SURVEY OF RESIDENT`S WILLINGNESS TO SEPARATE WASTE COLLECTION AND IMPROVEMENT OF WASTE MANAGEMENT IN SRI LANKA

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***ABSTRACT*:** Inappropriate solid waste disposal is a major threat to the environments of developing countries since most of the solid waste generated in developing countries end up directly in open dumps which are uncontrolled and overloaded. Air pollution from landfill emissions, ground water pollution from leachates, health problems due to breeding of disease causing pests and social problems such as decreasing land values and aesthetic appeal of an area etc. are some associated problems. Over the next several decades, globalization, rapid urbanization and economic growth in the developing world tend to further deteriorate this situation.

Currently waste segregation is not being practiced in Sri Lanka and there are lack of detail information about household waste generation and composition. The load reduction on solid waste management system at the point of generation and at the centralized disposal facility is essential. Therefore, we carried out questionnaire survey and household waste generation survey in Sri Lanka to identify the characteristics of household solid waste generation and composition. In this study, based on the results, we proposed an evaluation method for waste separation and recycling system and applied to Colombo Municipal Council area. For estimation, five scenarios with different participation ratios were adopted to compare the influence of participation on the amount of landfill waste, GHG emission and cost-benefit. Study found that it is posible to reduce the current landfill waste amount and CO2 emission by half with 30% of resident's participation on waste separation. Moreover found that the waste transportation cost is decreased by half at 70% of resident's participation.

KEYWORDS: Solid Waste Management, Sri Lanka, Separate waste collection

1. INTRODUCTION

According to the population increase of Colombo city, Sri Lanka, a large amount of waste generation became serious municipal problem, as well as other Asian cities are experiencing. At present, waste collection by municipality does not cover the whole of Colombo city area and the waste stored at city landfill spills over the road. These facts express the city have much weight on solid waste management (SWM). Same case as in Japan, new landfill construction is quite difficult due to citizen's opposition. Hence, it is valuable to apply 3R (reduce, reuse, and recycling) actions to Colombo city.

Removing any waste material from the waste stream by recycling or composting has an influence on the composition of the waste which is subsequently sent either to landfill or treatment such as energy recovery. As such, the emission of greenhouse gases and other forms of pollutants will be reduced by a large percentage. Reusing and recycling of used items will also result in less production of new products. This helps in the conservation of natural resources. Currently waste separation is not practicedin the target area and most of the waste generation is sent to the landfill. Therefore, it is necessary to apply waste separation method to prevent environmental impact as well as wasting valuable natural resources.

As a result of our questionnaire survey and household survey, conducted in Colombo and also neighbor cities in 2009, it was identified that organic components occupy about 70 % of household waste. (Madhushan and Fujiwara. 2010) Therefore, composting or bio-fuel production from biomass waste is an effective way to reduce the waste and to increase material recycling.

In this study, we develop five scenarios with the different waste sorting levels in household for Colombo Municipal Council (CMC) and the separate waste collection by municipality, and evaluate environmental impact on CO2 emission and cost-benefit. By using Geographic Information System (GIS), CO_2 generation and cost of waste transport are evaluated. Finally, current Solid Waste Management (SWM) and 3R-impremented SWM are compared.

2 BACKGROUND

(1) Sri Lanka

Sri Lanka is an island in the Indian Ocean located in the southern part of the Indian subcontinent. It is located between 6 and 10 North latitude and 80 and 82 Eastern longitude. Sri Lanka has a tropical climate with little seasonal variation. It consists of three major climatic zones namely, wet zone, intermediate zone and dry zone. The total land area and population are 62,705 km^2 and about 21 million, respectively. Colombo city is the largest city and commercial capital of Sri Lanka. Colombo Municipal Council area covers 37.21 km^2 with 642,020 of population.

(2) Solid waste management

The issue of solid waste is becoming a major problem in Sri Lanka; unfortunately no one can leave Sri Lanka without noticing the piles and piles of garbage on the roadsides of many urban areas and Figure 1 shows a very good example. Most of the municipal solid waste is dumped on land in uncontrolled manner. In most disposal sites the garbage was simply dumped with no soil cover and drain system to collect the leachate. Waste is disposed at the site and it appears that due to high costs involved, there exist little or no basic operations such as leveling and covering of waste. Often, soil cover is applied only at the final stage if and when there is a projected use for the land, or due to public pressure. In addition to dumpsites operated by the relevant authorities, illegaldumping takes place along streets, marshes and abandoned paddy fields by private individuals. These dumps make very inefficient use of the available space, allow free access to waste pickers, animals and flies and often produce unpleasant and hazardous smoke from slow-burning fires. The uncollected waste, which is often also mixed with human and animal excreta, is dumped indiscriminately in the streets and in drains, so contributing to flooding, breeding of insect and rodent vectors and the spread of diseases.

(3)Statistics of waste generation

The data available that would help estimate the total quantity of municipal waste collected or generated in the country is not entirely accurate. However, the best estimate of total waste generation in Sri Lanka is around 6,400 tons per day. Daily waste collection by LAs is estimated at 2,500 tons. Of the total waste collected the Western Province accounts for 57 percent. There are three types of LAs in Sri Lanka. They are Municipal Councils (MC), Urban Councils (UC) and ‘‘Pradeshiya Sabha’’ (PS) – rural LA of a smaller scale.Table 1lists the waste generation rates of the three types of LAs in Sri Lanka.Overall, there is significantly low level of collection service coverage in UC and PS. The fundamental problem faced by the LAs in providing adequate service coverage is the lack of resources: primarily in respect of suitable collection vehicles, adequacy of finances and shortage of manpower. LAs can exercise little control over these practices mainly owing to a lack of resources.

Table 1 Waste generation rates (kg/capita/day)

Local Authority	No. of LAs	Per capita waste
Municipalcouncil(MC)	12	0.65-0.85
Urban council (UC)	37	0.45-0.65
Pradeshiyasabha (PS)	255	0.20-0.45

Sources: (a)MoFE(1999) and (b) adapted from ERM Data (1997)

(4)Recycling

Recycling of materials is carried out through an informal market-driven system. Items are recovered at various points of the waste stream: at household level, collection and transport by LA workers or at the final disposal site by rag pickers and municipal workers. The retrieved materials are sold to collection shops where they are cleaned and sold for recycling by local industrialists or being exported overseas.

Legislatively, the Central Environmental Authority (CEA) – the environmental regulatory agency in Sri Lanka – is obliged to ensure that industries as well as waste disposal sitescarry out activities without adverse environmental impacts. While there are standards for industrial effluent discharge, there are no prescribed standards for disposal of MSW in landfills. Currently LAs that are not disposing waste in an environmentally acceptable manner are dealt with under Section 12 of National Environmental Authority (NEA) and the Public Nuisance Ordinance. The CEA has already developed general guidelines for waste disposal site selection. However, achievable environmental standards are urgently needed, and the CEA has recently appointed an expert committee to investigate MSW disposal standards in other developing countries and propose suitable standards for adoption in Sri Lanka.

Figure1 Open dump site located in Colombo city area

(5) Waste composition by previous survey (Madhushanand Fujiwara. 2009)

To identify the composition of household waste and willing to participate in separate collection, we conducted questionnaire survey and household survey as well. Both surveys were carried out simultaneously for a period of one month (Nov to Dec 2009) in Colombo and surrounding cities. 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%.

The questionnaire consisted of 33 questions and they can be gathered into four categories being attribute, awareness, household waste generation and peoples' willingness to participate in waste separation. The majority of respondents belong to Sinhalese (91%) which is major ethnic group of Sri Lanka and others are belonging to the minor groups as follows Tamil (3%), Muslim (4%), Burger (1%), other (1%), which balance of responses is similar to the balance of races in Sri Lanka.

Households were asked about weekly generated waste amount according to seven waste categories, and resident's willingness to participate in waste separation was asked.

In household waste generation survey, we selected twelve households in Elpitiya city, Sri Lanka. The households were requested to separate their waste into several categories, to measure the weight of it, and to record them at end of the day.

Statistical analysis was conducted using the windows versions of Statistical Package for Social Sciences (version 17.0, SPSS Inc.)The per capita solid waste generation in Sri Lanka is 0.20-0.85 kg/day, which is shown in Table 1. The estimated value of per capita waste generation based on questionnaire survey was 0.33 kg/day and this value is very close to household waste generation survey results, 0.34 kg/day.

Estimated results of the questionnaire survey and household waste generation survey are shown in following Figure 2 and Figure 3; there is a high content of organic waste in both surveys(72% and 70%), moderate content of paper (12% and 9%), plastic (6% and 6%) , low content of metal (4% and 3%), glass (3% and 4%), rubber(1% and 2%), and other (2% and 6%).

According to Department of Census and Statistics of Sri Lanka, (1998) solid waste composition data show high content of organic waste (66%), paper (13%), plastic (8%), metal (3%), glass (2%), etc. When these values were compared with estimated values from the questionnaire survey, it was observed that most of the waste component values were similar. Therefore, it was concluded that the survey data was highly accurate.

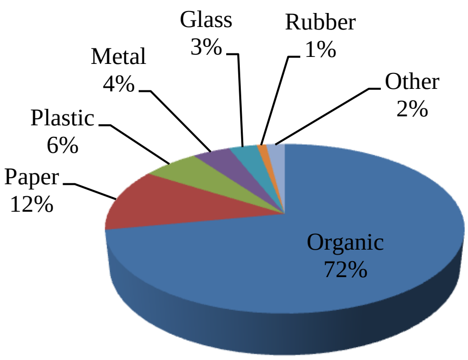

Figure 2 Household solid waste composition resulted from questionnaire survey

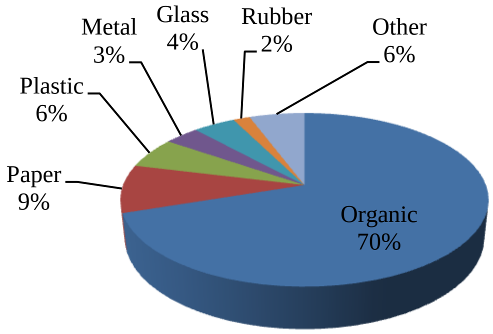

Figure 3 Household waste composition resulted from household waste generation survey

The result of questionnaire survey data shows that only 47% of respondent access to the current waste collection system and the others do not have a waste collection system in their living area. The survey revealed that the majority of households are not served by a waste collection system. Instead they treat their waste by open burning (41%), dumping into a backyard (27%), home composting (25%), and others (7%).

3 METHODOLOGY

3.1 Outline

A solid waste managementmodelincluding household sorting, separate collection by municipality, pre-treatment of bio-degredable and recyclable waste is created in order to estimate the amount of final landfill waste, GHG emission through waste transport actionand disposal, and cost of the them. This model deals with the accuracy ratio of waste separationand the ratio of resident's participation to separate collection. In estimation, five scenarios with different participation rate are adopted to compare the influence of participation on the amount of landfill waste, GHG emission and cost-benefit. As for the waste transportation, the point to point distance is calculated with the network analysist toolbox of ArcGIS.

3.2 Model of waste sorting and discharge

Figure 3 shows the flow diagram of waste management model used in this study. Household waste streamis divided into 3 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". After the separation garden waste and kitchen waste are mixed and discharged as bio-degradable waste. At discharging the household waste, the kitchen waste and the garden waste which is generated from gardening are brought together as "bio-degredable waste". Assuming that municipal waste collection covers whole area and all households in Colombo Municipal Council area,

First of all, W_g, W_k, W_r, and W_o are defined as the true amounts of the garden, kitchen, recycable, and other waste categories, respectively. Actual data of them are obtained separately, by refering the waste database released by environmental authourity of Sri Lanka. Set W is summation of W_g, W_k, W_r,and W_o.

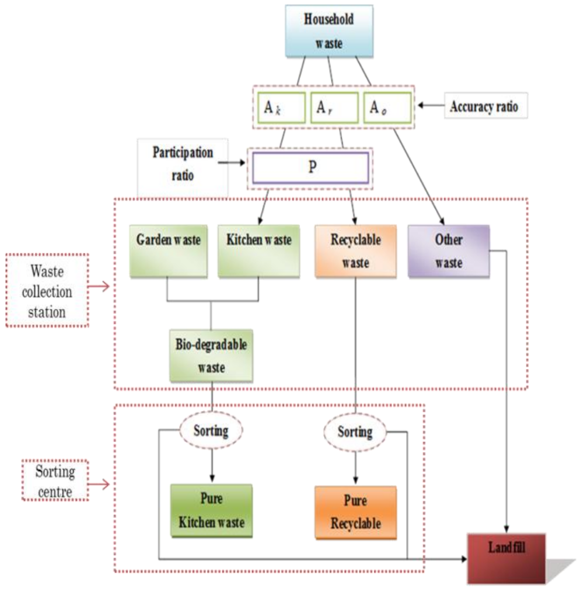

Figure 3 Proposed SWM based on separte collection and recycling

(1) Calculation of aparent waste amount

Accuracy ratio is described in the following. Some kitchen waste and other waste will bethrown into the bin for "Recyclable waste category". According to the judgement of waste category, the inclusion ratio of the genuine waste component in the corresponding waste category varies. In this model, the proper inclusion ratio of proper waste and improper inclusion ratio of non-genuine waste are defined. The former, for example the ratio of the pure kitchen waste in the kitchen waste category,is defined asa_k. The other a_r and a_o are also for recyclable and other waste, respectively. As for the latter, assuming the inclusion ratio of different waste category is common for all non-genuine wastes,X_k, X_r, and X_o, the apparent kitchen, recyclable, and other category waste,are described as the following equations.

$$X_k = a_k W_k + b_k W_r + b_k W_o$$
$$X_r = b_r W_k + a_r W_r + b_r W_o \quad (1)$$
$$X_o = b_o W_k + b_o W_r + a_o W_o$$

Where,

$$1 = a_k + b_r + b_o$$
$$1 = b_k + a_r + b_o \quad (2)$$
$$1 = b_k + b_r + a_o$$

Each of b_k, b_r, and b_o is the inclusion ratio of improper waste. In analysis of waste compostion, accracy ratio is expresed as the ratio of proper component to the apparent waste, here it is denoted as A_k, A_k, and A_k.

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

From Eq.(1) and Eq.(3), *a*is expressed using *b*.

$$a_i = (A_i / W_i)(W - W_i)/(1 - A_i) b_i \quad (4)$$

Set λ_i as

$$\lambda_i = \frac{1 - A_i}{1 - A_i (W / W_i)} \quad (i = k, o, r) \quad (5)$$

Then, a_i is described as

$$a_i = \left(1 - \frac{1}{\lambda_i}\right) b_i \quad (6)$$

These $a_i(i=k,r,o)$ are substituted in Eq.(2), b_k, b_r, and $b_o$are obtained from Eq.(7) using Eq.(5)

$$\begin{pmatrix} b_k \\ b_r \\ b_o \end{pmatrix} = \begin{pmatrix} 1 - 1/\lambda_k & 1 & 1 \\ 1 & 1 - 1/\lambda_r & 1 \\ 1 & 1 & 1 - 1/\lambda_o \end{pmatrix}^{-1} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \quad (7)$$

Where,

$$Det \begin{pmatrix} 1 - 1/\lambda_k & 1 & 1 \\ 1 & 1 - 1/\lambda_r & 1 \\ 1 & 1 & 1 - 1/\lambda_o \end{pmatrix} = \frac{\lambda_k + \lambda_r + \lambda_o - 1}{\lambda_k \lambda_r \lambda_o} \quad (8)$$

Eq.(7) becomes the following Eq.(9)

$$\begin{pmatrix} b_k \\ b_r \\ b_o \end{pmatrix} = \frac{1}{\lambda_k + \lambda_r + \lambda_o - 1} \begin{pmatrix} \lambda_k \\ \lambda_r \\ \lambda_o \end{pmatrix} \quad (9)$$

Finally, we can calculate the apparent waste by category.

$$X_i = \frac{a_i}{A_i} W_i = \left(1 - \frac{1}{\lambda_i}\right) \frac{W_i}{A_i} b_i \quad (i = k, o, r) \quad (10)$$

$$\begin{pmatrix} X_k \\ X_r \\ X_o \end{pmatrix} = \frac{1}{\lambda_k + \lambda_r + \lambda_o - 1} \begin{pmatrix} (\lambda_k - 1) W_k / A_k \\ (\lambda_r - 1) W_r / A_r \\ (\lambda_o - 1) W_o / A_o \end{pmatrix} \quad (11)$$

Using genuine waste amount W_i, apparent waste amount X_i with accuracy ratio A_i is calcuted using Eq.(11).

The inclusion of inadequate waste depends on citizen's awareness of waste collection rule or willingness to participate of separating waste collection. Such awareness and willingness are related to endevor of education and enligtenment on waste collection manners. According to (McGartland. 2005) accuracy ratio of kitchen waste and recycable waste was 0.9 and 0.95 respectively. In this study, these two accuracy ratios are used. Although there is no information on the accuracy ratio of other waste, 0.9 is adoped on the analogy of these of kitchen and recyclable waste.

(2) Discharged waste amount considering resident's participation ratio

At present, separate collection is not reaized in Colombo city. If the separate collection law is established and municipality advatizes, educates, and holds trainings to citizens to explain how to sortthe waste and when to discharge it, then most of citizens will finally separate kitchen waste and recyclable waste from others, respectively. However, it usually takes much time until waste separation becomes common. In this study, resident's patricpation ratio for kitchen and recyclable waste is defined as *P*. (Figure 3)

Consequently, the waste amounts of the bio-degredable, recyclable, and other waste categories that the municipality can collect become the following Y_b, Y_r and Y_o, respectively.

$$Y_b = P X_k + W_g$$
$$Y_r = P X_r \quad (12)$$
$$Y_o = W - P(X_k + X_r)$$

Where, all garden waste is diretly disposed as the bio-degredable waste without any hesitation.

In this study, resident's participation ratio on waste separation *P* is set in different senarios.

(3) Frequency of waste collection

The waste of each category is put in separated disposal bag and discharged in specified day in a week. Municipality periodically collects the waste cateogry by category, and bring it to a waste recycling facility to purify the waste. Plastic, inorganic, and other inadequate items in bio-degredable waste are removed manually, finally purified kichen & green waste becomes the resource for composting. The residuals including such inadequate items are taken to the landfill as disposal waste. Regarding of the recyclable waste, inadequate items are also removed and the recyclable waste is separated again into fine category: cans, glass bottles, and plastic. The purified recyclable materials are purchased by the recycling company in the recycling center. The residual is also taken to the landfill site. The other waste is conveyed to the landfill directry from residential area.In this model assumed that wastes are collected separately by waste category in different collection truck. Collection ferequency is set be two times a week for bio-degradable and other waste, and two times a month for recyclable waste.

3.3 Transport distance for waste collection and moving to landfill site

1)Transport of waste

In this stage, transport of household waste in CMC area is calculated. The travel distance of waste collection car between collection spot and the waste collection centeris actually estimated by using Network Analysist tool box of ESRI ArcGIS 10.0.

The method of waste collection is station collection. It is assumed that each household brings the waste in a plastic bag to the waste collection station. Waste compaction car stops at the station, picks the bags up and takes to the waste collection center or the landfill site.

Due to the lack of population distribution data of CMC, the average population density 17, 254 (persons/km^2) is used. Using waste generation ratio of database of national statistic 1.09 (kg/capita/day) and considering typical waste collection car has 5 tons loading capacity, the waste collection area by 1 trip of the collection car becomes 0.27 (km^2). Using ArcGIS, whole CMC area is divided into 140 lattice cells, each of which is 1 trip collection area. Based on total waste generation and the loading capacity of collection truck 140 collection trips are necessary for current waste collection system. In scenario analysis the number of cells was modified by considering collectable waste amount of each waste category.

Referring a road map of Colombo city, road network information is extracted and vector data of the roads are implemented on GIS system. Only trunk roads (national roads with7.35 (m) width), are extracted as main roads of waste transportation. Totally, 132 (km) length road network is implemented. The waste collection cells and road network are shown in Figure 4.

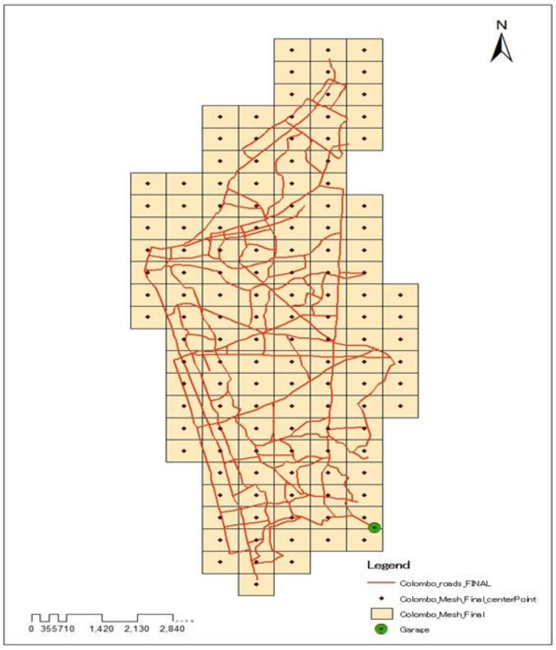

Figure 4 Waste collection cells and road network of Colombo Municipal Council area

Then using the network analyst tool box of ArcGIS, the shortest transportation distance for waste collection is calculated, and also transportation cost and the amount of CO2 emission are calculated for each five scenarios.

The detail of transportation is as follows:

1) Travel from the waste sorting center to a collection cell

In this study, it is assumed that a waste sorting center having parking area for waste collection trucks is constructed at the center place of the Colombo city that means the gravity point of CMC region. An empty truck starts from the parking area and moves to a waste collection cell. In this travel, it is assumed that the fuel efficiency is 10 (km/liter) and the CO2 emission ratio is 300 (g/km).

2)Travelbetween waste collectionstations in a cell
In the cell, a collection car visits waste colle ction stations one by one, and loads the waste. After loading fully, the car returns to the sorting center.

In the case of current waste collection, it is assumed one waste collection station is placed per 30 households. If the average number of household members is 4.4 (person/household), 35 collection stations must be placed and the average collection block becomes 7,590 (m^2/station). Therefore, the average distance between stations is set to be the square root of the collection block area 87.1 (m) and total traveling distance is 2,960 (m) by considering 34 stations in a cell.

It is assumed that the truck keeps a half of the loading capacity during traveling in the cell, fuelefficiency at that time is 7 (km/liter), and CO2 emission ratio is (480 g/km).

3) Travel from the cell to the sorting center or landfill
After loading bio-degradable waste or recyclable waste, the truck goes back to the waste sorting center. Only residual from sorting is carried to landfill site from the sorting center.
This study supposed to use current existing landfill site at Kolonnawa city. Actually, the distance of the landfill site is 4.7 (km) far from the sorting center. To simplify the calculation of distance, the collection truck for the category of other waste goes to the landfill site via the sorting center. In other words, the distance to landfill is defined as the distance from the collection cell to the sorting center and 4.7 (km) for the landfill site. Of course, the empty truck returns to the sorting center. In this travel, it is assumed that the truck is fully loaded then, fuel efficiency is 5(km/liter) and CO2 emission ratio is 660 (g/km) when going to landfill. When the truck returns to the sorting center, truck is empty then the fuel efficiency is 10 (km/liter) and CO2 emission ratio is 300 (g/km).

4) GHG emission from landfill
Physical components of waste is converted to chemical components by using Table 3

Table 3 Elemental component in physical waste component (-)

Element	Plastic	Metal	Glass	Paper	Food	Wooden	Others
C	0.72	0.00	0.00	0.42	0.45	0.49	0.04
H	0.11	0.00	0.00	0.07	0.06	0.06	0.01
N	0.01	0.00	0.00	0.00	0.03	0.01	0.00
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.03	0.00	0.00	0.00	0.00	0.00	0.00
O	0.07	0.00	0.00	0.40	0.33	0.42	0.03
Inorganic	0.06	1.00	1.00	0.10	0.13	0.02	0.92

Source: Japan waste management association

CO2 and CH4 reaction equation is used in theoretical model described in JSCE (2004). N_2O emission factor of land filled waste is substituted by the factor of fertilizer used for vegetable production, 0.0097 (tN2O/tN). CH4 and N_2O emissions are converted to equivalent CO2. In this study not estimated GHG emission by composting or recycling, only focused on GHG emission by waste disposal. Therefore in future studyit necessary to discuss about GHG emission due to waste composting and recycling.

4 RESULTS AND DISCUSSION

4.1 Scenarios

The amount of the waste collected separately for each scenario is shown in Table 4. The amount of “bio-degradable waste” and “recyclable wastes” both increase from scenario1 to 5 and regarding “other waste” the amount decreases sharply.

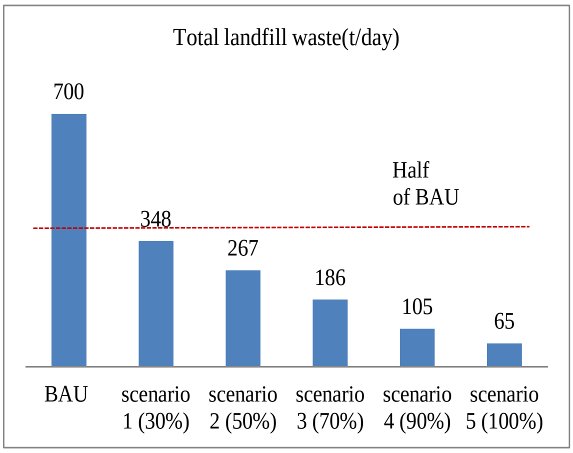

Figure 5 Total landfill waste amount by each scenario

Due to this waste separation system the final disposal waste amount decreases rapidly. Therefore assumed that waste separation is a good method for reducing landfill waste amount. Figure 5 shows the graph of landfill waste amount according to each ratio of separate collection. Comparing current waste management system (BAU) with each scenario results, it is possible to reduce landfill waste amount by half with 30% of resident's participation on waste separation.

Table 4 Estimation of waste by each category at different participation ratio on waste separation

Condition		BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Participation ratio to separate collection P(-)		0	0.3	0.5	0.7	0.9	1
Result (1) Collectable waste at station							
Collectable waste(t/day)	Bio-degradable	0	346	423	500	576	615
	Recyclable	0	19	31	43	56	62
	others	700	335	246	157	68	23
Result(2) Final recycling & disposal							
Recyclable waste(t/day)	Bio-degradable	0	335	404	473	542	576
	Recyclable	0	18	29	41	53	59
Total landfill waste(t/day)		700	348	267	186	105	65

4.2 Estimation of cost and CO2 emission

Estimated results of waste collection calculation are shown in Table 5**.** According to the table, total cost for collection and transportation is very high at usual waste collection system (BAU). But when considering scenario 1 to 5 the cost decreases. As shown in Figure 6 transportation

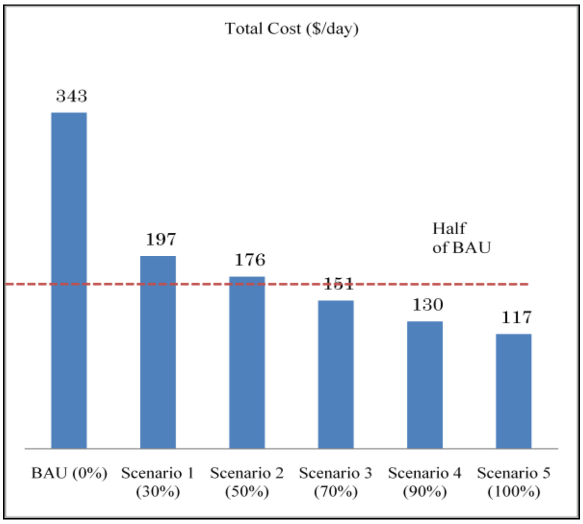

Figure 6 total waste collection and transportation cost

cost is decreased by half at 70% of resident's participation (scenario 3) in waste separation.

Figure 7 shows, CO2 emission of BAU is 2009 (t/day). From scenario 1 to 5 CO2 decreases rapidly and it reaches to half of emission at 30% of resident's participation on waste separation.

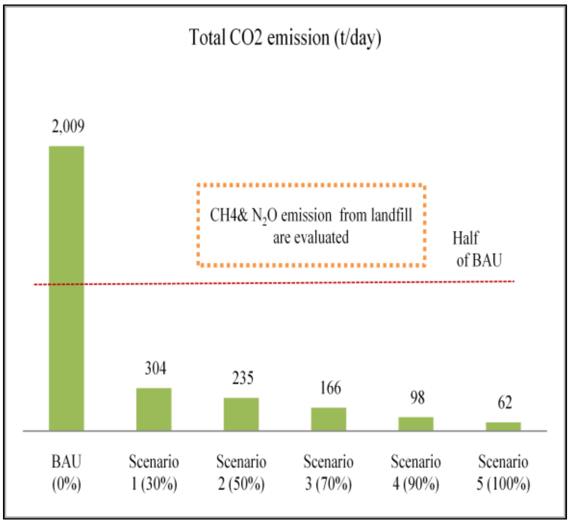

Figure 7 total CO2 emission due to transportation and disposal

Landfill gas amount is calculated by considering that the waste amount goes to landfill site by following waste categories; kitchen, garden, plastic, paper, glass, metal, and other waste. Using actual quantities of these waste categories

Table 5 Estimation of cost and CO2 emission

Condition		BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Participation ratio to separate collection P(-)		0	0.3	0.5	0.7	0.9	1
Result (1) Distance of waste transport							
Distance(km/day)	to collection	1,581	1,013	996	950	931	900
	to landfill	1,452	721	554	386	218	135
	total	3,033	1,734	1,550	1,336	1,149	1,035
Result (2) Fuel cost of waste transport							
Fuel cost($/day)	to collection	178	115	113	107	105	102
	to landfill	166	82	63	44	25	15
	total	343	197	176	151	130	117
Result (3) CO2 emission from waste transportation & land filling							
CO2(t/day)	by transportation	1.46	0.83	0.74	0.64	0.55	0.50
	by landfill	2,008	303	234	165	97	62
	total	2,009	304	235	166	98	62

the emission of CO2, CH4 and N_2O gases are evaluated. It was found that the landfill gas amount is very high compared to the gas emission by fuel burning during the waste transportation. Therefore waste separation can reduce high percentage of landfill waste and it is helping to recover more resources by recycling and composting. These results show that resident's participation is an essential factor and it has a great effect on reducing landfill waste.

5 CONCLUSIONS

We proposed an evaluation method for waste separation and recycling system, and it was applied to Colombo Municipal Council area. For estimation, five scenarios with different participation ratios were adopted to compare the influence of participation on the amount of landfill waste, GHG emission and cost-benefit. This method is effective and it is aplicable to other municipalities in Sri Lanka as well as other cities in overseas.

The results from this application to Colombo Municipal Council are summarized:

1) It is possible to reduce the current landfill waste amount by half with 30% of resident's participation on waste separation.
2) Waste transportation cost is decreased by half at 70% of resident's participation on waste separation.
3) CO2 emission of current waste management system (BAU) is 2009 (t/day) and it can be reduced to the half of emission at 30% of resident's participation on waste separation.

REFERENCES

ERM, Environmental Resource Management , Estate of the environment Sri Lanka, , 1997.

DCS, Department of Census and Statistics Colombo, Municipal Solid Waste Statistics, Sri Lanka, 1998.

MoFE, Ministry of Forestry and Environment, Estate of the environment Sri Lanka, 1999.

CEA, Central Environmental Authority Colombo, Guidelines for the Identification of Solid Waste Disposal Sites, p. 4. 2001.

UNEP, United Nations Environmental

Programme, Regional Resource Center for Asia and Pacific, Sri Lanka: State of theEnvironment, 2001.

Nick Clure, Charles Ling, Quantifying and minimising contamination in Adelaide’s kerbside collected green organics, EPA, November 2001

JSCE, Japan Society of Civil Engineers, Formulas, Models and Tables in Environmental Engineering, p,211,2004

Database of Municipal Solid Waste in Sri Lanka, Ministry of Environment and Natural Resources, January 2005.

John McGartland (Solid Waste Manager, Mackenzie District Council), Mackenzie District Council [Personal communication, 31 January 2005.

Barber, N., Wine Consumers' environmental knowledge and attitudes: Influence on willingness to purchase, International Journal of Wine Research,Texas Tech University, USA, Vol.1, p.67, 2009.

http://www.rrcap.unep.org/pub/soe/srilanka_waste.pdf>, (Accessed 20.05.2010).

Weranga Madhushan KAHAWE GURUGE, Takeshi FUJIWARA,Survey of Household Waste Generation and Willingness to Separate Waste Collection in Sri Lanka, International Conference on EcoBalance, 2010.

MOE, Ministry of Environment, List of calculation method and emission factor in GHG calculation, report, and publication, 2011.

JEMAI , Japan Environmental Managemnet Association of Industry Option data pack for JEMI-LCA Pro, 2008.

JWMA, Japan Waste Managemnet Association, Planing and Design Guideline for construction and maintanance of waste treatment facility, Japan waste management association, p.141