Improvement of municipal solid waste management system in developing countries

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開発途上国における廃棄物処理システムの改善

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開発途上国の廃棄物処理の現状について行った調査を踏まえて、現状の埋立て処分に加えて焼却、及び微生物処理を導入した廃棄物処理システムを合成した。微生物処理については、一次処理と二次処理に分割して行うものとした。計算により、総括的な埋立て処分量、処理所要エネルギー等を推定し、開発途上国における本システムの実行可能性について検討した。

1. Introduction

In many developing countries, with advance of urbanization and improvement in an income level, the amount of municipal solid waste (MSW) to be managed is increasing. Most of the waste is disposed to landfillsites and the shortage of the site is getting serious.

The landfilled MSW contains a large amount of food waste, which cause the emissions of water with a load on environment, and generation of the methane; the strong Green House Gas (GHG). On the other hand most of landfill site do not have any facilities for controlling the emissions.

Therefore, it is necessary to introduce the MSW management method which will replace Landfilling.

To introduce the new management system method, cooperation of local residents is indispensable. It is important to examine the possibility based on the present condition of the local conditions.

Nowadays not only each methods of MSW processing technology but integrated waste management is studied. The method of LCA (Life Cycle Assessment) has been used to study integrated waste in aspects of the influence of environment such as GHG, toxic, and energy consumption the study considering the possibility should be done[1].

The purpose of this research is to propose MSW management system which will replace Landfilling, and to reduce the unwilling environmental influence of the whole system.

For this reason first of all, the present condition of a developing country was investigated to reveal the elements which becomes the hindrance of that new management system. Next, the MSW management system which combined composting and incineration in addition to landfilling was built up, and its feasibility is examined.

2. Present conditions of MSW in developing countries

The amount and properties of MSW

Although the amounts of MSW generation per capita in a developing countries are now low compared with an advanced nation, considering the high rate of increase of economic conditions of these countries, it will be expected that the future rate of increase far exceeds advanced nations.

The ratio of food waste is high in the developing countries such as Philippines 62.1% , India42.5% and Bangkok 63.7% compared with Yokohama 31.2%. In Japan, it is the feature that composition of paper is large 44.8% compared with Philippines 18.5% , India5.8% and Bangkok 5.7%.

The percentage of collected MSW to the amount of discharged MSW is 22 to 80% in many developing countries, comparing with Japan nearly 100% in Japan. In these areas non-collected MSW is left behind to a common dump for this, and also illegal abandonment is carried out by the river, the vacant lot, the road, etc., and the quantity is increasing with the increase in the amount of MSW generating. Although many trial is made aiming at improvement in a collection rate, financial restrictions are large and the present condition is not progressing easily. However, both the amount of MSW generating and a collection rate are expected to increase, and its improvement in the amount of MSW to be managed is indispensable in near future.

Table 2.1 Percentage of collected waste for recycling to MSW generation

City, Nation	Collected waste	Year	Source
Manila	11	1995	2)
Japan	13.1	1998	4)

Table 2.2 Percentage of paper recycle

	Collected paper to consumption	Recycled paper to production	Year	Source
India	14	62	1995	3)
Japan	55.5	58.4	1998	4)

Table 2.3 Percentage of Plastic recycle

	Collection to consumption	Recycle to production	Year	Source
India	40—80	37.2	1995	3)
Japan	12	9.2	1998	4)

Management method

In Japan, 78.1%, of MSW is processed by incineration . Other 6.7% is landfilled, 3.6% recovered , and 0.1% is composted. On the other hand developing countries depend on Landfilling disposal of the collected waste in many cases, as India 89.9% Manila 99%. Composting is another processing method. Before the collected waste is carried to disposal, some valuables are classified and collected by collection workers and the drivers of a collection vehicle, .

Percentage of waste collected for recycling to MSW is shown at Table 2.1

Recovery of valuables in Japan are made by some organizations and carried out in the suitable processing.

On the other hand, recovery of the valuables in a developing country is made by work of the buyer who comes for recovery to a home, the worker of collection, and scavenger who works at disposal site. It turns out that the recovery rate of the valuables of Manila and Japan hardly changes, the valuables recovery by the private sector in Manila is functioning effectively. Considering low production of row material, worth of valuables is high in these areas.

the rate of reuse of used paper as materials is quite high therefore, Even if the amount of consumption of paper increases, due to the usage of used paper is high, the rate of the paper in waste will seldom increase.

However as plastic is difficult to reuse, the rate of reuse will not be increase. Thus the rate of the plastic in waste will increase

In a developing country, although awareness of the issues over environment is increasing, the exact knowledge has seldom permeated. The Survey which were performed to the home in Manila showed many residents have dissatisfaction with MSW management service but at same time, it revealed that the rate which discharges garbage by the defined method is very low.

In such a situation, if the discharge method becomes complicated like sorting collection, it is expected that a collection contractor's burden becoming very large and not performing after all

3. MSW processing way suitable for developing countries

Landfilling is easy to take in for a developing country. However, it cannot respond to the increase in the amount of MSW. And an environmental problem such as methane generation, is also serious. By introducing other processing of waste, it is important to manage intentionally composition of the waste carried into a lamdfilling site and quantity.

Streamlining of waste by incineration processing is attractive. However, the calorific value of waste is small and is not suitable for combustion. In order to achieve effectively, a large-scale plan is required. However, taking into consideration of initial investment and maintenance management , in the present condition, it is difficult to introduce

Considering bioconversion is easy to operate and organic fertilizer can be recovered it is suitable to developing countries. To achieve good efficiency, three things are considerable. First option is reducing the quantity of the impurity in the waste carried into a processing facilities, as much as possible. There is high possibility in a developing country, where there is little mixing of paper, and plastic at the generation , and the worth of recovered valuables is high. However, this is hardly applied to urbanization area where the impurity content is increasing and sort separate collection is not working well.

The second option is devising the method of microbe processing. Some mechanical equipment do not matter the impurity much even they consume energy.

The last is about scale. Large scale facility can not gather enough waste and controlling is difficult.

It can be considered that the middle-scale facility which is easy to introduce around in the center of city.

Moreover, It is also considered attaching bioconversion facilities on the occasion of maintenance of the relay point from city center to final disposal place.

4. Integrated MSW management system

4.1 Outline of the system

Fig. 1 shows the MSW management system flowchart.

The wastes flow (MSW) F_0 from which valuable resources, such as metal, glass, and a bulky garbage, are collected in a generation is input to the system. This includes three kinds of waste ingredients Food waste(Fd), Wood and Paper (WP), and plastic (Pl).

This F_0 is sorted to three kinds of waste flows F_{01}, F_{06}, and F_{07} according to the stage of system where they are presented.

The management system combines Composting A and B (1) and (3), and Incineration(6), and landfiling(8) .

Near the waste generation area, the unsuitable substance may be contained in the MSW processed to composting.

Then, composting is divided two phases, first bioconversion composting A (1) where mainly easy biodegradable substance is biodegradedand second bioconversion composting B (3) where other biodegradable substances are also biodegraded. Composting A is small to middle scale and

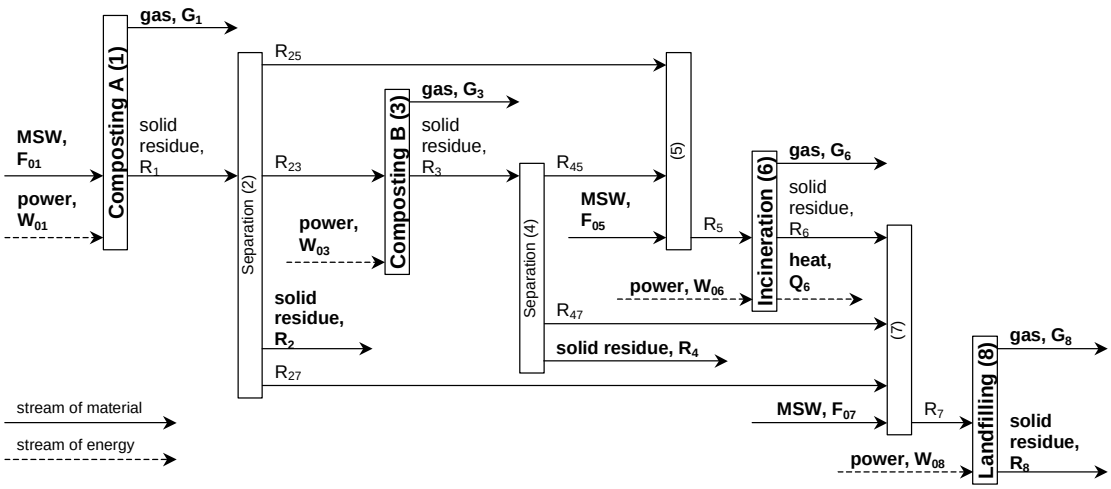

Fig.1 Block flowchart of solid waste management system

locate suburban-area. Composting B is large scale and locate far from city.

Total amount of MSW disposed to landfill site, mass fraction of water, and residue after enough long time energy consumptions of each equipments and recovered heat energy from incineration, and recovered equivalent energy of organic fertilizer from composting are calculated.

GHG emission CO_2, CH_4, and N_2O are objected as GHG.

4.2 Assumption

(1) General assumption

F_0 contains Food waste (Fd), Wood and Paper (WP), and Plastic (Pl). These consist of cellulose(Cl), Lignin(Lg), a Easy Biodegradable substance(EB), No Biodegradable substance(NB) and ash (As).

(2) composting

At composting A Cl and EB are decomposed. At composting B, Cl, EB, and Lg are decomposed. Generated gas contains Methane CH_4, AmmoniaNH_3, and Nitrous suboxide $N_2O$with proportion 96:2:2 [1)].Part of composting residue is recovered as organic fertilizer, and others are landfilled, or incinerated.

(3) Incineration

Perfect combustion of the combustibles is carried out. Generated gas contains only CO_2. heat recovery is calculated by ratio of mass fraction of water and ash.

(4) Landfilling

When water mass fraction is lower than 0.7 aerobic decomposition of a part of Cl and EB is carried out . and when it is higher than 0.7, anaerobic decomposition of Cl, and EB is carried out. Generated gas contains CO_2 and CH_4.

Table4.1 Mass fractions $x_{F0,i}$of ingredients i inF_0

Model cities	$x_{F0,I}$ [-]		
	i=Fd	i=WP	I=Pl
Bangkok, Shanghai, India, Manila	0.8	0.1	0.1

Table 4.2 Mass fractions of substances j in waste components; $x_{i,j}$

i	$x_{i,j}$ [-]					
	J=Cl	j=Lg	j=EB	j=Vo	j=As	j=Wt
Fd	0.070	0.004	0.118		0.008	0.800
WP	0.700	0.250			0.050	
Pl				0.950	0.050	

Table 4.3 Mass fractions of elements k in substances j

j	$x_{j,k}$[-]			
	k=C	K=H	K=N	K=O
Cl	0.444	0.062		0.494
Lg	0.730	0.070		0.200
EB	0.527	0.080	0.086	0.307
NB	0.800	0.130		

Table 4.4 Scenarios of separation

Run No	F_{01}	F_{05}	F_{07}
1	Fd, WP, Pl		
2	Pl	Fd, WP	
3		Fd, WP, Pl	
4	WP, Pl		Fd
5	Pl		Fd, WP
6			Fd, WP, Pl
7		Wd, Pl	Fd
8		Pl	Fd, WP
9	Pl	WP	Fd

Table 4.5 Specification of compost

				Residue
Ⅰ	R L I		Composting B With pretreatment	Fertilizer Landfilling Incineration
Ⅱ	R L I	Composting A	Composting B Without pretoreatment	Fertilizer Landfilling Incineration

4.3Calculation

Waste flow input F_0 was 1 kg/h. Composition of F_0 is shown in Table 4.1 This was determined with considering considered as the typical composition seen in the developing country.

Composition of each waste ingredient used for calculation are shown in Table4. 2. Compositions of food waste was based on Okara used as model food waste.[7)5)] Compositions of WP and Pl were estimated with literature[6)] and reported experiments[7)]. Composition of a plastic referred to composition of the polyethylene

The mass fraction of C, N in Cl, Lg, NB are shown in Table 4.3. It bases on the rate of a mass part of the carbon atom contained in cellulose from the chemical formula $(C_6H_{12}O_5)_n$ of cellulose. The contents of Lg [6)] and EB are estimated from literature.

The specifications of the separation are shown at Table 4.4. The specification of composting is shown at Table 4.5.

Total amount of MSW disposed to landfill site, mass fraction of water, and residue after enough long time, were calculated.

4.4 Result and discussion

Fig.2 shows the amount of MSW disposed landfill site, mass fraction of water, and residue, Fig.3shows energy consumption, and Fig.4 shows GHG emission. In Case 1 ,3, and 6, all the waste is disposed to landfill site, in case1, is incinerated in Case3, and composted in case6. Case 9 integrate all the methods Food waste to composting , Wood and Paper to incineration and plastic to Landfilling. For Case 6 4 composting method are considered. Composting in Case 9 is done at composting A.

The amount of MSW disposed to landfill site was significantly decreased by composting even the residue is landfilled. Energy consumption of composting A was much higher than others so most of energy consumption are from the composting facilities. However energy consumption does not contribute to GHG generation. GHG from composting process was almost same not concerned with a process. Methane from landfilling is even much as the generation form incineration. Case 9 required lowest energy and achieved lowest generation of methane. Environmental effect are same, the mechanical However small composting can be considered to introduce.

5. Conclusion

Based the developing countries condition it is revealed that to introduce integrated MSW management Scale and method should devised.

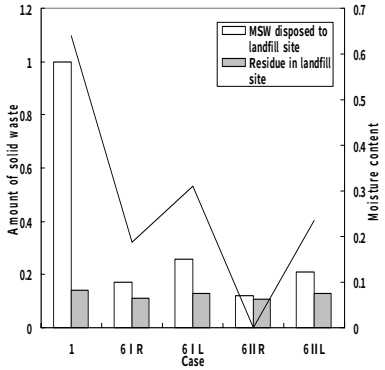

Fig.2 The details of landfilling

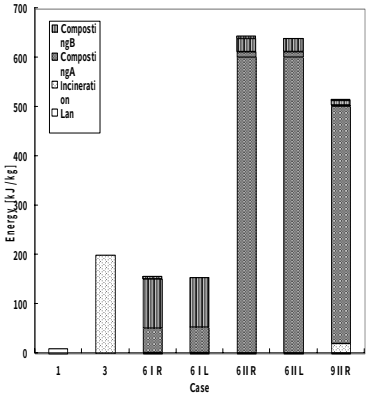

Fig.3 The details of energy consumption

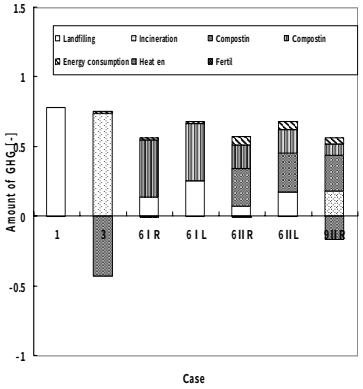

Fig.4 The details of GHG emission

6. Literature

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