B-53.2 Evaluation of Control Technology for the Emission of Greenhouse Gases from Recycling Treatment of Waste Materials

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Abstract

We proposed some tools for estimating the GHGs emission form waste recycling practices. We accumulated and compiled about 1500 kinds technologies for recovering and recycling of such as, paper, glass or plastic bottles, and steel or aluminum cans from various documents. Then, the database on these technologies was constructed and data on their energy consumption were analyzed. We developed the mathematical model for estimating the GHGs emission form collection and transportation of MSW by GIS data. The GHG emission from waste management strategies of some selected materials were also estimated by means of reviewing data on literatures and introducing USEPA's method to Japanese situation.

Key Words Greenhouse gas, Recycling, Waste treatment, Life Cycle, Control Technology

1. Introduction

In year 2000, the framework law for construction of the cycle society was enacted in Japan. Japan is now moving toward "recycling of waste". However, there are not enough considerations on the harmonization between recycling and environmental protection yet. For implementation of recycling, it will need to introduce some additional processes to existent waste management systems. This means that additional energy will be needed for system construction and running. Consumption of energy should link to emit green house gases (GHGs). Therefore, we have to estimate the life cycle GHGs emission from new recycling and waste management system and to select the system of less GHGs emission.

In this study, we tried to propose some tools for estimating the GHGs emission form life cycle of waste recycling practices. We accumulated technologies for recovering and recycling of waste materials, the database on these technologies was constructed and data on their energy consumption were analyzed. We developed the mathematical model for estimating the GHGs emission form collection and transportation of MSW. The life cycle GHGs emissions from waste management strategies of some selected materials were also estimated.

2. Framework of this study

In this study, we considered three different scales of waste recycling analysis as follow;

(1)Micro scale analysis; on relationship between the treatment capacity and the energy consumption of unit processes and facilities for waste management and recycling,

(2)Macro scale analysis; on management and recycling of selected waste materials in Japan, and

(3)Area scale analysis; on collection and transportation of waste in local areas.

3. Analysis on technologies and their energy consumption for waste recycling

3.1 Establishment of database on recycling and waste management devices

Many devices for waste recycling have been developed or put to practical use. However, various media separately transmit information of these devices, so it is difficult for user to see an overall picture of them. Moreover, when user will select devices, it is necessary to compare their performance on environmental protection and energy saving, as well as treatment capacity. In order to remove these inconveniences for user, we attempted to establish the database on recycling and waste management devices and their environmental performance. This database can also provide basic information for life cycle assessment of recycling and waste management devices and systems.

We used brochures collected from exhibitions and article/advertisement in industry journals as primary sources. We picked up data of name; producer; application; input/output materials; processing technology; treatment capacity; electric power and fuel consumption; and weight; of devices form primary sources.

Table 1 Summary of database on recycling and waste management devices

	1st Category	2nd Category	No. of Source		No. of Device
1	Software		16	16	16
2	Separation and Selection	for Recycable	51	17	25
		for Bulky Waste		5	5
		for Plastics		8	14
		with Magnes		5	287
		at Collection		16	40
3	Volume Reduction	Crushing	101	64	167
		Volume Reduction		28	101
		Others		9	155
4	Anhydration		4	4	31
5	Incineration		28	28	96
6	Melting		10	10	30
7	Pyrolysis (to Oil)		6	6	8
8	RDF Molding		12	12	28

	1st Category	2nd Category	No. of Source		No. of Device
9	Composting	Large	29	13	13
		Middle/Small		16	49
10	Pollution Prevention		26	26	69
11	Recycling	Eco-Sement	42	3	3
		Plastics		6	22
		Others		33	48
12	Instrumentation		2	2	2
13	Others	Carbonization	18	2	7
		Transportation		6	43
		Others		10	48
14	Treatment Plant		36	36	44
15	Union Catalog (Maker)		24	24	122
16	Union Catalog (Others)		40	40	63
Sum			445		1536

At this time, we have collected 445 primary sources with 1536 devices. Current summary of the database is shown in **Table 1**. This database was worked on Microsoft Windows 98 environment and installed a simple search system.

3.2 Analysis of energy consumption of waste recycling facilities and devices

We estimated energy consumption of about 680 bulky waste treatment facilities in the national statistics on 1990 (**Table 2**). Annual amount of treatment for all analyzed faculties was 3.49 million ton, which was 30% of total treatment capacity. More than 90% of energy consumption was supplied by electric power, which was 121 GWh as electricity charges and was comparable to 10% of electricity consumption in incineration and night soil treatment plants.

We also analyzed the relationship between treatment capacity and electricity consumption by recycling devices. Energy consumption and weight is related to running and initial energy consumption, respectively, in life cycle inventories of devices. In separation and selection devices for plastics, electricity consumption is sharply increased with installing the comminution process. The magnetic separation devices for separation of low magnetic metals tend to consume high electricity (**Fig. 1**). Energy consumption and weight of size reduction machines are depended on treating materials, such as bulky waste, plastics, glass bottles, and waste paper.

Table 2 Data on Bulky Waste Treatment Plant (FY1990)

	Municipality	Capacity (ton)	Utilization (h/day)	Utilization (day/year)
N.	719	679	641	622
SUM		33744.1	14860.75	140590
AVG		49.7	23.2	226.0
	Total Cost	Propane (kg)	Oil (kL)	Gas (m^3)
N.	449	75	124	17
SUM	17600 mil. Yen	32404.8	51171.9	20209.5
AVG	39 mil Yen	432.1	412.7	1188.8
Calorie (Tcal)		0.421	0.511	0.222
	Cost for Electricity	Estimated Electricity	Electricity/ Treatment (ton)	Reported Electricity
N.	422	422	418	406
SUM	18990 mil. Yen	121.4Gwh	46046kwh	89.96Gwh
AVG	4.5 mil. Yen	0.288Gwh	110kwh	0.22Gwh
Calorie (Tcal)		104.4		
	Cost for Chemicals	Cost for Other Utilities	Others	Recovered Material (ton)
N.	67	376	400	426
SUM	72.6 mil. Yen	1454 mil. Yen	1425 mil. Yen	612767.7
AVG	1.1 mil. Yen	3.9 mil. Yen	35.6 mil. Yen	1438.4

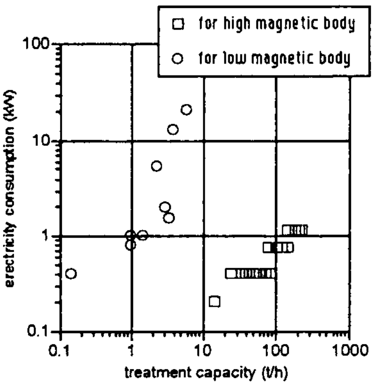

Fig.1 Relationship between Capacity and Energy (Magnetic Separation)

4. Development of collection and transportation model for local community.

For life cycle assessment of waste management system in local communities, it is critical to assess environmental impact from collection and transportation system as well as waste facilities. Therefore, we developed a primary model for estimating total mileage of waste collection and transportation and the optimal location of waste facilities, which minimize total mileage.

We used the GIS of the population density for basic data. We divided a local area into 400m x 400m square meshes, and estimated waste generation from each meshed area's population density. Daily waste generation per capita was assumed at 0.5 kg/day/capita. Then we searched a location of mesh, which minimized sum of the product of number and mileage of waste transporter (2 tons load) in all mesh by the conjugate gradient method. The minimal point of liner search in the conjugate gradient method was estimated by the golden section method.

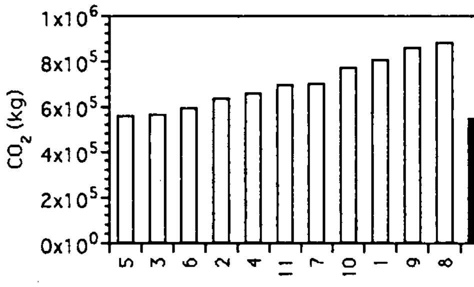

Fig 2 CO_2 emission from waste transportation

Fig. 2 shows CO_2 emission by waste transportation to candidate locations of waste facilities in a local municipality. We used the emission factor of CO_2 from waste transporter at 0.323 kg/km. At this time, we simplified the mileage of transpiration as a liner path. This model is a primary component for the actual waste collection model, so it is necessary to consider the road map, location of waste collection point, frequency of collection, traffic snarl-up, and avoidance of vehicle concentration around a facility in further study.

5. Assessment of life cycle GHGs emission from management of recycling materials

Some waste materials, such as waste paper, glass bottles, steel and aluminum cans already have been reused and/or recycled in Japan. Although there are many study about the "life cycle assessment (LCA)" for these recycable materials, most of them were compared only one-way use and reuse and/or recycling of materials. In practice, there are some options for waste management and reuse/recycling, and source reduction is most important strategies in the formation of cycle society. To be able to compare environmental advantages of waste management and reuse/recycling strategy material by material, we estimated the life cycle GHGs emission from some selected product/waste stream.

This assessment was based on the USEPA's report titled "Greenhouse gas emission from management of selected materials in municipal solid waste"[1]. We attempted to apply some methodologies in this report to Japanese situations with some alternations.

We collected information of life cycle stage (**Fig.3**) and mass flow of six materials for the drink container, which includes steel and aluminum can, glass and PET bottle, and paper carton, from literatures and reports. We also collected energy consumption and GHGs emission from them at each stage from former LCA studies in Japan. In the case of a PET (plastic) bottle, CO_2 from incineration was assumed that all carbon in the resin could be transformed to CO_2. In the case of waste paper, we estimated degradable carbon content (DOC) in this material and converted DOC to CH_4 using IPCC's default methods for estimating CH_4 emission from waste landfills[2]. Moreover, transportation mileage between each stage was assumed at 100 km for the overland route and actual distances from procurement location for the sea road route.

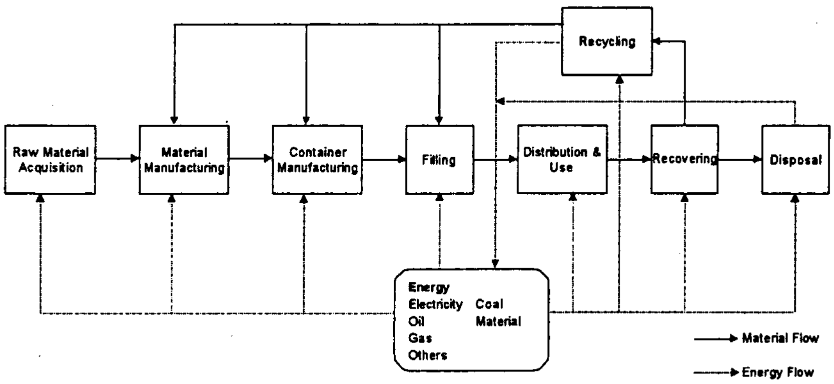

Fig.3 Life Cycle of Materials

We set following scenarios as waste management strategies;

(1)Direct Landfilling: a product made from virgin materials will directly be disposed to landfill after use.

(2)Incineration: a product made from virgin materials will be disposed to landfill after use and incineration.

(3)Energy Recovery: a product made from virgin materials will be disposed to landfill after use and incineration. Energy is recovered as electric power during incineration.

(4)Reuse (of returnable container): a product made from virgin materials will be completely recovered after use, and 75% of recovered materials will be reused as returnable container.

(5)Recycling: a product made from virgin materials will be completely recovered after use, and recovered materials will be processed and used for production of same product.

(6)Current Mix: A product made from virgin materials will be recovered, reused, recycled and disposed after use at current proportion.

Finally we estimated the energy consumption (Gcal/ton) and GHGs emission (MTCE/ton) in whole life cycle for each scenario. In estimation, we assumed that products made form virgin materials would supplement loss of products from reused/recycled processing, other usage (cascade recycling) and disposal.

Results are shown in **Table 3**. For GHGs reduction, use of returnable containers has first priority and recycling of steel can has next priority. Use of returnable bottle can reduce energy to half as much as other strategies. In comparison with the incineration and the recycling scenario, aluminum and steel cans have same priority and next are glass bottles. Former two need more energy at the martial production and latter one needs more energy at the container production. However, it is noted that production and recycling of aluminum cans need much more energy than other containers. These estimates are presented as an emission factor per weight of material. Therefore, it is easy for waste managers or citizens to think "which do materials have priority to establish the more intensive recycling system?" or "can our effort of source separation in my home be valuable to environmental protection?" .

Table 3 Energy consumption and GHGs emission from material management

energy (Gcal/ton)	reuse	recycle	energy recovery	inciner-ation	current mix	direct landfill
paper carton	---	5.42	4.34	5.61	5.21	5.60
PET bottle	4.85	---	10.4	11.8	11.8	11.8
steel can	---	3.07	---	6.29	5.77	6.26
alminium can	---	28.6	---	68.4	44.7	68.4
glass bottle	0.91	1.92	---	2.55	1.22	2.52

GHGs (MTCE/ton)	reuse	recycle	energy recovery	inciner-ation	current mix	direct landfill
paper carton	---	0.50	0.53	0.59	0.53	1.72
PET bottle	0.34	---	3.01	3.09	2.73	0.80
steel can	---	0.21	---	0.57	0.47	0.57
alminium can	---	11.0	---	39.7	22.7	39.7
glass bottle	0.08	0.14	---	0.22	0.10	0.22

6. Conclusion

We accumulated about 1500 kinds technologies for recovering and recycling of such as, paper, glass and PET bottles, and steel and aluminum cans from various documents. Then, the database on these technologies was constructed and data on their energy consumption were analyzed. We developed the mathematical model for estimating the GHGs emission form collection and transportation of MSW by GIS data. The GHG emission from waste management strategies of some selected materials was also estimated by means of reviewing data on literatures. We presented the factor for estimating the energy saving and GHGs reduction from reuse and recycling of some drink containers.

Reference

1) USEPA (1998): Greenhouse gas emission from management of selected materials in municipal solid waste, EPA530-R-97-013

2) IPCC (1996): Chapter 6 Waste, *In Revised guideline for national greenhouse gas inventories*