VERIFICATION OF CLOSED SYSTEM DISPOSAL FACILITIES BASED ON SURVEY DATA

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SUMMARY: We conducted investigations at actual Closed System Disposal Facilities (CSDFs) to evaluate their internal working environment (stench, dust, temperature and humidity, inflammable gases, oxygen deficiency, etc.), stabilization of waste, and water balance. Concerning working environment, the inflammable gases and the odor levels were relatively low, but countermeasures against the dust generation during waste dumping and the temperature in summertime are necessary. Artificial water spray is effective for waste stabilization, but the decreasing rate in organic matter like TOC in leachate tended to be late compared with that in the inorganic matter like Cl^-. The water balance in a CSDF revealed that quantity of leachate was smaller than that of water sprayed, in the summertime. The leachate coefficient (the ratio of the leachate quantity to the water sprayed quantity) has good correlate with the internal temperature and internal humidity.

1. INTRODUCTION

Applications of Closed System Disposal Facility (CSDF) to general waste disposal facilities have been increasing from the aspects of a small amount of leachate. The CSDF is a waste disposal facility that is covered up with covertures such as an artificial floor slab, a roof, and a tent, and is concealed from the external conditions.

Though CSDF is not affected by rainwater and does not cause groundwater contamination, there are problems related to air quality such as stench and harmful and inflammable gases and dust arising in the working environment of the facilities. Concerns have been raised regarding the impact of these environmental measures on the surroundings. Furthermore, disaster-prevention measures in the closed space and stabilization of the landfilled wastes also have to be investigated.

We conducted investigations at actual CSDFs to evaluate their internal working environments (stench, dust, temperature and humidity, inflammable gases, oxygen deficiency, etc.) , stabilization of waste, and water balance in order to study these issues.

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2.SURVEYED DISPOSAL FACILITIES

A general outlines of the three actual CSDFs surveyed (Masugatayama disposal facility, Thanks BB, and Green City, Yamanaka) are listed in Table 1.

3. RESULTS OF THE SURVEY

3.1 Temperature within the facilities

At CSDFs, since the waste carrying-in entrances are shut, except at the time of carrying in these wastes and dumping, the facility is usually sealed. Since the temperature within the facilities can be influenced by the external temperature and can exceed the temperature defined by the working environment rules (i.e., below 37°C), the internal temperature may have a huge impact on the working environment and landfilled wastes. Due to these reasons, we measured the internal temperatures (continuous and periodic measurements).

Table 1 Outline of Disposal Facilities

	Masugatayama Disposal Facility	Thanks BB(Yamagata-village)	Green City Yamanaka
Biginning of operation	Aug-98	Apr-98	Apr-01
Roof structure	Membrane Skeleton	Steel flam constraction and folded plate	Steel flam constraction and folded plate
Landfill area	952m^2	800m^2	2,300m^2
Lndfill capacity	7,100m^3	2,660m^3	13,500m^3
Landfilled waste	Shredded incombustible waste	Incineration residue, Shredded incombustible waste	Incineration residue, Shredded incombustible waste
Ventilation equipment	Ventilation fan	Roof fan,louver	Ventilation fan,louver
Sprinkle equipment	Sprinkler	—	Nozzle

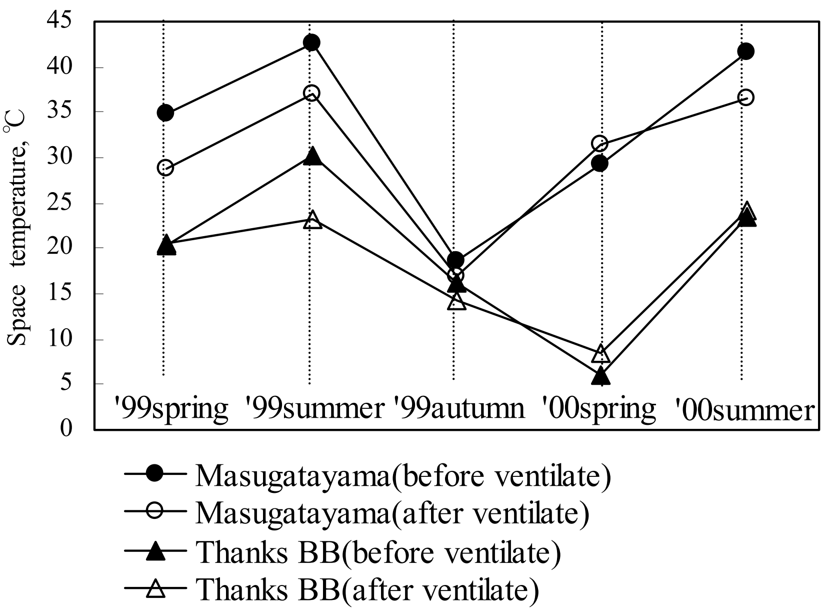

Figure 1. Effects of ventilation on space temperature.

Figure 1 shows the results obtained at the Masugatayama disposal facility and Thanks BB, respectively. At the Masugatayama disposal facility, though the internal temperature in summer exceeded the working environment limit of 37°C, when sealed (before ventilation), operation of a big ventilation fan at 37°C reduced the internal temperature to 35°C. In contrast, the internal temperatures in a sealed condition during summer at Thanks BB, were approximately 30°C before ventilation, and were reduced to the similar temperatures to the external temperatures after ventilation.

The difference in the internal temperatures in sealed conditions at both the facilities can probably be attributed to the fact that the Masugatayama disposal facility, which is completely sealed, has a system by which the big fan starts to operate only when the internal temperature exceeds over 37°C. On the other hand, Thanks BB is equipped with ventilating windows around the facilities; therefore, natural ventilation occurred.

3.2 Dust generation and its countermeasures

We studied dust generation and its countermeasures during waste dumping. At the Masugatayama disposal facility, an experiment was performed under four conditions as follows: a) Shredded incombustible waste without moisture (intact). b) Shredded incombustible waste prepared for moisture. c) Spraying water at the waste entrance during dumping shredded incombustible waste without moisture. d) Spraying water throughout the surface of waste layer before dumping shredded incombustible waste without moisture. The experimental results have been indicated in Table 2.

The amount of dust generated by dumping shredded incombustible waste prepared for moisture (condition b) and that with spraying water at the entrance(condition c) was less in comparison with the untreated one (condition a) that generated more dust. Further, lesser dust generation was possible when water was sprayed all over the surface of waste layer (condition d).

At Thanks BB, dust generation was investigated when wastes such as raw bottom ash, fly ash, and shredded incombustible waste with or without moisture control were put in directly from a dump truck. The bottom ash with a higher moisture content resulted in less dust generation. On the other hand, fly ash generated relatively little dust because of the chemical treatments. Meanwhile, we observed that shredded incombustible waste without moisture control could not reduce dust generation, as seen in the case of the Masugatayama disposal facility.

Table 2 Dumping condition and dust generation at Masugatayama disposal facility and Thanks BB

Field	Dumping condition		Water content (%)	Total amount of dust (mg/m^3)		Dumping amount
				Near dumping spot	Waste surface	
Masugatayama (Shredded incombustible waste)	Waste without moisture		0.4	2.20	3.60	about 2ton
	Waste with moisture		12.4	0.86	1.90	about 2ton
	Spraying at waste entrance		0.9	0.66	0.99	about 2ton
	Spraying throughout the surface of waste		2.8	0.42	0.62	about 2ton
Thanks BB	Bottom ash		25.3	0.09	0.03	about 2ton
	Fly ash		13.6	0.47	0.32	about 2ton
	Shredded incombustible	Without moisture	0.1	3.83	0.82	about 2ton
		With moisture	3.1	0.10	0.12	about 1ton

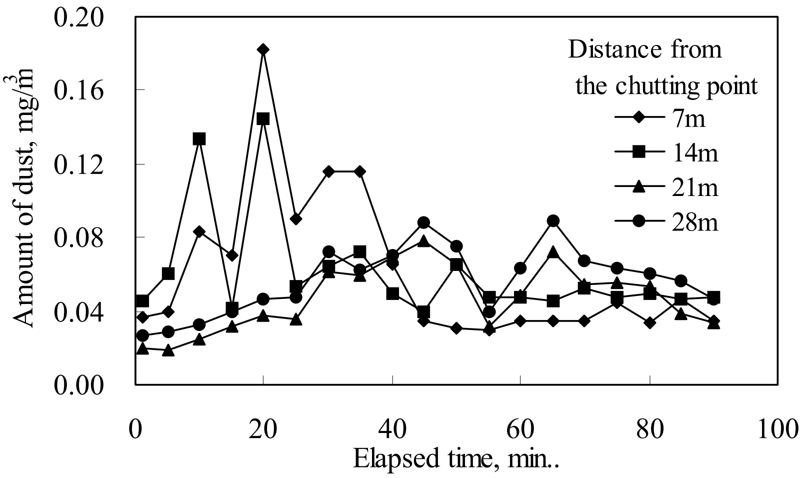

Figure 2. Relationship between distance from chutting point and dust diffusion

At Green City, Yamanaka, we measured the status of dust diffusion using the digital dust meters (LD-1, Sibata Scientific Technology Ltd.) on throwing the shredded incombustible wastes through a vertical chute. Results of dust concentrations at a distance of 7, 14, 21, and 28 m apart from the chute are indicated in Figure 2. At a point further from the chutting point, we assumed that dust concentration became high with an increase in elapsed time, and more time was required to decrease the concentration. We also ensured that dust is suspended along the fringe of the facilities. The results suggest that spraying water along the suspending route is necessary to reduce dust generation of smaller (lighter) particles.

3.3 Generated gases and stench

Gases and the stench generated from landfilled wastes were measured with time using detectors for inflammable and harmful gases (GOMHC-3A, Gastech. Corp. and XPO-317, New Cosmo Electric Co., Ltd.), gas detector tubes, and an odor sensor (XP-329, New Cosmo Electric Co., Ltd.).

3.3.1 Inflammable gases and oxygen deficiency

Gases generated from the landfilled waste, such as methane and hydrogen, were measured at regular intervals in the facilities. Their concentrations were too low to be detected with the inflammable and harmful gas detector. Oxygen concentration in the facilities was at the same level as that in the ambient air. Therefore, it did not pose a problem.

3.3.2 Malodorous substances and odor concentration

It has been confirmed that the malodorous substances from the incinerated ash were mainly ammonia and trimethylamine, and the malodorous substance from the shredded incombustible waste was acetaldehyde, which is derived from alcoholysis.

Infinitesimal amounts of ammonia, trimethylamine, and acetaldehyde were detected at both the Masugatayama disposal facility and Thanks BB facilities as shown in Table 3. Other substances such as toluene, stylene, and xylene were also detected, but their concentrations were quite low in the detectable limits and were observed irregularly. On the other hand, at Green City,

Table 3. Malodorous densities at Masugatayama disposal facility, Thanks BB and Green City Yamanaka

Malodorous substance	unit	Masugatayama			Thanks BB			Green City Yamanaka	Standard
		08/31/99	07/24/00	08/28/02	09/01/99	07/25/00	08/30/02	11/13/03	
ammonia	ppm	<0.1	0.1	<0.1	<0.1	0.4	<0.2	<0.1	1～5
methylmercaptan	ppm	<0.001	-	-	<0.001	-	-	-	0.002 ～ 0.001
hydrogen sulfide	ppm	<0.002	-	-	<0.002	-	-	-	0.02 ～ 0.2
methyl sulfide	ppm	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.001	0.01 ～ 0.2
methyl disulfide	ppm	<0.001	-	-	<0.001	-	-	-	0.009 ～ 0.1
trimethylamine	ppm	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.005 ～ 0.07
acetaldehyde	ppm	<0.005	0.16	0.017	0.007	<0.01	<0.01	<0.01	0.05 ～ 0.5
propionaldehyde	ppm	<0.003	-	-	<0.003	-	-	-	0.05 ～ 0.5
n-butylaldehyde	ppm	<0.003	-	-	<0.003	-	-	-	0.009 ～ 0.08
isobutylaldehyde	ppm	<0.003	-	-	<0.003	-	-	-	0.02 ～ 0.2
n-valeraldehyde	ppm	<0.002	-	-	<0.002	-	-	-	0.009 ～ 0.05
isovaleraldehyde	ppm	<0.002	-	-	<0.002	-	-	-	0.003 ～ 0.01
isobutanol	ppm	<0.01	-	-	<0.01	-	-	-	0.9 ～ 20
ethyl acetate	ppm	<0.01	-	-	<0.01	-	-	-	3 ～ 20
methylisobutylketone	ppm	<0.01	-	-	<0.01	-	-	-	1 ～ 6
toluene	ppm	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.05	10 ～ 60
styrene	ppm	0.03	<0.01	0.01	<0.01	<0.01	<0.01	<0.05	0.4 ～ 2
xylene	ppm	0.10	<0.01	<0.02	<0.01	<0.01	<0.01	<0.05	1 ～ 5
propionic acid	ppm	<0.003	-	-	<0.003	-	-	-	0.03 ～ 0.2
n-butyric acid	ppm	<0.0005	-	-	<0.0005	-	-	-	0.001 ～ 0.006
n-valeric acid	ppm	<0.0005	-	-	<0.0005	-	-	-	0.0009 ～ 0.004
isovaleric acid	ppm	<0.0005	-	-	<0.0005	-	-	-	0.001 ～ 0.01
odor concentration	-	73	130	41	19	<10	<10	13	-

Yamanaka,such substances were not detected at all due to the still smaller amount of landfilled waste. The observations support the fact that even though malodorous substances were sometimes detected in infinitesimal quantities, there was no problem of a stench.

3.3.3 Changes with time of stench

Figure 3 shows the values obtained with the odor sensor at ThanksBB, where waste landfilling is advancing more in comparison with that in other facilities. The results suggest that more the landfilling advances the stronger the stench becomes in the upper and bottom parts. Furthermore, the decrease in the internal space in addition to the increase in the amount of wastes that generate the stench influences about this.

3.4 Characteristics of landfilled wastes

3.4.1 Temperature of the waste layer

The temperature of the waste layers was measured by placing thermo sensors in the layers. Figure 4 shows differences in the layer temperatures caused by differences in the type of landfilled waste and the landfill conditions at Green City, Yamanaka. The types of wastes and the presence of air supply are apparently attributed to the difference in the layer temperatures, although these temperatures are affected by the internal temperature within the facilities because of a small amount of wastes and placement of the sensor in shallow layer positions.

Thus, higher temperatures can be obtained with bottom ash and shredded incombustible wastes containing organic matters in comparison with fly ash. In particular, the layer temperatures decrease with a reduction in the internal temperature of the facilities during winters, but the reduction of the shredded incombustible waste is small. With regards to bottom ash, the

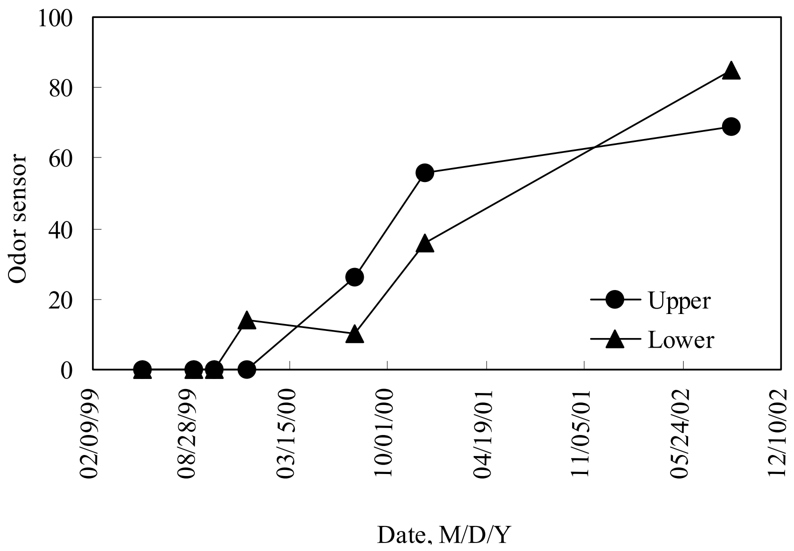

Figure 3. Changes with time of stench obtained with odor sensor

temperatures in the areas with or without air supply differ between 2°C to 3°C, whereas higher temperatures are recorded in the case of rich air. Therefore, we conclude that the artificial air supply contributes to the promotion of degradation.

3.4.2 Elution test for landfilled wastes

The elution tests were performed with the collected wastes at each depth at three points in the Masugatayama disposal facility and at two points in Thanks BB. Figure 5 and Table 4 indicate the results of the elution test. As for the water spray, 5 m^3 a day of water was sprayed daily at the Masugatayama disposal facility, while no water was sprayed at Thanks BB.

The concentration of Cl^- changed in all the layers between 10–20 mg/l at the Masugatayama disposal facility, indicating that most of it had been washed out. On the other hand, at Thanks BB, the concentration of Cl^- was 1000–2500 mg/l at No. 1, and 7000–10000 in the upper layer and 2000–6000 in the bottom layer at No. 2. The results vary widely; however, little change is observed because of absence of a water spray.

TOC concentrations at the Masugatayama disposal facility are as follows: approximately 20 mg/l at No. 2 and No. 3, 50 mg/l in the upper layer, and 75 mg/l in the bottom at No. 1. At No. 1, TOC seems to remain in the bottom layer because the washing and degradation have not occurred as thoroughly as that in the Cl^- case. The TOC concentration ranges between 30–150 mg/l at Thanks BB, indicating the same trend as Cl^-; however, a phenomenon such as biodegradation was not observed.

As far as T-N is concerned, the concentration varies between 2–4 mg/l at the Masugatayama disposal facility and the result provides a possibility of a fairly advancing degradation.

Table 4. Concentration of landfilled waste by elution test

Material	Masugatayama disposal facility	Thanks BB	
	Shredded incombustible waste	Shredded incombustible waste	Bottom ash
Cl^-(mg/l)	256	198	3095
TOC(mg/l)	106	93	85

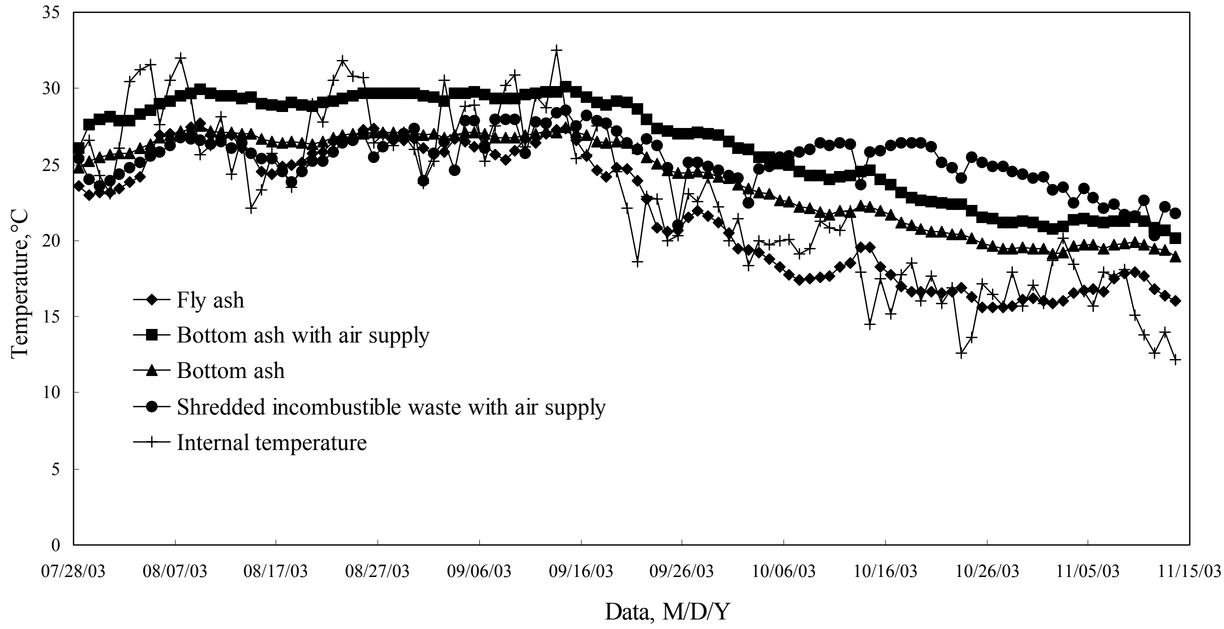

Figure 4. Comparison between waste temperature and landfilled waste

Meanwhile, at Thanks BB, widely dispersed concentrations of 3–18 mg/l were obtained. The concentrations in this case seem to be higher than the initial values and a biodegradation process has not been observed.

As described above, water spray can washout the pollutants and promote to degrade them in a biological process at the Masugatayama disposal facility; however, at Thanks BB, both these processes have hardly progressed in the absence of a water spray.

3.5 The spraying water quantity and the leachate quantity

In order to grasp relationship between the spraying water quantity and the leachate quantity, we installed a flowmeter in the Masugatayama disposal facility and measured cumulative flow quantity.

We computed the monthly leachate coefficient for 5 months from May to September by the following equation and the results are shown in Table 5. As for the leachate coefficient, you can see the tendency which summertime becomes small.

The monthly leachate coefficient C = the monthly leachate quantity / the sprayed water quantity

Also, relationship between the monthly leachate coefficient and the monthly average of the internal temperature and the monthly average of internal humidity is shown in the Figure 6. The higher the internal temperature is and the lower the internal humidity is, the smaller the leachate coefficient becomes.

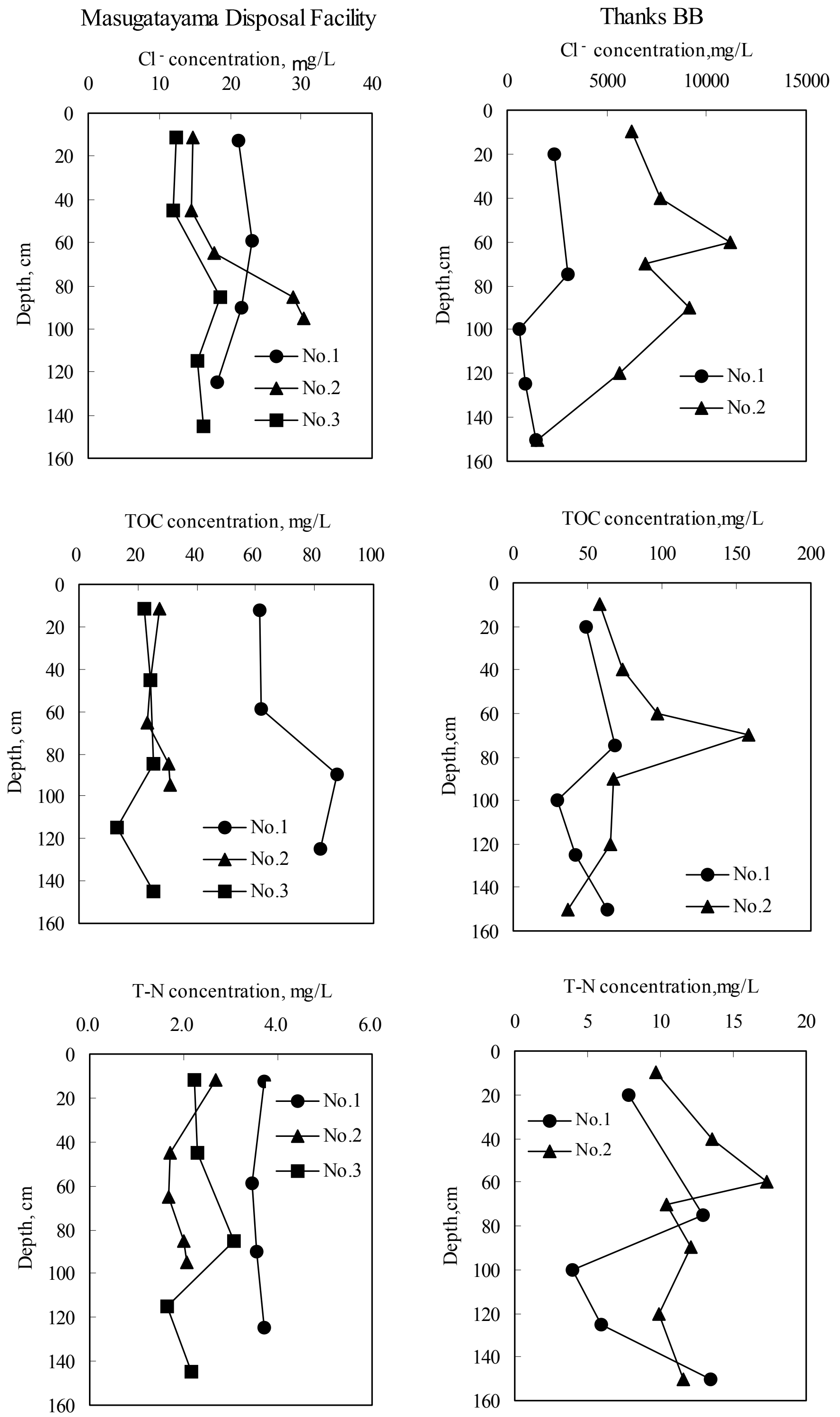

Figure 5. Concentration by elution test on landfilled waste in each depth

The main factors which influence on the evaporation are temperature, humidity, sunlight quantity, and wind velocity. In the CSDF, because a landfill is covered with roof, it is thought the influence of the sunlight and the wind is small. Therefore, we did a regression analysis of the monthly leachate coefficient C on the monthly average temperature t and the monthly average humidity h, and examined correlation. Results are shown in Table 6.

Table 5. Monthly leachate coefficiennt, temperature, and humidity

Month	May	June	July	August	October
Leachate coefficient	1.00	0.86	0.77	0.44	0.67
Temperature(°C)	19.6	23.9	28.3	27.2	24.6
Humidity(%)	78.2	75.5	75.3	71.2	79.6

Table 6. Results of regresion analysis

	explanatory variable,x	dependent variable,y	multiple coefficient, R
Simple regression analysisi	Tenperature,t	Leachate coeficient,C	0.393
Simple regression analysisi	Humidity,h	Leachate coeficient,C	0.524
Multiple regression analysisi	Tenperature,t Humidity,h	Leachate coeficient,C	0.760

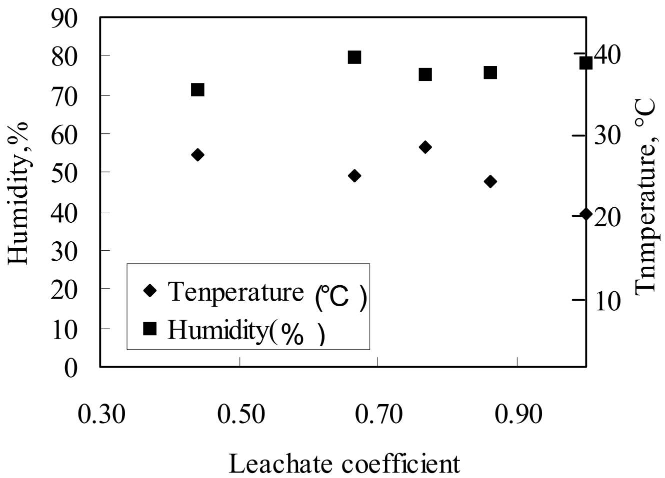

Figure 6. Relationship between leachate coefficient and temperature, humidity

As for the correlation with the leachate coefficient, the humidity is higher than the temperature. Moreover, a correlation of the leachate coefficient with the temperature and the humidity becomes high.

As a result of the multiple regression analysis, the following equation was gotten in Masugatayama disposal facility.

$$C = 0.113 - 0.034t + 0.019h(19.6 \le t \le 28.3, 71.2 \le h \le 79.6)$$

4. SOIL TANK EXPERIMENT

A large experimental soil tank was conducted at the Masugatayama disposal facility, and we examined both the pollutant outflow from the waste, and the waste properties. The soil tanks, having a width and depth of 1 m, and a height of 1.2 m, were filled with the shredded incombustible waste and bottom ash, respectively. Changes in the leachate quality were analyzed. Amounts of water sprayed daily corresponded to the general amount of rainfall (5 mm).

Changes in the concentrations of Cl^-, TOC, and T-N with elapsed time are illustrated in Figure 7. Concentration of Cl^- and T-N, leaching out from the shredded incombustible waste tank, were found to decrease in a short period of time and is suggestive of an ongoing washout process. As for TOC, although the reduction in the concentration starts somewhat late, it declines relatively early, indicating the existence of washout and biodegradation simultaneously.

With the bottom ash tank, washout also induces a rapid reduction of Cl^- concentration in a short time. In contrast, concentrations of both, TOC and T-N, are maintained at a high level despite a reduction in early stages. In particular, TOC reduction in the bottom ash is slow, and TOC degradation takes a longer time.

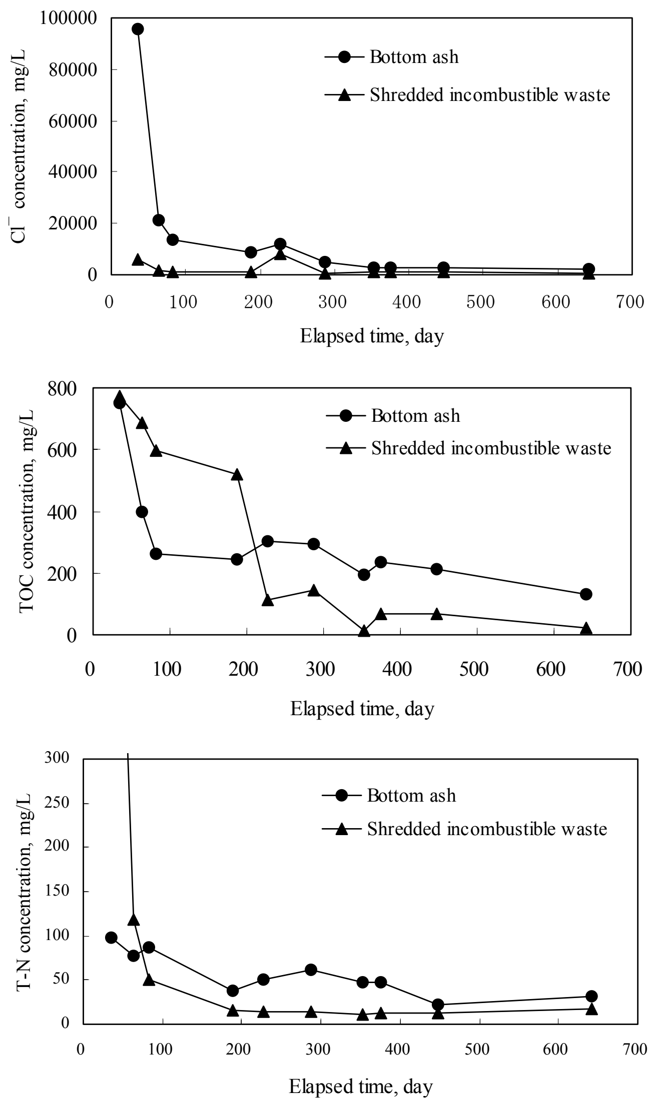

Figure 7. Changes in leachate concentration of experimental tank filled with bottom ash and shredded incombustible waste

5. CONCLUSIONS

We have tested the working environment, waste stabilization, and water balance at CSDF utilizing three actual CSDFs and test tanks. As a result, following things were proved.

- Because the water spray can decrease almost the amount of dust generated, the water spray are desirable for the working environment countermeasure.
- As the temperature countermeasure, the natural ventilation is desirable. However, mechanical ventilation is necessary in cases where natural ventilation does not work.
- A concentration of gases generated from the waste layer, such as methane and hydrogen, were too low to be detected with the harmful gas detector. Oxygen concentration in the facilities was at the same level as that in the ambient air; therefore, it did not pose a problem. Also, even though odorous substances were sometimes detected in infinitesimal quantities, there was no problem of a stench.
- The rate (the leachate coefficient) with leachate quantity to the water spray quantity was tendency which becomes small in the summertime. A correlation of the leachate coefficient with the temperature and the humidity is high.
- Water spray is effective for waste stabilization, but the decreasing rate in organic matter like TOC in leachate tended to be late compared with that in the inorganic matter like Cl^-.

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