STUDY ON THE EFFECT OF WATER SPRINKLING FOR REMOVAL OF CHEMICALS FROM WASTES DISPOSED IN CLOSED SYSTEM LANDFILL SITES

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ABSTRACT

For the closed system landfill sites, the roof that covers the facilities prevents rain water from permeating the layers of disposed waste. Thus, this type of waste landfill sites allows control of water sprinkling parameters such as time (hours), intensity and interval. Our study found that these parameters affect the mode of transfer of organic substances and salts from the layers of buried wastes. The water sprinkling time is defined as the hours of continuous water sprinkling per day (hours/day), and the water sprinkling intensity is defined as the amount of sprinkled water permeated into unit area of waste layers per hour (mm/hour・m2). The water sprinkling interval is the period of time (hours or days) in which the water sprinkling is stopped. Our study conducted two kinds of water sprinkling tests; the test using a small scale column and the test using a relatively large scale experiments. From the results of former test, we obtained knowledge that higher water sprinkling intensity produces higher efficiency of removal of salts and organic matters contained in the wastes and that daily water sprinkling is more efficient than weekly water sprinkling. On the other hand, we utilized the data obtained in the latter experiment to attempt calculation of chlorine ion concentration of leachate at arbitrary time on the assumption that the phenomenon can be represented by a simple linear function on a time series plot because eluting action of salt presumptively depends on time dominantly. In

these two approaches that use the stabilization models, the former (column) test studied the phenomenon at microscopic level treating incineration ash particles, and the latter test treated individual landfill sites as an experimental model to study the phenomenon at macroscopic level.

In this study, we examined the salt removing property at the macroscopic level based on the measurements obtained from existing open type landfill sites. As a result, we were able to verify quantitatively that the salt removing property varies among several landfill sites that contain different types of wastes. This research paper introduces two types of chemicals removing models and reports the results of examination of the macroscopic model.

1   INTRODUCTION

The purpose of this study is to resolve technical issues that occur in planning and designing the closed system landfill sites, such as what specifications we should establish for water sprinkling facility for stabilizing the buried wastes and how we should control the facility, which are uncertain now. To achieve this purpose, we conduced fundamental studies with regard to the method of acceleration of waste stabilization, such as laboratorial experiment on the stabilization of wastes and examination of stabilization model simulation through formulation of numerical models

in the period from fiscal years 2002 to 2006. From fiscal year 2008, we implement the studies on multilateral point of view such as arrangement and analysis of leachate property data collected from existing landfill sites for their temporal changes, and examination of the target values of the stabilization from the point of view of utilization of closed disposal facility sites and

disposal methods that allow earlier stabilization of the wastes, aiming at "establishment of concrete techniques for designing the closed system landfill sites.

For the methods of water sprinkling effective for the closed system landfill sites, we examined them based on the results of removal of chemicals through the column tests and test using relatively large scale elements. From the results of former tests, we obtained knowledge that higher water sprinkling intensity produces higher efficiency of removal of salts and organic matters contained in the wastes and that daily water sprinkling is more efficient than weekly water sprinkling. On the other hand, we utilized the data obtained in the latter experiment to attempt calculation of chlorine ion concentration of leachate at arbitrary time on the assumption that the phenomenon can be represented by a simple linear function on a time series plot because eluting action of salt presumptively depends on time dominantly. In these two approaches that use the stabilization models, the former (column) test studied the phenomenon at microscopic level treating incineration ash particles, and the latter test treated individual landfill sites as an experimental model to study the phenomenon at macroscopic level.

The following chapters reports the results of our study that succeeded in obtaining the chemicals eluting properties of individual landfill sites by estimating the eluting properties of chlorine ion of each disposal facility using a macroscopic model.

2 CHEMICALS REMOVING MODEL

When designing a chemicals removing model, we construct the following two types of models to verify actual phenomenon multilaterally, aiming at obtaining the models that allow highly accurate simulation.

2.1 Microscopic chemicals removal model

The microscopic chemicals removal model is defined here, in a limited sense, as an analytical model that allows simulation of eluting properties of organic components and salts in a relatively small domain for small waste particles such as incineration ashes. This microscopic model is a three phase (fluid phase, unmovable water phase and solid phase) chemicals removal model that allows relatively accurate simulation of eluting properties of organic components (TOC) and chlorine ion as a result of water sprinkling in a domain ranging from several centimeters to several tens of centimeters from the surface of waste layer.

This model has the following three issues to be verified at present; (1) the consistency of this model with eluting properties of chemicals from actual waste layers (more than several meters), (2) knowledge about unsaturated infiltration property of waste layers that influences pore fluidity of flowing water during water sprinkling, and (3) knowledge about effect of microbial degradation (other than eluting properties).

2.2 Macroscopic chemicals removal model

The macroscopic chemicals removal model is defined here, in a limited sense, as an analytical model that allows simple simulation of eluting properties of organic components and salts in entirety of waste layer of actual landfill sites. The macroscopic chemicals removal model allows quantitative simulation of eluting properties of chemicals from wastes such as organic components (such as COD, BOD and TOC), chlorine ion and nitrogen by utilizing data of buried waste, leachate and precipitation (water sprinkling). Refer to Figure 1. Concretely describing, the amount of leachate discharged from a disposal facility Q_n is estimated based on the precipitation I_n (statistic data) that flows into the facility at a year Nth from the beginning of the operation, and the amount of substance removed from waste by precipitation (leachate) W_n is estimated by using actual measurement of concentration data of the substance removed from leachate. The amount of individual substances

contained in the buried waste accumulated in the landfill sites S_n is estimated by using the data of amount of buried waste during the years of operation and content of individual substances.
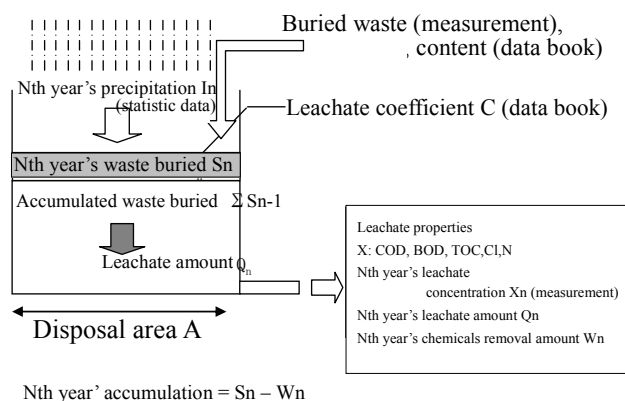

Figure 1   Macroscopic chemicals removal model

3   DATA OF EXISTING LANDFILL SITES

3.1. Outline of landfill sites surveyed

Before applying the macroscopic model for the analysis, we surveyed literatures that describe the results of continuous monitoring of temporal change of properties of leachate samples obtained from the disposal sites that are in operation and that closed the operation. The literatures that were surveyed were the reports issued by "Landfill Systems & Technologies Research Association of Japan, NPO". Table 1 shows the state of landfilling of six landfill sites (A to F)

Table 1   State of landfilling of landfill site surveyed

Landfilling information		landfill site					
		A	B	C	D	E	F
State of landfilling	Began in	1994	1979	1978	1993	1994	1988
	Completed operation in	in operation		1997	in operation		1996
Type of waste	Incineration ash	37%	—	76%	—	12%	50%
	Combustible materials	—	63%	—	—	53%	—
	Incombustible materials	54%	37%	24%	100%	21%	50%
	Sludge	9%	—	—	—	14%	—
Annual mean precipitation[mm/y]		1,509	1,106	1,363	1,440	2,304	1,599

extracted from the literatures that record properties of leachate of the facilities, and type and amount of wastes buried in the facilities for approximately five years.

3.2. Material balance of microscopic model

We obtained the material balance with regard to the buried wastes and leachate based on the measurement data collected from existing landfill sites. The annual infiltration of precipitation (I) of each facility (Q [m^3/y]) that is equal to the annual infiltration minus annual evaporation was obtained by using the rational formula (1). C [nondimensional], I [mm/y] and A [m^2] of this formula represent the leachate coefficient, annual precipitation, and area of disposal respectively. For the value of C, annual mean value of the leachate coefficient near the relevant disposal facility that is presented in "Construction of Waste Landfill sites; Planning and Design Guide" was used. The amount of leachate discharged finally out of the landfill sites was assumed to be equal to the amount of infiltration (Q) (assuming that all infiltrated water is discharged as leachate). The amount of chemicals removed from wastes (W [t]) was calculated as load that is given by the formula (2). In the formula (2), X [mg/L] represents the concentration of object substance contained in the leachate, which is the concentration of chloride ion (Cl$^-$) contained in the leachate. The content of chloride contained in the buried waste was assumed to have the ratio shown in Table 2.

$$Q = \frac{1}{10^3} C \times I \times A \qquad (1)$$

$$W = \frac{1}{10^6} Q \times X \qquad (2)$$

4   ANALYSIS OF DATA

・   As an index that indicates the amount of chloride accumulated in landfill sites, exposed to rain and then removed from the wastes, we used the numerical value equivalent to liquid-solid ratio (L/S) that is utilized for

Table 2   Content of chlorine in buried waste

Buried waste	Content of chlorine		Reference
Principal incineration ash	0.8%	8kg-Cl/ton of buried waste	*1
Flying incineration ash	20%	200kg-Cl/ton of buried waste	
Note: Ratio of principal ash to flying ash ＝9:1			*2
Incombustibles	0.15%	1.5kg-Cl/ton of buried waste	*1
Combustibles	0.3～0.8%	3～8kg-Cl/ton of buried waste	*3

*1 : "2003 research report", Research Committee for Closed System Landfill sites, 2004
*2 : "Disposal standard of specially controlled domestic waste", Japan Waste Research Foundation, 1993, P.71
*3 : "Garbage-Disposal Facility Design Scheme redaction in 2006", Japan Waste Management Association, 2006, P.33

column tests or dissolution tests. The LS here is the ratio between the following two factors; total amount of leachate infiltrated into disposal site in a given period (L [m^3]), and total volume of wastes buried in the same period (S [m^3]). The value of L is obtained from the precipitation of a disposal site (I) multiplied by mean leachate coefficient of the site (C). As an index that indicates the amount of chloride accumulated in landfill sites, exposed to rain and then removed from the wastes, we used the numerical value equivalent to liquid-solid ratio (L/S) that is utilized for column tests or dissolution tests. The LS here is the ratio between the following two factors; total amount of leachate infiltrated into disposal site in a given period (L [m^3]), and total volume of wastes buried in the same period (S [m^3]). The value of L is obtained from the precipitation of a disposal site (I) multiplied by mean leachate coefficient of the site (C). Figure 2 shows the results of measurement of concentration of chloride ion contained in the leachate produced in the landfill sites A to F ("A" to "F" are codes that represent individual facilities). From these results, it is known that the facilities other than C and F elute chloride ion with the concentration less than 1000 mg/L. It can be estimated that level of the elution depends on the content of chloride ion in the buried waste, but, for the facility E, the estimated content of

chloride ion in the waste buried in the entire facility is more than twice of the facility F, meaning that other factors can exist. Figures 3 and 4 show correlation between the chloride ion and L/S ration for the facilities C and F that showed the tendency of significant reduction of chloride ion concentration after their operation was closed. The facilities C and F shows low value of L/S ratio when they are in operation, but after they closed their operations, the ratio started to increase, and as the ratio increase, the concentration of Cl$^-$ reduces. The landfill sites A and D showed no increase of L/S ratio, and thus, showed no such tendency clearly.

5   CHEMICALS ELUTING PROPERTY

To analyze the difference of elution of chemicals among the facilities A to F quantitatively, we compared them by using a simple macroscopic model as described below. As an index for the analysis, we defined the single year Cl elution factor A$_{Cl1}$ as given by the formula (1).

$$A_{Cl1}(i) = \frac{C_{Cl}(i)}{C_{Cl100}(i)} \qquad (1)$$

where;

$A_{Cl1}(i)$: Elution factor [nondimensional] of Cl in any one year (i th year from burying, the same for the following explanations),

$C_{Cl}(i)$: Concentration of Cl(i) elution in any one year [mg/L], and
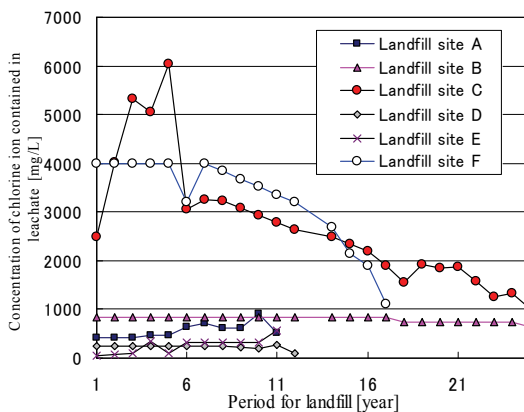
Figure 2 Temporal change of chlorine ion of
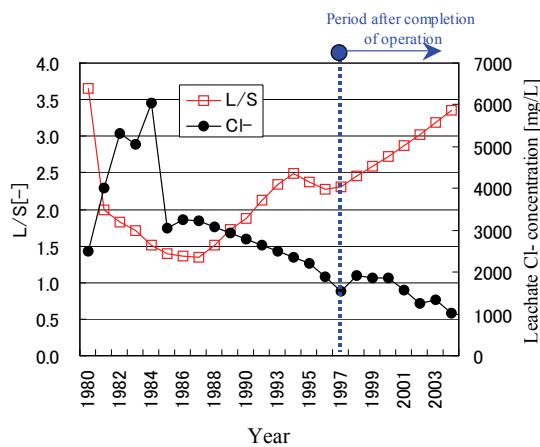landfill sites

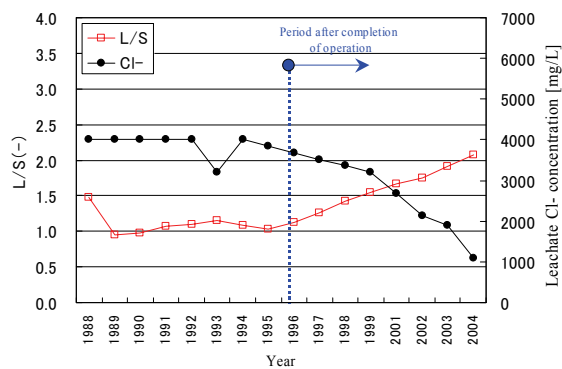Figure 3   Temporal change of Cl⁻ and L/S of
landfill site C

Figure 4   Temporal change of Cl⁻ and L/S of
landfill site F

Table 3 Results of calculations using the simple chemicals removal stabilization model

Landfill site	A	B	C	D	E	F	Max.	Min.	Average
Max A_{Cl1}	0.099	0.677	0.329	1.006	0.035	0.449	1.006	0.035	0.433
L/S	2.428	2.348	3.646	6.037	0.397	1.472	6.037	0.397	2.721
C_{Cl100} [mg/L]	4,157	1,255	7,570	248	9,583	8,901	9,583	248	5,286
Period for landfill [year]	1	2	1	1	4	1	4	1	1.7
Min A_{Cl2}	0.016	0.044	0.011	0.049	0.009	0.022	0.049	0.009	0.025
L/S	0.294	0.112	0.096	0.388	0.405	0.158	0.405	0.096	0.242
C_{Cl100} [mg/L]	33,075	16,922	147,052	1,792	9,718	50,762	147,052	1,792	43,220
Period for landfill [year]	11	24	18	12	3	17	24	3	14.2
			completed		completed				

$C_{Cl100}(i)$: Concentration of Cl elution in any one year when all Cl(i) contained in the buried waste is eluted completely [mg/L].

The result of analysis of leachate that was actually measured at the sites was used as the value of Cl(i) as described previously.

$C_{Cl100}(i)$ was obtained from the following formula (2).

$$C_{Cl100}(i) = 10^{6}\left(\frac{W_{TCl}(i)}{W_w(i)}\right) \qquad (2)$$

where;

$W_{TCl}(i)$: Total weight of Cl contained in the buried wastes in any one year [tons],

$W_w(i)$: Weight of water infiltrated into buried wastes in any one year [tons], and

$W_{TCl}(i)$ and $W_w(i)$ are obtained by using the following formulas (3) and (4) respectively.

$$W_{TCl}(i) = W_{TCl}(i-1) + A_{Cl2}(i)W_S(i) - W_{Cl}(i-1) \qquad (3)$$

$$W_w(i) = A_w(i)W_{wr}(i) \qquad (4)$$

where;

$W_{TCl}(i-1)$: Weight of total Cl content of buried wastes at $i-1$ th year after burying [tons],

$A_{Cl2}(i)$: Rate of content of Cl in waste [nondimensional],

$W_S(i)$: Total weight of wastes buried in period up to i th year,

$W_{wr}(i)$: Weight of rain water that falls in a disposal site during one year of i th year [tons],

$W_{Cl}(i-1)$: Weight of Cl that elutes during one year of i-1 th year [tons]

$A_w(i)$: Leachate coefficient [nondimensional]

W_{Cl} in any one year is obtained by using the following formula (5).

$$W_{Cl}(i) = \left(\frac{1}{10^6}\right)C_{Cl}(i)\frac{W_w(i)}{\rho_w} \qquad (5)$$

where;

ρ_w : Density of leachate [tons/m^3], which is assumed "1.0" for the calculation.

The ratio of $W_w(i)/W_S(i)$ is defined as the single year liquid-solid ration ($L/S(i)$), which is given by the following formula (6).

$$L/S(i) = \frac{W_w(i)}{W_S(i)} \qquad (6)$$

The results from these calculations are shown in Table 3 and Figures 5 and 6. Figure 5 shows correlation between L/S that is given by the formula (6) and A_{Cl1}, and Figure 6 shows correlation between C_{Cl100} and A_{Cl1}. These results quantitatively demonstrate that properties of elution of Cl from waste layers vary among individual disposal sites. Concretely analyzing the results, A_{Cl1} of Cl component of leachate that is eluted from wastes distributes very widely in the range from   (disposal site A) to 1.006 (disposal site D). This wide distribution of A_{Cl1} may be due to difference of waste type, precipitation conditions, and permeability of buried waste layers of individual facilities. It is confirmed that there is a very strong correlation between both L/S and A_{Cl1} and C_{Cl100} and A_{Cl1} for the facilities except E. As for the difference of elution property between the operating period of the facilities and the period after completion of the operation, the facilities show a higher elution property in

initial stage of operation because the precipitation is larger than the amount of waste buried in such period, and then, show a lower elution property after completing the operation because the precipitation is smaller than the amount of waste buried. As for full elution property of the facilities, the results show that the elution property is affected not by C_{Cl100} but by the precipitation.

6   CONCLUTION

This study implemented an approach that evaluates and validates the elution property of substances from existing disposal sites quantitatively, which has never been conducted. As a result, we succeeded in understanding the elution property of chlorine ion in individual landfill sites. From now on, we are planning to work out the elution activities of individual substances in existing landfill sites by applying this approach to many other landfill sites, and then to apply this approach to the water sprinkling method for closed system landfill sites. In the future, we would like to continue to examine the water sprinkling method that is required during the period of disposal and after completion of the operation of the facilities, by sorting out and analyzing the leachate property data of existing landfill sites for their incineration ash, inflammable materials and incombustibles and analyzing actual elution activities of organic substances and chlorine from wastes, aiming at improving the accuracy of the stability model. Also, we would like to examine, through surveying literatures, the effect of microbial degradation that is deemed contributing to the stabilization of buried wastes as well as the water sprinkling effect.
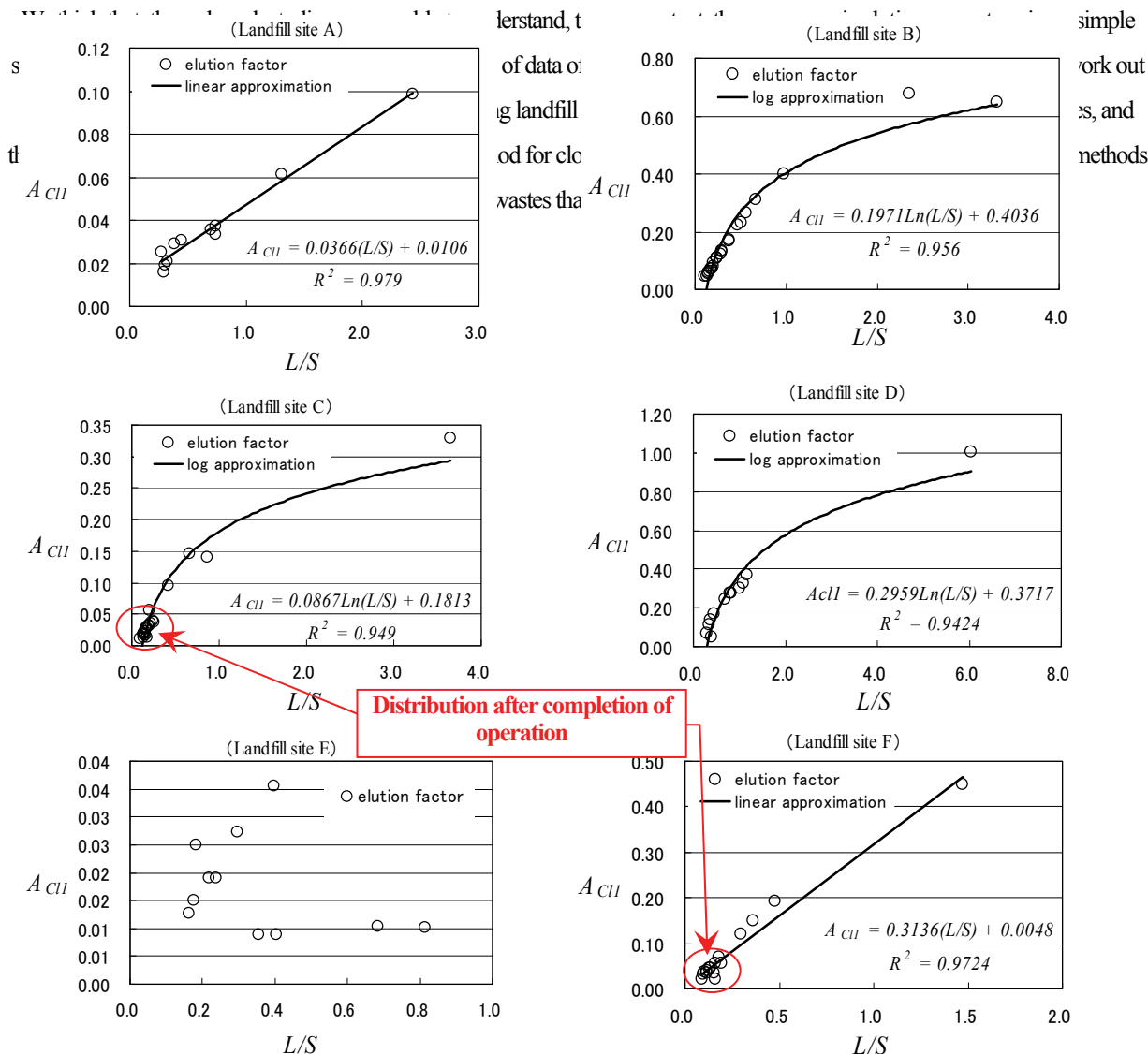
Figure 5 Relationship between L/S and A_{ClI} of disposal facilities A to F

from existing landfill sites. We express our appreciation for their cooperation very much.

ACKNOWLEDGMENTS

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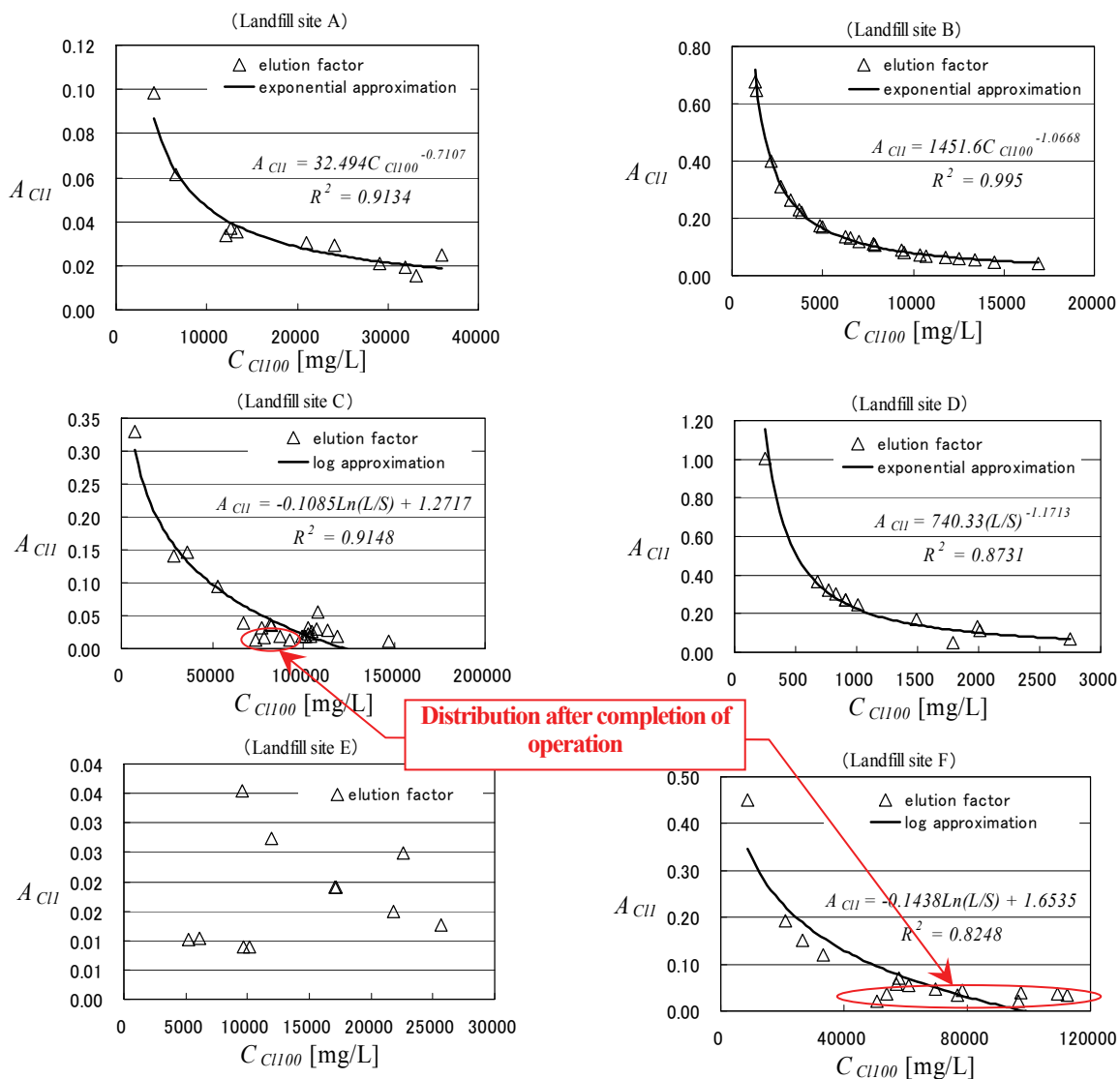2) Ricardo C. de Abreu, Enrique J. La Motta and Kenneth L. McManis (2004). Facultative Landfill Bioreactors (FLB):

Figure 6 Relationship between C_{Cl100} and A_{Cl} of disposal facilities A to F

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