3-10 Partnership project of solid waste management in bandung, Indonesia

*Takeshi Fujiwara[1)], Tomoshi Hamada[2)], Koji Kawaguchi[3)], Hiroaki Obayasi[3)] ,Mochammad Chaerul[4)], and Enri Damanhuri[4)]

1) Waste Management Research Center, Okayama University
2) Graduate School of Environmental Science, Okayama University
3) Faculty of Environmental Science and Technology, Okayama University
4) Faculty of Environmental Engineering, Institute of Technology Bandung

ABSTRACT

In this project, in order to identify issues in the current waste management of Bandung City and in the promotion of 3R, under the partnership among four: Okayama University (OU), Okayama city, University of Technology Bandung (ITB) and Bandung city, we had a solid waste management (SWM) experts meeting and a 3R Seminar in ITB, also OU invited a lecturer of ITB and 3 city officials of Bandung. As for the collaborative research with ITB, we carried out to develop an evaluation modeling of new SWM which can reduce landfill waste amount by introducing household waste separation, composting, methane fermentation, incinerator, and so on. Moreover we tried to develop a model to evaluate the impact of the new SWM on the present recycling material society.

KEYWORDS

Bandung city, Exchange program, SWM based on 3R, Evaluation models

INTRODUCTION

In the city of Bandung, the amount of solid waste increases with the increase of population, the large amount of the waste is transported to the final disposal site more than 40km away from the city by track. Since the disposal site is expected to be full within a few years later, West Java Province is constructing a new landfill. To reduce discharge of household waste that could help to not only saving capacity of the landfill, saving the cost of disposing and transportation of waste, but also preventing scatter of mud and dust at roadside, noise pollution, and traffic jam. Funded and supported by the organization of foreign aid, such as IGES or JICA from Japan, concept of 3R (Reduce, Reuse, and Recycle) for household waste has been spread in Southeast Asian countries. In Surabaya city, Indonesia, home composting has been popular

in recent years, but not in Bandung city. It is said that the difference is caused by both strong initiative by mayor and citizen's concern for waste problem in Surabaya.

West Java province, to which the city of Bandung belongs, has a plan of 1) composting of kitchen waste at household, 2) collecting residual waste separately in public collection, and 3) dealing them in the methane fermentation plant which is currently under construction. On the other hand, Bandung local authority itself, in order to significantly reduce the amount of landfill waste, is considering the introduction of a municipal solid waste incinerator facility. This is where the concrete reduction measures are different between city and state. In addition, there are complicated circumstances in waste management: household waste is collect by not worker of local authority but private waste collector hired by residential community. In the transfer station where the waste collector brings waste, scavengers pick up valuable materials from the waste, and also mobile scavengers in landfill site pick up the valuable. The organization in charge of transporting the waste from transfer station to landfill site had been separated from local authority to be corporatized. From these reasons, new 3R countermeasures planed by local authority cannot be smoothly implemented. In this way, when waste reduction and recycling process are introduced, to know the history and mechanism of administrative regions is required.

In this project, in order to identify issues in the current waste management of Bandung City and in the promotion of 3R, under the partnership among four: Okayama University (OU), Okayama city, University of Technology Bandung (ITB) and Bandung city, we had a solid waste management (SWM) experts meeting and a 3R Seminar in ITB, also OU invited a lecturer of ITB and 3 city officials of Bandung. As for the collaborative research with ITB, we carried out to develop an evaluation modeling of new SWM which can reduce landfill waste amount by introducing household waste separation, composting, methane fermentation, incinerator, and so on. Moreover we tried to develop a model to evaluate the impact of the new SWM on the present recycling material society.

As for the business activities especially, Okayama University and the Institute of Technology Bandung hold a joint seminar and expert meeting. In the seminar, know-how and success stories about the waste separation and household composting were presented and discussed, on the other hand, in the expert meeting, officials of Okayama city presented technical information on municipal solid waste incineration which is running in Okayama city, after the presentation, they responded to many questions given by experts of Bandung city. As a second activity, during end of November through beginning of December, Dr. Chaerul from ITB and three heads of environmental board, cleansing enterprise and city planning of Bandung city were invited to Okayama University. The purpose of the visit is to watch separation, recycling and treatment processes in Japan and discuss about introducing the technologies to Bandung city in future waste management. The facilities visited were a landfill site, a bio-diesel fuel (BDF) plant, a modern incinerator and a recycling plaza, a plant for composting kitchen waste with livestock excreta, methane fermentation from sewage sludge, and so on. After that, the possibility of in-

troducing the technology in Bandung city was discussed in Okayama University with participation of an official of Okayama city. We believe research subjects can be found in evaluating the effectiveness of introducing the technologies from Japan to Indonesia.

In the research aspect, to evaluate the effectiveness in reduction of landfill waste by introducing several countermeasures, such as household separation, composting, methane fermentation, and incineration in Bandung city, we created several variations of scenarios which describe combined countermeasures, and based on the scenario, the amount of landfill waste were projected and evaluated. From the viewpoint of preserving the recycling society of Bandung city, the impact of new SWM countermeasures designed based on 3R on the workers of waste collecting transporting, scavenging, and dealing of waste must be important. To evaluate the impact, in the study, the model expressing economics and waste flow was formulated.

EXCHANGE ACTIVITIES

1. International Exchange (1)

Seminar and expert meeting in the Bandung Institute of Technology (ITB)

1.1 Technical visiting

1)Visitors

- Takeshi Fujiwara, Waste Management Research Centre, Okayama University
- Mr. Koichi Yamada, Director of Konan Clean Center, Okayama City
- Mr. Toshiaki Kodama, General Manager, Project and General Coordination Division, Environment Bureau of Okayama City
- Mr. Masatoshi Nagareo, Okayama ESD Project Coordinator in RCE Okayama, Environmental Conservation Division, Environment Bureau of Okayama City
- Mr. Tomohito Hamada, Master course student, Graduate School of Environmental Science, Okayama University

2) Visit Schedule

(Period: June 25 – July 2, 2011)

June 26: Visit to transfer stations, etc.

June 27: Expert meeting in ITB

June 28: 3R Seminar in ITB

June 29: Visit to final disposal site

June 30: Visit to RCE Bogor office

July 1: Visit to UNESCO Jakarta office

3) Contents of business trip

Technical visit to transfer stations and methane fermentation facility

· Date: June.26, 2011.
· Place: Transfer station, and fermentation facility

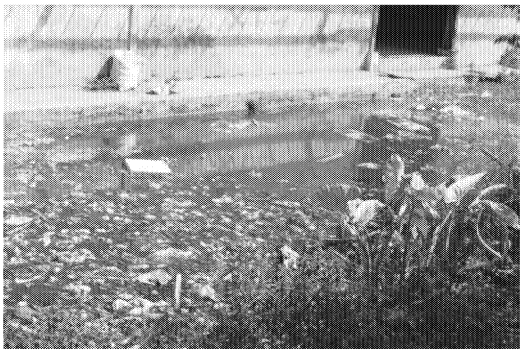
a)Transfer station (Imdrayu)

We visited a small transfer station in the center of Bandung City (Imdrayu). Waste collectors carried a cart in front and back of the cart body with full of waste. In the site scavengers with a family were sorting the garbage. Such transfer station is placed in each large community of the city. Photo-2 is a scene that plastic bottles were sorted by the scavenger, the recyclable waste is sold to the buyer.

b)Composting facility in transfer station (Gede Bage) (for market)

In Gede Bage, the waste generated from the big market near the transfer station is mainly collected, specially a lot of coconut shells have been piled up. The plastic waste is also sorted and sold after cleaned. Here is the place where an incineration facility will be constructed in future, the facility will accept the waste coming from not only the market but also many other transfer stations. The compost plant in the transfer station, after crushing biodegradable waste finely, makes the production of compost in the open air. After dried the improper component is removed in the final process. The surrounding environment, especially in the composting facility, bad odour, and the drain water flows from the market into the passage during heavy rain and moreover the channel was contaminated with large amounts of garbage.

Picture-3 Mountain of coconuts shells



Picture-4 Chanel contaminated by garbage

c)Methane fermentation process by anaerobic digestion and methane gas generation facility (Sekelimus)

Methane gas generation facility in Sekelimus generates the methane gas by performing the anaerobic digestion in the fermenter after crushing organic matter into the small particles (restaurants mainly , others are banana trees, garbage from the florist, etc.). It was demonstrated that the generated gas was used as a fuel for cooking stove or for electric generator.

The methane gas generation process is simple: in pre-processing, organic matter is sorted and grinded at a pace of 1 ton per day. Next, the organic matter (mainly garbage) is mixed

with an appropriate amount of water by human power and charged into the mixing tank. Inside of the tank, biological digestion is carried out by bacteria over the next 40 days. The approximate size of this fermenter is: the depth about 1.5m, the length of flowing direction about 15m. Generated methane gas is collected through the pipe into a large plastic bag hanging below the ceiling. This type of facility is planned to be developed in Bandung city in the future.

Picture-5 Mixing garbage and water

Picture-6 Storage plastic bag for generated gas

d) Largest transfer station in Bandung city (Tegallega)

Tegarega transfer station which is the largest in Bandung city and the waste is collected from 37 districts to, as well as the other transfer station, selects inorganic recyclables (plastic bottles, plastics, etc.) and organic matter (such as coconut). The total amount of garbage is transported extends to 70m3 come one day. In addition, composting is done by a different location, here is doing only screening and crushing. The residuals which cannot be traded nor composted are piled up on the track container, covered with plastic sheet so as not be fallen, and transported to the final disposal site.

Picture-7 Crashing coconuts shell

Picture-8 Truck transporting to landfill site

1.2. Expert meeting

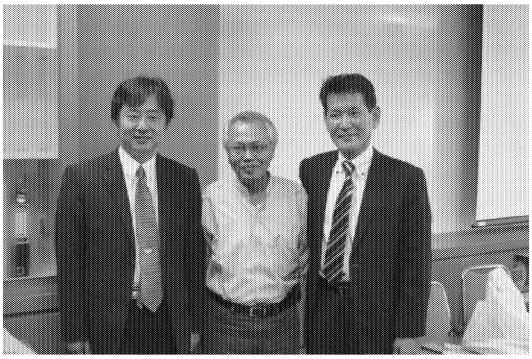
· Date and time: 9:00 to 12:00, June 27, 2011.
· Venue: Conference Room, Bandung Institute of Technology
· Participants: 25 (3 from West Java Environmental Health, 2 from Department of Environment Bandung, 12 from Bandung Institute of Technology, 3 from Bandung Environment Corporation, 3 from Okayama city local authority, 2 from Okayama University)

· The contents

After a lecture of an overview of the waste treatment system in Japan was given by professor Fujiwara from Okayama University, a lecture about the incineration facility was given by Mr. Yamada, who is a director of Kounan Clean Center (incinerator) of Okayama city. The high interest in Bandung side was on the running and maintenance costs of the incineration facility and operation of incineration facilities, as well as dioxins from incineration. About 1 hour presentation, a two-hour question and answer session was continued.

Picture-9 Expert meeting in ITB

Picture-10 Question and answer



Picture-11 Prof. Fujiwara, Prof. Damanhuri, and Mr. Yamada

Picture-12 Dean of Civil Engineering and visitors

1.3 Seminar on solid waste management through 3R practices

· Title: “Improving municipal solid waste management practices through 3R implementation”
· Date and time: 9:50 to 18:00, June 28, 2011.

· Venue: Hall, Bandung Institute of Technology
· Participants: about 110 (municipalities in West Java state including Bandung and Surabaya city, private company, Bandung Institute of Technology, Okayama City, Okayama University, others)
· Schedule

08.00-08.30 Registration

08.30-08.40 Welcome Speech from Head of Air & Waste Management Research Group ITB (Dr. Ir. Tri Padmi)

08.40-08.50 Welcome Speech from Mayor of Bandung City or Director of Bandung City Cleansing Enterprise

08.50-09.00 Welcome Speech from Dean of Civil and Environmental Engineering ITB (Prof. Dr. Ir. Suprihanto N.)

09.00-09.30 BREAK

09.30-10.30 Panel Session 1 (Moderator: Dr. Benno Rahardyan)

1. Research related to MSW management in Indonesia (Prof. Ir. Enri Damanhuri, ITB)
2. History and remarkable activities on 3R in Japan (Prof. Takeshi FUJIWARA, Okayama University, Japan)
3. Policy related MSW management in Indonesia (Ir. M. Sjukrul Amien, MM, Director of Sanitation Development, Ministry of Public Work)

10.30-12.30 Panel Session 2 (Moderator: Dr. Ir. Tri Padmi)

1. Concept and implementation of 3R in Bandung City (Cece Husen Iskandar, Bandung City Cleansing Enterprise)
2. Concept and implementation of 3R in Surabaya City (Hidayat Syah, Surabaya City Cleansing Department)
3. Actual projects on 3R in Okayama City, Japan (Mr. Toshiaki KODAMA, General Manager of Project and General Coordination Division, Environmental Conservation Division, Okayama City, Japan)
4. Current situation of waste treatment in Okayama City (Koichi Yamada, Division of Environment, Okayama City, Japan)

12.30-13.30 LUNCH

13.30-16:00 Panel Session 3 (Moderator: Dr. Sukandar)

1. Community empowerment related to 3R activities in Bandung City (Ria Ismaria, ST, MT)
2. Community experience on Composting activity (Bpk Suarjiman)
3. Community empowerment related to 3R activities in Surabaya City (Nunuk Maghfiroh, NGO of Mandiri)
4. Sharing experience based on community green and clean competition in cities in Indonesia (Astri Wahyuni, Private company of Unilever)

5. Experience in education and enlightenment for 3R (Mr. Masaaki NAGAREO, Okayama ESD Project Coordinator, RCE Okayama)

16.00-16.15 BREAK

16.15-16.50 Panel Session 4: Report on questionnaire (Moderator: Dr. M. Chaerul)

16.50-17.00 Concluding Remarks and Closing (Dr. M. Chaerul)

During the discussion, from the viewpoint of various sides: Indonesian side, the Japanese side, industry, academia and government, lively exchange of views was held.

Picture-13 Presentation in Seminar

Picture-14 Questions in break time

Picture-15 Discussion and comment

Picture-16 Group picture of participants

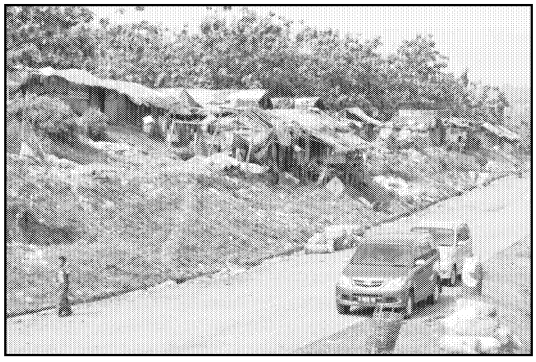
1.4 Technical visit to final disposal site

・Date: June.29, 2011

・Place: Sari Muti final disposal site

We visited Sari Muti landfill site. The same disposal site has been accepted at a rate of 3,900 m3 per day of waste generated from urban areas in and around Bandung city. There is a facility for making compost from organic matter in the landfill site. Since visit day was a holiday, many scavengers were picking up recyclable matters.

Picture-17 View of landfill site



Picture-18 House of scavengers in the landfill

1.5 Visit to Bandung City Hall

・Date: June 30, 2011
・Venue: Bandung City Hall

a)Courtesy call in Bandung City

Due to the absence of mayor and deputy mayor, we were welcomed by the head secretary .We explained the purpose of the 3R seminar and the expert meeting, and mentioned the preparation of the MOU between Okayama University and Institute of Technology Bandung. This meeting was meaningful from viewpoint that academia side and government side discussed siting around a table under the international partnership. (Each university and each city official gathered)

Picture-19 Discussion in Bandung City Hall

Picture-20 Group picture of meeting members

1.6 Visit to RCE Bogor office

・Date: June.30 2011.

・Venue: RCE Bogor office

RCE is abbreviation of Regional Centre of Expertise, Bogor is a center city in Indonesia, which studies on life research of biology and agriculture and so on. RCE Bogor has an activity together with research institutions, private companies, universities, government, and community, having socializing with each other toward the big goal in exploring solutions to poverty. More specifically, the education of knowledge about organic farming and expertise for the citizens, environmental education for the citizens, as well as initiatives such as outreach and research to improve public services of waste management have been carried out.

In particular, the power of the RCE Bogor is put to initiatives related to organic farming and waste management. For organic farming, pesticide is often used in Indonesia when growing a lot of crops, and the crops grown by using pesticide are widely distributed. Therefore, activities to change the situation by studying the organic cultivation of pesticide-free have been examined, and to educate a lot of people the results has been carried out. Target of education is not only poor farmer but also the people without know-how.

For waste management research and development, 3R education and waste collection and transportation planning has been done. The education or educational materials to help learn or develop knowledge about the waste while enjoying the game through television are included. School teachers are invited to conduct environmental education facility, and learn environmental education at school. However, the school curriculum is determined by the country consistently, so it is not easy at present to put the environmental practice into the curriculum of environmental education. As for the study on the planning for collection and transportation, research and development of models to simulate how it changes in the course of waste transportation and to evaluate how much it take cost have been conducted.

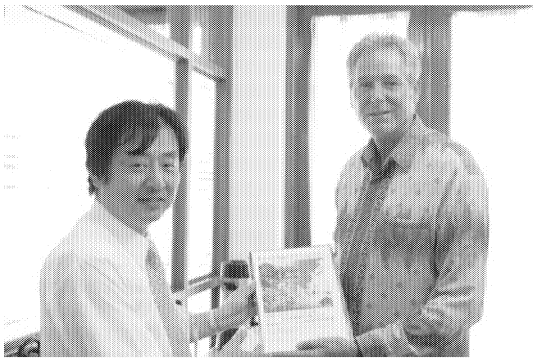
Picture-21 Explanation of 3R educational Game

Picture-22 Group picture in RCE Bogor

1.7 Local visits and meetings with Japanese companies UNESCO Jakarta

・Date: July.1 2011.
・Venue: UNESCO Jakarta

Professor Fujiwara explained our activity of the partnership project. After that, Okayama city officers appealed that the Okayama city is now inviting the conference "A final conference on a decade of ESD United Nations" in 2014 and explained for the preparation, and they requested and discussed about the support from the UNESCO Jakarta to introduce the conference to Okayama city.



Picture-23 Picture with director Heizen

Picture-24 Group picture with UNESCO Jakarta members

2. International Exchange (2)

Okayama University invited 3 city officials of Bandung city local authority and a lecturer of the Bandung Institute of Technology.

1) Persons invited
・Ir. Cece H. Iskandar, President Director of Bandung City Cleansing Enterprise
・Ir. H. Ahmad Rekotomo, MBA, Head of Environmental Agency of Bandung City
・Dr. H Gunadi Sukma Bhinekas, MKes, Head of City Planning Agency of Bandung City,
・Dr. Mochamad Chaerul, Lecturer of Institute of Technology Bandung

2) Invitation outline

Partnership project runs a research on the construction of new waste management system of the Bandung city in Indonesia through waste separation, recycling of organic garbage and the introduction of incinerator. In this project, Okayama city provides practical solid waste management for the cooperation with the Bandung city, and Okayama University promotes modeling of waste management to find better waste collection and recycling. In June, a 3R seminar

was held by Okayama University and Institute of Technology Bandung at ITB campus. This time, since introducing of the incinerator facility and planning of a new recycling system are in progress in the city of Bandung, this invitation was promoted to make the Bandung city officers watch Japanese technology in order to discuss about the model building based on technological treatment and disposal.

3)Invitation period

・Date: Nov. 29- Dec. 6, 2011.

Nov.30 Arrival at Okayama, technical visit to the final disposal site

Dec.1 Courtesy call to Okayama city mayor.
Technical visit to BDF plant, Kounan Clean Center

Dec.2 Tobu Clean Center & Recycling Plaza,
Meeting with Okayama City Eco-Technology Research Association (NGO)

Dec.3 Holiday

Dec.4 Discussion about waste treatment technology at Okayama University on Dec.5 Agriculture, Forestry and Fisheries Research Institute Livestock Research Center visited Okayama Prefecture

A sewage treatment plant in Tamashima district, Kurashiki city

3) Invitation contents

a)Technical visit to final disposal site

Officers of Bandung City visited Yamanoue landfill site after a little short of arrival at Okayama. The landfilling situation of Bandung city that total amount of waste is directly transported to landfill site is absolutely different from the incineration situation in Okayama city that only ash is landfilled after incinerating combustible waste. Because Bandung city has a plan to construct an incineration facility, they had a high interest of ash landfilling and made a lot of questions to Okayama city officers.

Picture-25 Explanation of landfill site

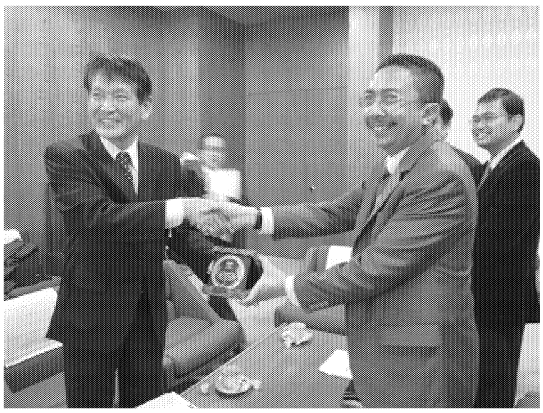
Picture-26 Watching actual site

Picture-27 Explanation of lining materials

Picture-28 Group picture in Landfill site

b)Courtesy call and technical visit to environmental facilities in Okayama

In the courtesy call to the city of Okayama, director of Okayama City Environmental Bureau, Mr. Matsuda, had a greeting. Mr. Yamada of Okayama City gave a description of the waste disposal business to visitors. The visiting party looked over a site of recyclables recovery at basement near the city hall.



Picture-29 Cortesy call to Okayama city

Picture-30 Visit to recycables collection Basement near the city hall

c)Visit to incinerator and recycling facilities

Visitor group visited BDF(Bio-fuel Diesel) plant, Eastern clean center and Eastern recycling plaza, as well as by bus. After the visit in the morning, the party discussed with Okayama City Eco-Technical Research Association at the office about the activity on food waste recycling in household, and others.

Picture-31　Visit to Bio-Diesel Oil Production (DOWA Bio-Diesel Okayama)

Picture-32 Visit to Kounan Clean Center

d) Discussion of waste disposal at the Okayama University

In the morning, we had a meeting with officers of Bandung city to discuss about recycling society in Bandung city. Questions about the relationship and the organizational structure and recycling society in Bandung, role of scavenger engaging in refuse collection, role of buyer, median income for the occupation of the cleaning business, and so on. In addition, we took an explanation of recyclable buy back system and incinerator in planning. Moreover, Mr. Yamada of Okayama city, director of Kounan clean center, gave us additional lecture of incineration facility in Okayama City.

Picture-34 Discussion in Okayama University

e)Visit to Okayama Prefectural Livestock Research Center

The party visited the Okayama Prefectural Livestock Research Center in the town of Misaki, Kume-gun, Okayama Prefecture. A lecture of "A Study on biogas generation utilizing the methane fermentation technology and energy extraction technology ", which has been implemented by Gr Environmental Research, and the other lecture of "The development of a production system of high quality compost by mixed livestock excreta with organic resources from kitchen waste, and establishment of recycling system", after lectures, we visited the methane fermentation facility.

The former lecture is that biogas obtained by anaerobic fermentation of the pig excreta are collected and recovered as energy use. The latter, which has conducted a demonstration test produced compost mixing livestock excreta and the food waste. Towards the development of material recycling system of organic resources, a research target of this study is to provide high quality and safe compost which is demanded farmers though examining various component with different balance of the kitchen waste discharged from the area and the livestock excreta. After the lectures, we watched a methane fermentation facility. The interest in compact facilities with power generator was high. It should be noted that many students of Okayama University participated in this visit.

Picture-35 Visit to Okayama Prefectural Livestock Research Center

RESEARCH AND RESULTS

1. Research Report on the Evaluation of waste disposal scenario

1.1 Purpose

In Indonesia, increase in the amount of waste generation and final disposal has become a serious problem due to rapid population growth. In the city of Bandung, recycling activities has been carried out by the trader who buys recyclable matter from household or the scavenger who picks up recyclable matter without any payment in residential area or the landfill site. However, recovery of valuable resource in the source is not enough for reduction of landfill waste. Composting in household is one of the reduction alternatives, but promotion of the composting to households takes a long time. The West Java, the state government, is building a methane fermentation plant beside the new landfill under construction. On the other hand, Bandung City local authority has a plan to construct an incinerator. Inappropriate component except biodegradable organic waste should be removed from general waste before composting, and the moisture of waste should be reduced when the waste is burned in incinerator. The operation efficiency in both facilities is not well if current waste collection system is continued. Combination of separate waste collection and waste treatment and recycling should be considered to gain high efficiency in total solid waste treatment. In this study, kids of alternatives, such as composting at household, sorting and separate discharge in household, composting in transfer station, incineration facilities, and methane fermentation, are combined in various scenarios and the reduction of landfill waste are estimated and evaluated.

1.2 Method

Study flow is 1) to figure out the waste flow through waste discharge, collection, treatment, and disposal process, 2) to create several scenarios describing which countermeasure processes, such as waste separation and recycling, should be included in current solid waste treatment, 3) to project reduction of landfill waste of future and its cost, and 4) to compare the results and discuss the effective solid waste management. The target year is fixed at 5 year later from the present time because construction of incineration facility and distribution of household composting will take 5 years.

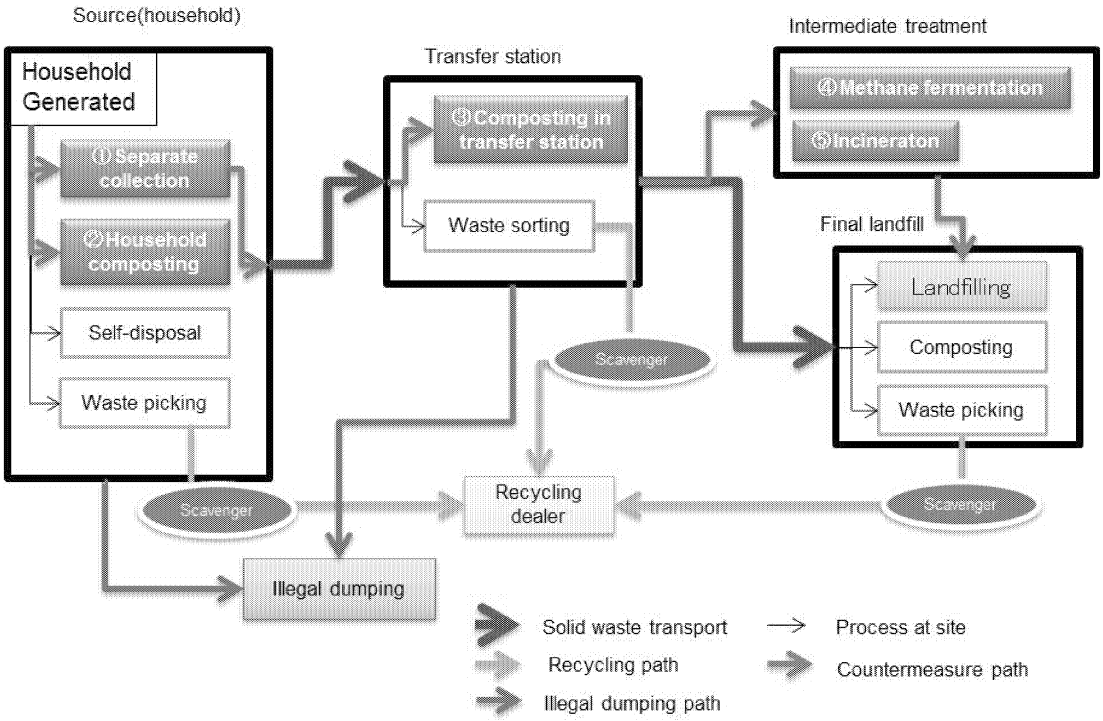


Figure. 1 Flow of considered waste flow of Bandung city

In this study, we set the following scenario.

Scenario 0: Current situation (BAU: Business as usual)
Source →Transfer station → Landfill site
Scenario 1: Expansion of composting at transfer station
Source →Transfer station (composting) → Landfill site
Scenario 2 - Implementation of separate collection
Source(separate collection) →Transfer station (composting)→ Landfill site
Scenario 3: Introduction of household composting
Sources (separate collection, composting at household) → Transfer station (Compost) →Landfill site
Scenario 4: Installation of compost facility
Sources (separate collection, composting at household) → Transfer station (Compost) →Compost facility → Landfill site
Scenario 5: Installation of incineration facility with separate collection
Sources (separate collection, composting at household) → Transfer station Incineration → Landfill site
Scenario 6: Installation of incinerator without separation collection
Sources →Transfer station → Incineration → Landfill site
Scenario 7: Integration

Sources (separate collection, composting at household) → Transfer station (composting) → Incineration, fermentation → Landfill site

1.3 Results and Discussion

The simulation result of the treatment and disposal of household waste was conducted for each scenario in Figure 2. First of all, waste reduction amount in scenario 1, the case of expanding composting in transfer station, and scenario 2, the case of adapting separate collection, decrease the waste discards, but the amounts are less than the increase in waste amount due to population growth. In addition, scenario 3, the case of introducing household composting, and scenario 4, the case of utilizing a methane fermentation facility gain the waste recycling amounts of 394 tons and 494 tons, respectively, but the amounts is no more than the increase of waste amount by population growth. Scenario 5 of Scenario 6, Scenario 7, can reduce to about half of the the landfill waste amount in the BAU case, and Scenario 5 and 7, can make the recycled waste 2 times and 3 times, respectively. By Comparing scenario 5 and 7, treatment amount of methane fermentation become is almost equal to decrease in landfill waste.

As a result of comparison amount scenario simulations, scenario 7, which is the case of integrating all kinds of countermeasures, contributes the most reduction of landfill waste. (For details left to the announcement of future research)

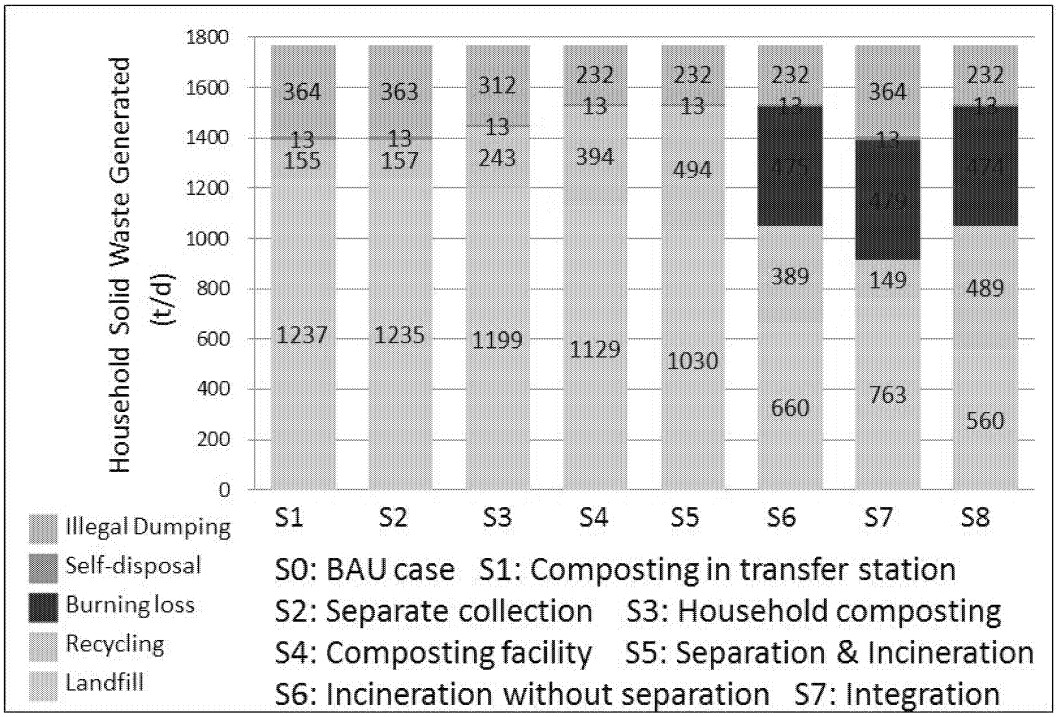


Figure 2 Comparison between scenarios by ratio of waste recycling, treatment, and disposal.

2. Research on impact of introducing separate collection on the current recycling society

2.1 Purpose

Due to the rapid economic development and rapid population increase, it is expected that the amount of waste generated will increase inevitably. However, many large cities have same situation that the household waste collected is directly dumped into landfills and only valuable materials are picked up by scavenger in transfer station or landfill site. Effective countermeasure to reduce the household waste is not performed.

While we evaluated how much Bandung city can reduce the amount of final disposal by introduce 3R policies, such as composting and separate collection and so on, in order to lengthen the lifespan of final disposal site, we focused on the effect of introducing 3R policies on the recycling society in SWM.

We build a model connecting socio-economic and waste disposal to consider whether the newly introduced SWM system based on segregated collection influences on the present recycling system. To express the relationship between the amount of waste generated by household consumption. The relationship between economic society and solid waste treatment tried to be represented by using the applied general equilibrium model, that can represent the elements of household and business activities.

2.2 Method

Model structure expressing the behavior of economic stakeholders as well as the relationships between money flow and waste flow is shown in Fig 3. As for the stakeholders, we regards household and government as the final consumers, waste collector and truck driver as transporter, and scavengers in transfer station and landfill site, and dealer for buying and selling recyclable materials are described. Resources are collected by scavengers and sold to recycling industry as the goods through the buyers and dealers.

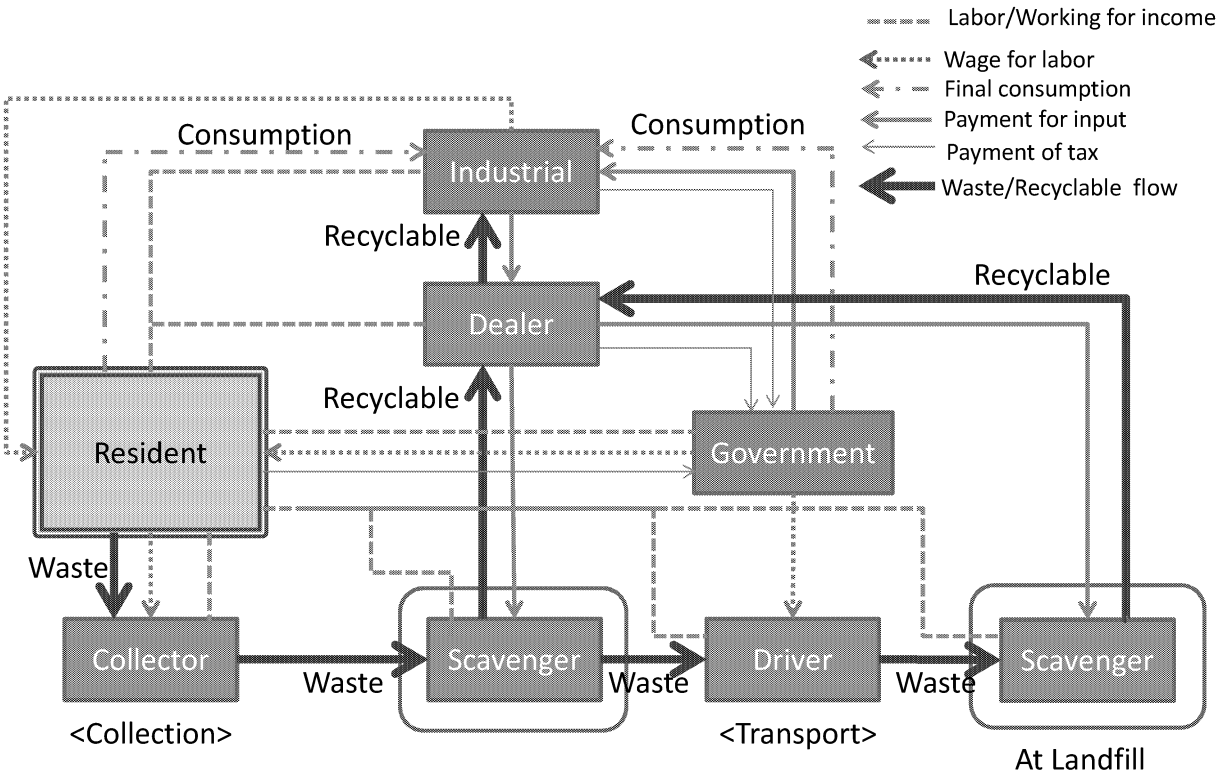


Figure-3(a) Present solid waste management in Bandung city

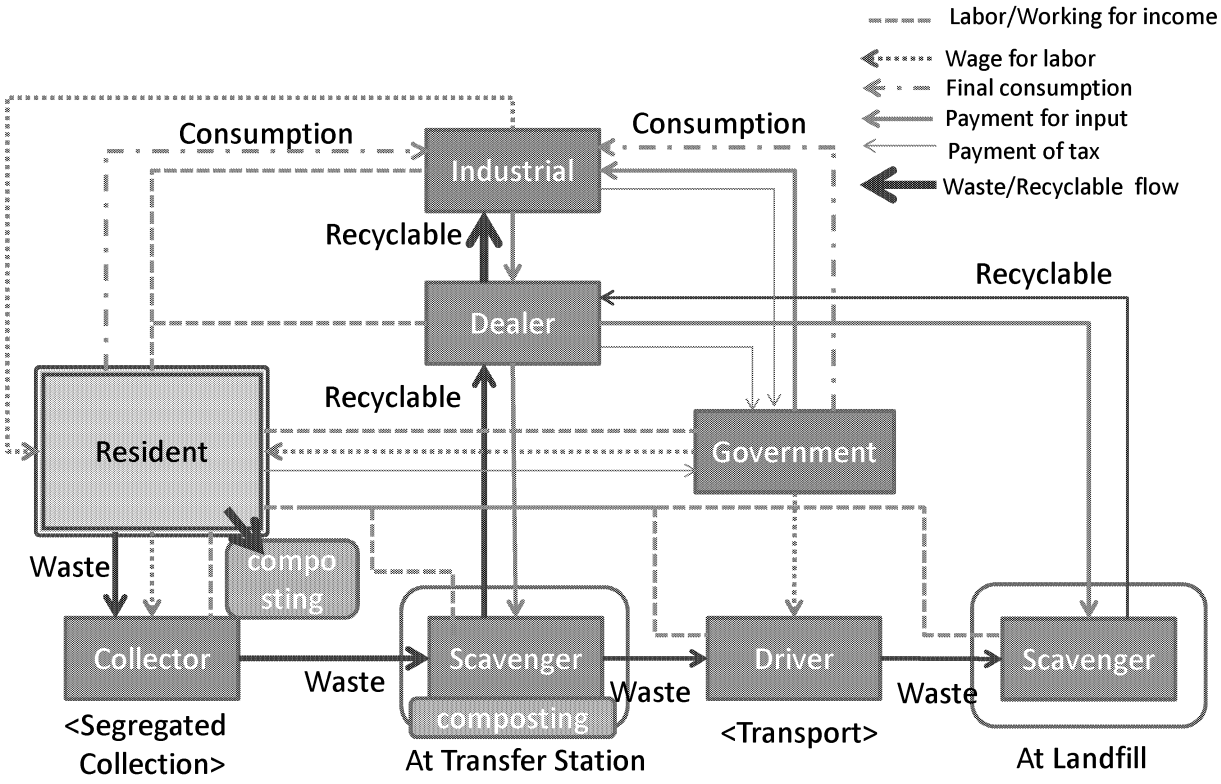


Figure 3(b) Solid waste management based on segregated collection

In this modeling, a social accounting composed of national accounting and IO table, which express the monetary flow between sectors and which is created so that row and column sums become equal. In this study, the social accounting table of the entire Indonesia in 2005 is shrunk by the size of the population and industry of Bandung City. After that, extension of stakeholder column and row were added.

Computational general equilibrium (CGE) model is a model of economy and society, which is described as a formula system, for instance, household consumer behavior and industrial production behavior are described as typical production functions. The solution for the system of simultaneous equations is sought so as to maximize the utility of households and industry. The system of simultaneous equations includes several coefficients (proportional rate for expense in utility function, scale factor and input rate in production function, the tax rate for production, the propensity to save, and so on), the values are realized by using economic data of the current or past. Then, by giving the conditions (values) in the exogenous variables on the basis of scenario, to calculate the endogenous variables from the model, it is possible to clarify the economic society in accordance with the scenario.

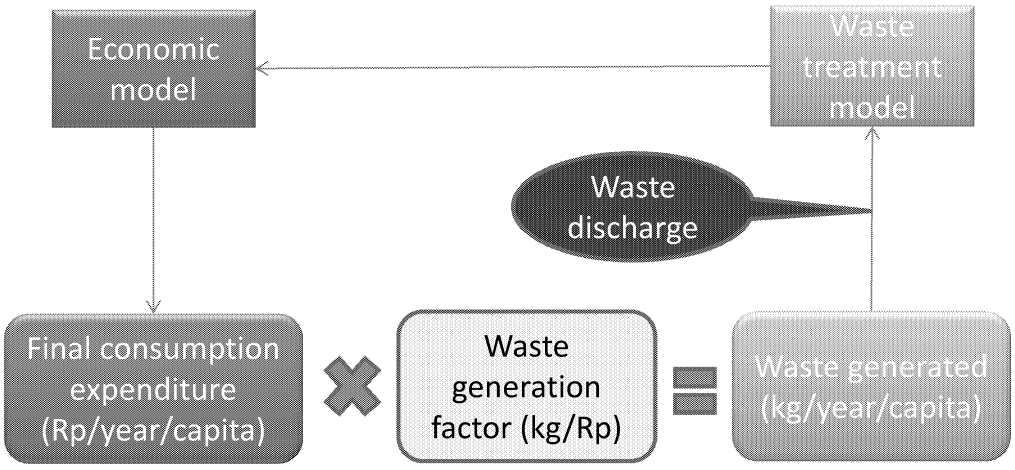


Figure 4 Relationship economic model and waste treatment model

The relationship between socio-economic model and waste treatment is as shown in Figure 4. Household consumption (the amount of final consumption) can be obtained from the economic model and it is multiplied with the waste generation coefficient. The amount of waste treatment is estimated by introduced into the model calculated, as the result, the amount of waste disposal of waste generated is the amount of recyclable waste recycling is confirmed, returned to the economic model. According to the concept of the model basic structure, the waste generation coefficient was calculated by using Japanese solid waste statistics.

CONCLUSIONS AND PERSPECTIVES

This year, through exchanges with Indonesia Bandung City and Institute of Technology Bandung, we knew the future plan of SWM as well as to grasp the present condition of waste disposal of Bandung city. In addition, in the research aspect, by the support of the cooperation of ITB, the amount of final landfill waste was calculated in several scenarios composed of the combination of the possible waste separation and waste treatment processes. Moreover, we could considered the method to evaluate the impact of the improvement of SWM on existing recycling-oriented society. However, the accuracy of calculation in the system evaluation is not enough, and only formulation was conducted as for the CGE model. In the next fiscal year (from April 2012), we will improve the accuracy of the calculation and complete the CGE model.

REFERENCES

Activity materials

・Newspaper articles about the seminar in the city of Bandung

・Newspaper articles about the visit Okayama city in Bandung, Bandung Institute of Technology

・Keynote lecture of IESL-SSMS Joint International Symposium on Social Management Systems 2011 was held in Bandung Institute of Technology

Planning and Evaluation of 3R-based Solid Waste Management

Takeshi Fujiwara[1]

[1]Waste Management Research Center, Okayama University
3-1-1, Tsushima-Naka, Kita-ku, Okayama City, 700-8530 Japan

Abstract. Large cities in many Asian countries have similar types of solid waste management problems: increase of waste generation, shortage of landfill capacity, and long distance between urban area and landfill sites. In Japanese history, there have been conflicts between citizens in Tokyo and other districts about landfill construction. However, such circumstance boosted up the waste separate collection which was supported by citizens' participation, shown in the case of Numazu city. Achieving a separate collection system becomes difficult under the condition of weak participation by citizen. It is thought that visualizing the effectiveness of citizens' participation on increase of public benefits is important when educating citizens about separate collection. In this paper, we present a planning and evaluation method of 3R based solid waste management. Furthermore, the procedure of the method and application to Colombo city, Sri Lanka, are illustrated. The purpose of the evaluation is visualization of changes in reduction of landfill waste, CO_2 emission, and cost according to citizens' participation in separate collection. Comparison of results between scenarios with different values of participation rate has persuasive power.

Keywords: *Solid Waste Management; 3R; Planning and Evaluation; Modeling and Simulation; Visualization.*

1 Introduction

Solid Waste management is a big issue in large cities of not only on developed countries but also on developing countries. Construction of a new landfill within or near the urban area has been difficult because of citizen's opposition against coming of the nuisance facility. For example, Bandung city in Indonesia has the problem of the solid waste collected within the city taken to Sari Mukti landfill in Figure 1 located at 44.4 km away from the city, where transportation trucks often cause traffic jams on the way.

About a century ago in Japan, central government proposed the policy of incinerating solid waste in incinerators, from view point of sanitation. At that moment, since incineration equipment was expensive even if the size was small, only the specific municipalities with large population could have an incineration

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facility. However, at present most of the municipalities have an incineration facility or complex. Incineration reduces the volume of solid waste to a 5%, and only the residual inert ash is landfilled. Regardless of the high volume reduction by incineration, prolonging lifetime of landfill is an absolutely important issue. Finding possible places for a new landfill and getting citizens' approval of landfill construction is always a difficult task for local authorities.

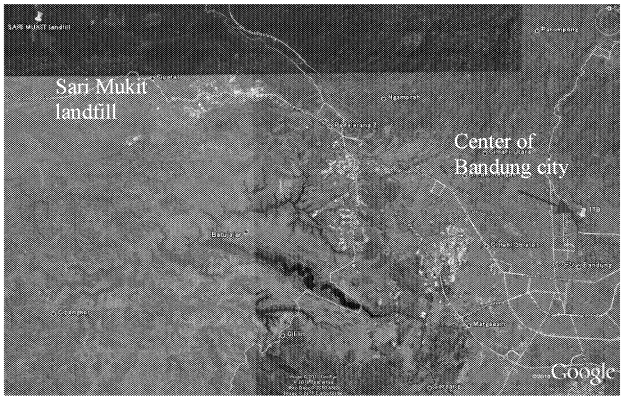


Figure 1 Distance from the center of Bandung city to Sari Mukti landfill. (Indonesia)

In order to reduce the frequency of which landfills are constructed, *minimization of waste generation* and *maximum reduction of waste discharge* are essential concepts as countermeasure. "M*inimization of waste generation*" means reducing amount of goods input to household, for instance, refusing to buy what will be unused, rejecting excess packing and wrapping, using refill bottles and so on. On the other hand, "*maximum reduction of waste discharge*" means to reuse the generated waste or recycling it before discharging it as waste. For instance, to pass over the waste to a person who wants it, to recycle it by oneself, to give or sell it to a scavenger, to gather by community and sell it, and so on. Collection and recycling of reusable waste is absolutely necessary for reducing landfill waste.

At the moment of designing a solid waste management system including waste collection, transportation, recycling, treatment, and disposal processes, special considerations begin from waste generation at source. Source separation means sorting waste into specified waste categories at household and taking the waste of each category to designated place on designated day. However, the style of waste collection should be locally specialized based on traditional custom.

Comparison between waste collection methods between countries will be useful information to improve the collection style.

3R based solid waste management will save energy, materials, and will reduce costs, especially through recovery of biomass energy and reduction of the amount of landfill waste.

This paper introduces examples of Japanese 3R-based solid waste management and the trigger to the activation of 3R in Japanese history of waste management. In addition, our evaluation method to evaluate the effectiveness of 3R based solid waste management from view point of reduction of environmental impact and cost, with a case study of Sri Lanka.

2 Japanese 3R-based Solid Waste Management

2.1 Citizens' Conflict in Terms of Solid Waste Management

Japan entered in a high-speed growth period of economy from the middle of 1950's, and huge amount of waste was generated according to the economic growth. This situation was expressed as "*mass production, mass consumption, and mass waste generation*". Many conflicts rose in urban areas due the opposition by citizen against landfill construction plans proposed by municipalities. Especially, bigger conflicts were present in Tokyo at the end of 1950's.

Since the amount of generated waste in Tokyo was over the capacity of waste incineration at the time, about 70% of the waste was being transported to a sea area solid waste disposal site at Tokyo bay, which was in Koto-ward. Over 5,000 trucks run across Koto-ward, causing unpleasant odors, traffic jams, fires within landfills, and plagues of flies that upset citizens in the ward. As a consequence of this, Tokyo metropolitan city established the "*decade plan of incineration plant construction*" to support waste management in each ward.

However, citizens in Suginami-ward, who lived near by the selected site for incinerator construction, were against this construction and terminated the plan consequently. On the other hand, Tokyo metropolitan city promised Koto-ward to improve the bad environmental circumstance of waste transportation and also to switch from landfilling to entire incineration by 1970, nevertheless landfilling was continued due to the delay of incinerator construction.

Congress of Koto-ward finally decided to oppose against waste acceptance. In response to this, Mr. Minobe, the mayor of Tokyo metropolitan city declared the "*Tokyo gomi-war*" and revealed his determination to solve the waste disposal problem. Actually, conflicts between citizens and city authorities, for

example, citizens living near by the candidate site organized groups against the construction of these sites not only in Koto-ward but also other wards, on the other side, citizens in Suginami-ward barricade themselves to prevent waste transportation trucks entrance from other wards.

2.2 Start Point of 3R

Provincial city also had a problem in the treatment of a large amount of waste. Numazu-city was the first local authority which adopted 3R policy in solid waste management in Japan in 1975. The trigger of the separate collection was given by the municipality, and a residential association started up an actual movement.

Initially, there were three categories of waste separation: combustible waste, landfilling waste and recyclable waste. Importance in waste separation is fixing waste collection days of the week according to each waste category. The waste collection style which was established there was the station collection style, that is different from the waste collection style of Bandung city. A corner of a residential block was used for a waste collection site in order to gather the plastic bags, carrying combustible or incombustible waste, brought by people from residential sector. Combustible waste was collected twice per week, and incombustible waste once per week. Recyclable waste was gathered in a community park or at the side of the road in residential areas. Volunteers from the residential areas assisted citizen's segregation in the site. The waste separation style was diffused to other local authorities, and currently almost all local authorities carry out waste separate collection and recycling. This Numazu collection style was improved and succeeded into the current collection style in Numazu-city.

Figure 2 Separate collection of glass bottle in Numazu. (1990s, Japan)[1]

2.3 3R Activity by Local Authority in Japan

Based on "*Waste Management Law*" under "*Basic Law for Establishing the Recycling-based Society*", any local authority is now responsible to collect recyclable waste separately and recycle it. Okayama city should be a leader of 3R in Chugoku and Shikoku regions as one of government-ordinance-designated cities in Japan.

The waste separation categories are decided by local authority. In the case of Okayama city, the household waste is segregated into four categories: combustible, incombustible, recyclable, and bulky wastes; this categorization is general in many cities. Combustible (twice a week), incombustible (once a month), and recyclable (one or twice a month) waste is gathered at designated waste collection station on the different day, respectively.

On the day that recyclable waste is collected, a representative selected by the community opens and sets colored holding boxes, and supervises whether residents put their recyclable waste accurately into the corresponding box. A truck of the municipality comes to the station to take the boxes to the recycling plaza.

Based on the principle "*pay as you throw*", Okayama city has taken a bag charging system for combustible waste and incombustible waste. Citizen must buy a set of designated plastic bags in convenience stores or supermarkets, and use it when discharging the waste. This system is expected to lead the citizen to discharge, as recyclable waste, what has been discharged as combustible or incombustible waste.

Figure 3 shows the facility in Okayama city where each separated waste is conveyed. The combustible waste is burned out in incineration facility. Recyclable waste is purified and baled in pre-treatment process at the recycling plaza. Incombustible waste and bulky waste are crushed and separated into recyclable parts and residual parts in the recycling plaza. Table 1 shows the capacity of each incineration center and landfill. Totally, incineration capacity is 970 ton/day, average amount of landfilled waste is 57 ton/day, recyclable waste is 27 ton/day, and bulky waste is 58 ton/day (some parts are recycled after decomposing bulky waste)

Table 2 shows the treatment amount and the cost of each facility. Treatment cost of recyclable waste per ton of TOHBU recycling plaza is very high comparing to clean center. Since dirty or not suitable materials are included in the collected recyclable waste, labor fee for manual separation to remove inadequate materials is costly. It can be concluded that participation in separate

collection influences on the amount of recyclable waste and the accuracy of waste separation influences on the recycling cost.

Table 1 Capacity of solid waste management facility (Okayama city)

Facility type	Facility name	Capacity (ton/day)
Municipal solid waste incineration facility	KOHNAN clean center	110×2
	TOHSHINDEN clean center	150×2
	TOHBU clean center	150×3
Intermediate treatment facility	TOHBU recycling plaza	Bulky waste 58 Recyclable 27
	SHINPO waste separation yard	Yard only
Final disposal facility (landfill)	YAMANOUE Final disposal site	57

Table 2 Cost of waste treatment and disposal facility (Okayama city).

Facility name	Running cost (M yen)	Treated amount (ton/year)	Cost per weight (yen/ton)	Initial cost (M yen)
KOHNAN clean center	1,168	50,780	22,999	Construct. 6,470 Renovation 2,444
TOHSHINDEN clean center (including recycling plaza)	1,646	52,754	19,829	12,494
TOHBU clean center	1,612	102,625	15,707	13,577
TOHBU recycling plaza	544	11,079	49,146	4,169

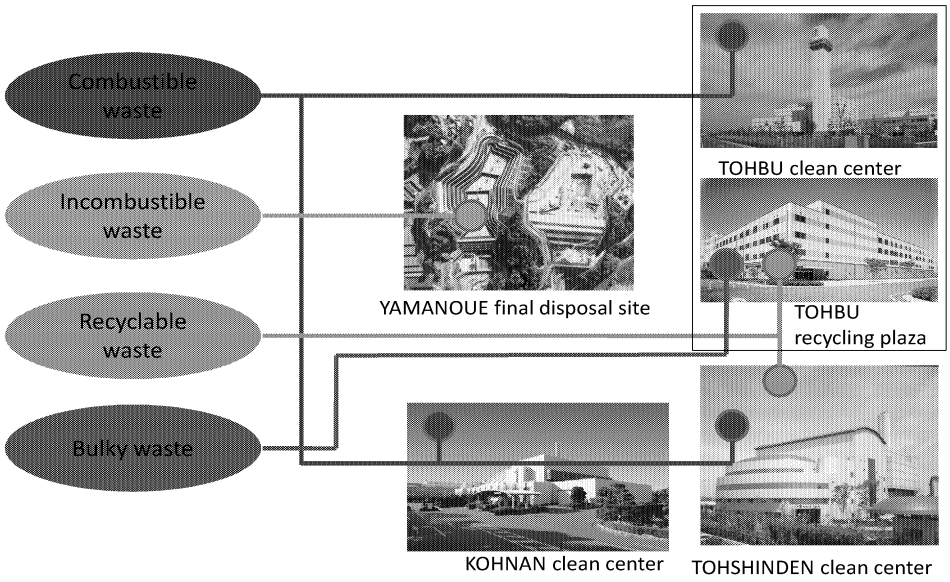


Figure 3 Waste separation categories and corresponding treatment/disposal facilities. (Okayama city)

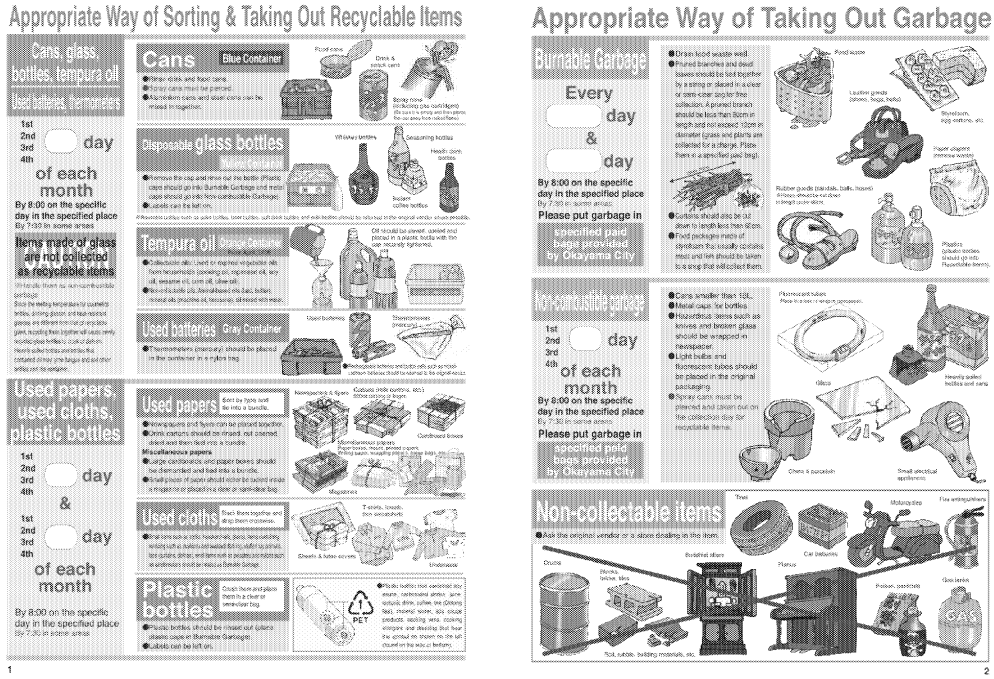


Figure 4 Items of recyclable waste in each waste separation category. (Okayama city)

2.4 Solid Waste Management in Bandung City

In Bandung city, the style of waste collection from household is different from Japanese style. Waste collection from households is managed by a community of residential area (RT). The community hires waste collectors to come and pick up household waste by hand cart, house by house, without any separation. The collected waste is carried to a transfer station where many scavengers separate materials to recyclable waste and others (Figure 6). The others are stored in a truck container where finally they are taken to the landfill by truck. Other group of scavengers with a living in the landfill in poverty conditions pick the remaining recyclable materials and sell them to earn their living. (Figure 5)

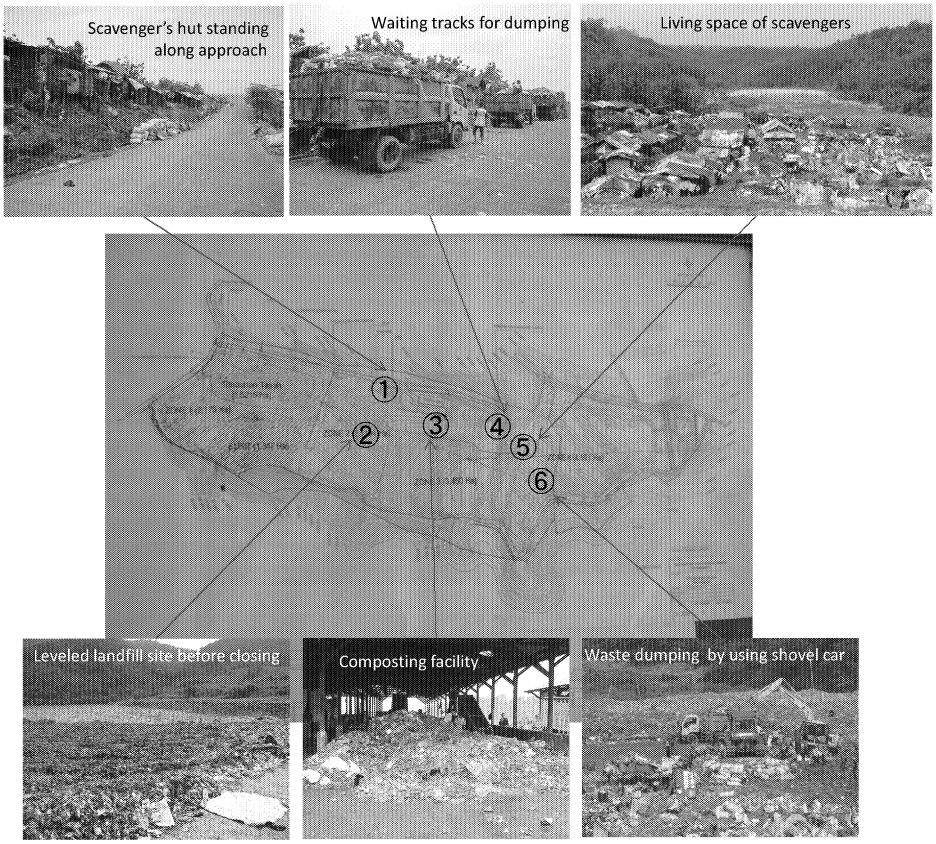


Figure 5 Pictures of Sari Mukti landfill with composting facility and scavenger houses.

If waste sorting and separate discharge at household became mandatory, what kind of collection system is suitable for the city? Figure 7 is shown as an alternative of separate collection plans. Frequency of waste collection will

increase because of taking separate collection by each waste category, on the other hand, the separation benefits by the scavengers in transfer station will decrease. Making compost from the bio-degradable waste, such as collected food waste and garden waste, will reduce the landfill waste. Actually, Bandung city has examined the composting in transfer station (Figure 8). It is uncertain whether the scavengers would be able to fulfill the new jobs demanded by the new waste collection system. It will be necessary to make a plan and evaluate the new waste collection system considering management of labor employment.

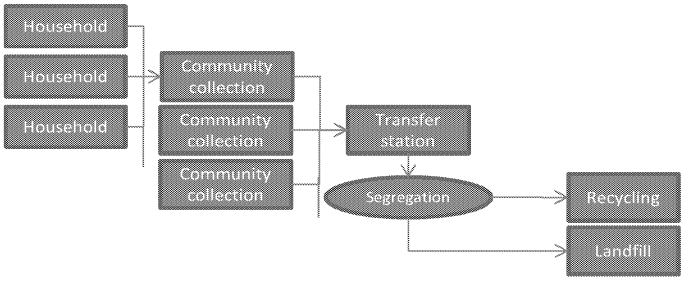


Figure 6 Current waste collection and treatment system houses.

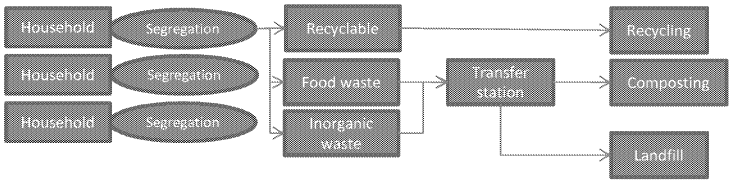


Figure 7 New waste collection and treatment system

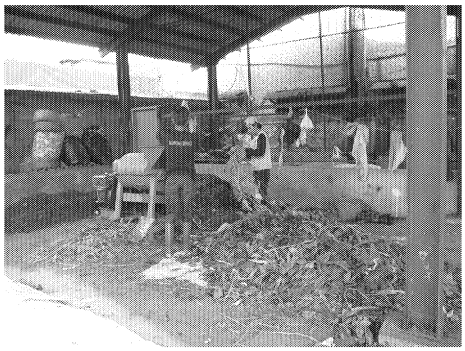


Figure 8 A pilot scale test of composting in transfer station by the enterprise of city cleansing, Bandung city

3 Study of Planning and Evaluation of 3R-Based Solid Waste Management

Many large cities in Asian countries have similar SWM problems: large amounts of waste generated, long distances of transportation, and shortage of landfill. Since there exists a domestic recycling business society having a hierarchical structure composed of scavengers, waste transporters, domestic factory for waste separation and purification, buyers and dealers of recyclable materials in such large cities, the valuable materials, such as paper, plastic, steel, aluminum, glass and the other recyclable, have already been extracted from landfill waste. Therefore, the target for recycling is the bio-degradable waste including mainly food and garden waste. In Hanoi, Vietnam, a big campaigns for recycling bio-degradable waste generated from household was held, which was supported by JICA for several years. However, citizen participation to separate collection of food waste is low. Namely, the citizens do not participate in separation of food waste under the condition of no reward given. The important point is whether the citizens change their mind about participation in the separation when they aware the separation collection leads to public benefits.

Visualization of the effectiveness of participation in separation is sometimes effective in educating the citizens. We have examined the introduction of 3R and evaluated the impact to environment and cost in our research. In this paper, we would present a recent study on the planning and evaluation method of 3R based solid waste management, with a case study for Colombo city, Sri Lanka.

3.1 Outline of Planning and Evaluation Method

The procedure to evaluate solid waste management (SWM) is shown in Figure 8. First, we carried a questionnaire survey and a household waste generation survey for obtaining waste generation data. Secondly, we developed a SWM model including separate collection and recycling. For the next step, after setting the distribution of generated waste and the locations of related facilities, such as landfills, recycling facilities, incinerators, on the GIS map, transportation distance between source and facility or facility and facility was calculated, moreover, environmental impact like air pollutants and CO_2 emission was estimated as well as the transport cost. Finally, we analyzed the sensitivity of the cost and environmental impact by different citizens' participation. This approach has been attempted in Sri Lanka[2,3] and Malaysia[4,5,6].

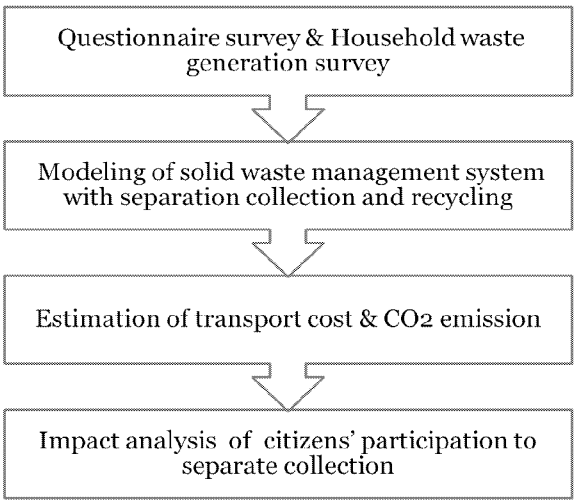


Figure 9 Procedure to evaluate solid waste management.

3.2 Questionnaire Survey & Household Waste Generation Survey

To understand the quality and quantity of household waste is important in the first step of the system evaluation. In developing countries of Asia, local authorities have operation data of solid waste management but sometimes they are not always available for researchers. The quantity data of waste should be the total amount of the waste transported to landfill site. However, the data is sometimes not really measured in weight but is predicted from the number of transportation by trucks. Most of the landfills do not count with scaling equipment, except for modern large landfills. We do not have much information available on waste composition.

To obtain the quantity and quality information of household waste, we conduct two kinds of surveys: one is a questionnaire survey and the other is a household waste survey; these surveys are conducted during the same term. In questionnaire survey, the questions regard four categories: 1) attributes of respondent, 2) knowledge of waste collection, 3) experience to participate in environmental activities, and 4) willingness to participate in household sorting. Target respondents to the questionnaire survey are wide and the number is large; for example about 1,000 questionnaires were distributed in the survey of Sri Lanka and Malaysia. On the other hand, in household waste generation survey, the a sampled household sorts the generated waste into several categories and measure the each weight every day for one month. Comparing to the questionnaire survey, the number of sampled households is small,

actually it was about 20 to 30 households in the case studies of Malaysia and Sri Lanka.

3.3 Modeling for Evaluation of Citizens' Participation

Figure 10 shows the flow chart of waste management model we proposed in Sri Lanka study [2]. Waste stream from household is divided into three categories known as "kitchen waste", "recyclable waste" including paper, plastic, metal, glass and so on, and remaining part of the waste called as "other waste". At discharging the household waste, the kitchen waste and the garden waste which is generated from gardening are brought together as "bio-degradable waste". The bio-degradable waste and recyclable waste are respectively taken to the composting center and recycling center in order to purify and utilize the waste. The residuals generated in this process, which is the improper contaminants of the waste of different category, are conveyed to the landfill.

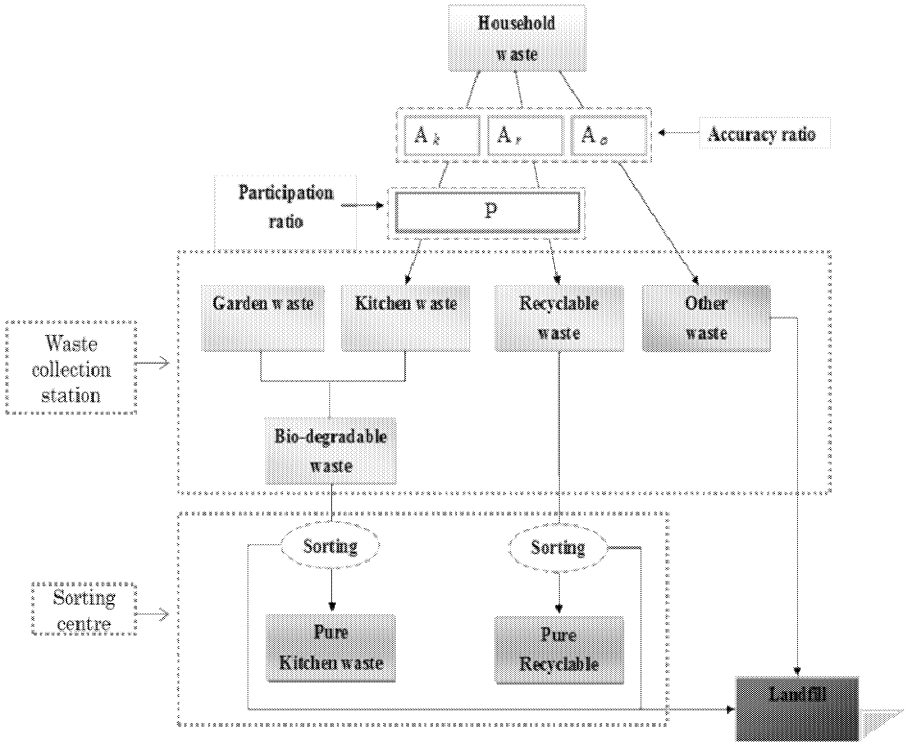


Figure 10 Modeling of waste separate collection and treatment system. [3]

In Japan, waste categories are decided by local authorities, and typical categories are combustible, incombustible and several kinds of recyclables. In the case study of Colombo city, the kinds of waste separation was simply three: 1) bio-degradable waste including kitchen waste and green waste, 2) recyclable waste including glass bins, cans, and PET bottles, and 3) other waste.

Parameters used in this model are accuracy ratio and participation ratio. The accuracy ratio means the proper inclusion ratio, that is, the percentage which genuine waste is included in the true waste category. In this example, actual component weights of kitchen, recyclable, and other waste are respectively denoted as W_k, W_r and W_o, and the weights of waste in the kitchen, recyclable, and other categories are respectively denoted as X_k, X_r and X_o. Here, a ratio which means how many percentage of kitchen waste is included in the kitchen waste category (true category) is defined as a_k, and also a_r and a_o are defined as well. A ratio which means how many percentage of wrong waste is included in kitchen waste category is defined as b_k, and also b_r and b_o are defined as well.

Using defined variables, the weights of waste categories are described as the following equation.

$$\begin{aligned} X_k &= a_k W_k + b_k W_r + b_k W_o \\ X_r &= b_r W_k + a_r W_r + b_r W_o \\ X_o &= b_o W_k + b_o W_r + a_o W_o \end{aligned} \tag{1}$$

Where,

$$\begin{aligned} 1 &= a_k + b_r + b_o \\ 1 &= b_k + a_r + b_o \\ 1 &= b_k + b_r + a_o \end{aligned} \tag{2}$$

Accuracy ratio A_k means how many percentage of waste in the kitchen waste category is truly kitchen waste. This A_k can be obtained through waste characterization analysis. The relationship between ratios A_k and a_i is expressed as the next equation.

$$a_i W_i = A_i X_i \qquad (i = k, o, r) \tag{3}$$

The λ_i in the follow equation is introduced. W means the total of W_k, W_r and W_o.

$$\lambda_i = \frac{1 - A_i}{1 - A_i (W / W_i)} \quad (i = k, o, r) \tag{4}$$

Then, the weight of the waste in the kitchen, recyclable, or other waste categories is obtained from the next equation.

$$\begin{pmatrix} X_k \\ X_r \\ X_o \end{pmatrix} = \frac{1}{\lambda_k + \lambda_r + \lambda_o - 1} \begin{pmatrix} (\lambda_k - 1) W_k / A_k \\ (\lambda_r - 1) W_r / A_r \\ (\lambda_o - 1) W_o / A_o \end{pmatrix} \quad (5)$$

Citizens will separate kitchen and recyclable waste from others, respectively. Citizen's patricpation ratio for waste separation to kitchen and recyclable waste is defined as P. Then, the waste amounts of the bio-degredable, recyclable, and other waste categories are described as the following Y_b, Y_r and Y_o, respectively. W_g is the sumation of kitchen waste and gargen waste.

$$\begin{aligned} Y_b &= PX_k + W_g \\ Y_r &= PX_r \\ Y_o &= W - P(X_k + X_r) \end{aligned} \quad (6)$$

3.4 Estimation of Waste Transportation

In the next step, the waste transportation is estimated. Using land-use information and population distribution, waste generation distribution in target area is calculated. Moreover, using the road network information, the waste transport distance among locations of residential area, treatment facilities and landfill site are calculated by using GIS. Frequency of waste collection trips is considered according to the loading capacity of transportation truck. Fuel cost is calculated by considering the fuel price and the fuel consumption of the truck.

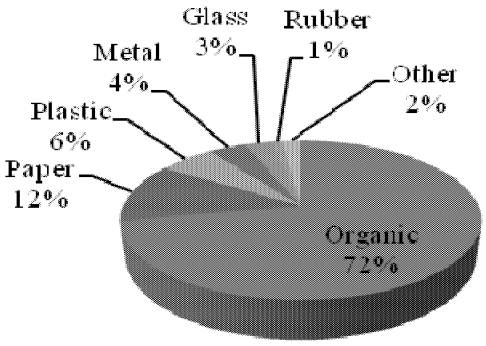
4 Result and Discussion

This planning and estimation approach was applied to Colombo municipal council area. The objective was to evaluate the new waste separation system. Reduction of landfill waste, CO_2 emission, and transportation cost were estimated. Sri Lanka is an island in the Indian Ocean located in the southern part of the Indian subcontinent, where is 62,705km^2 total land area and 21 million population. Colombo Municipal Council area covers 37.21 Sq.km with 642,020 of population.

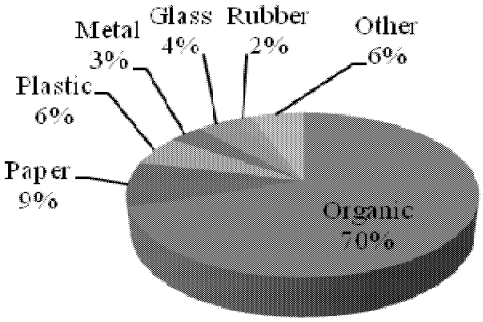
Questionnaire survey and household waste generation survey were carried out simultaneously for a period of one month (Nov to Dec 2009) in Colombo and surrounding cities[2]. In the questionnaire survey, 1000 questionnaires were randomly distributed within 13 districts in Sri Lanka out of 25 districts. Questionnaires were distributed either by post or through the cooperators. They

included a self-addressed postage-paid envelope and collected by the means of post. 840 of the questionnaires distributed were filled and returned giving a response rate of 84%.

Figure 11 shows the results from both surveys. The results are pretty similar; ratio of organic waste component is high (about 70%), followed by paper, plastic, metal, and glass components. It was resulted that the recycling of organic waste is effective for reduction of landfill waste.



(a) Questionnaire survey



(b) Household waste generation survey

Figure 11 Results of household waste composition according to questionnaire survey and household waste generation survey

In the step of calculating waste transportation, it was assumed that municipal waste collection covers whole area and all households in Colombo city, but we could not obtain the population distribution data of the city. As shown in **Figure 12**, the city area was divided into meshes and waste generation at the

center point of each cell was calculated using average population per cell. Travel distance along the road and frequency of trips of trucks were calculated by using GIS.

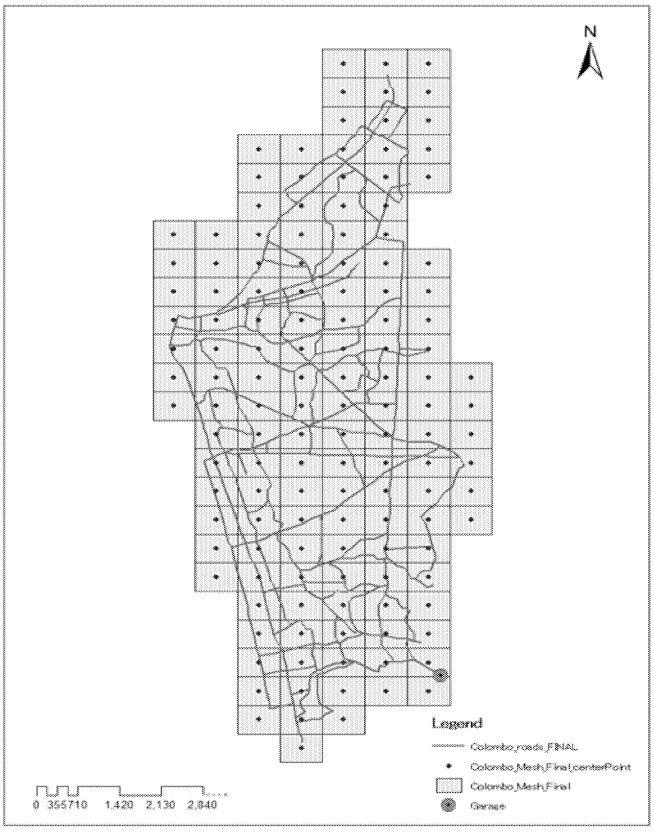


Figure 12 Estimation of waste transportation distance in Colombo city, Sri Lanka. [3]

Figure 13 shows the simulation results of the total amount of landfill waste according to the different participation ratios. Accuracy ratio was set to be 90%. Due to this waste separation system the final disposal waste amount is decreased. By comparing current waste management condition (0% of participation ratio) with other results (30% - 100%), it was found that the amount of landfill waste will reduce by half at 30% of participation ratio. This result means that half reduction of landfill waste will be achieved if about one of three households cooperates with complete waste separation.

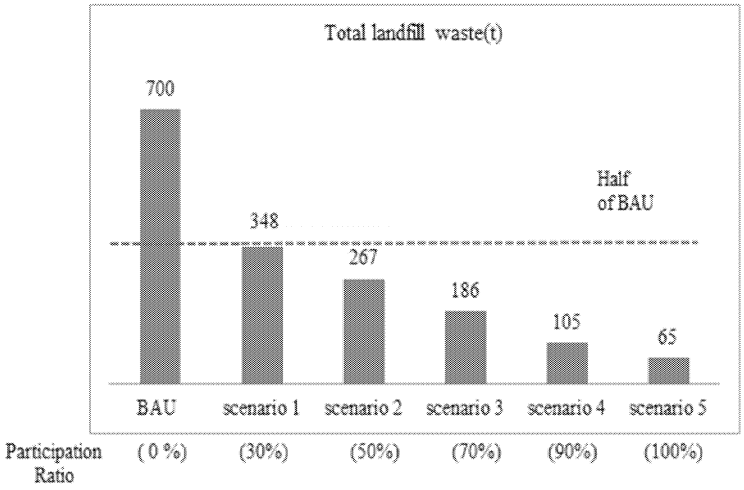


Figure 13 Estimation of total landfill waste[3]

Estimated results of waste collection and transportation cost and CO_2 emission shows in **Figure 14**. Total cost for collection and transportation is high at BAU (0% of resident's participation), however, the cost decreases by half at 70% of resident's participation (Scenario3) in waste separation. This cost only including transportation cost. It is necessary to evaluate total cost of solid waste management system.

As for total CO_2 emission, not only the emission of CO_2 from waste transportation but also the emission of greenhouse gases from landfill site was taken into account. The emission of CO_2, CH_4 and N_2O from aerobic and anaerobic reactions within landfill was estimated by considering the content of carbon element in kitchen and green waste which was disposed to the landfill. The result is shown in **Figure 15**. Although the total CO_2 emission of BAU is high, according to the 30% - 100% participation ratio the total CO_2 emission decreases more. It reaches to the half of emission at 30% of participation ratio. It was found that the amount of landfill gas is larger than that of the gas emitted from fuel burning during the waste transportation.

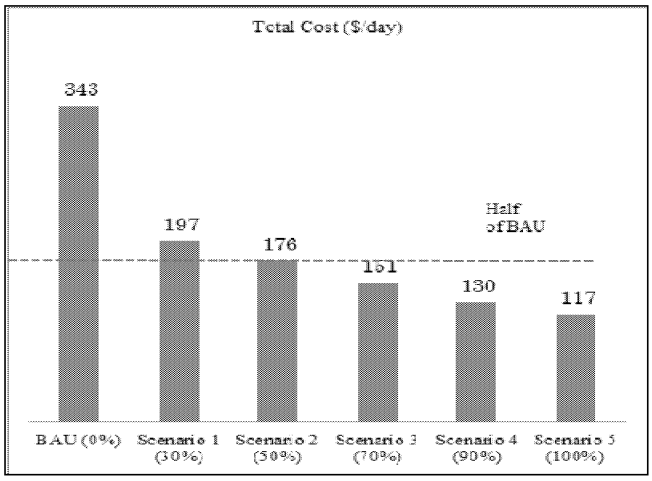


Figure 14 Estimation of waste transportation cost[3]

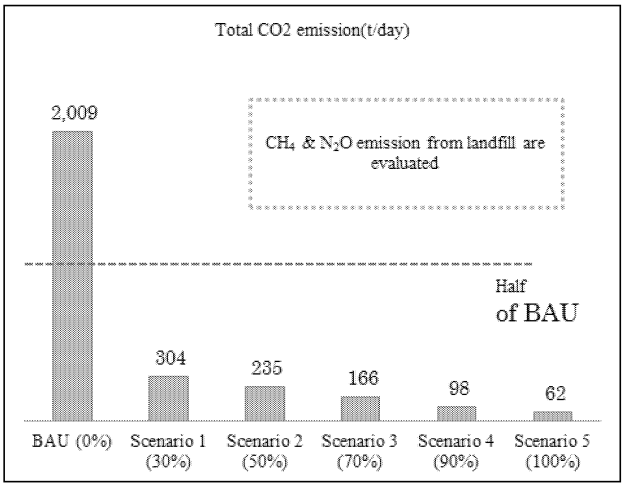


Figure 15 Estimation of total equivalent CO_2 emission due to transportation and disposal[3]

5 Conclusion

Large cities in many Asian countries have similar types of solid waste management problems: increase of waste generation, shortage of landfill capacity, and long distance between urban area and landfill site. Japan had selected the way of incineration to realize volume reduction as well as safing, detoxifying, and stabilizing of organic waste, however, still have landfill

shortage issue. There were conflicts between citizens in Tokyo and other districts about landfill construction in Japanese history, however, such circumstance boosted up the waste separate collection which was supported by citizens' participation, shown in the case of Numazu city.

Separation collection becomes difficult under the condition of weak participation by citizen. It is thought that visualizing the effectiveness of citizens' participation on increase of public benefits is important when educating citizens about separate collection.

The latter half of this paper, planning and evaluation method of 3R based solid waste management was presented. Procedure of the method and application to Colombo city, Sri Lanka, were illustrated. Purpose of the evaluation is visualizing change in reduction of landfill waste, CO_2 emission, and cost according to citizens' participation in separate collection. The accuracy of data for calculation is not enough, but comparison of results between scenarios with different values of participation rate has persuasive power.

Waste Management Research Center, Okayama University, promotes "*Practical Research and Education of Solid Waste Management Based on Partnership between Universities and Governments in Asia and Pacific Countries*", which aim is that we form a partnership among Okayama University, university in Asian or Pacific country, local governments of Japan and local government in the country, and tackling actual solid waste management issues. Our collaborative research between Institute of Technologi Bandung and Okayama University is one of the activities. In June 2011, we hold a seminar which title is "*Improving municipal solid waste management practices through 3R implementation*", in Institute of Technologi Bandung. Officers of Okayama municipality Japan and officers from many local governments in Java Island were invited and own experience of 3R practical activity were presented and discussed. We hope to contribute improvement of 3R in Bandung and other cities in Indonesia.

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