50. Flow Analysis of Metals in Municipal Solid Waste (MSW) Management System

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ABSTRACT: Metals have toxicity property leading to adverse effect on human health and become scarce resource. If metals in end-of-life goods (wastes) are controlled or treated inadequately, they will eventually result in high environmental risk on human health and ecosystem and valuable resource loss. Treatment and recycling process of solid waste is last stage in goods' life cycle and also critical stage to determine whether heavy metals are released to the environment or not. This study aimed to estimate metal flow in solid waste management system and to evaluate quantitatively environmental burden. By integrating output values in each process, metal content in composition of household waste was estimated. For most metals except Cr, total contribution rate of paper/textile/plastics, bulky waste, and incombustible waste is over 80 %. Approximately 40% of Cr originated from plastic packaging. Several SWM scenarios showed that the leaching potential of metals to the environment was quite small and most metals were transferred to the landfill.

KEYWORDS: solid waste management, metal, flow analysis

1. Background

Metals are common and essential materials to our daily needs. They have been used since the 5th millennium B.C. and the production amount has been raised drastically with the increase of the global population and industrial development in 20th century, particularly the base metals such as copper (Cu), lead (Pb), zinc (Zn) and tin (Sn). The primary production of most metals is still increasing, which will result in natural resource consumption and accumulation in the urban area or emission to the environment, causing adverse effects on human health and ecosystem.

Thus, in the viewpoint of natural resource conservation and environmental risk reduction, the appropriate control of metal is required. For better control of metals, i.e. proper treatment and efficient recovery, it is essential to identify their material flow in product life cycle. Up to now, various studies have been performed on the metal flow in a society. However, most works have focused on production and consumption stage. Waste management system is last stage in product life cycle and a critical stage to determine whether metals are recovered, deposited in a landfill, or dispersed to the environment.

This study aims to identify the metal flow in solid waste management (SWM) to obtain the basic information for efficient recovery and appropriate treatment of metals.

2. Methodology

To estimate metal flow in a process, input/output analysis is needed. But, representative sampling and analysis in input is normally very difficult or impossible since the composition of solid waste

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Table 1. Input waste composition for SWM facilities surveyed in this work

	Food waste	Paper /Textile	Plastics		Recyclable waste	Bulky waste	Other wastes (Incombustible#)
			Plastic packaging	Others			
Resource recovery					●		
RDF (refuse-derived fue	●	●	●	●	○*		
Liquefaction			●				
Composting	●						
Bio-gasification	●						
Shredding & Separation						●	●
Carbonization	●	●	●	●		●	●
Incineration	●	●	●	●			

Recyclable waste: PET bottle, Glass bottle, Steel/Aluminium can
*PET bottle among recyclable waste is fed to RDF facility
#Incombustible waste separated at the source

fluctuates significantly from one day to the next. Therefore, outputs of each process were analyzed for metal content and leaching concentration, and input values were determined by totaling the various output values.

In previous works, the metal balance in all MSW management processes commonly used in Japan, i.e. thermal treatment (incineration, ash-melting, gasification-melting), material recovery process of bulky waste, resource recovery, RDF production, carbonization, plastics liquefaction, composting, bio-gasification facility, was studied (Jung et al., 2004; Matsuto et al., 2004; Jung et al., 2005). In this study, flow analysis in the entire SWM system was performed. To estimate the metal flow in SWM system, the metal balance in each MSW processes was integrated. And scenario evaluation was conducted to investigate the influence of a waste management option on metal flow.

3. Surveyed SWM Facilities and Input Waste

Input wastes to the surveyed facilities are shown in Table 1. Municipal solid waste (MSW) was classified into six groups, i.e. food waste, paper/textile, plastics (plastic packaging, other plastics), recyclable waste (PET bottle, glass bottle, steel/aluminum can), bulky waste, other wastes (incombustible waste). In Japan, most municipalities collect PET bottles, glass bottles, and steel/aluminum cans by the Container and Packing Recycling Law. Plastic and paper packaging are the other targets specified by the law, but plastic packaging was collected in 40% of municipalities, while only 8% collected paper packaging in 2003.

Table 2 lists target metals selected based on the possible use year and toxicity.

Table 2. Target metals determined based on the possible use year and toxicity

Group 1	Scarce metals	Lead, Zinc, Tin, Cadmium, Copper, Selenium, Bismuth
Group 2	Hazardous metals	Arsenic, Chromium, Antimony
Group 3	Widespread metals	Aluminum, Iron

4. Metal Flow in SWM System

Based on metal balance in each MSW management process, the metal flow in SWM system was calculated. But discussion is limited to household waste due to a lack of data on commercial and business waste, which are the other elements of municipal solid waste.

4.1. Estimation of metal content in household waste composition

Metal contents in each waste component defined in Table 1 were estimated in the following manner:

(a) Food waste

Composting and bio-gasification facilities treat food waste. Most facilities receive food waste from both commercial and household areas. Among them, composting facility M was chosen for calculating metal content in food waste because 93 % of feedstock is generated from households.

(b) Plastic packaging

The results from the liquefaction facility were used.

(c) Recyclable waste (Cans, PET bottles, Glass bottles)

The result from resource recovery facility K was used because a mass balance of outputs was obtained.

(d) Paper/Textile/Plastics

This fraction is treated by RDF production, carbonization, and incineration. However the carbonization facility receives both incombustible and bulky waste and incineration facilities treat commercial waste along with household waste. Thus the RDF facility was selected for the calculation of metal content in paper/textile/plastics. The RDF facility treats food waste and plastic packaging as well as paper/textile/plastics as shown in Table 1. So, metal content in paper/textile/plastics was calculated by subtracting metal content in food waste and plastic packaging from metal content in the total input waste. The collected amount of household waste per capita-day was taken from reference (Matsuto et al., 2001).

(e) Bulky waste

The estimated value in the previous work (Matsuto et al., 2004) was used.

(f) Incombustible waste

The analyzed value in the previous work (Jung et al., 2004) was used.

Estimated metal content in MSW composition is summarized in Table 3.

Table 3. Metal content of waste composition in household waste

		Paper/Textile/Plastics	Food waste	Recyclable	Plastic packaging	Bulky waste	Incombustible	Unit
Metal Content	As	0.07				5.8	2.8	mg/kg [wet basis]
	Bi	11.6	0.6	1.8	0.6	6.6	31.3	
	Cd	0.0				1.5	8.7	
	Cr	38.5	2.8	40.3	211.8	23.1	425.2	
	Cu	65.9		0.2	3.3	6021.0	383.0	
	Pb	43.0		0.2	5.6	478.8	357.0	
	Sb	50.2	2.9	0.4	13.1	208.4	39.1	
	Se	1.8	0.1	0.6	0.2	0.3	3.4	
	Sn	12.8		1.3		317.0	25.0	
	Zn	344.6	6.4	1.8	25.1	640.6	1282.5	
Collected amount		248.4	251.0	65.7	73.1	27.6	28.0	g/capita/day

Blank: Not detected

4.2. Contribution rate of MSW composition to metals

Table 4. Contribution of waste composition on metals in household waste

[%]

	Paper/Textile/Plastics	Food waste	Recyclable	Plastics packaging	Bulky waste	Incombustible
As	6.7				62.6	30.7
Bi	67.9	3.5	2.7	0.9	4.3	20.6
Cd	2.0				14.2	83.8
Cr	23.4	1.7	6.5	37.8	1.6	29.1
Cu	8.5		0.01	0.1	85.9	5.5
Pb	31.1		0.05	1.2	38.5	29.1
Sb	59.3	3.5	0.1	4.5	27.4	5.2
Se	71.8	3.9	5.8	2.3	1.3	14.9
Sn	25.0		0.7		68.8	5.5
Zn	60.0	1.1	0.1	1.3	12.4	25.2

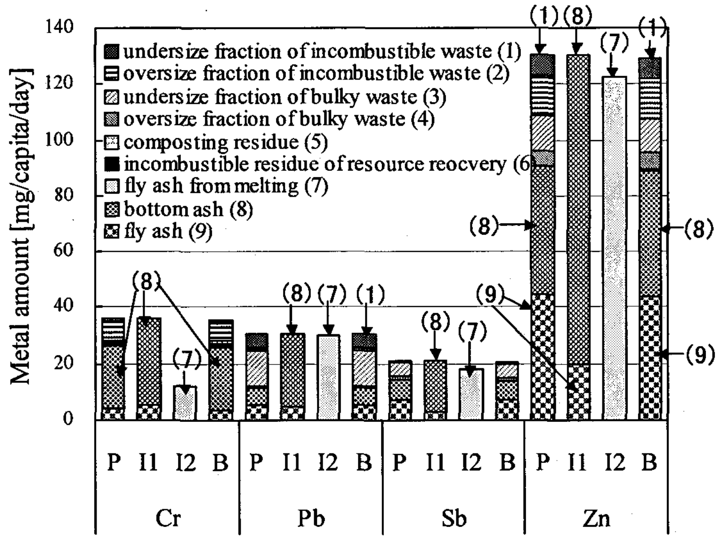
(shaded) : over 30%

By using Table 3, the contribution rate of each waste composition to metal content was calculated as shown in Table 4. Paper/textile/plastics show the highest contribution for Bi, Sb, Se, and Zn. High amounts of As and Pb were contained in bulky waste and incombustible waste was a large source of Cd. Plastic packaging contributed highly to Cr. As expected, the contribution rate of food waste to metal content was very low.

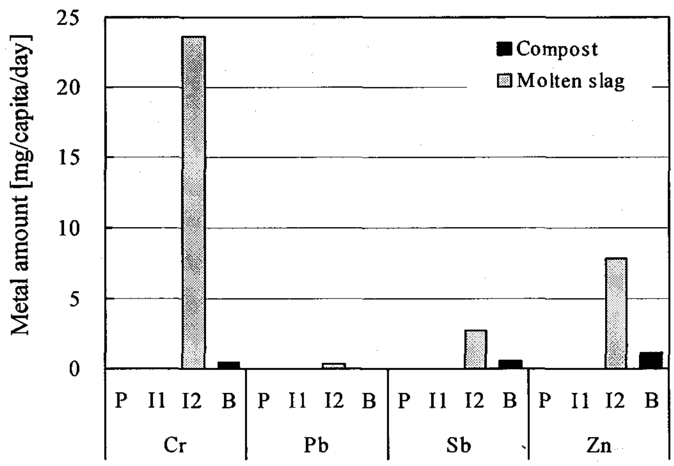
5. Evaluation of MSW Management Scenarios

In order to investigate the influence of a waste management option on metal flow, four typical scenarios of MSW management are assumed as follows. In all scenarios, recyclable waste is assumed to be collected and sorted in resource recovery facilities:

- Present scenario (P): Bulky waste and incombustible waste are landfilled after shredding, and other waste components are incinerated.
- Incineration scenario (I1): Incineration is maximized. All



(a) Landfilling



(b) Release to the environment

Figure 1. Fate of metals in different SWM scenarios

waste components are incinerated and residues are landfilled.

- Gasification-melting scenario (I2): A gasification-melting system is used instead of the incineration process in scenario I1. Molten slag is supposed to be used as construction and road material.
- Bio-waste recycling scenario (B): Food waste is collected and composted in scenario P. Residue is landfilled.

Each scenario was evaluated with the amount of metals and leaching amount for Cr, Pb, Sb, and Zn. Generally, fly ash from MSW incinerators has to be stabilized before landfilling. In this study, however, the metal leaching potential of untreated fly ash is used for safety side. The metal distribution ratio in the incineration process and the melting process were taken from the previous studies (Jung et al., 2004; Jung et al., 2005). The result is provided in Figures 1 and 2.

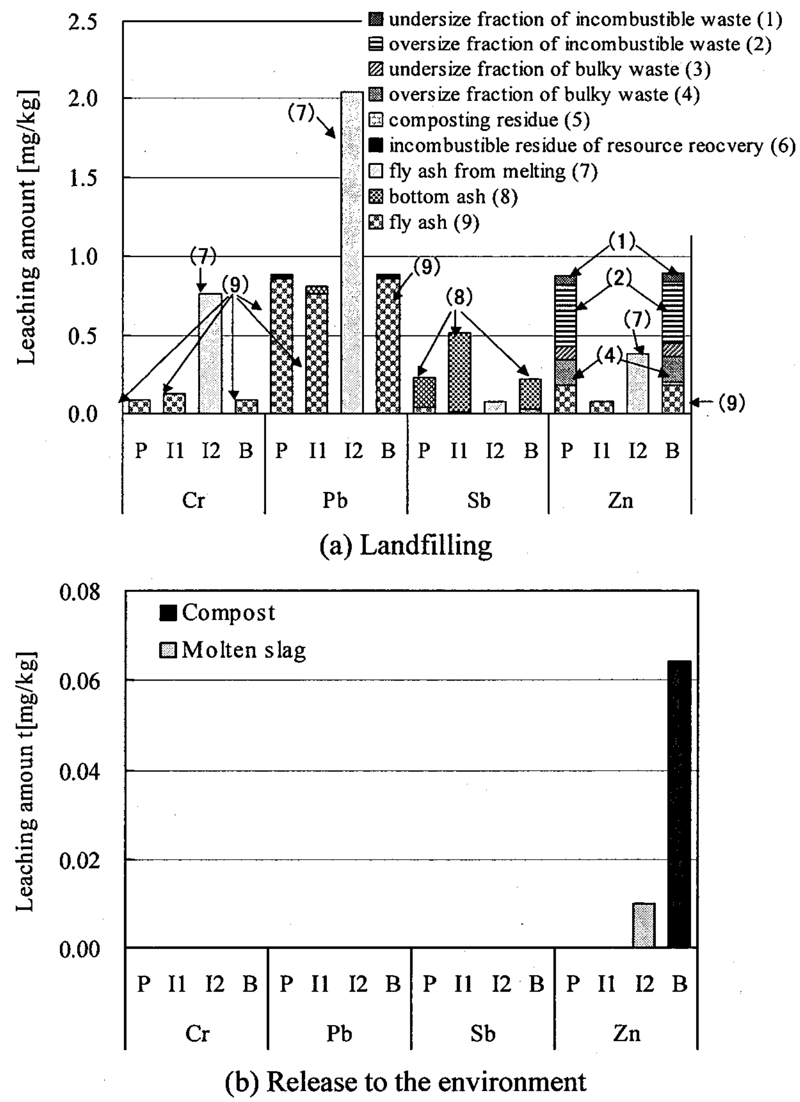


Figure 2. Leaching amount of metals in different SWM scenarios

The gasification - melting scenario shows the lowest metal transfer to landfill. In particular, Cr is much lower than that in the other scenarios, since molten slag including a high Cr content is recycled for construction and road material. For other metals, the distribution is not different between scenarios and metals are deposited in landfill. The leaching potential of metals from molten slag is very low (Jung et al., 2004), so the risk caused by leaching of hazardous metals from molten slag is negligible. Zn is released to the environment through compost but the release is quite small due to the low metal content of food waste.

As for the leachability of metals, fly ash and bottom ash show a high potential compared to other components (Figure 2). Especially, Pb leachability from fly ash is remarkably high in the gasification-melting scenario. However, fly ash is stabilized before landfilling to prohibit the leaching of hazardous metals, so the risk can be ignored. Under the present system scenario and bio-waste recycling scenario, the leaching concentration of Sb from bottom ash and Zn from shredded incombustible residues is a little high, which might cause an environmental burden in the surroundings of a landfill.

6. Summary

Flow analysis of metals in SWM system was performed to obtain the basic information for appropriate control of metals in the viewpoint of natural resource conservation and environmental risk reduction. The main findings are as follows:

- In household waste flow, the total contribution rate of paper/textile/plastics, bulky waste, and incombustible waste to metals was over 80 % except for Cr. Approximately 40 % of Cr originated from plastic packaging.
- SWM scenario evaluation showed that the leaching potential of metals to the environment is quite small and most metals were transferred to landfills.

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