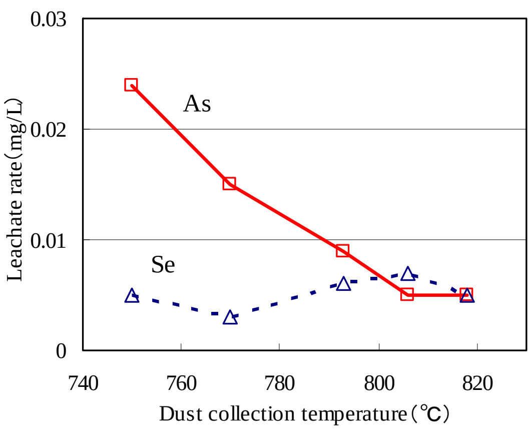


Fig. 4: Dust Collection Temperature and Leachate rate

Fig. 4 shows the relationship between the dust-collection temperature and the arsenic and selenium leachate rates for high-temperature cyclone ash. The arsenic leachate rate decreased with a rise in the dust collection temperature. Higher incinerator internal temperature is known to be effective in the suppression of dinitrogen monoxide exhaust as a greenhouse gas, and is also suggested to be more effective in the suppression of arsenic leachate when using the high-temperature dust collection technology. The selenium leachate is thought to have been sufficiently reduced because of the high-temperature dust collection effect already occurring at the dust collection temperature of 750°C or more. Therefore, no relationship was observed between the dust collection temperature and the selenium leachate rate.

Fig. 5 shows particle size distribution for high-temperature cyclone ash and low-temperature bag filter ash. The high-temperature cyclone does not collect fine incineration ash, which means its particle size is larger than that of the low-temperature bag filter ash. Since fine ash has a large specific surface area and allows ready adhesion of heavy metals, one of reasons the heavy metal leachate rate of high-temperature cyclone ash is lower than that for the low-temperature bag filter is thought to be the effect of particle size distribution.

Accordingly, both ashes were classified according to particle size, and the arsenic leachate rate was analyzed for each ash. The result is shown in Fig. 6.

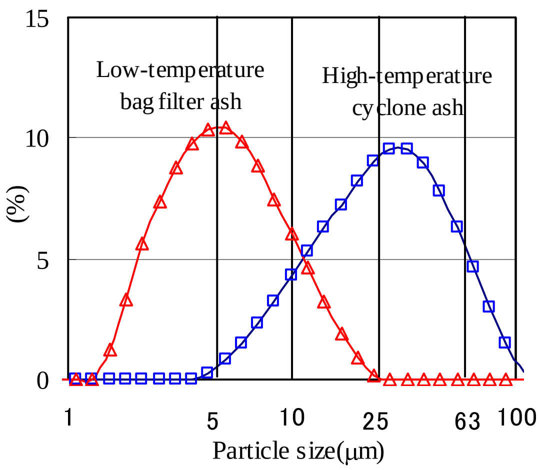


Fig. 5: Incineration Ash Particle

For both ashes, the leachate rate was higher when the particle size was smaller. However, an evident difference could be observed when the leachate rate for the same particle size class was compared for the high-temperature cyclone and low-temperature bag filter ashes. It was therefore confirmed that the effect of high-temperature dust collection on reduction of the arsenic leachate rate is more substantial than the effect of particle size.

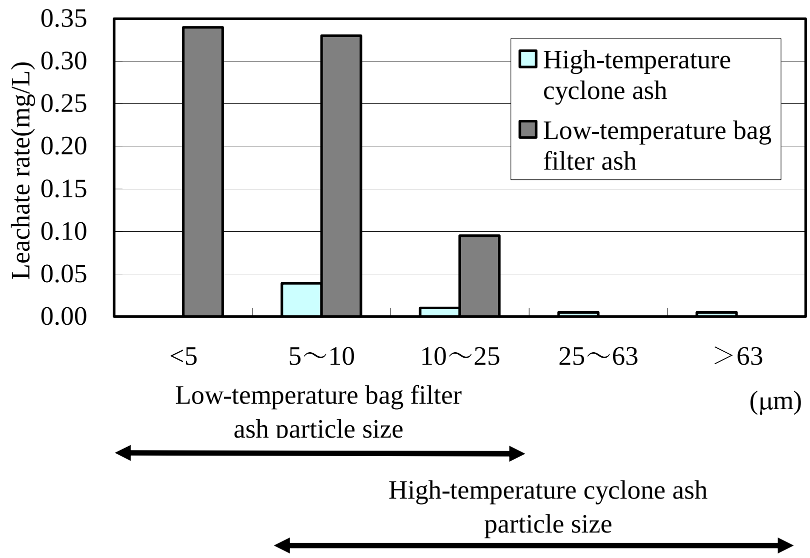


Fig. 6: Arsenic Leachate Rate by Particle Size

Fig. 7 illustrates the similar result obtained for selenium. However, no evident relationship is seen between particle size and leachate rate. It is thought that high-temperature cyclone ash demonstrated a reduced leachate rate in all particle size classes.

Note that low-temperature bag filter ash treated according to the conventional leachate control method (cement addition) meets the land-filling standard based on the Waste Disposal and Public Cleansing Law of Japan. In other words, this ash is confirmed to be safely applicable for land disposal.

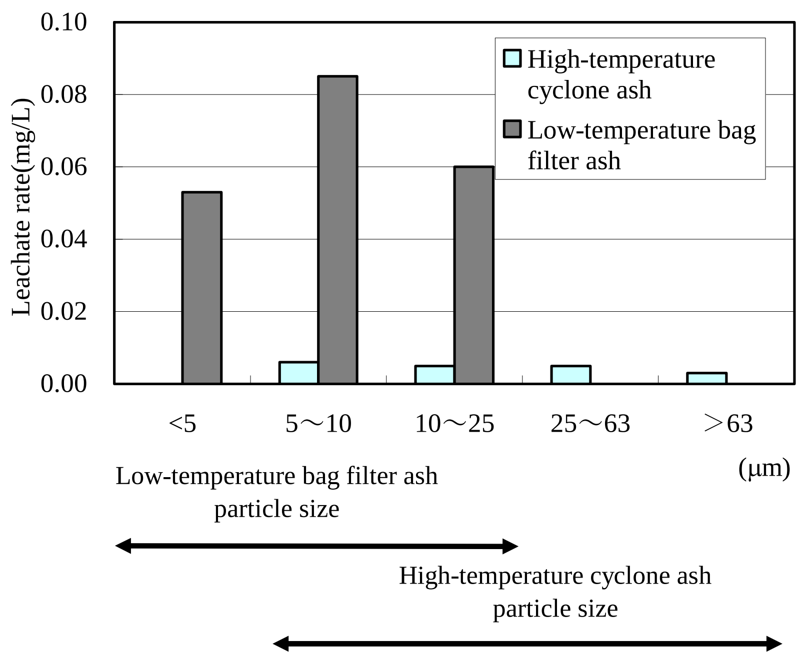


Fig. 7: Selenium Leachate Rate by Particle Size

2) Study with actual facilities

Ash sampled with a thimble filter at the incinerator outlet and that collected with the existing dust collector in the S Water Reclamation Center were compared, as shown in Table 4. When compared with ordinary incineration ash, the former ash demonstrated substantial reductions of arsenic and selenium content and leachate rates. In other words, the high-temperature dust collection technology proved to be effective also in the actual facility.

However, this result indicated that the arsenic leachate exceeded the limits set in the Japanese Standard. This is due to the relationship between particle size and leachate rate described above. It may be considered that, while the high-temperature cyclone cannot collect fine incineration ash with small particle size, collection with the thimble filter is not dependent on the particle size. In other words, inclusion of extremely fine ash may be the factor causing the increase in the arsenic leachate.

Table 4: Study Result with the Actual Incinerator

Test item		Unit	Incinerator outlet ash	Ordinary ash
Content test Method based on Japanese Ministry of Environment Notice No.19, 2003 *	As	mg/kg	14	16
	Se	mg/kg	<0.5	0.6
Leachate test Method based on Japanese Ministry of Environment Notice No.46, 1991	As	mg/L	0.064	0.14
	Se	mg/L	0.002	0.11

* Determination method according to the Soil Contamination Countermeasures Law of Japan

(4) Conclusion

These results of the study confirmed the effectiveness of high-temperature dust collection technology and proved that this technology can recover incineration ash meeting the Japanese Standard without any further treatment. This technology not only promotes utilization in various applications, but also is expected to be used for new purposes, for mixing ash into refilling soil or landfill coverage soil, etc. It is therefore expected to contribute to an improved rate of resource recycling of incineration ash.

CONCLUSION

Three types of heavy metal leachate suppression technologies have been introduced in terms of their mechanism and study results. All of these technologies are intended to meet the Japanese Standard by alleviating the effects of heavy metals that is a factor hindering recycling of incineration ash. Prerequisites for recycling of incineration ash after leachate suppression treatment according to these methods are low costs and expected continuous demand. Since all of these methods involve treatment with a low energy requirement, they have the potential for cost reduction.

Each method has following features:

1. Reagent Addition Method
This treatment involves the addition of small amounts of common reagents and heating at moderately high temperatures of 200° C.

2. Hydrothermal Treating Method
This method produces spheres about 1 mm in diameter. Recycling in which this shape is used is possible.

3. High-Temperature Dust Collection Method
This method can produce incineration ash with low heavy metal content directly.

Industrial applications of these methods that combine the best of their respective features should enable utilization of incineration ash in a wide range of fields.