Source Control Technologies in MSW Incineration Plants

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1. Introduction

The Canadian researchers analyzed fly ash samples including a sample from Kyoto in 1979, and they detected dioxins in these samples [1]. This fact did not attract public concern at that time. In November 1983, R.Tatsukawa *et al.* reported high concentrations of dioxin including 2,3,7,8-T_4CDD in residues from a MSW incineration plant [2]. Since then, public concern on dioxin problems have become very serious. The Ministry of Health and Welfare of Japan organized an expert committee for dioxin problems in May 1984. The expert committee evaluated the risk of dioxins related to MSW incineration as a temporary assessment on the basis of the knowledge available at that time. When the Institute of Public Health of Japan launched the three-year investigation program of dioxins (1982-1984), researches concerning dioxins in Japan were behind the level of the other countries. The Ministry carried out the investigation of the situation from 1984 to 1985. The result was published in 1986 [3]. Moreover, the Ministry launched the five-year study program on dioxins (1985-1989) [4], and the three-year supplementary study program (1990-1992) [5,6,7,8,9]. On the basis of these studies, guidelines for controlling dioxin in MSW treatment were issued by the Ministry in December 1990 [10]. **Table 1** shows the estimated contribution of each dioxin emission source. Although data are presented using rough ranges, the contribution of MSW incineration plants in Japan is larger than that in European countries [11,12], consequently the importance of thermal process and dioxin emission control in MSW incineration plants can be understood. The purpose of this short paper is to summarize the present status of MSW incineration and related dioxin emission control technologies.

2. Status of MSW Incineration in Japan

The total and per capita MSW generation in 1991 were $50,770 \times 10^3$ tons/year and

Table 1 Roughly Estimated Annual Emissions of Dioxin from Some of the Known Sources in Japan (1990)

Source	Emission (g-TEQ/year)
MSW incineration	3100~7400
Incineration of organic chloride waste & waste oil	460
Clinical waste incineration	80~240
Sewage sludge incineration	5
Paper mill sludge incineration	2
Paper mill black liquor boiler	3
Wood & waste wood incineration	0.2
Metal works	250
Cigarette smoke	16
Paper & paperboard	40
Motor vehicles	0.07
Lubrication oil	20

1,118grams/day, respectively [13]. Approximately 73% of total MSW was incinerated as shown in **Table 2**. Moreover, it implies that the amount of MSW incinerated in Japan is more than that in other countries. Under the conditions of limited land area available, high population density, and active industrial activities, reducing the volume of MSW in reliable sanitary way is very important to protect the urban environment from pollution. Furthermore, since Japan is scarce of energy resources, applications of heat recovery from MSW incineration process have been introduced in many plants.

The type of MSW incinerator is classified into four categories; that is, "continuous", "semi-continuous", "mechanical-grate batch" and "fixed-grate batch" type incinerator. Continuous type incinerator is incessantly operated for 24 hours a day. Semi-continuous, mechanical-grate batch and fixed-grate batch type incinerators are operated intermittently. The operation times are 16 hours, 8 hours and 8 hours a day, respectively. **Figure 1** shows the proportions of each type of incinerator [11]. Emissions from MSW incineration plants are regulated to be less than the standards shown in **Table 3**, depending on their capacities. Since there are various pollutants such as dust, hydrogen chloride, sulphur oxide, nitrogen oxide and dioxin, the number of MSW incineration plants equipped with advanced emission control devices is increasing. **Table 4** shows the status of dust collector equipment and acid gas removal equipment in MSW incineration plants in December 1991. The fabric filter equipment to improve dust collection efficiency was installed in over twenty plants. Because of the more stringent requirements of the prefectural standards and the dioxin guidelines than that of the country, the expansion of advanced pollution control technology has caused the substantial reduction of pollutants from the viewpoint of total emissions.

Table 2 Comparison of MSW Incineration (1990/1991)

Country	Amount of waste incinerated (1000ton/year)	Percentage of waste (%) Incinerated	Incinerated with energy recovery	No. of MSW incinerators
Japan	37582	73	20~30	1841
Canada	1100	4	4	13
United States	28900	16	15	152
Austria	300	18	18	2
Denmark	1500	70	70	48
France	6350	40	13	260
Fed. Rep. of Germany*	9300	23	22	49
Italy	2000	10	4	54
Netherlands	2805	46	36	11
Norway	440	23	13	50
Sweden	1550	55	55	22
Switzerland	2300	80	60	48
United Kingdom	2780	10	3	33

Note : * Original and new federal states.
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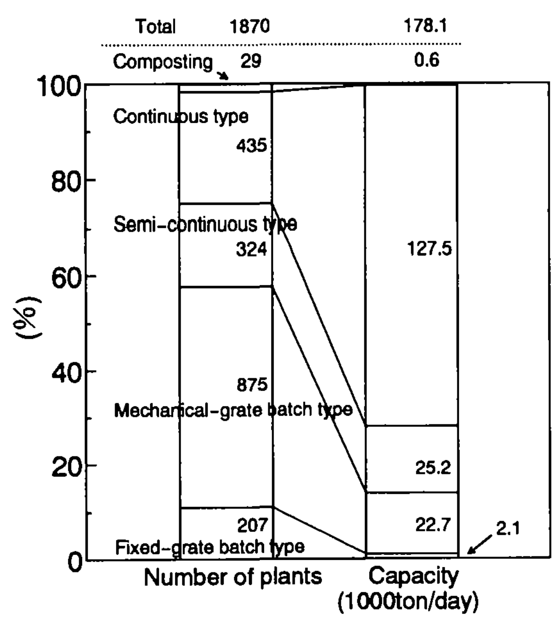

Fig.1 Status of MSW Treatment in Japan (FY1991, including plants under construction)

Table 3 Emission Control Standards for MSW Incineration Plants in Japan

Contaminant	Typical concentrations	National minimum standards	Stringent prefectural standards	Dioxin guidelines	
Dust	1~500	80~500	20~100	20~100	mg/Nm³
HCl	5~400	430 (700 mg/Nm³)	20~200	−	ppm
SOx	5~120	(K value)	−	−	ppm
NOx	25~200	250	50~150	−	ppm
CO	1~2000	−	−	50~200	ppm
Hg	0.02~0.5	−	−	−	mg/Nm³
Cd	0.01~0.5	−	−	−	mg/Nm³
Dioxin	0.1~100	−	−	0.5*	ng-TEQ/Nm³

Notes : 1) Measured emission gas concentrations are corrected to 12% oxygen in the stack gas.
2) * Dioxin concentration in new continuous type MSW incineration plants is expected to be less than 0.5ng/Nm³ under the guidelines.

Table 4 Survey on Exhaust Gas Treatment Facilities in MSW Incineration Plants in Japan (December 1991)

Dust collector equipment (Number of plants)

Type of MSW incinerator	ESP	MC	FF	Spray/Scrubber	Others	Not installed	Total
Continuous	389	6	15	0	0	0	410
Semi-continuous	258	8	3	0	0	0	269
Mechanical-grate batch	325	364	6	76	21	23	815
Fixed-grate batch	3	37	0	52	57	44	193
Total	975	415	24	128	78	67	1687
(%)	(57.8)	(24.6)	(1.4)	(7.6)	(4.6)	(4.0)	(100.0)

Acid gas removal equipment (Number of plants)

Type of MSW incinerator	Dry system	Wet-dry system	Wet system	Others	Not installed	Total
Continuous	201	32	101	14	62	410
Semi-continuous	187	5	10	10	57	269
Mechanical-grate batch	160	2	2	97	554	815
Fixed-grate batch	2	0	0	16	174	193
Total	550	39	113	137	848	1687
(%)	(32.6)	(2.3)	(6.7)	(8.1)	(50.3)	(100.0)

Notes : 1) Data are based on the survey carried out by Japan Waste Research Foundation. Approximately 90% of MSW treatment plants was covered in this survey.
2) ESP : Electrostatic precipitator, MC : Multi-cyclone, FF : Fabric Filter.

3. Control of Dioxin Emission from MSW Incineration Plants

Control technologies for dioxin are categorized into four measures; that is, 1) good combustion practice, 2) rapid cooling of exhaust gas, 3) removal of dioxin in exhaust gas, and 4) dechlorination/destruction of dioxin in fly ash. For the last decade, many practical applications of reducing dioxin emission have reported; for example, good combustion practices [14,15,16], dry or wet/dry scrubber system with a fabric filter [17,18,19], and catalytic decomposition [20,21,22]. In addition to practical applications, we also have presented the experimental results on dioxin emission control at *DIOXIN conference* [23,24,25,26,27,28,29], and here I will show some examples [26,27,29] from our studies. **Figure 2** shows the outline of retrofitted furnace in an existing MSW incinerator for Run 1. The purpose of retrofitting furnace on nose and secondary air nozzle was to improve combustion performance with keeping the nitrogen oxide at the current level. In the Run 2 (**Figure 3**), the incorporation of automatic combustion control and the installation of quenching reactor supplemented to the Run 1 in order to reduce gas temperature passing the electrostatic precipitator. The result of dioxin measurement is summarized in **Figure 4**. Compared to the data prior to retrofitting the furnace (Run 0), the modified furnace successfully reduced the dioxin concentration at the furnace outlet. Simultaneously, the supplemented automatic combustion controller and quenching reactor also controlled the formation of dioxin and related precursors in the electrostatic precipitator. For the pilot plant equipped with a fabric filter shown in **Figure 5**, we compared a fabric filter to an electrostatic precipitator. The result of PCDDs in the exhaust gas is shown in **Figure 6**. The concentrations of PCDDs in the exhaust gas between the gas/air heat exchanger and the electrostatic precipitator increased because of taking much time to pass through equipment around 300℃, and PCDDs removed at the fabric filter with the efficiency of over 97%. **Figure 7** shows the schematic diagram of the pilot plant of catalytic decomposition experiment. The results of the decomposition ratio of PCDDs and the reduction of nitrogen oxide using the same dioxin decomposition catalyst are shown in **Figure 8** and **Figure 9**, respectively. **Figure 8** indicates PCDDs were reduced with the decomposition ratio higher than 99% by properly selecting the space velocity, the artificial velocity and the temperature. Moreover, **Figure 9** indicated the reduction of nitrogen oxide could be simultaneously achieved using the same dioxin decomposition catalyst.

The effectiveness of practical control methods to reduce dioxin emission is shown in **Figure 10**. This rough estimation was carried out on the proceedings presented at the annual conferences of the Japan Society of Waste Management Experts and the Japan Waste Management Association [30,31]. The summarization includes lots of uncertainties due to insufficient data on full-scale testing. First of all, we have to consider complete combustion referred as the 3-Ts (Level 1 in **Figure 10**); that is, 1) high combustion temperature (Temperature), 2) sufficient gas retention time (Time), and 3) complete mixing of gas with secondary air (Turbulence). In addition to steady operation, start-up, burn-out and shut-down are important operation conditions for the plants operated intermittently such as semi-continuous type, mechanical-grate batch type and fixed-grate batch type incinerators. Second step is to operate a dust collector at a lower temperature than 300℃

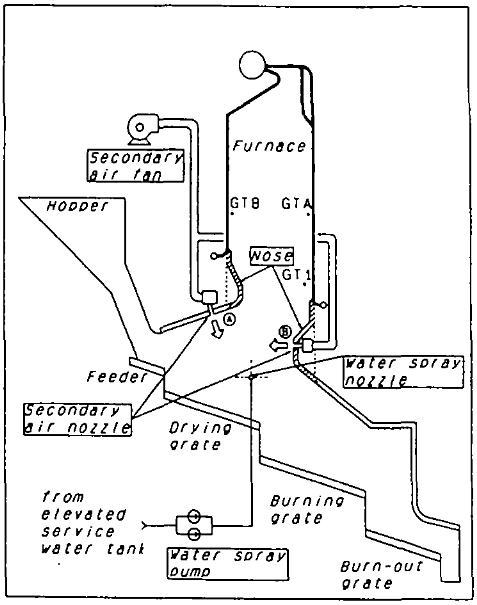

Fig.2 Outline of Retrofitting for Run 1

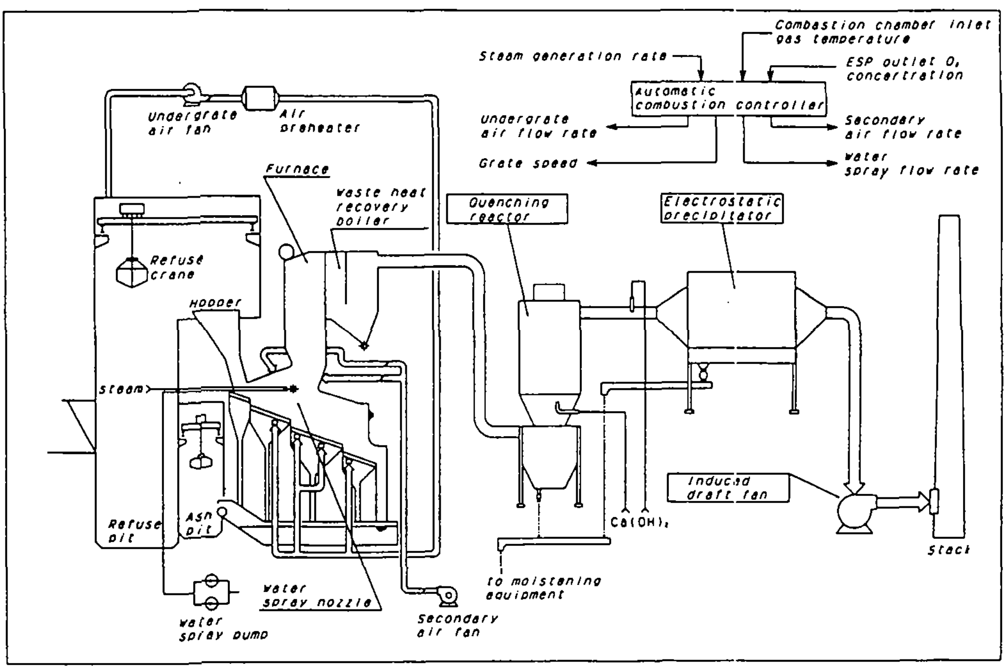

Fig.3 Outline of Retrofitting for Run 2

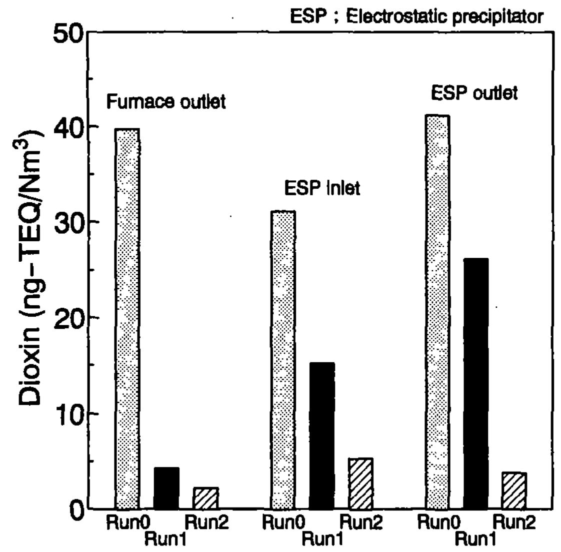

Fig.4 Dioxin in the Exhaust Gas (retrofitting of an existing plant)

(Level 2 in **Figure 10**). It is well known that dioxin are most favorably formed from precursors with fly ash in an oxidative atmosphere at around 300℃ by catalytic reaction. The temperature range of approximately 300℃ has been conventional in electrostatic precipitators. Injection of adsorbents before a dust collector, and installation of an adsorption tower [32,33] or a catalyst reactor after a dust collector as an advanced technology have been developed in order to assure lower dioxin emission (Level 3 in **Figure 10**). However, because it is necessary for adsorption technologies to treat or reactivate used adsorbents containing much dioxin and heavy metals, further investigations of adsorption technologies need to be studied. Moreover, catalyst technologies have insufficient field experiences to be evaluated in respect of a stable decomposition performance.

The Ministry of Health and Welfare organized an experts committee in September 1990, and the guidelines were published for controlling dioxin in MSW treatment in December 1990 [10]. **Table 5** shows the summary content of the guidelines for new and existing facilities according to the types of MSW incinerator. The countermeasures pointed out in the guidelines are 1) to practice good combustion, 2) to operate a dust collector at a lower temperature than 200℃ for new plants or 250℃ for existing plants, and 3) to improve dust collection efficiency in exhaust gas processing. In addition, we assumed 1) 75% of existing plants will be reconstructed step by step within 15 years, 2) 25% of existing plants will be retrofitted (one tenth reduction), and 3) operation conditions of all existing plants will be improved (one third reduction). **Figure 11** shows the estimated cut-down of dioxin emission from MSW incineration plants under the guidelines and the assumptions. As a result of the estimation, dioxin emission from MSW incineration plants throughout Japan is

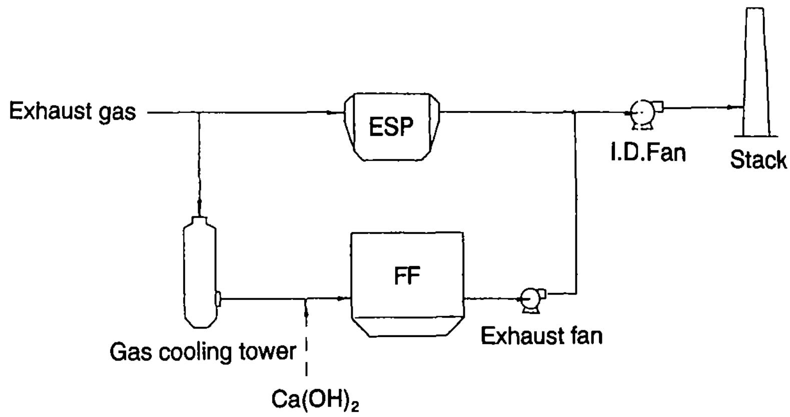

Fig.5 Schematic Diagram of the Pilot Plant (comparison of dust collector efficiency)

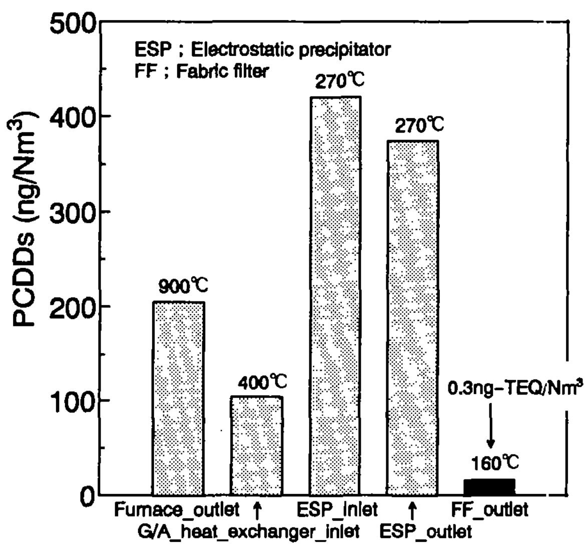

Fig.6 PCDDs in the Exhaust Gas (comparison of dust collector efficiency)

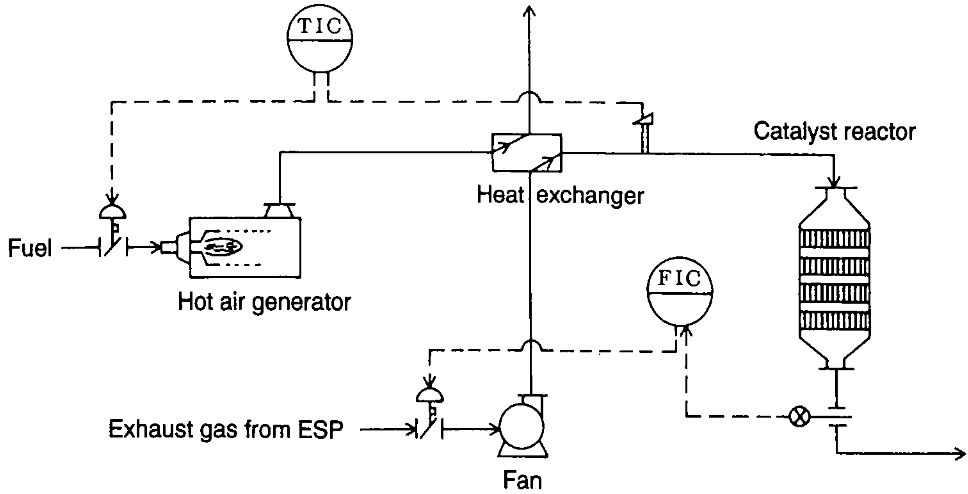

Fig.7 Schematic Diagram of the Pilot Plant (catalytic decomposition)

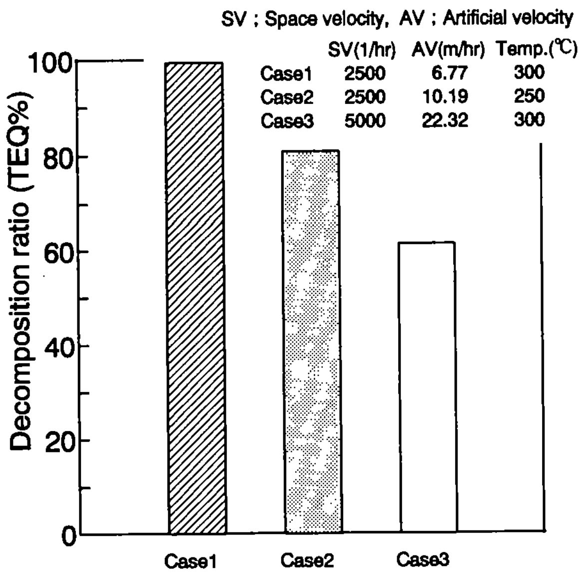

Fig.8 PCDDs Decomposition by Catalytic Oxidation

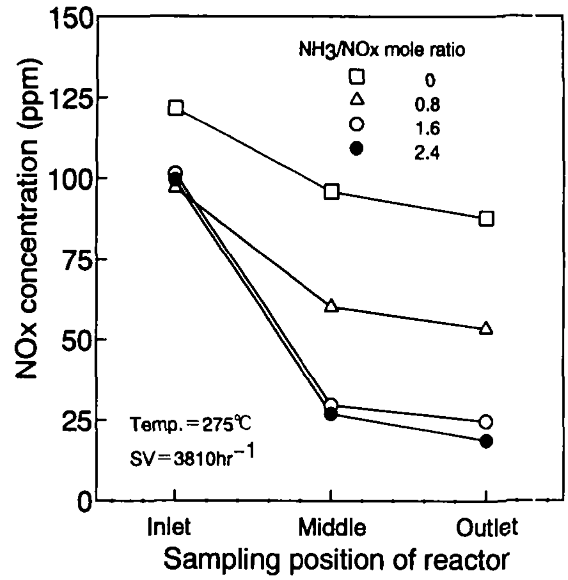

Fig.9 NOx Reduction by Catalyst

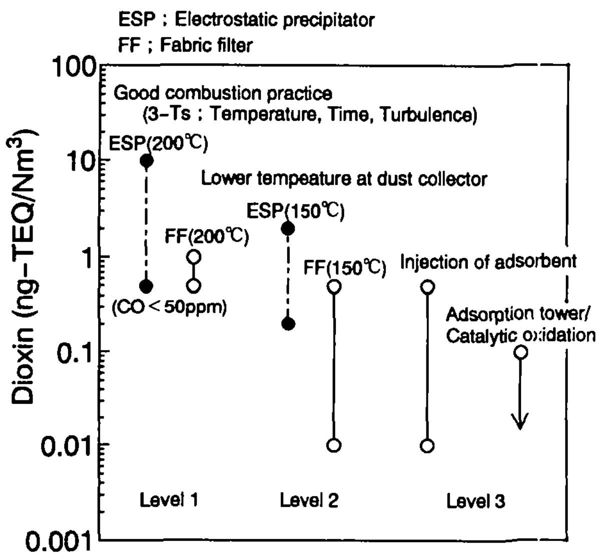

Fig.10 Dioxin Control in MSW Incineration Plants

Table 5 Guidelines for Controlling Dioxin Emission from MSW Incineration Plants in Japan (December 1990)

Parameter	Type of MSW incinerator					
	Continuous		Semi-continuous and Mechanical-grate batch		Fixed-grate batch	
	New	Existing	New	Existing	New	Existing
Carbon monoxide concentration at stack outlet (ppm)	<50	<100	<100	<200	<200	<400
Combustion temperature (℃)	>800	>800	>800	>800	>800	>800
Retention time (sec)	>2* >1*	– –	>1	–	>1	–
Oxygen concentration at furnace outlet (%)	>6	>6	>6	>6	>6	>6
Temperature at dust collector inlet (℃)	<200**	<250	<200	<250	<200	<250
Dioxin (ng-TEQ/Nm³)	<0.5***	–	–	–	–	–

Notes : 1) Carbon monoxide concentration is an average of 4-hour concentration corrected to 12% oxygen in stack gas.
2) * 2sec. for the full boiler type and 1sec. for other types of gas cooling.
3) ** It could be 230 ℃ if carbon monoxide concentration was less than 30ppm and using deNOx catalyst.
4) *** Dioxin concentration in new continuous type MSW incineration plants is expected to be less than 0.5ng-TEQ/Nm³ under the guidelines.

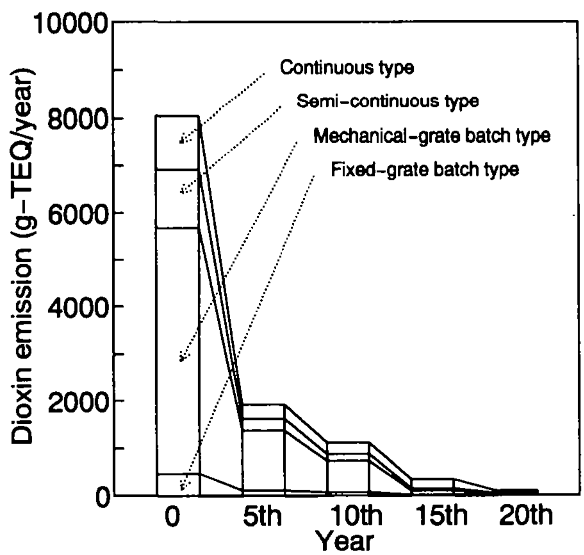

Fig.11 Cut-down of Dioxin Emission from MSW Incineration Plants in Japan

expected to decrease below one tenth of the current level. **Figures 12, 13** and **14** show the types of dust collector equipment installed for MSW incineration plants according to their capacities after the guidelines issued. In these figures, data were plotted in the order of time at which plants were starting operation. The installation of fabric filter equipment as a countermeasure of dioxin emission, instead of an electrostatic precipitator, has been gradually extended. **Figures 15, 16** and **17** show whether these plants were designed based on the guidelines for new plants or not. Since plant construction needs time, most of the plants starting operation in 1994 were designed based on the guidelines for new plants. **Table 6** shows some of dioxin emission data from MSW incineration plants which were designed based on the guidelines for new plants. Lower dioxin concentrations to 0.5ng-TEQ/Nm^3 in new continuous type MSW incineration plants were obtained in most of these plants.

Table 6 Dioxin Emission Data from MSW Incineration Plants which were Designed Based on the Guidelines for New Plants

Type of MSW Incinerator	Emission (ng-TEQ/Nm^3)
Continuous	0.002～0.04
Continuous	<0.05～0.11
Continuous	0.11
Continuous	0.12～0.19
Continuous	0.12～0.40
Continuous	0.45
Continuous	0.48
Continuous	0.78
Semi-continuous	0.06～0.27
Semi-continuous	1.74
Semi-continuous	2.3～8.6
Mechanical-grate batch	0.14
Mechanical-grate batch	1.0

4. Conclusion

Many considerable efforts were directed toward reducing dioxin emission, and applications of emission control technologies have been spread as mentioned above. Fly ash generated from MSW incineration contains more dioxin and heavy metals than stack emissions. Therefore, it would be more important to manage fly ash carefully.

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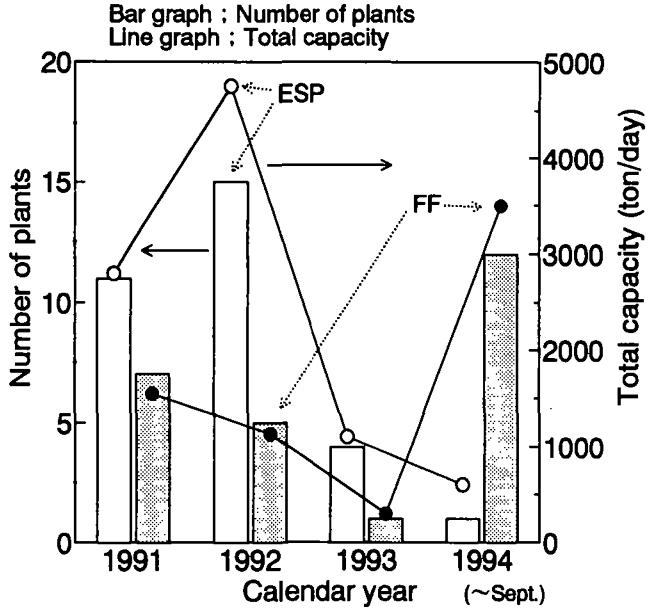

Fig.12 Types of Dust Collector Equipment for Continuous Type MSW Incineration Plants

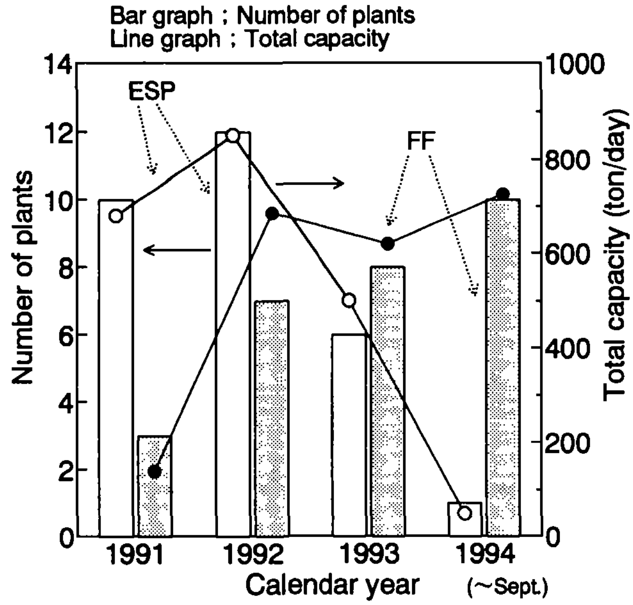

Fig.13 Types of Dust Collector Equipment for Semi-Continuous Type MSW Incineration Plants

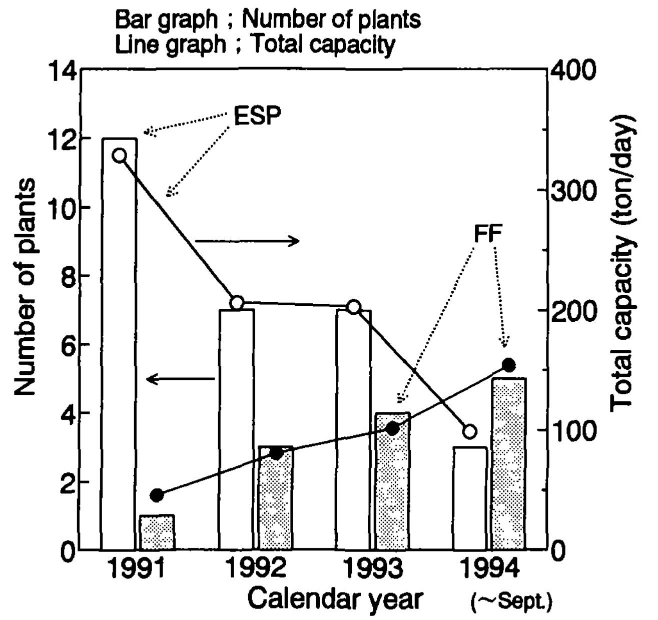

Fig.14 Types of Dust Collector Equipment for Mechanical-Grate Batch Type MSW Incineration Plants

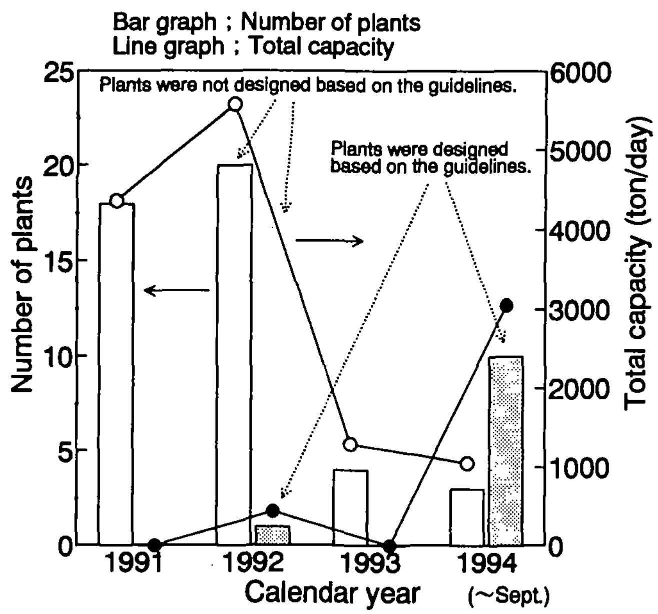

Fig.15 Dioxin Control in Continuous Type MSW Incineration Plants

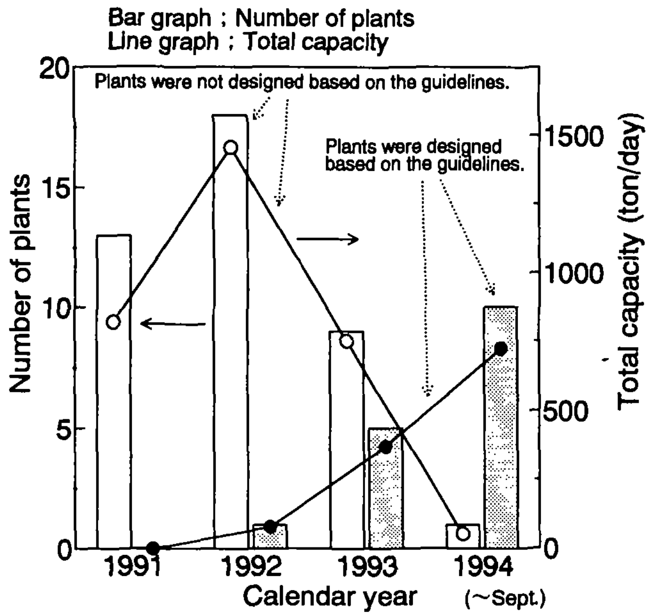

Fig.16 Dioxin Control in Semi-Continuous Type MSW Incineration Plants

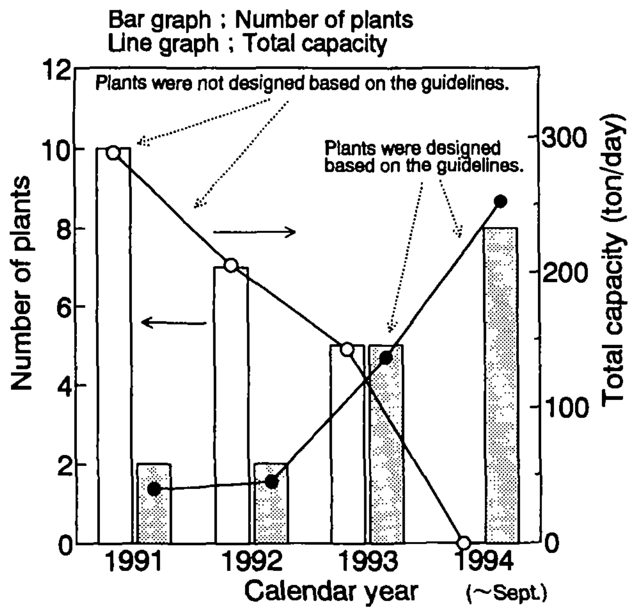

Fig.17 Dioxin Control in Mechanical-Grate Batch Type MSW Incineration Plants

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