ENVIRONMENTAL AND ECONOMIC ASSESSMENT OF ORGANIC MUNICIPAL SOLID WASTE DISPOSAL SYSTEMS FOR TRADITIONAL MARKET PLACES IN INDONESIA

(Kajian Lingkungan dan Ekonomi Penanganan Sampah Organik Pasar Tradisional di Indonesia)

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ABSTRACT

Waste from traditional market places is the second source of municipal solid waste in Indonesia. At current condition of the absence of source separation, the traditional market waste may be more attracted to be managed in a business scale compared to household waste. The attributed reason is that the waste has characteristic of more uniform waste, more concentrated source, higher organic fraction and less hazardous waste. The aim of this study is to compare different options of organic fraction MSW disposal systems by means of Life cycle assessment (LCA) and economic assessment. The options compared are aerobic digestion in labour intensive, aerobic digestion that utilise simple capital of wheel loader, anaerobic digestion and landfill for electricity generation. The current open dumping scenario was also included as the baseline of comparisons. The relevant impact categories assessed in LCA are the green house effect and the acidification potential. Result shows that all options proposed could reduce the environmental impact of current dumping. Anaerobic digestion performs the lowest impact of greenhouse effect. Anaerobic digestion may perform the highest impact of acidification potential among options proposed, though the environmental impact of biogas electricity production from this scenario is lower than the environmental impact of existing grid electricity production. Landfill for electricity generation performs the highest impact of greenhouse effect among options proposed. Economic analysis shows that only aerobic digestion scenario is economically feasible.

Key words : municipal solid waste, organic fraction municipal solid waste, life cycle assessment, Economic analysis

ABSTRAK

Sampah pasar tradisional merupakan sumber kedua terbesar sampah perkotaan di Indonesia setelah sampah rumah tangga. Pada kondisi saat ini di mana pengolahan sampah di Indonesia belum dilakukan secara efektif dan efisien, terutama belum adanya pemisahan sampah organic dan non organic langsung dari sumbernya, pengolahan sampah organic yang berasal dari pasar-pasar traditional yang diusahakan pada skala bisnis akan lebih menarik jika dibandingkan dengan pengolahan sampah rumah tangga. Hal ini disebabkan sampah pasar tradisional mempunyai karakteristik komposisi sampah yang lebih seragam, komposisi komponen organiknya lebih tinggi dan kandungan bahan berbahaya dan beracun(limbah B3) kecil. Studi ini bertujuan untuk mengkaji aspek lingkungan dan aspek ekonomi empat scenario pengolahan sampah organic pasar-pasar tradisional di Indonesia. Empat scenario yang dikaji adalah 1) Pengkomposan tersebar dengan sistem padat karya, 2) Pengkomposan terpusat dengan menggunakan alsin wheel loader, 3) Degradasi secara anaerobik, gas bio yang dihasilkan dimanfaatkan sebagai sumber pembangkit tenaga listrik, 4)Pembuatan gas bio di tempat pembuangan sampah (landfill) dimanfaatkan sebagai sumber pembangkit tenaga listrik. Skenario sistem pembuangan sampah saat ini, open dumping, dikaji sebagai scenario pembanding (baseline scenario). Aspek lingkungan yang dikaji dengan menggunakan Life Cycle Assessment (LCA) adalah efek rumah kaca (greenhouse effect) dan potensi terjadinya pengasaman (acidification potential). Kajian lingkungan menunjukkan bahwa empat scenario tersebut di atas dapat secara signifikan menurunkan efek rumah kaca dan efek pengasaman yang terjadi akibat sistem pembuangan sampah saat ini. Degradasi secara anaerobik merupakan cara terbaik dalam memperbaiki dampak lingkungan yang terjadi saat ini dibandingkan skenario yang dikaji pada studi ini. Namun hanya pengkomposan yang layak (feasible) secara ekonomi.

Kata kunci : sampah perkotaan, sampah organic perkotaan, pengkajian life cycle, analisis ekonomi.

INTRODUCTION

Municipal solid waste (MSW) in Indonesia has not been managed efficiently and integrated. The disposal system followed is open dumping and open burning. In big cities, such as Jakarta, sanitary landfills have been built, but in practice, it follows the open dumping operation such as no leachate treatment and rarely applying daily cover. The current waste disposal has impacted not only the environment but also the social acceptance (Anonimous[1], 2001)

Studies on handling the MSW have been conducted and several methods have been proposed. One of the suitable approaches is involving the private sector in waste management system. For non-organic recyclable waste stream, small/medium entrepreneurs have shown their interest in recycling the non-organic waste stream by a cooperation with scavengers (Anonimous[1], 2001). For organic fraction municipal solid waste (OFMSW) stream, the private sectors have also shown their interests to convert this waste into secondary valuable materials. However, at current situation of no source separation, the private sector may be more interested in handling the organic waste from traditional market compared to household. The attributed reason is that the traditional market waste has characteristic of more uniform waste and more concentrated source compared to household waste, and therefore handling the traditional market waste could reduce the cost of waste management. Another reason is that some parts of household waste collection are still done by informal institution while the traditional market waste management is under formal management; therefore the traditional market waste management may have lesser social obstacles compared to household waste if it will be managed privately.

There are several technologies of biological conversion of the OFMSW into secondary valuable materials. Some of the available technologies are aerobic digestion to produce soil amendment, anaerobic digestion to produce biogas & soil amendment and landfill to produce gas for electricity generation. To assess the most sustainable option, this involves at least three conditions: financially affordable, environmentally effective and socially acceptable. There has been a lack of environmental consideration in making a decision in developing countries. The fact has shown that when environmental aspect is unconsidered, the impact caused by such activities may require high cost of environmental impairment and high risk of social acceptance. This study assesses the options of handling the waste from traditional market in Indonesia from environmental and economic point of view. The life cycle assessment (LCA) was used in environmental assessment. The LCA has been increasingly used in developed countries for comparison of products or services in the stage of decision making. The LCA is popular because the LCA result could be more comprehensively communicated to the public as it quantifies the environmental aspects of all operations within the boundary condition. However, it is important to note that the impact values calculated in LCA correspond to a potential impact that could occur and not an actual impact. The actual environmental effects of emissions and wastes will depend on the specific condition, time and place where they are releases into the environment, but the LCA still allows the comparison among scenarios constructed, as the purpose of the analyses is for a 'first cut' of comparison (McDougal et al., 2001). The economic assessment was also included in this study with the intention to provide support information in making a recommendation of the best OFMSW management system for traditional market places in Indonesia.

MATERIALS AND METHODS

Materials

The inventory data for physical waste composition was found from local references that are summarised as in Table 1. These studies show that more than 80% of the waste weight (wet basis) is putrescible. The average waste composition data of these four markets was used for further analysis in this study.

The chemical waste composition was found by conducting waste sampling at 6 traditional market places in Jakarta, followed by laboratory testing that was done at solid waste and hazardous waste laboratory, Dept of Environmental Engineering, Bandung Institute of Technology. For other inventory data, this study frequently used the Australian Data Base Library (Grant, 2003) due to the lack of Indonesian data and references. The Australian Data Base Library was selected as it provides Indonesian data base of fuel and Indonesian electricity grid that is useful for energy inventories data in this study.

This study was used SIMAPRO 5.1 software for life cycle inventory (LCI) stage and life cycle impact assessment (LCIA) stage.

Methods

A. Life Cycle Assessment

LCA consists of the following phases: Goal and Scope Definition, Inventory, Impact Assessment and Interpretation.

- Goal and scope definition: define the purpose of study, functional unit for comparison and system boundaries
- Inventory: define inputs and outputs for each process or material, calculates the flow material, energy and emissions
- Impact assessment and interpretation: results of inventory are analysed by the relevant impact categories

There are four scenarios constructed that were compared in this study. The four scenarios constructed are as follow:

- AE (lbr): aerobic digestion of putrescible fraction in 30 small scale labour intensive plants of open windrow composting and dumping other fractions. The soil amendment is applied at horticulture production area, about 40 km from the plants.
- AE (cent): aerobic digestion of putrescible fraction in a centralised plant of open windrow composting and dumping other fractions. In this centralised open windrow composting, a wheel loader 136 kW is utilised for handling 200 tonnes/day of incoming OFMSW. The soil amendment is applied at horticulture production area as in previous scenario.
- AD: anaerobic digestion of putrescible fraction and dumping other fractions. The gas produced is used for generating electricity, while the effluent is treated in horticulture production area as previous scenario.
- LFE : disposing all fractions in an engineered landfill for electricity generation.
- The current business as usual (BAU), - dumping operation was also included as the baseline scenario of comparison.

The waste collection and transportation modelled in all scenarios follows the current waste transportations that are in operation at traditional market in Jakarta.

There are two environmental impact categories assessed at life cycle impact assessment (LCIA) stage. These impact categories are greenhouse effect (kg CO_{2-e}) and acidification potential (kg SO_{2-e}). The emision factors used in this study follows the characterisation factors of Eco-indicator 95. Characterisation factor of Eco-indicator 95 applies 50 years time horizon for greenhouse effect in which 1 kg of methane has the impact of 11 times more than 1 kg of CO_2 in greenhouse effect.

Table 1. Waste composition from traditional markets in Bandung and Jakarta

Component	Quantity in % weight (wet basis)				
	Pasar induk Gede Bage Badung*	Pasar Santa Jakarta**	Pasar Caringin Bandung***	Pasar Baru Bandung****	Average
Organic waste:					
- Putrescibles[1]	86.9	81.1	85.3	82.8	83.8
- Paper, cardboard, rubber	6.6	7.1	6.4	5.3	6.3
- Wood	1.8	4.7	0.9	3.2	2.4
Non-organic waste:					
- Plastics	3.4	5.1	7.0	7.1	5.9
- Glass and metal	1.1	0.8	0.3	0.7	0.7
- Others	0.3	1.1	N/A	1.0	0.9

*Sources: (*Saptari, 2004; **Maharani, 1998; ***Indiany, 2002; ****Shanti, 2002)*

[1] *The putrescible waste is specifically categorised for organic waste which is rapidly degradable and it usually produces bad smell during the decomposition*

B. Economic Assessment

The economic analysis was modifed from financial analysis in which the costs and benefits of financial elements are modified by removing direct transfer payments, using shadow prices and accounting externalities:

- Several transfer payments which are removed are taxes, subsidies and interest from local loans/credit.
- Shadow prices remove the tradable goods costs of other countries prices (imported goods) to international prices using shadow conversion factor (CFS). This study applies the CFS issued by Asian Development Bank (ADB). The shadow conversion factors for civil works, non-tradable and tradable parameters for Indonesia are 0.87, 0.9 and 1.0 respectively (Lagman-Martin, 2004).
- The externalities account the benefits/costs of society and environment caused by generation of a project to the national welfare. The economic valuation in this study involves the externality of methane mitigation as greenhouse gas (GHG) saving.

The net present value (NPV) and benefit cost ratio (BCR) of each scenario were analysed to find the feasibility of the options compared.

RESULTS AND DISCUSSIONS

Life Cycle Impact Assessment

A. Greenhouse effect

According to the result of impact assessment to the greenhouse effect, LFE presents the highest greenhouse effect among all alternatives option, though applying LFE could performs 43% lower greenhouse effect of current dumping. Both AE (lbr) and AE (cent) could contribute greenhouse effect, though the impact is only 6% of the impact current dumping. Applying AD could save current greenhouse effect of dumping. This is shown by the minus value (saving impact) in AD is higher than its positive value at Figure 1.

Figure 1 also identifies which process contributes highest impact to greenhouse effect. In LFE, the 60% of un-captured methane contributes the highest impact to greenhouse effect. Figure 1 shows that the amount of greenhouse saving from electricity production (Area under x-axis) is smaller than the greenhouse impact of 'methane not captured but under cap', -the un-captured methane in the engineered landfill. This could be interpreted that electricity production in landfill does not reduce the greenhouse effect of existing grid electricity production. In AE (lbr) and AE(cent), the impact saving from the avoided product (mineral fertiliser production) is also lower than the greenhouse impact of AE operation. The main contributions of greenhouse impact in AE (lbr) and AE(cent) are from dumping wood and paper fraction. On contrary in AD, the saving of greenhouse effect from electricity and mineral fertiliser production is higher than the greenhouse effect of applying AD.

The SIMAPRO 5.1 result shows that fuel consumption of wheel loader only contributed 3.7 % of the greenhouse impact of overall processes in AE (cent). This could be interpreted that there is no significant difference applying AE (cent) or AE (lbr). Waste transportation to treatment plant at the distance 30 km and compost soil amendment transportation at distance 40 km also does not contribute high significant impact to greenhouse effect.

B. Acidification Potential

Figure 2 shows LFE presents the highest value of saving the acidification effect. The saving is mainly from avoided electricity production in existing grid. The existing electricity grid was used Indonesian database. Indonesian electricity grid supplied sources from hydro, geothermal, coal, gas and petroleum. The electricity productions from coal, petroleum and natural gas have high impact on acidification.

Figure 2 shows AD has the highest impact on acidification effect compared with other scenarios. The contribution is mainly from biogas combustion to produce electricity. However, the acidification potential from existing grid electricity production is greater than the impact from biogas combustion.

Economic Assessment

Comparisons of the economic parameters of the BAU and constructed scenarios are presented in Table 2. This study applied the discount rate factor of 12% that is ussualy used in generating a project in Indonesia. Saving of greenhouse gas (GHG) emission is calculated from the

Methane emission avoided in BAU scenario. Methane emissions from dumping the organic fraction have significant contribution to GHG emission; and this is one of the reasons of dumping operation banned in developed countries. Methane has been identified to contribute 11 times more powerful GHG than CO_2 over a 50 years period.

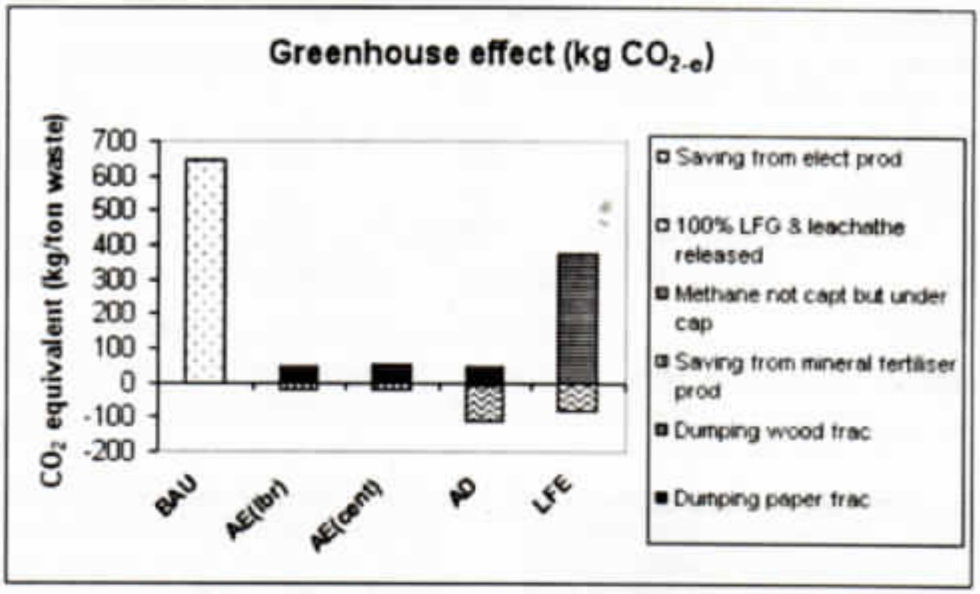

Figure 1. Process contribution of each scenario to greenhouse effect

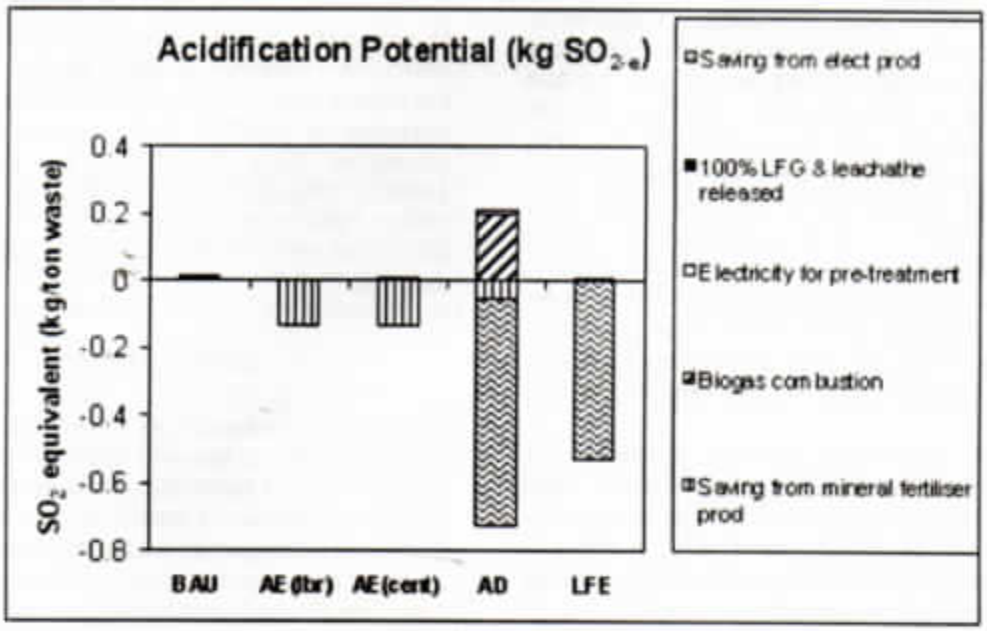

Figure 2. Processes contributions of each scenario to acidification potential

Table 2. Economic Analysis of BAU and scenarios constructed

Scenario	BAU	Aerobic (lbr)	Aerobic (cent)	Anaerobic	LFE
Investment cost (US$)	N/A	1,552,941.18	3,314,772.59	16,010,739.42	5,982,759.67
O&M cost (US$/year)	231,882.35	2,071,941.18	1,096,470.59	2,190,000.00	171,000.00
Revenue (US$/year)	0	2,668,897.30	2,729,444.24	1,806,099.20	551,424.00
Project lifetime (year)	20	20	20	20	20
MSW (tonnes/year)	90 520	90 520	90 520	90 520	90 520
Shadow price coef.	0.90	0.90	0.92	0.97	0.92
CO_2 saving (kg/ton waste)	-	0.7	0.7	0.7	0.3
Discount rate	12%	12%	12%	12%	12%
NPV Cost (US$)	1,732,032.16	15,520,718.39	11,504,797.84	32,368,820.95	7,260,034.53
NPV Revenue (US$)	-	19,935,177.92	20,387,429.88	13,490,556.15	4,118,830.48
NPV Benefit (US$)	(1,732,032.16)	4,414,459.53	8,882,632.04	(18,878,264.80)	(3,141,204.05)
BCR	N/A	1.28	1.77	0.42	0.57

The economic analysis was modified from financial analysis. The investment cost, O&M cost and the revenue was calculated without taxes, subsidies and interest. Investment cost in each scenario consists of land acquisition, machineries, civil works, planning and design costs. These elements of costs were shadowed priced. The shadow conversion factors for civil works, non-tradable and tradable parameters for Indonesia are 0.87, 0.9 and 1.0 respectively (Lagman-Martin, 2004). The revenue was calculated from selling compost at AE scenario, selling electricity to the national grid & compost at AD scenario and selling electricity to the national grid at LFE scenario. Revenue in this economic analysis was also added by the GHG saving (CO_{2-e}). Potential GHG emission of each scenario was distracted to the potential GHG emission of the current operation of waste dumping. The carbon prices are varied widely. The most recent modelling analysis indicates an international carbon price in the range of (US$ 4-7) per tonne carbon dioxide (Anonimous[2], 1997). This study applies US$ 4 per tonne carbon dioxide.

Table 2 shows that the LFE option is not feasible. This is due to the high cost of land acquisition. However, this option has been more attracted to be established in some big cities in Indonesia because under current condition of the absence source separation, landfill with electricity generation may be the most profitable option without requiring intensive source separation. Nevertheless, source separation should be introduced more progressively in the Future. Without source separation, it causes the more waste sent to the landfill and the more space required. Land in big cities, such as Jakarta, Bandung and Surabaya is very precious at the moment. If the land price is not subsidised, this option may not be financially feasible. Moreover, finding a new landfill site becomes more difficult. Table 2 also shows that AD for MSW still requires high investment cost and operational & management cost. The available technology was adopted from european countries, and this is still expensive at the moment. Further, local climate of Indonesia which is tropical humid could cause high corrosion and it may cause the life time of the digester is shorter than those in European countries. Only AE options are feasible. The aerobic digestion in centralised plant, AE (cent), has more benefit than in centralised plant,-AE (lbr). This is due to high labour cost in Jakarta.

CONCLUSIONS

Biological conversions (aerobic digestion, anaerobic digestion and landfill for electricity production) of OFMSW from traditional market places in Indonesia could significantly reduce the current impact of waste dumping. Life cycle assessment results that anaerobic digestion could be the best option reducing the impact of current dumping compared to others. However, economic assessment results that only aerobic digestion both in labour intensive plant and in centralised plant are feasible. Therefore, this

Study recommends that aerobic digestion is the best option to be applied in traditional market waste disposal system. However, participations from other stake holders, including the government, are still required to facilitate the successfulness of the program.

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