# Dioxin Emission Behavior in MSW Incinerator Designed after Guidelines for Controlling Dioxin

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## 1. Introduction

In 1990, Japan's Ministry of Health & Welfare issued "A Guideline For Controlling Dioxin". It elaborates the methods of maintaining the commonly accepted factors called three T (3-T). This is the theory that the reduction of dioxin formation is possible when the 3-T's, the residence Time of exhaust gas at high temperatures, Turbulence of the mixture of unburned gas and air, and high Temperature of exhaust gas, are controlled adequately.

Since 1994, a number of MSW incinerators designed with dioxin-reduction measures was built. This paper describes our findings in comparing emission behaviors of furnaces before and after dioxin reduction, with emphasis on the 3-T's. It also reports specifically on the behavior of dioxin from the furnaces after the improvement.

## 2. The Effect of Dioxin-Reduction Measures

We present an example of dioxin reduction at Plant A that has been modified by relocating the secondary air injection port. Table 1 shows the plant outline, and Figure 1 shows the exhaust gas flow. Figure 2 displays the dioxin emission concentration at each sampling point before and after the improvement. Table 2 lists the data of 3-T's.

Table 1 Outline of Modified Plant A

| | | | | |
|---|---|---|---|---|
| Type of Incinerator | Batch Type (16 hour/day operation) | | | |
| Gas Cooling Method | Water Spray | | | |
| Incineration Capacity | 65 ton/day | | | |
| Fuel Heat Value | 2,100~2,400kcal/kg | | | |
| Sampling points | ① | ② | ③ | ④ |
| Gas Temperature(℃) | 340 | 300 | 190 | 175 |

At first, CO was quite high at 424ppm, and while TEQ data at water spray exit was not collected then, it was presumed to be equal or higher than that at QC exit, 33.1ng/Nm$^3$.

We relocated the secondary air nozzle so that the unburnt gas within the furnace would mix effectively with the secondary combustion air. After adjusting the opera-

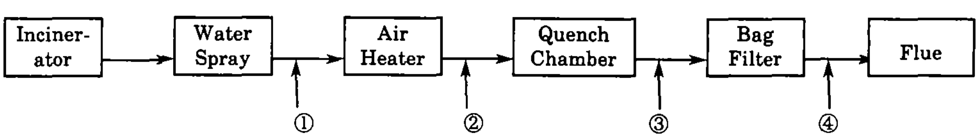


Figure 1 Exhaust Gas Flow Sheet

ting conditions, secondary air injection was increased from 6,600 $m^3N/h$ to $10{,}200 m^3N/h$, which lowered the gas temperature at furnace exit from 980℃ to 842℃.
CO was reduced from 424ppm to 43.4ppm due to the turbulent mixing of combustion gas. TEQ was lowered at QC exit from 33.1 to $6.1 ng/m^3N$, even though out of the 3-T's, residence time and gas temperature did go down as a result of this relocation.
From this, we can safely assume that turbulent mixture of combustion gas within air-rich atmosphere is more effective than the other two T's for reducing dioxin.

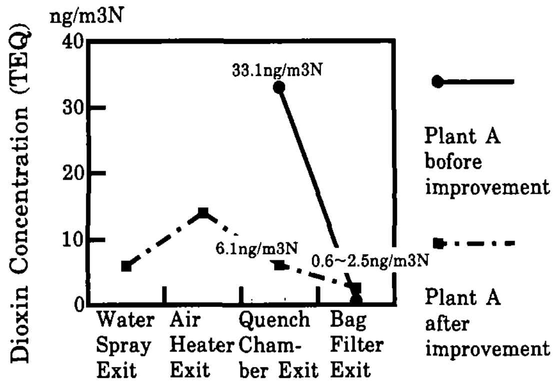


Figure2 Dioxin Emission Behavior at Each Sampling Point

Table 2 3-T's Data

| | Plant A before improvement | Plant A after improvement | Guideline |
|---|---|---|---|
| Exhaust gas Residence Time | 1.8sec | 1.6sec | ≧1sec |
| Exhaust Gas Temperature at Furnace Exit | 980℃ | 842℃ | ≧800℃ |
| CO corrected to 12% $O_2$ | 424ppm | 43.4ppm | ≦100ppm |

3. Dioxin Behavior at Dioxin-Reduced Furnaces

We report on the behavior of dioxin emission at the incinerators which were built according to the guideline. Table 3 lists the outline of four such plants, and Figure 3 displays the two types of exhaust gas flow in such plants.
Plant B and C are water sprayed, while Plant D and E are equipped with boilers. Designed residence times are 1 second for B & C, and 2 seconds for D and E. Design fuel heat value is approximately 3,000kcaℓ/kg for all plants whereas actual value at tests were around 2,300kal/kg. Load factors for B, C and D were at their design capacity, while Plant E operated at 110% load.
Figure 4 shows dioxin emission concentration at each sampling point of plants B, C, D & E. Table 4 lists data according to the 3-T's factors.

Table 3 Outline of Each Plant

| | Plant B | | | | Plant C | | | | Plant D | | | | Plant E | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Incinerator | Continuous | | | | Continuous | | | | Continuous | | | | Continuous | | | |
| Gas Cooling | Water Spray | | | | Water Spray | | | | Boiler | | | | Boiler | | | |
| Capacity | 120ton/day | | | | 120ton/day | | | | 55ton/day | | | | 300ton/day | | | |
| Refuse Heat Value | 2,100~2,200 kcal/kg | | | | 2,200~2,300 kcal/kg | | | | 2,300~2,400 kcal/kg | | | | 2,200~2,400 kcal/kg | | | |
| Sampling Point | ① | ② | ③ | ④ | ① | ② | ③ | ④ | ① | ② | ③ | | ① | ② | ③ | |
| Exhaust Gas Temperature(℃) | 467 | 276 | 166 | 159 | 418 | 209 | 175 | 162 | 291 | 253 | 165 | | 314 | 236 | 207 | |

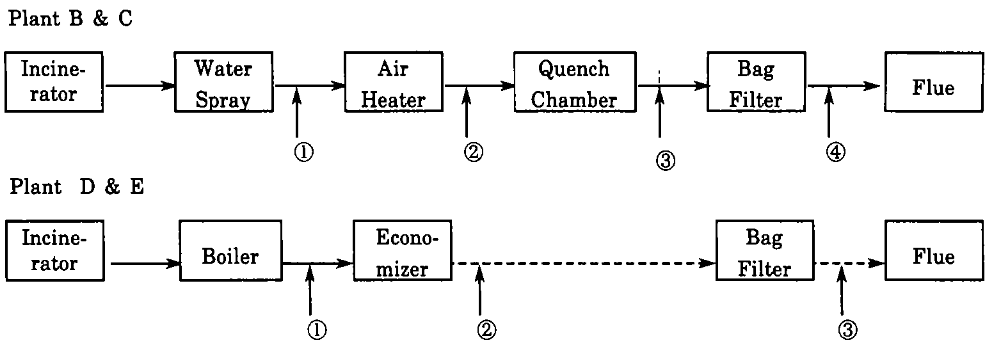


Figure 3 Exhaust Gas Flow Sheet

We would have sampled at the furnace exit, if it were not for the lopsided flow of gas there that prevented collection of reliable data. We therefore chose to use those from water spray exit and boiler exit. We saw TEQ became higher as CO concentration climbed, regardless of gas cooling methods - water spray or boiler. Both Plant B and C use water spray. At Plant C where low CO level and longer residence time were maintained for the complete destruction of dioxin. Little synthesis was seen when the exhaust gas was chilled. The water spray furnaces are designed with one second residence time of hot exhaust, followed by sudden chilling by the water spray. Cooling gas with boilers is designed with two seconds residence time, and the gas will be kept at relatively high temperatures even in the secondary combustion chambers.

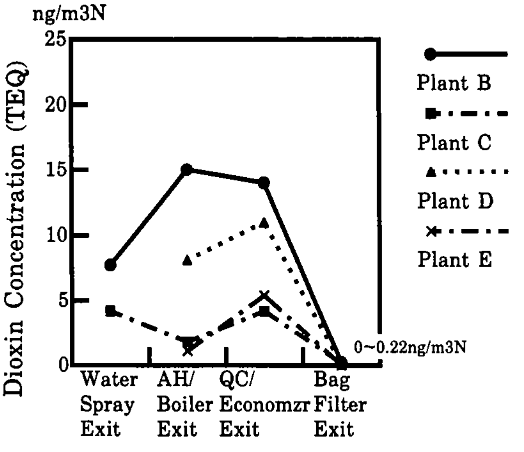


Figure 4 Dioxin Emission Behavior at Each Sampling Point

From the above observations, we can assume that incineration plants with boilers work effectively toward destruction of dioxin even though the gas takes longer to go through the critical temperature range (500℃~300℃) for its formation. As demonstrated by the results, we have proven with the working furnaces that TEQ can be reduced by keeping the CO low, and adhering to the 3-T's conditions.

Table 4 3-T's Data

| | Plant B | Plant C | Plant D | Plant E | Guideline |
|---|---|---|---|---|---|
| Operation | Continuous | Continuous | Continuous | Continuous | – |
| Residence Time | 1sec | 1.5sec | 2.0sec | 2.8sec | ≧1 sec or 2 sec |
| Gas Temperature at Furnace Exit | 844℃ | 950℃ | 850℃ | 958℃ | ≧800℃ |
| CO average corrected to 12%$O_2$ | 45ppm | 6ppm | 50ppm | 14ppm | ≦50ppm |
| NOx average corrected to 12%$O_2$ | 94ppm | 118ppm | 120~140ppm | 70~90ppm with non-catalytic NOx reduction | – |

4. Dioxin Behavior at the Air Heater

Figure 5 shows the behavior of dioxin at the air heater inlet and exit of water spray plants. This behavior is commonly associated with the average value of CO concentration, but the test results this time do not reveal definitive tendency of dioxin to increase along with the rise in CO concentration. It does not encourage a simple explanation. One theory might explain this phenomenon as Memory Effect. Plant B, while it is a continuous furnace, shuts down once a week. Furnaces F and G operate 16 hours a day, and go through startup and shutdown every day. We have already reported[1] that high dioxin concentrations are generated at startup and shutdown. It is possible that in furnaces B, F and G, such high dioxin concentrations may have remained in the air heater, and migrated into the exhaust gas stream during the normal operation of the furnace. We would pursue this matter in the future.

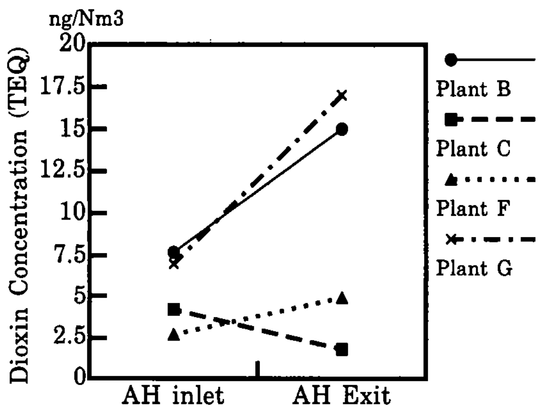


Figure 5 Behavior of Dioxin at AH

| Plant | B | C | F | G |
|---|---|---|---|---|
| CO Average corrected to 12% $O_2$ | 45ppm | 6ppm | 45ppm | 26ppm |
| Operation | 24h/day | 24h/day | 16h/day | 16h/day |

5. Coplanar PCB

Figure 6 illustrates the ratio of coplanar PCB in the TEQ. The sample was exhaust gas, and the sampling points were water spray exit, air heater exit, quench chamber exit and bag filter exit. The ratio of coplanar PCB was small, generally in the 1.5~3.5% range. It can be seen, though, that whenever dioxin were produced, a certain amount of coplanar PCB was still present.

We did not have a large enough number of samples to make a firm statement, but it appears that as TEQ goes up, the coplanar PCB ratio seems to go up somewhat. We would like to find out what causes this in our future study. Figure 7 shows that there is a pattern in the relationship between the dioxin and coplanar PCB. From this, we can assume that while reducing dioxin, we can cut down coplanar PCB simultaneously. Incidentally, we have used toxicity equivalency index suggested by Ahlborg[2] for calculating TEQ of coplanar PCB.

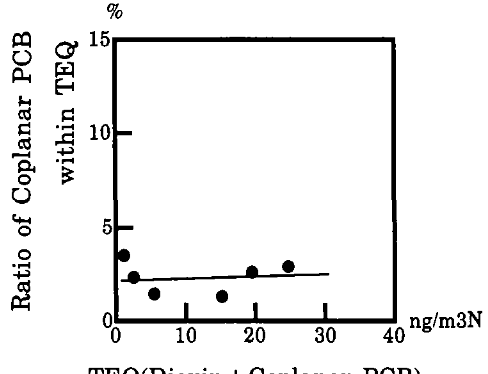


Figure 6 Ratio of Coplanar PCB in the TEQ

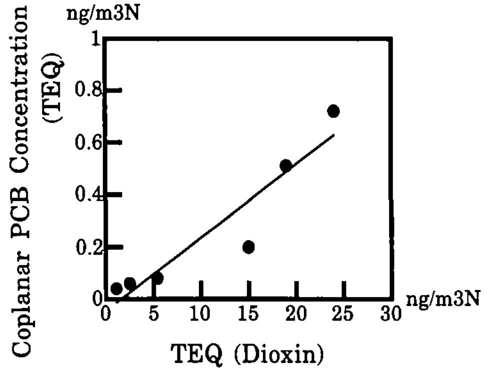


Figure 7 Relationship between Dioxin and Coplanar PCB

6. Conclusion

① For reducing dioxin, turbulent mixture of exhaust gas within an air-rich environment is most essential among the so called 3-T's.

② With dioxin-reduced furnaces, the guideline target of 0.5ng/m$^3$N at bag filter exit is attainable by maintaining low CO concentration and adhering to the 3-T's. With the same CO concentration, boiler-equipped furnace will achieve lower TEQ than those with water spray.

③ The ratio of coplanar PCB within TEQ is generally 1.5~3.5%, contributing little toxicity. Also, the behavior of coplanar PCB is similar to that of dioxin, thus the efforts of reducing dioxin directly help to lower the coplanar PCB concentration at the same time.

References:

1)Tejima.H: Full-scale Plant Study on Reduction of Dioxin Emission of Batch Operation Type MSW Incineration Plant, DIOXIN'93, Vol.12, p45-48(1993)

2)Ahlborg U. G., G.C.Becking, L.S.Birnbaum, A.Brouwer, H.J.G.M.Derks, M.Feely, G.Golor, A.Hanberg, J.C.Larsen, A.K.D.Liem, S.H.Safe, C.Schlatter, F.Wærn, M.Younes and E.Yrjänheikki(1994): Toxic equivalency factors for dioxin-like PCBs. Chemosphere 28, 1049-1067