IMPACT OF DIOXINS EMITED FROM FIRE OF A WASTE TREATMENT FACILITY ON THE ENVIRONMENT AND CROPS

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Abstract
Dioxin concentrations in the environmental samples and crops were measured to evaluate the impact of dioxins emitted from a fire of a waste treatment facility. Dioxins were detected from the atmosphere, water, sediment, crop and soil samples around the facility. However, dioxins emitted from the fire could not affect human health and the environment. Waters in channel and river which drainage of the facility flowed into were contaminated with dioxins of 3800 pg-TEQ/L at the maximum. The high level of contamination could be derived from overflowed water for extinguishing fires. Dioxin emission from the facility during the fire was estimated by using the plume model and the puff model. The maximum ground-level concentrations during the flames of the fire raged furiously were 32 pg-TEQ/Nm^3 (source height of 10 m) and 3.8 pg-TEQ/Nm^3 (source height of 25 m).

Introduction
Generations and emissions of dioxins from burning of domestic wastes[1], municipal solid waste[2], landfills[3] and chemicals[4], have been reported. Therefore, fires including forest fires[5] and domestic fires[6] are sources of dioxins. In September 2007, a fire broke out in a waste treatment facility in Japan. About 10 t of wastes including plastic wastes could be burned down during the fire, and generated dioxins were emitted around the facility. To evaluate the impact of the fire on the surrounding area, the atmosphere, water, sediment, crop and soil were sampled and measured for dioxins. Moreover, dioxin emission from the facility during the fire was estimated by using the plume model and the puff model. In this report, we describe the outline of the investigation including dioxin concentrations in the samples and the estimated diffusion of dioxins with the maximum ground-level concentrations.

Materials and Methods
A fire broke out in a waste treatment facility at midnight of September 5, 2006. The facility located in Kitakami, Iwate, Japan. The facility had an incinerator with a throughput capacity of 101.6 t/day. The flames raged furiously during 2:21 a.m. through 9:25 on September 5. The fire was extinguished toward 2:55 p.m. on September 6. About 10 t of wastes including plastic wastes could be burned down.

Air samples were collected at eight sites around the facility during September 5 to 22. A sample was collected for a week using a middle-volume air sampler and 19 samples were collected for 24 hours using high-volume samplers. Water samples were collected at 12 sites from channels and rivers which drainage of the facility flowed into. The samples were collected during September 6 through 29. Sediments were also sampled at eight sites at the channels and the rivers as well as a grease trap tank of the facility during September 8 to 29. Groundwaters were collected at 11 sites during September 20 and October 2. Forty-two crops, three grasses and a rice straw were sampled around the facility during September 11 to 15. Seventeen kinds of crops, including

Table 1. Summary of dioxin concentrations in samples.

	Atmosphere (pg-TEQ/m^3)	Water* (pg-TEQ/L)	Sediment** (pg-TEQ/g)	Groundwater (pg-TEQ/L)	Crop (pg-TEQ/g)	Grass and straw (pg-TEQ/g)	Soil (pg-TEQ/g)
Number of sites	8	12	9	11	28	3	45
Number of samples	20	36	21	11	42	4	45
Min	0.0067	0.045	0.20	0.069	0	0.19	0.19
Max	0.25	3800	3600	0.070	0.11	0.34	130
Median	0.063	2.1	11	0.069	0.00030	0.255	11

* Channel and river water. **Channel and river sediments; including four samples from a grease trap tank of the facility.

tomato, cabbage, corn, cucumber, leek, eggplant, soybean and rice, were collected. Surface soils were sampled at 45 sites around the facility during September 8 to 15.

PCDD and PCDF congeners, tetra- through octachlorodibenzo-*p*-dioxins and tetra- through octachloro-dibenzofurans, and dioxin-like PCBs, tetra- through heptachlorinated- biphenyls, in the samples were determined using standard methods (JIS K 0312:2005, manuals on determination of dioxins, Ministry of the Environment, Japan, and Provisional Guideline on Determination of Dioxins and Coplanar PCBs in Food, Ministry of Health and Welfare, Japan).

Dioxin emission from the facility during the fire was estimated by using the plume model and the puff model. Maximum ground-level concentrations of dioxins were simulated using the source height of 10 m and 25 m. The plume model and the puff model were used to calculate the atmospheric diffusion of dioxins on windy conditions and breeze and calm conditions, respectively.

Results and Discussion

Dioxin concentrations in samples are summarized in Table 1. Although dioxins were detected from all atmospheric samples at the range from 0.0067 to 0.25 pg-TEQ/m^3, no sample exceeded the Japanese environmental quality standard for dioxins (0.6 pg-TEQ/m^3). This could reflect that no sample was collected during the strong force of the fire. The maximum concentration (0.25 pg-TEQ/m^3) in the atmosphere was detected at site A4 during 7 p.m. on September 6 to 7 p.m. on September 7; the fire was already extinguished at the period. Variations of dioxin concentrations in the atmosphere from five sampling sites are given in Figure 1. The concentrations at sites A6 and A8 were at the maximum during the fire, whereas those at the other sites were at the maximum after extinguishing. Dioxin concentrations in the atmosphere from Kitakami City were 0.019 to 0.050 pg-TEQ/m^3 (0.027 pg-TEQ/m^3 in arithmetic mean) in FY2004 and 0.026 to 0.032 pg-TEQ/m^3 (0.022 pg-TEQ/m^3 in arithmetic mean) in FY2005[6]. Therefore, the concentrations at sites A4, A5, A6 and A8 on September 22 were decreased to the levels not exceeding the reported values. In contrast, that at site A7, 0.11 pg-TEQ/m^3, was four to five times higher than the arithmetic mean reported. Thereby, it appears that dioxins at the site generated from another sources. Consequently, the

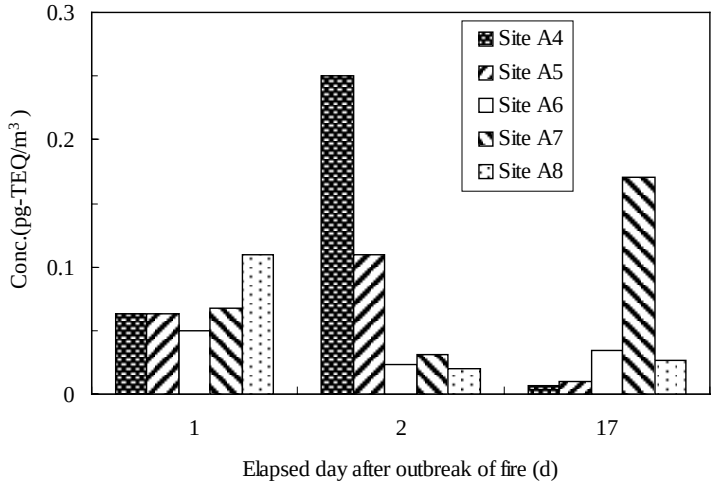

Figure 1. Dioxin concentrations in the atmosphere.

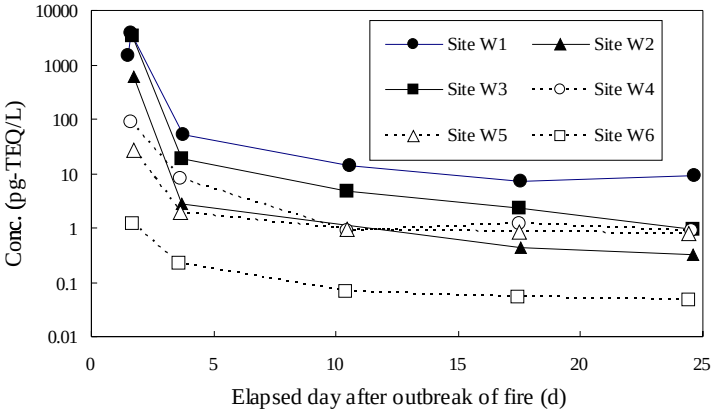

Figure 2. Dioxin concentrations in waters *vs*. elapsed time after the outbreak of the fire.

atmospheric dioxins emitted from the fire could not affect human health and the environment.

Variations of dioxins in channel/river waters with the elapsed time after the outbreak of the fire are shown in Figure 2. The maximum concentration (3800 pg-TEQ/L) of water sample was observed at 3 p.m. on September 6 at site W1 where drainage of the facility flowed. Almost the same level (3500 pg-TEQ/L) was also observed at 3:50 p.m. on the same day at site W3 apart 900 m from site W1. The high level of contamination could be derived from overflowed water for extinguishing fires. Although dioxin concentration at site W1 exceeded the Japanese environmental quality standard for dioxins (1 pg-TEQ/L) on 24 days after the outbreak of the fire, the concentrations at the other sites were decreased to below the standard value. Moreover, dioxin concentrations at site W6 located at the downstream of site W1 were below the standard value except the value of 1.2 pg-TEQ/L obtained immediately after the fire was extinguished. Therefore, the dioxins emitted from the fire to river could not affect human health and water environment. Variations of dioxins in channel/river waters with the distance from the drainage of the facility are shown in Figure 3. The dioxin concentrations almost decreased with the distance from the drainage. Regarding growndwater samples, dioxin concentration at each investigated site was below the environmental quality standard as shown in Table 1.

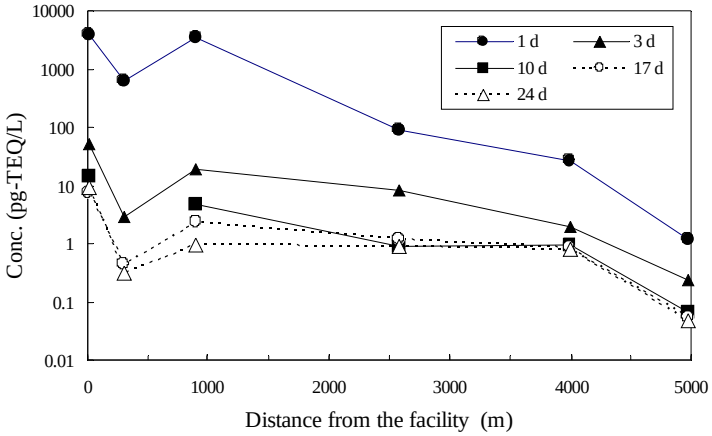

Figure 3. Dioxin concentrations in waters *vs*. distance from the drainage of the facility.

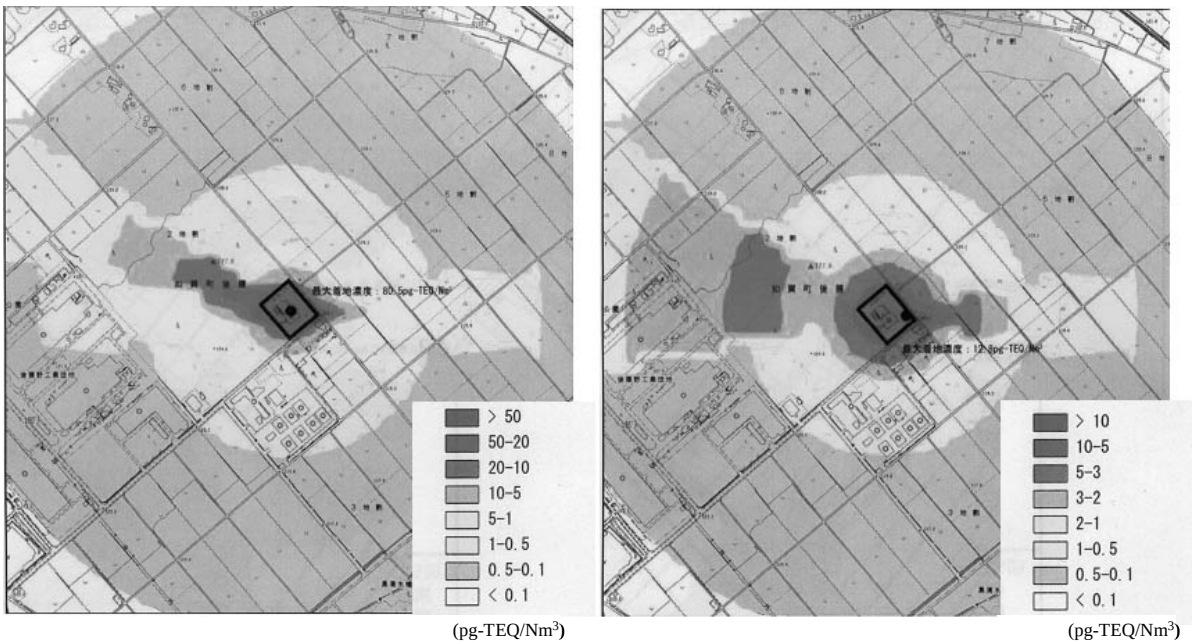

Figure 4. Simulated ground-level dioxin concentrations around the waste treatment facility during 2 to 7 hours after the outbreak of fire. Solid circle indicates the site at the maximum ground-level concentration. Maximum ground-level concentrations were simulated as 80 pg-TEQ/Nm^3 using the source height of 10 m (left) and 13 pg-TEQ/Nm^3 using the source height of 25 m (right).

From the sediment samples, dioxins were detected at the range from 0.2 to 3600 pg-TEQ/g (Table 1). The maximum concentration was observed at site W3. Sediments from the grease trap tank of the facility contained 200 – 790 pg-TEQ/g dioxins. Dioxin concentrations from the other sites were below the Japanese environmental quality standard for dioxins (150 pg-TEQ/g) for sediment.

Dioxins were detected from 25 crop samples out of 42 samples at the range from 0.00002 to 0.11 pg-TEQ/g. These values were comparable to those of Japanese crops reported by the Ministry of Health, Labour and Welfare of Japan[7]. Consequently, these crops would not affect human health. The maximum dioxins detected from a dentcorn sample, whereas no dioxin detected from eggplant, soybean and rice samples. On the other hand, dioxins of 0.19 - 0.34 pg-TEQ/g were detected from grasses and a rice straw. The values were rather higher than those of crops. Therefore, they seems to be caused by deposits of airborne dioxins generated by the fire.

Dioxin concentrations in soil were ranged from 0.19 to 130 pg-TEQ/g. It is remarkable that dioxin concentrations were below the Japanese environmental quality standard for dioxins (1,000pg-TEQ/g) for soil. Dioxin concentrations in the soils from Iwate prefecture were reported as 0 to 7.7 pg-TEQ/g in FY2003 through FY2005 [G]. The dioxin concentrations of 26 soils were higher than 7.7 pg-TEQ/g (9.0 - 130 pg-TEQ/g). However, the impact of dioxins emitted from the fire on the soils could not be evaluated. Additional investigation is required to conclude exactly the origins of dioxins in the sites.

Ground-level concentrations of dioxins around the facility were calculated. Figure 4 shows calculated concentration contour maps giving the highest values of the maximum ground-level concentration. The highest values were obtained under the calculation during 2 to 7 hours after the outbreak of fire as 80 and 13 pg-TEQ/Nm^3, using the source height of 10 m and 25 m, respectively. The points at the highest values were located in the facility site. The maximum ground-level concentrations during the flames of the fire raged furiously (19 hours) were calculated as 32 pg-TEQ/Nm^3 (source height of 10 m) and 3.8 pg-TEQ/Nm^3 (source height of 25 m); the former were located at 180 m southeast of the facility site, whereas the latter at 80 m west of the site. Dioxin intake (DI) at the highest point during the 19 hours was estimated by the following equation:

$$DI = C \times V / W$$

where C is the maximum ground-level concentration (32 pg-TEQ/Nm^3), V is the respiratory volume (15 m^3/day) and W is the weight (50 kg). DI was calculated as 7.6 pg-TEQ/kg. This value was higher than the tolerable daily intake (4 pg-TEQ/kg/day) provided as the intake of dioxins that can be taken daily over a lifetime without appreciable health risk. However, the calculated intake was temporally one only during the fire. Therefore, it is distinct that the intake did not affect human health on the chronic toxicity. Although the acute toxicity of dioxin has not been seen frequently, the acute toxicity value of dioxins is estimated at several 10^5 pg-TEQ/kg level[7]. Therefore, the intake also did not affect human health on the acute toxicity.

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