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An Analysis on Waste Processing in Residential Sector due to LCA Concept

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ABSTRACT

Indonesia still faced a serious problem related to the waste processing. Bandung city which is one of big cities in Indonesia has currently generated 1.800,14 tons of waste per day as of 2011. Here, the highest amount of waste (mostly organic waste) is the residential sector origin. Only around 65% of solid waste can be collected every day. The uncollected situation would exist due to some reasons. This condition might be attributed to negative effects, if the processing process would not be handled properly. The worse condition of greenhouse gas emission would be affected by the environmental impact due to emergence of landfill gas (mainly methan).

Thus, in this study, we think about the good strategy for processing solid waste so as to contribute global warming protection. According to the conjoint study, the result shown the highest importance values is a strategy which Bandung City should reflect their policy for the future so as to reduce the environmental impact. There are many processing systems such as landfill, composting, incineration, anaerobic degradation and recycling. Also, this study is evaluated based on Life Cycle Assessment (LCA) methodology. Especially, the following three different possible methods of (1) landfill, (2) composting, and (3) incineration are considered.

Due to the LCA, the inventories of greenhouse gas emission, cost and social acceptance are evaluated. For these indexes on each option, they are utilized by the questionnaire through the residential people in Bandung. Finally, we analyzed the following condition; what strategy is much better?

Keywords Bandung city, greenhouse gas emission, household organic solid waste, life cycle assessment, waste processing methods

1. INTRODUCTION

Waste problem at Bandung city rapidly evolved into a serious problem. Waste amount is always growth everyday meanwhile the waste management system is still inappropriate. This has already been a major issue for government at all level (Suryakusumah 2008). In 2005, landslide disaster happened in Leuwigajah final disposal and buried alive at least 140 people. Due to the scarcity of land in Bandung city, tons of wastes is unlogged during that time and give the image of Bandung city as a “Garbage City”.

Bandung city produce mostly an organic waste from the resident sector. The amount of organic waste in Bandung city rapidly growth follow the growth of population and economic of Bandung city citizens.

Waste management has to be balance between three important factors, environmental sustainability, economic and social acceptability (Thanh and Matsui 2012). Assessment of environmental, economic and also social aspect of the alternative strategy for waste treatment is important in order to abate GHG (Ayalon *et al* 2001). To evaluate waste treatment processing “life cycle” approach is appropriate to apply for a comparative evaluation between various of waste processing (Del Borghi *et al* 2009). Evaluation on the performance of alternatives for solid waste disposal is by applying LCA concepts and methods (White et al, 1995 in Weitz *et al* 1999).

The purpose of this study is to assessed the effect of each waste processing strategy,especially from residential organic solid waste sector. The study proposess to apply the LCA methodology. Due to the LCA methodology, GHG emission and reduction, economic aspect can be evaluated. Beside that this study also will describe social preferences from Bandung city citizen seen from conjoint analysis result.

A case study will be investigated include all possiblity of waste processing method. Waste processing method that can apply for Bandung city such as (1) landfill without landfill gas (LFG) recovery, (2) composting, and (3) incineration (mass-fired combustion systems).

2. METHODOLOGY

2.1 Research area

Bandung City is located in West Java and is the capital of West Java Province. Bandung City lies between the 1070 32 '38.91" East Longitude and 60 55'19 .94" South Latitude. Bandung city have four different district area : West Bandung, South Bandung, North Bandung and East Bandung.

Population Bandung city based on the census results in 2011 were 2,394,873 people (1,179,525 female populations and 1,215,394 male populations). The average population of Bandung density is 14,314 person/Km^2 (BPS Jawa Barat 2011).

2.2 Waste Generation

Waste generation in this study focussed in organic waste especially food kitchen waste from residential sector. The data of waste generation provided by regional hygiene company Bandung city (PD. Kebersihan of Bandung city). Table 1 shown the amount of waste generation from residential sector in Bandung city in 2011.

Table 1 Waste generation in residential sector in Bandung city

Total waste (kg/day)	Anorganic waste (kg/day)	Organic waste (Food waste) (kg/day)
1000147.20	41085.03	959062.17

**PDK 2011*

2.3 Conjoint Analysis

Conjoint analysis is one of multivariate statistic technique that develop to understand how respondents develop their preferences for any type of object (can be products, services or ideas). By judging objects formed by combinations of attributes, respondents can best provide their estimates of preference. It is can help to understanding respondent reactions to and evaluations of predetermined attribute combinations that represent potential products or services (Hair *et al*. 2010). Conjoint analysis is a survey-based approach that has been widely used to evaluate consumer preference for various products.

In this study SPSS 20 software will used as a tool to conducted a conjoint analysis.

Table 2 Factors and Factor Levels Used

Factors	Factor Levels
Environmental effect	With environmental effect Without environmental effect
Health effect	With health effect Without health effect
Machine capacity	High capacity Low capacity
Operational cost	High operational cost (expensive) Low operational cost (cheap)
Operational methodology	Easy Difficult

Table 3 Stimuli or Combination from Factors and Factor Levels Used

Card	Environmental effect	Health effect	Machine capacity	Operational cost	Operational methodology
1	Without environmental effect	Without health effect	High capacity	High operational cost	Difficult to operate
2	With environmental effect	Without health effect	Low capacity	High operational cost	Difficult to operate
3	With environmental effect	With health effect	High capacity	High operational cost	Easy to operate
4	With environmental effect	With health effect	Low capacity	Low operational cost	Difficult to operate
5	With environmental effect	Without health effect	High capacity	Low operational cost	Easy to operate
6	Without environmental effect	With health effect	Low capacity	High operational cost	Easy to operate
7	Without environmental effect	Without health effect	Low capacity	Low operational cost	Easy to operate
8	Without environmental effect	With health effect	High capacity	Low operational cost	Difficult to operate

Data processing for questionnaire was done by using SPSS 20 software for conjoint analysis and descriptive statistics to describe respondent's profile. In this study, factors and factor levels (Table 2) were determined to obtain stimuli as combination.

Using SPSS 20 as a tool to produce stimuli, 8 stimuli or combinations has formed (Table 3). Based on these 8 combinations, respondents have to rank the combinations from 1 to 8. Number 1 is the most preferable combination and 8 is the least preferable combination.

Conjoint analysis is suited for understanding respondent reactions to and evaluations of predetermined attribute combinations that represent potential products or services. (Hair *et al*. 2010). In this study, based on conjoint analysis, the result will shown the highest importance values which aspect Bandung City citizen most concern for waste processing strategy in the future.

2.4 LCA application

2.4.1 Goal and scope definition

The LCA models have included all process, emissions within the system boundaries defined in Fig. 1.

2.4.2 Inventory analysis of alternative treatment practices for residential solid waste

This study will evaluate three different possible methods for residential solid waste treatment, landfill, incinerator and composting. The GHG emission for each method can be different.

2.4.3 GHG emission from landfill

One of the main emission that were considered due evaluate GHG emission from organic waste from residential solid waste buried in landfill is CO_2 and CH_4 (EPA 2002, Thanh and Matsui, 2012). The net emission normalization reference of landfill without landfill gas recovery method is listed in Table 4. According to Tchobanoglous *et al*, 1993 CH_4 emission expressed in term of CO_2 is 25 tons CO_2/ton CH_4.

2.4.4 GHG emission from incinerator (mass-fired combustion)

During the combustion process (by incinerator), GHG that was generated mainly CO_2, N_2O (EPA, 2002). According to IPCC, 1997 the net emission factors from material combusted at incinerator were calculated as shown below in Eq. (1) :

$$E_{ni} = G_{ei} – U_{ei} - R_{em} \quad (1)$$

where

E_{ni} = Net GHG emissions factor from material $_i$ combusted at incinerator (tons CO_2 eq./ton)
G_{ei} = Gross GHG emission/ton material $_i$ combusted (tons CO_2 eq./ton)
U_{ei} = Avoided CO_2 emissions per ton material $_i$ combusted (tons CO_2 eq./ton)
R_{em} = Avoided CO_2 emissions per ton combusted due to metal recovery (tons CO_2 eq./ton)

Normalization reference of the net emission factor emitted by the incinerator of residential organic waste is listed in Table 4.

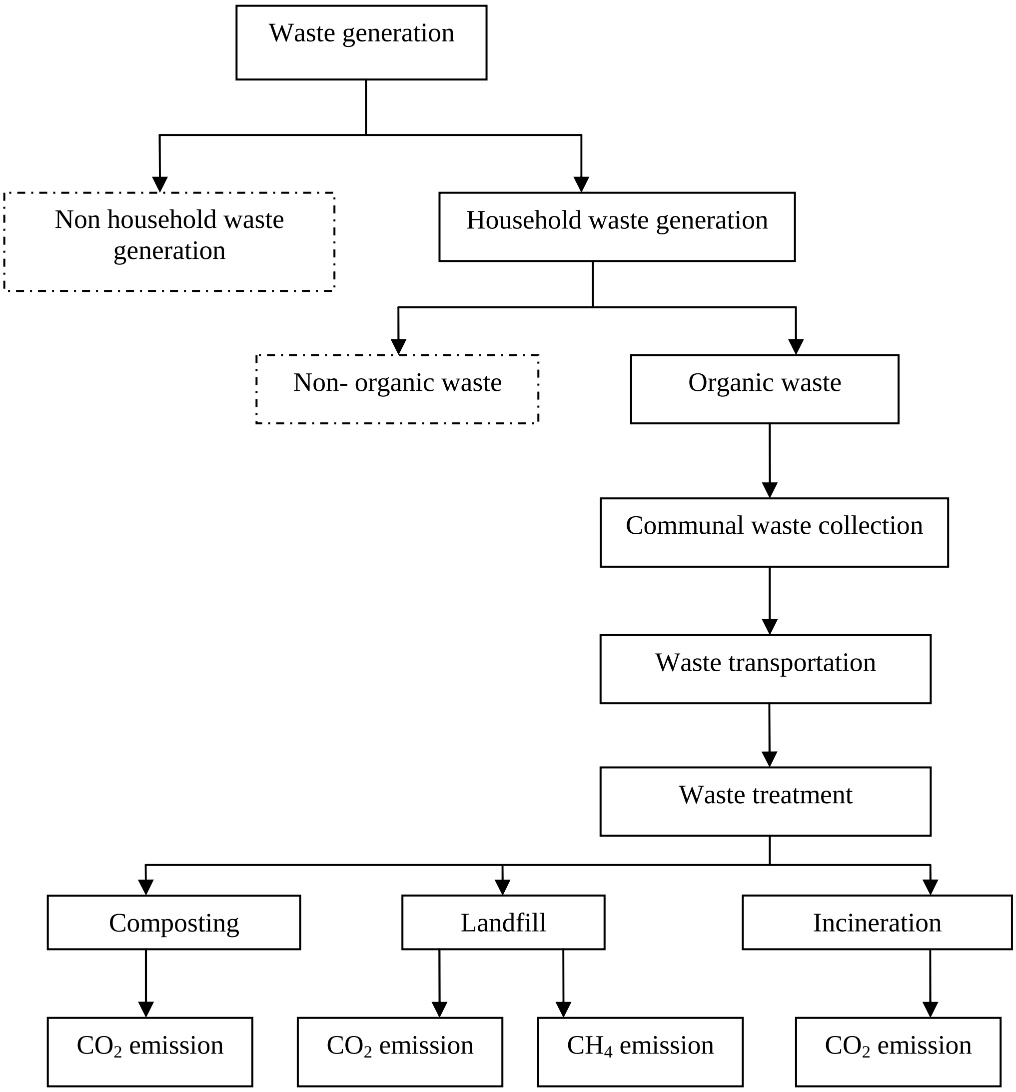

Fig. 1 System boundary of concept models for LCIA

Table 4 Net emissions from combustion and landfill method

Waste component	Net GHG emissions from combustion (tons CO_2 eq./ton)	Net GHG emissions from landfill without LFG recovery (tons CO_2 eq./ton)
Kitchen waste (food waste)	- 0.05	0.29

2.4.5 GHG emission from organic waste composting

According to EPA, 2002 a well-managed composting process mostly do not generate CH_4. Composting process typically maintain an aerobic environment with proper moisture content to encourage aerobic decomposition of the materials, even if CH_4 is generated in anaerobic pockets in the center of the compost pile, the CH_4 is most likely oxidized when it reaches the oxygen-rich surface of the pile, where it is converted to CO_2. Net carbon flux is net GHG emissions from long-term carbon storage.

This emission factor had a value of (-0.055) tons CO_2 eq./ton (EPA, 2002). This study considered CH_4 and N_2O emission that generated by composting process. Emission factor for CH_4 is 4 g CH_4/kg waste treated and emission factor for N_2O is 0.3 g N_2O/kg waste treated (IPCC 2006 at Thanh and Matsui 2012). Global warming potential of CH_4 and N_2O by 100 year given time horizon is 25 and 298 times greater than CO_2 (IPCC 2007).

2.4.6 Economic assessment

This study also will evaluate from some economic perspective. The chosen alternative strategy for waste management should deliver both economic and environmental sustainability (Ayalon *et al*. 2001). This study was not considered about operating and maintenance cost for each strategy because there are many uncertainty condition during the implementation of each strategy.

Product like compost fertilizer and also energy generation can be occurring during household solid waste treatment activity. GHG emission reduction in addition can be converted into Certified Emission Reductions (CERs) and be credited for trading (Thanh and Matsui 2012). In this study, economic assessment will be calculated based on GHG emission reduction certificate and compost selling. During the composting process, the mass loss due to the evaporation and also biodegradation of organic fraction, because of this condition 50% final compost is accounted of the input of composting process (Thanh and Matsui, 2009). Approximately around 30% of final compost product accounted for good quality compost (Thanh and Matsui 2012).

Current trading price for of "carbon credits" in Indonesia is between US$ 5/ton CO_2 *eq* and US$ 10/ton CO_2 *eq.* In this study the price of US$ 10/ton CO_2 *eq* was used as an estimate. Price for organic fertilizer in Indonesia is around IDR 1000/Kg (Rachman and Sudaryanto 2010). This study used average exchange rate IDR 9700/US$.

Table 5 Scenario for HSW alternative strategy

Alternative strategy	Definition/scenario
Landfill	Landfill method without LFG recovery 100% of organic household solid waste was transport and dumped in landfill
Composting	Organic waste composting method 100 % of organic household solid waste was transport and treat in composting plant
Incineration	Incineration (mass-fired combustion) 100% of organic household solid waste was transport and treat in incineration plant (without energy generation)

2.4.7 Scenario

Classification of the scenario is categorized based on the alternative strategy that appropriate to implement for household solid waste treatment in Bandung city. This study will provide a definition for each alternative strategy. Table 5 present the definition for each alternative strategy that evaluate in this study.

3. RESULT AND DISCUSSION

3.1 Conjoint Analysis

Result of conjoint analysis through questionnaire is listed in Table 6. Table 6 shown an utilities result.The utilities results summarize the utilities from each factor levels, from utilities result we would assume that strategy with higher utility values are more preferred and have a better chance of choice (Hair *et al*. 2010). According to this result shown that alternative strategies without generated environmental effect (-0.012), without generated health effect (-0.068), with high machine capacity (-0.088), with low operational cost (-0.088), and with difficult operational methodology (-0.008) are Bandung's city citizens most preferable factor levels when they think about future alternative strategies to overcome waste problem in Bandung city. The result show that the citizens are open with a new technology even it have a difficult operational methodology.

The importance values result shown in Table 7. The result shown the importance level for each factor. Importance values described that there was a different importance level among the respondents in term of the importance of each factor. According to the result environmental effects (24.369) is the most important factors that considered by the citizens.

Table 6 Utilities result for each factor

		Utility Estimate	Std. Error
Environmental	with	.012	.012
	without	**-.012**	.012
Health	yes	.068	.012
	no	**-.068**	.012
Machine	**high**	**-.088**	.012
	low	.088	.012
Cost	high cost	.088	.012
	low cost	**-.088**	.012
Method	Easy	.008	.012
	difficult	**-.008**	.012
(Constant)		4.495	.012

According to the result, value of Pearson's R is 0.993 and value of Kendall's tau is 0.964, both of it have a value above 0.5. If both of Pearson's R and Kendall's tau value are above 0.5 it's indicates a high predictive accuracy in the process of conjoint analysis as for testing the significance of both correlation above.

Table 7 Important values for each factor

Environmental	**24.369**
Health	17.031
Machine	18.334
Cost	17.303
Method	**22.963**

According to the conjoint study, the result shown the highest importance values is environmental factor. This shown that for the future a strategy which Bandung City should reflect for waste processing so as to reduce the environmental impact.

3.2 Evaluation of waste processing

3.2.1 GHG emission and reduction

During the implementation of landfill without LFG recovery, emission that might be generated is CH_4 and CO_2. Table 8 present the GHG emission of each waste processing strategy. The result showed that landfill without LFG recovery have the highest GHG emission, the following were composting, while the smallest GHG emission generated was mostly in incinerator processing.

Table 8 GHG emission

Area	Strategy	Net GHG emission (tCO_2 eq./day)
North Bandung	Landfill without LFG recovery	59.64
	Composting	38.95
	Incinerator	-10.28
East Bandung	Landfill without LFG recovery	44.09
	Composting	28.80
	Incinerator	-7.60
South Bandung	Landfill without LFG recovery	72.79
	Composting	47.54
	Incinerator	-12.55
West Bandung	Landfill without LFG recovery	101.60
	Composting	66.36
	Incinerator	-17.52

According to the Table 8, the GHG emission presented with minus value, this means that this waste processing was contribution to GHG reduction. This was shown the GHG emission reduction factor.

Table 9 shown the GHG emission reduction for each waste processing activity. The result showed that landfill without LFG recovery was no emission reduction, while the lowest emission reduction is composting.

Fig. 4 shown the comparison of GHG emission and reduction for each waste processing.

Table 9 GHG reduction

Area	Strategy	GHG Reduction (tCO_2eq./day)
North Bandung	Landfill without LFG recovery	0
	Composting	20.69
	Incinerator	69.92
East Bandung	Landfill without LFG recovery	0
	Composting	15.30
	Incinerator	51.69
South Bandung	Landfill without LFG recovery	0
	Composting	25.25
	Incinerator	85.35
East Bandung	Landfill without LFG recovery	0
	Composting	35.25
	Incinerator	119.12

Therefore within the estimation of GHG emission and reduction, the waste processing were ranked priority in order as 1. Incinerator; 2. Composting; 3. Landfill without LFG recovery.

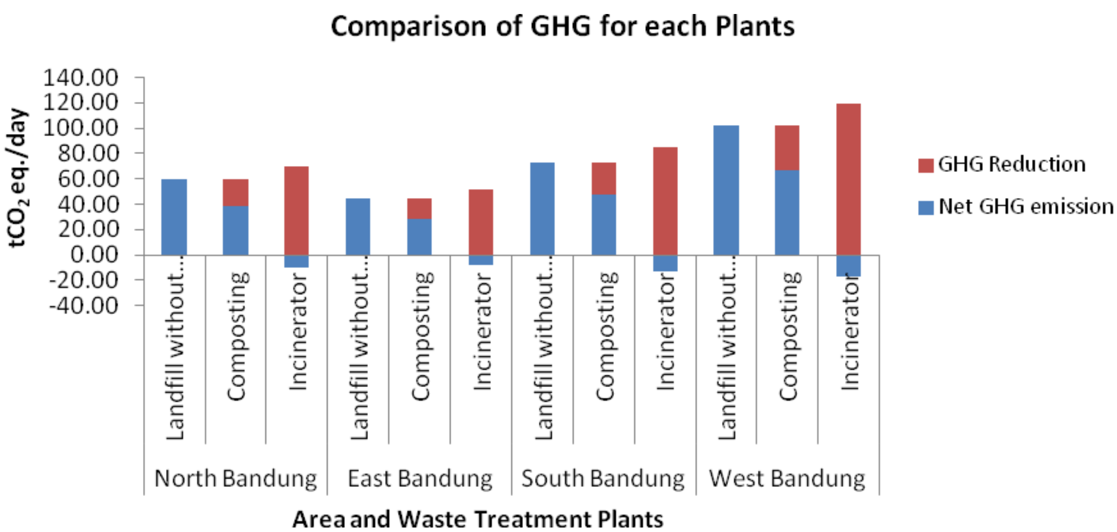

Fig. 4 Comparison of GHG emission and GHG reduction

3.2.2 Economic assessment

Economic assessment for waste treatment activity can be different depending on the strategy. Because the limitation of source to identified investment cost for each strategy in Bandung city, this study will used preference according to Ayalon *et al*, 2001. Table 10 presented the comparison of investment cost for each strategy.

Table 10 Investment cost for each strategy

Strategy	Size of plant (t/day)	Investment per plant (US$$10^6$)
Composting	250	1
Incinerator	500	50

*Ayalon *et al*. 2001

Table 11 CER Selling

Area	Strategy	CER Selling (US$)	Composting selling (US$)
North Bandung	Landfill without LFG recovery	0.00	0.00
	Composting	206.88	3180.06
	Incinerator	699.19	0.00
East Bandung	Landfill without LFG recovery	0.00	0.00
	Composting	152.95	2351.17
	Incinerator	516.94	0.00
South Bandung	Landfill without LFG recovery	0.00	0.00
	Composting	252.52	3881.68
	Incinerator	853.45	0.00
West Bandung	Landfill without LFG recovery	0.00	0.00
	Composting	352.46	5417.95
	Incinerator	1191.23	0.00
Bandung city	Landfill without LFG recovery	0.00	0.00
	Composting	964.82	14830.86
	Incinerator	3260.81	0.00

According to Table 10, it shown that investment cost for composting is lower than incinerator. It assumed that strategy landfill without LFG recovery was little investment cost. Therefore within the estimation of investment cost, the alternative strategies were ranked priority 1. Landfill without LFG recovery; 2. Composting; 3. Incinerator.

This study was evaluated economic assessment based on economic benefit from CER selling and composting selling. Table 11 present the result of CER selling and composting selling for each strategy. Therefore, within the estimation of economic benefit from CER selling and composting selling, the alternative strategies were ranked priority as order 1. Composting; 2. Incinerator and 3. Landfill without LFG recovery.

4. CONCLUSIONS

In Bandung city, more than 50% waste generated in residential level, and the highest number is organic waste which is a biodegradable waste. Result of this study expected to be helpful and give a broader perspective from the decision making to improve, choosing or planning the household solid waste treatment. Not only evaluate each strategy form environmental perspective but also evaluate from economic and social preference.

To find which strategy is acceptable by Bandung city citizens, we must find out first Bandung city citizen preference related with future household solid waste treatment alternative strategy. Based on conjoint analysis result, it was present Bandung city citizen preference for future household solid waste treatment alternative strategy. According to conjoint analysis we found out that environmental aspect is the most important aspect that considered by Bandung city citizen for future alternative waste treatment. Based on conjoint result, we then identified environmental effect that might be generated for each alternative strategy. GHG emission that occurred during the waste treatment can lead into a serious environmental effect.

Environmental effect might be generated in each alternative strategy for household solid waste treatment activity. Evaluation for environmental effect is present as GHG emission and reduction from each strategy. The result present that incinerator has the highest percentage for GHG reduction than the other strategies.

For economic aspect, the comparison of investment cost and also economic benefit from each strategy was held. Evaluation of economic benefit is from calculation of CER selling and composting selling from each strategy. Therefore, the result showed that landfill without LFG recovery strategy is required the lowest investment cost. However, based on economic benefit evaluation the result presented that composting have the highest economic benefit compare to other alternative strategies.

To evaluate waste treatment strategy from environmental perspective, life cycle assessment can be used as one tool. However, there is still limited guideline or method related to life cycle assessment in household waste management in Indonesia. For further research should be more focused to implement other life cycle assessment in household solid waste treatment activity, in the end the result can be compare and become more reliable for the decision makers.

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