VALIDATION OF CLOSED SYSTEM DISPOSAL FACILITIES BASED ON SURVEY DATA

Takashi Kohinata , Kazuei Ishii , Ryuji Yanase
Working of field investigation for waste stabilization, Research group of control,
Research Committee for Closed System Disposal Facilities
Chateau Takanawa 401,3-23-14, Takanawa, Minato-ku, Tokyo 108-0074

Masataka Hanashima*, Tohru Furuichi**
Research Committee for Closed System Disposal Facilities
Chateau Takanawa 401,3-23-14, Takanawa, Minato-ku, Tokyo 108-0074
*Chairman, **Vice-Chairman

ABSTRACT

We conducted a survey at actual Closed System Disposal Facility (CSDFs) to evaluate its internal working environments (stench, dust, temperature and humidity, inflammable gases, oxygen deficiency, etc.) and stabilization of waste. As a result, following things were proved.(1) Because the water spray can decrease almost the amount of dust generated but cannot remove fine particles, the water spray and the wear of the protection mask against dust are desirable for the working environment countermeasure (2) As the temperature countermeasure, the natural ventilation is desirable. However, mechanical ventilation is necessary in cases where natural ventilation does not work.

(3) Gases generated from the waste layer, such as methane and hydrogen, were measured at regular intervals in the facilities; however, their concentrations 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.

(4) Water spray is effective for waste stabilization, but the decrease rate in organic matter like TOC tended to be late compared with that in the inorganic matter like Cl^-.

INTRODUCTION

Applications of CSDF to general waste disposal facilities have been increasing from the aspects of a small amount of leachate. 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 a survey at actual CSDFs to evaluate their internal working environments (stench, dust, temperature and humidity, inflammable gases, oxygen deficiency, etc.) and stabilization of waste in order to study these issues.

Table 1 Outline of Disposal Facilities

	Masugatayama Disposal Facilities	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	Incineration residue, Shredded incombustible
Ventilation equipment	Ventilation fan	Roof fan,louver	Ventilation fan,louver
Sprinkle equipment	Sprinkler	—	Nozzle

SURVEYED DISPOSAL FACILITIES

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

RESULTS OF THE SURVEY

Temperature within the facilities

At CSDFs, as the waste carrying-in entrances are shut, except at the time of carrying in these wastes and dumping, the possibility that the facility is almost sealed is high. 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℃), 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). Fig. 1 shows the results obtained at the Masugatayama disposal facilities and Thanks BB, respectively. At the Masugatayama disposal facilities, though the internal temperature in summer exceeded the working environment limit of 37℃, when sealed (before ventilation), operation of a big ventilation fan at 37℃ reduced the internal temperature to 35℃. In contrast,

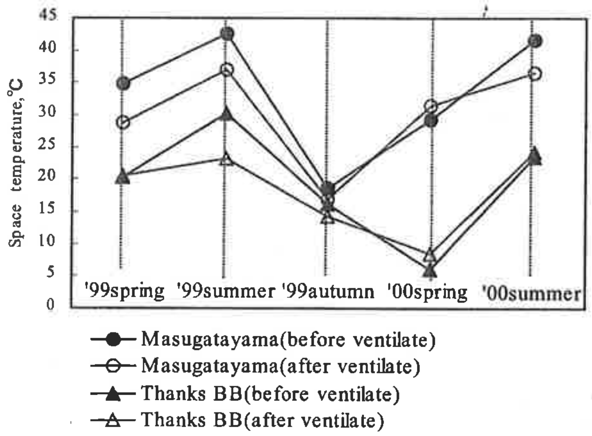

Fig. 1 Effects of ventilation on space temperature

the internal temperatures in a sealed condition during summer at Thanks BB, were approximately 30℃ 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 facilities, which is completely sealed, has a system by which the big fan starts to operate only when the internal temperature exceeds over 37℃. On the other hand, Thanks BB is equipped with ventilating windows around the facilities; therefore, natural ventilation occurred.

Thus, natural ventilation systems would be desirable for temperature regulation at CSDF. However, mechanical ventilation is necessary in cases where natural ventilation does not work because of the facilities structures and so on.

Dust generation and its countermeasures

We studied dust generation and its countermeasures during waste dumping. At the Masugatayama disposal facilities, an experiment was performed under four conditions as follows: 1) Shredded incombustible waste without moisture (intact). 2) Shredded incombustible waste prepared for moisture. 3) Sprinkling water at the waste entrance during dumping shredded incombustible waste without moisture. 4) Sprinkling water throughout the surface of waste layer before dumping shredded incombustible waste without moisture. The experimental results obtained have been indicated in Table 2.

The amount of dust generated by dumping shredded incombustible waste prepared for moisture and that with sprinkling water at the entrance was less in comparison with the untreated one that generated more dust. Further, lesser dust generation was possible when water was sprinkled all over the surface of waste layer.

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

Table 2 Dumping condition and dust generation at Masugatayama Disposal Facilities 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
	Sprinkle at waste entrance		0.9	0.66	0.99	about 2ton
	Sprinkle 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

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 facilities.

The size of a fine particle that enters into the human alveoli and affects the human body is less than or equal to 1.1 μm. Keeping these facts in mind, dust concentration was calculated to be less than 1.1 μm using the dust size distribution from the data of dust measurements at the Masugatayama disposal facilities, and the results are shown in Table 3.

Dust concentrations of fine particles were less than 1.1 μm and they ranged from 0.04–0.05 mg/m^3 in all cases except those involving moisture control. With moisture control, the fine particles were probably induced to stir up from wastes at the surface due to the falling of the shredded incombustible waste with wet weight in the form of a mass.

It became apparent that the removal of fine particles was impossible; however, water spray could decrease the large amount of dust generated. This fact indicates that water spray over the surface of waste layer before dumping might also be effective in the facilities in order to prevent from stirring up wastes by the dumped wastes.

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,

Table 3 Total amount of dust less than or equal to 1.1μm

Dumping condition	Total amount of dust ≦1.1μm(mg/m^3)
Waste without moisture	0.04
Waste with moisture	0.19
Sprinkle at waste entrance	0.04
Sprinkle throughout the surface of waste	0.05

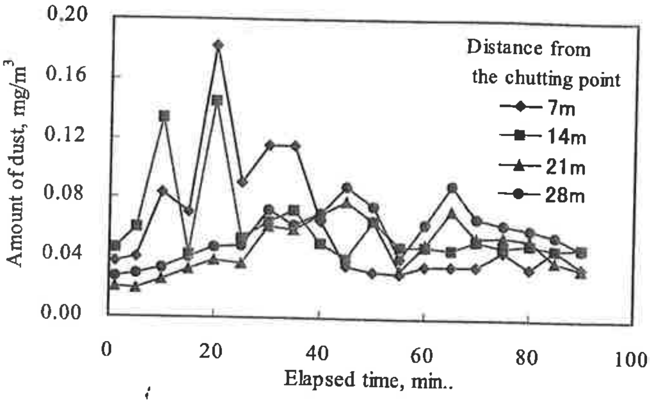

Fig. 2 Relationship between distance from chutting point and dust diffusion

Table 4 Malodorous densities at Masugatayama Disposal Facilities, 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	—

and 28 m apart from the chute are indicated in Fig. 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 sprinkling water along the suspending route is necessary to reduce dust generation of smaller (lighter) particles.

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.).

Inflammable gases and oxygen deficiency: Gases generated from the landfilled waste, such as methane and hydrogen, were measured at regular intervals in the facilities; however, 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.

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 facilities and Thanks BB facilities as shown in Table 4. 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, 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.

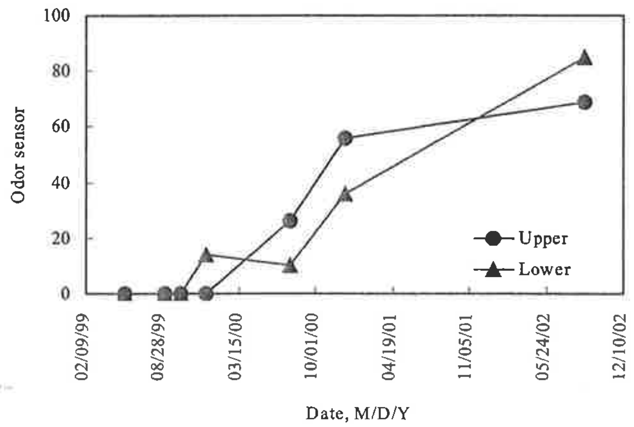

Fig. 3 Changes with time of stench obtained with odor sensor

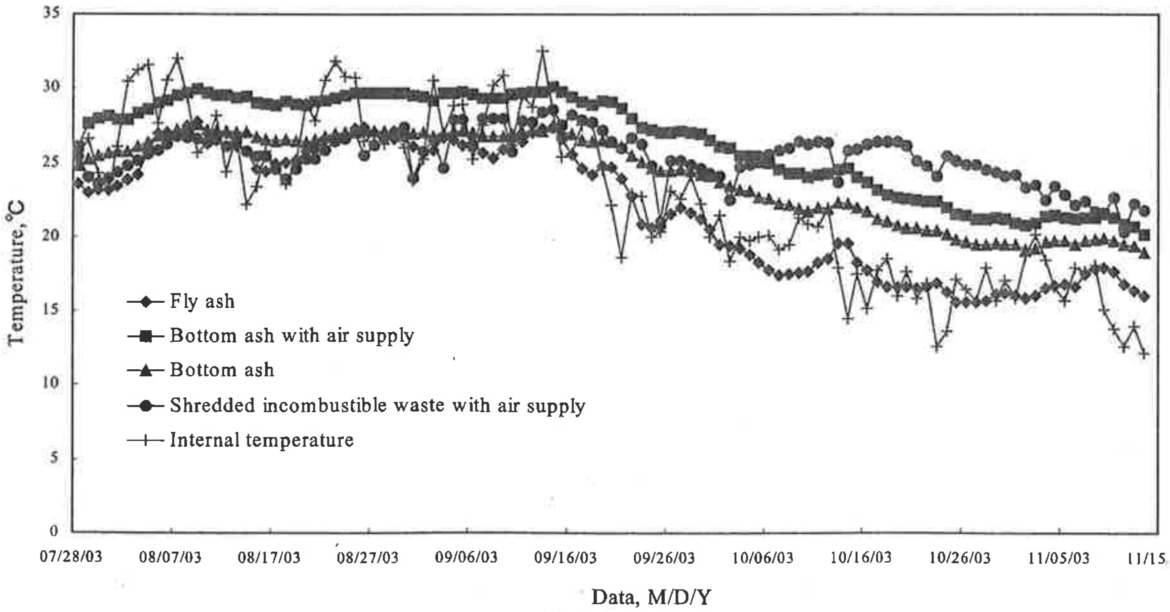

Fig.4 Comparison between waste temperature and landfilled waste

Changes with time of stench: Fig. 3 shows the values obtained with the odor sensor at Thanks BB, 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.

Characteristics of landfilled wastes

Temperature of the waste layer: The temperature

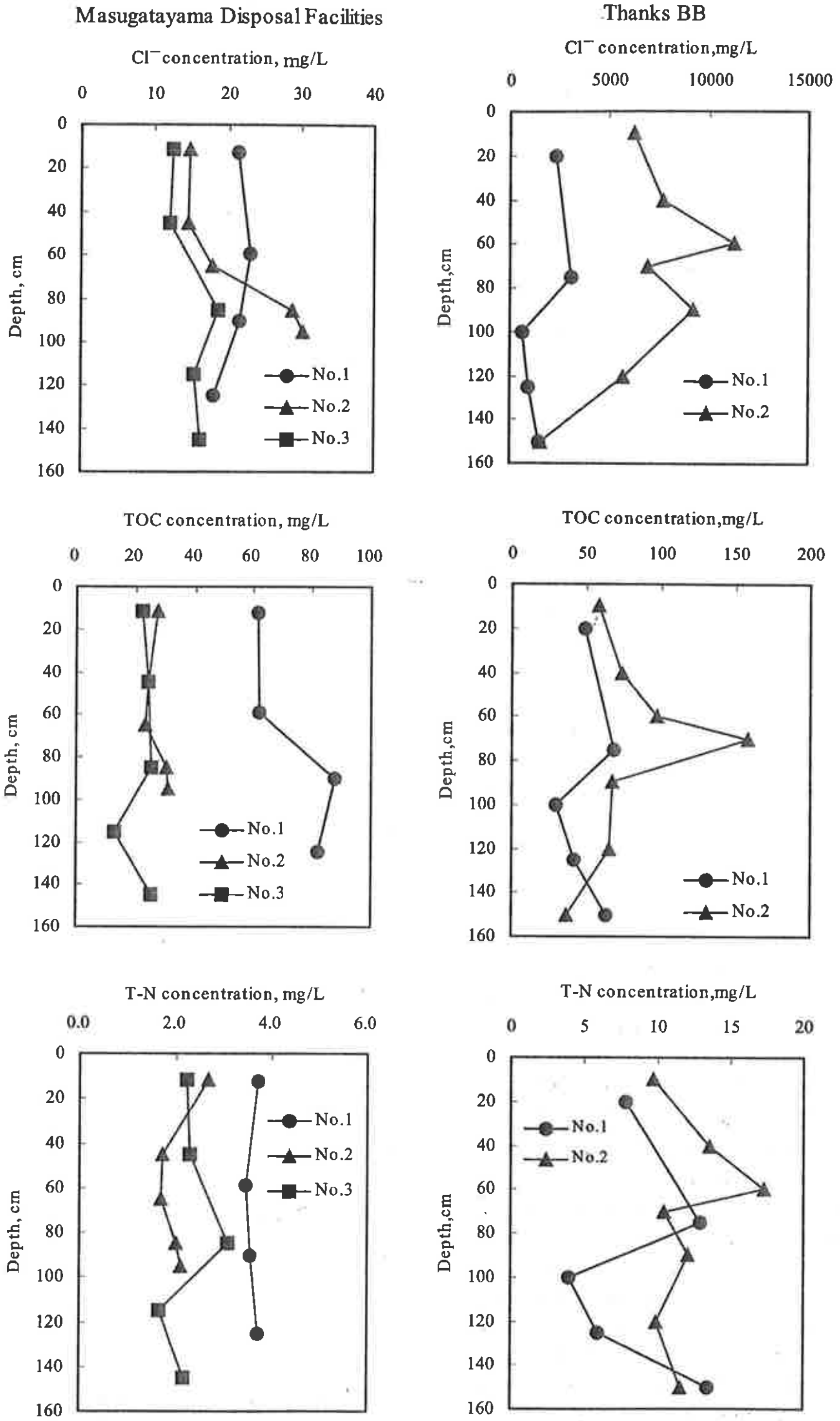

Fig.5 Concentration by elution test on landfilled waste in each depth

Table 5 Concentration of landfilled waste by elution test

Material	Masugatayama Disposal Facilities	Thanks BB	
	Shredded incombustible waste	Shredded incombustible waste	Bottom ash
Cl^- (mg/L)	256	198	3095
TOC (mg/L)	106	93	85

of the waste layers was measured by placing thermo sensors in the layers. Fig. 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 infusion 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 temperatures in the areas with or without air supply differ between 2℃ to 3℃, 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.

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

The concentration of Cl^- changed in all the layers between 10–20 mg/l at the Masugatayama disposal facilities, 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 facilities 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 facilities and the result provides a possibility of a fairly advancing degradation. 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

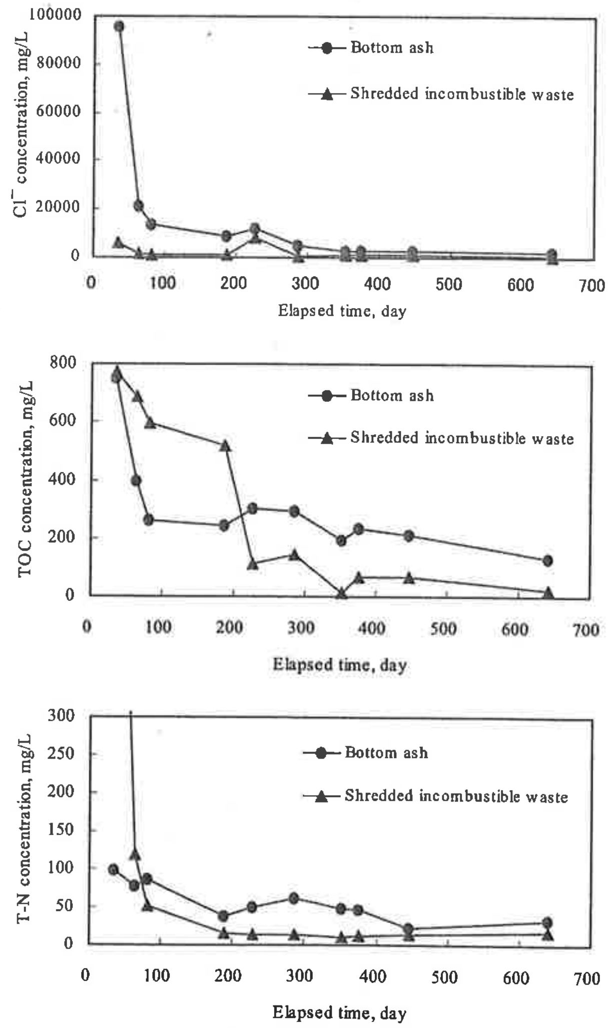

Fig.6 Changes in leachate concentration of experimental tank filled with bottom ash and shredded incombustible waste

process at the Masugatayama disposal facilities; however, at Thanks BB, both these processes have hardly progressed in the absence of a water spray.

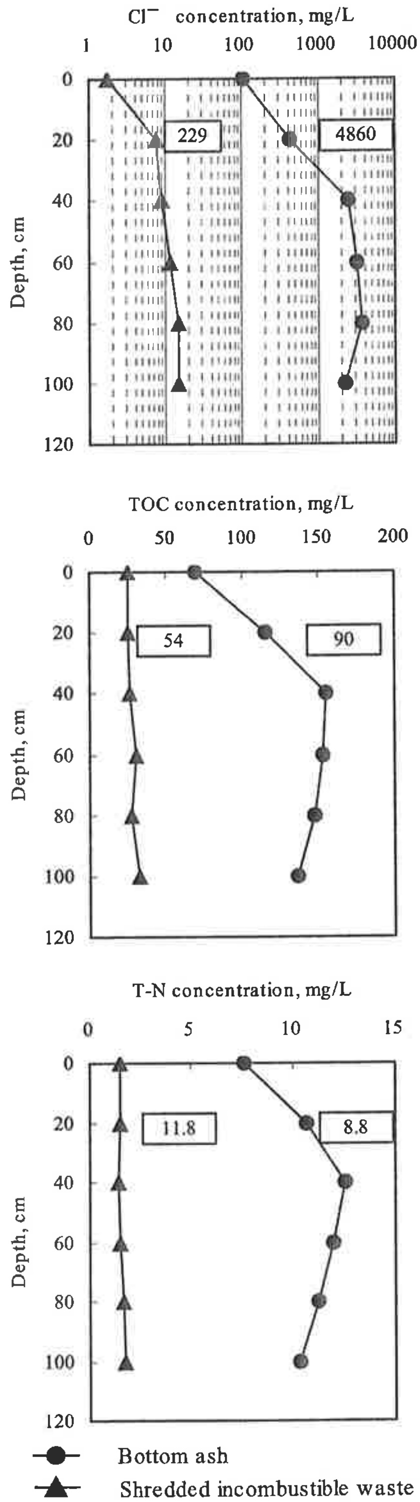

Fig.7 Substance concentration by elution test on experimental waste in each depth

SOIL TANK EXPERIMENT

Differences of landfill wastes

A large experimental soil tank was conducted at the Masugatayama disposal facilities, 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 Fig. 6. 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.

Results of the elution test with the wastes collected from the dismantled soil tanks are shown in Fig. 7. The values shown in each figure are those of the elution test at filling the waste. Washing and degradation promote the reduction in the concentration on Cl^-, TOC, and T-N in the shredded incombustible waste quite significantly as compared with the early period. In contrast, concentrations of these substances in the bottom ash are slightly lower in the air exposed upper part; however, no concentration reduction is observed in the middle to the bottom parts. The observations indicate that washing and biodegradation differ dynamically in the types of the waste even when the same amount of water spray is performed.

Differences of water spray conditions

One of the merits of CSDF is that it can regulate the amount of water spray as required.Leachate quality changes were observed with sprinkling water in the

Photo 1 Test equipment

cases of 100%, 50%, and 30% of daily average precipitation in order to obtain the proper amount of water spray for the waste stabilization.

A 70-kg waste mixture was prepared by mixing 80% of bottom ash and 20% of the shredded incombustible waste and was filled in a bucket (see Picture 1). Water was sprayed on the test bucket twice a week. It is noted that a little leachate flew out in the 30%-spray group during the test process. Fig. 8 shows the relations between the leachate volume and concentrations in Cl^-, TOC, and T-N. Although Cl^- concentration in the 100% group gradually decreased from about 20000 mg/l, its concentration in the 30% group shows a rapid increase, adversely. Meanwhile, in the 50% group, the concentration reduces as much as that in the 100% group; however, it also shows a rapid increase in the process.

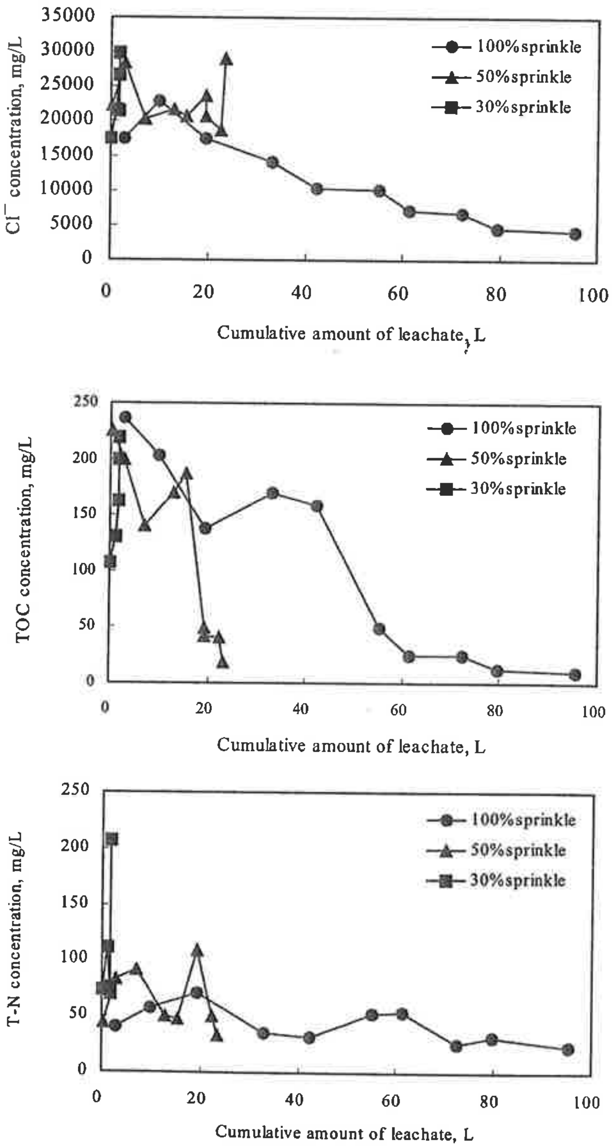

Fig.8 Changes in concentration of Cl^-, TOC, and T-N

In TOC, as well as in the Cl^-, the concentration in the 100% group tends to lower gradually but in the 50% group, the TOC concentration decreased rapidly after it had increased once. In the 30% group, the concentration rapidly increased as in the case of Cl^-.

As for T-N, the 100% and the 50% groups have the same tendency and the changes within each group are small, even though variations are present. In the 30% group, the concentration rises rapidly as in the case of Cl^-.

These findings suggest that a large volume of water spray affects the elution for Cl^- and others; however, it may not be always effective in the organic degradation. Therefore, it is preferable to maintain an adequate water spray level in order to maintain anaerobic conditions. Moreover, under the experimental conditions, the 30% group does not seem suitable for elution and biodegradation of all substances due to less moisture.

ENVIRONMENTAL COUNTERMEASURES IN CSDF

We have tested the working environment and waste stabilization at CSDF utilizing the actual CSDFs and test tanks. From the results and the experiences obtained in this study, problems and the countermeasures at CSDFs are summarized as follows:

1) Countermeasures for dust by water spray
2) Temperature and moisture control in the facilities by air ventilation
3) The working environment protection by air blasting
4) Response to high concentration and low volume of leachate
5) Maintenance of the adequate environment (moisture, air) for promotion of waste stability

ACKNOWLEDGEMENTS

Members of Working of Field Investigation for Waste Stabilization, Research Group of Control in Research Committee for Closed System Disposal Facilities; R.Yanase/Fukuoka University, K.Ishii/Hokkaido University, T.Kohinata/Fukuda Corp., Y.Shiozawa/Ebara Corp., T.Kita/Obayashi Corp., T.Hamada/Ohmoto Gumi Corp., T.Kobayashi/Kobelco-Eco Solutions Co., Ltd., T.Haha/Dai Nippon Const., T.Kaneko/Toyo Giken Co., Ltd., Y.Hamada/ Towa Kagaku Co., Ltd, H.Nakajima/Toda Corp., K.Miyazaki/Nishimatsu Construction Co., Ltd., N.Tarumi/Japan Engineering Consultants Co., Ltd., T.Okamoto/Nippon Koei Co., Ltd., J.Imai/JDC Corp., M.Kaminaga/Hitachi Zosen Corp., A.Matsuura/Fudo Construction Co., Ltd., N.Tajima/Maeda Corp.