PUSAT PENELITIAN LINGKUNGAN HIDUP
CENTER FOR ENVIRONMENTAL RESEARCH
INSTITUT PERTANIAN BOGOR

Working Paper No. 15

September 2009

Life Cycle Assessment Approach of Solid Waste Management: Case Study in Bogor City, West Java

Y. Aris Purwanto

ISSN 2085-3599

CENTER FOR ENVIRONMENTAL RESEARCH
Office address: Gedung PPLH 2-4 Fl., Jl. Lingkar Akademik, Kampus IPB Darmaga, Bogor 16680
Mailing address: PO Box 243 Bogor 16001
Tel: +62-251-8621262,8621085; Fax: +62-251-8622134
E-mail: pplh-ipb@indo.net.id; pplh@ipb.ac.id
Website: www.pplh.ipb.ac.id

PREFACE

Pusat Penelitian Lingkungan *Hidup - Institut* Pertanian *Bogor* (PPLH-IPB) [Center for Environmental Research - Institut Pertanian Bogor (CER-IPB)]was established in *1976.* One of the Center's goal is to develop policies and concepts for natural resources and environmental management based on ecosystem characteristics, community participation, local community tradition, economic justice, and global environmental change.

Paper published in this Working Paper edition is the output of selected research activities funded by the Osaka Gas Foundation of International Cultural Exchange (OGFICE),Japan for the fiscal year *2007-2008.*

We are pleased to publish Dr. Y. Aris Purwanto's paper **Life Cycle Assessment Approach of Solid Waste Management: Case Study in Bogor City, West Java. We** also express our gratitude and appreciation to Mr. Hendi Satrio Aji, Dr. Lilik Budi Prasetyo, and Ellyn K. Damayanti, Ph.D.Agr. for their cooperation in proof-reading and lay-outing the manuscript.

Finally, we hope this publication will be valuable and beneficial for those who have interest in Indonesia's natural resource and environmental management.

September *2009,*

Kukuh Murtilaksono

Director

CONTENTS

List of Tables

List of Figures

Life Cycle Assessment Approach of Solid Waste Management: Case Study in Bogor City, West Java

Y. Aris Purwanto
Center for Environmental Research-IPB

ABSTRACT

This study evaluated the solid waste management in Bogor city based on the life cycle assessment (LCA) approach. Data was obtained from survey which carried out in several Temporary Disposal Site (TPS) in Bogor City. The most available scenarios of waste management system in Bogor city based on the existing condition were: 1) Collection - transport - landfilling (CTL), and 2) Collection - Composting (CC). To find the best scenario of waste management system in Bogor city, energy requirement of each process for each scenario was evaluated using LCA. CTL scenario was analized for four locations of Temporary Disposal Sites which was located at Merdeka Market), Nyi Raja Permas Market, Bogor Market and Jambu Dua Market. Data obtained from field observation and depth interview.

Calculation of handling and transportation cost based on the energy requirement for four locations showed in the range of Rp. 8 360 000 to Rp. 20 200 000. For the scenario of CTL, the local government must provided of Rp. 8 360 000 to Rp. 20 200 000 per month for each TPS for solid waste handling and transportation cost. For the'scenario of CC, with the income from compost of Rp. 3 600 000, there was a subsidy of Rp 3 520 000 per month for each TPS must be provided by the local government. This calculation may changes due to the capacity of composting process, total labour or other operational cost. From both scenarios, it was concluded that the scenario of CC was better than that of CTL for solid waste management system in Bogor City. This study only explored the energy use in transportation and process of organic waste as tool for Life Cycle Assessment. To obtain more comprehensive result for LCA approach of waste management system in Bogor city, the environmental and the social aspects should also be considered in the further study.

Keywords: cost analysis, composting, transportation cost, scenario of solid waste management

1. INTRODUCTION

1.1. Background

Life Cycle Assessment (LCA) is an objective process to evaluate the environmental burdens associated with a product, process or activity, by identifying and quantifying energy and materials used and waste released to the environment, and to evaluate and implement opportunities to effect environmental improvements (Barton *et al., 1996).* LCA is a methodology for examining environmental impacts associated with a product, process or service from cradle to grave from production of the raw materials to ultimate disposal of wastes. LCA was developed in order to take into account issues that are not addressed by other environmental management tools such as statutory environmental impact assessment. It has proved itself particularly useful as a technique for comparing two or more alternative options in terms of their combined potential environmental impacts and ecological sustainability (Ozeler, *2006).*

LCA has a lot to offer in terms of selection and application of suitable Municipal Ssplid Wwaste management techniques, technologies, and programs to achieve specific waste management objectives and goals. Thus, several studies in the literature used the LCA as a tool for municipal solid waste management (Barton *et al., 1996;* Rieradevall *et al., 1997;* Barlaz *et al., 1999;* Aprili et *al., 1999;* Koller et al., *1999;* Schwing and Jager, *1999;* Valentini *et al., 1999;* Fuertes and Pedraza, *1999).*

The different scenarios of waste management system that include different municipal solid waste processing and/or disposal methods are developed and, then, compared with respect to their environmental impacts. Environmental impacts of waste management system are evaluated by considering their water emissions, air emissions, final solid waste produced, energy consumption and economics. The waste management system scenarios are developed based on the current waste management system. The assessment of these scenarios will provide to compare different possibilities for the waste management system, so that environmental sustainability can be achieved.

There are many scenarios that be considered in the model analysis. The scenario consist of a) collection, b) transport and landfilling, c) separation before collection, d) incineration process, e) anaerobic digestion before landfilling which is a commonly used application nowadays for the treatment of municipal solid wastes especially in Europe (Wheeler, *2000;* Zoethout, *2000).* These data include the population projections, the waste characteristics and composition, waste management applications, the comparison of the recommended transfer stations and landfill sites, the cost calculations for all the alternatives and operational recommendations for the landfill site.

Bogor city is typical of the surrounding cities of the Jakarta metropolis. Specifically, population growth and area expansion have greatly overextended city infrastructure resources, especially in the area of solid waste management. Bogor city has already experienced great difficulty in finding adequate landfills to meet the needs of the waste generation rate, which has almost doubled during the past decade. Total production of solid waste in Bogor city is 2124 m^3 per day. Among of this, 68 % or 1457 m^3 is transported to final disposal site. (Media Indonesia 7 May 2007, accessed 3 September 2008).

The problem on the solid waste management system in Bogor city was largely due to: 1) the city's rapid growth, 2) the landfill site in Galuga had faced some problems because are located outside Bogor municipality, 3) development of new estates increased pressure for a more adequate solid waste management system, 4) the total amount of waste collection, transportation and disposal were limited. As a consequence of these factors, decreases in both service area and service quality occurred. Indeed, these factors contributed to Bogor's failure to win (for five consecutive years) the national cleanest city competition (i.e., "Adipura").

As a hinterland of Jakarta, Bogor is also as transit place for the distribution of agricultural produce from area near Bogor city. The marketing activities of agricultural produce are usually carried out in the night and leaving the waste in the morning. The waste from agricultural produce is dominated from organic waste. There is no alternative of this handling except sending those wastes to the disposal areas located outside Bogor city. In this study, an alternative method on wastes handling in Bogor was investigated by the used of Life cycle Energy analysis based on the energy required for processing and transporting of waste especially of organic waste.

1.2. Objectives of the Research

This study evaluated the solid waste management in Bogor city based on the life cycle assessment (LCA) approach. The objectives of this research were:

1. To identify and analyze the solid waste management in Bogor city
2. To develop and compare the different scenarios of solid management system in Bogor Municipal by using the life cycle assessment (LCA) approach.
3. To determine the most feasible system of solid waste management for Bogor city based on the existing condition of solid waste management system in Bogor city.

2. METHODOLOGY

2.1. Location and Schedule

This study was carried out at Temporary Disposal Site (TPS) and Final Disposal site (TPA) in Bogor city. The period of study was January – November 2008.

2.2. Procedure

2.2.1. Identification of Waste management System in Bogor

Waste management system in Bogor city was analyzed from both secondary and primary data. The secondary data was obtained from literature and from the the Environment and Waste Management Agency of Bogor local government (DLHK Kota Bogor, 2007). The primary data was obtained from survey which carried out in several Temporary Disposal Site (TPS) in Bogor City. The location of Temporary Disposal Sites were selected according to the intensity of activities such as at Nyi Raja Permas Market, Jambu Dua Market, Merdeka Market and Bogor Market. Solid waste management system was also identified from the Temporary Disposal Site to Final Disposal Site (TPA) at Galuga area which is located at about 30 km from the center of Bogor city.

Data was then used to determine the boundary system and data acquisition method. There were two energy resources were considered for waste management system (handling and transportation process from waste resources, Temporary Disposal Site and Final Disposal Site) i.e. energy from human being and fuel energy.

2.2.2. Energy Analysis

Solid waste management process in Bogor City were consisted of: 1) collection from the source to Temporary Disposal Site (TPS), 2) transportation from TPS to Final Disposal Site (TPA) and 3) waste processing in TPA. The waste management system was analyzed according to the energy requirement which was converted to handling cost for each process.

The asumption in this study were : 1) The all activities of the waste collection from waste source to TPS and transportation from TPS to TPA was carried out by the waste management offical of local government; 2) The human energy was only covered the activity that was directly in contact with the process of collection and transportion of solid waste, not including the administrative part. Data were consisted of the total volume of waste per day, capacity of truck, frequent of truck deliver the solid waste to TPA, labour cost, number of labour, and fuel cost.

2.2.3. Scenarios of Solid Waste Management System

The scenarios in this study were determined based on the existing condition of waste management system in Bogor City which considered as: 1) Collection - transport - landfilling (CTL), 2) Solid reduction - collection - transport - landfilling (SCTL), and 3) Collection - transport - incineration - landfilling (CTIL), 4) Collection - composting - Landfilling (CCL). The proposed scenarios were then verified by identifying the existing condition of solid waste management in Bogor city. Solid waste was considered as waste from residential and commercial. The system of solid waste management which resulted less energy/cost requirement was then selected as the appropriate waste management system in Bogor City.

3. RESULTS AND DISCUSSION

3.1 Solid Waste Management in Bogor City

Bogor City, as a part of West Java Province, is the nearest territory to the capital city of Indonesia, Jakarta. It is about 60 km to Jakarta and 120 km to Bandung. Bogor City is known as a rainy town for the amount of rainfall is very high. Bogor city is surrounded by Mount Salak, Mount Pangrango and Mount Gede. The existing condition of solid waste management in Bogor city was not inplemented of separated discharge and separated collection of waste. Recycled wastes are collected from source of waste such as residential, commercial areas, Temporary Disposal Site (TPS), and Final Disposal Site (TPA). Most of the recycled wastes are collected by a waste picker; then, the waste picker sells them to a junkshop. The junkshop sorts and classifies them into many items depending on the types; then, it sells them to the recycle factory directly or to the bigger junkshop (agent). Apart of such wastes is processed (recycled) in the city, but most of them are delivered to others cities or exported to abroad.

Technically, the solid wastes are delivered from its sources (housing area, industrial area and market) by people to TPS or to the waste transporter (truck). In some cities, just a few numbers of sources of waste are delivered to TPS. Most of the households do not separate the waste for discharge and collection of their waste at the sources. There are 967 unit of Temporary Waste Disposal Site in Bogor city as shown in Table 1.

Table 1. Total TPS in Bogor City

No.	District	Total TPS
1	South Bogor	67
2	East Bogor	71
3	North Bogor	47
4	Central Bogor	371
5	West Bogor	407
6	Tanah Sareal	214
	Jumlah	967

Source: Dinas Lingkungan Hidup dan Kebersihan Kota Bogor, 2007

Bogor city has the Final Disposal Site (TPA) which is located at Galuga, Cibungbulang, Bogor District. This TPA has area of 13,6 ha and about 30 km from Bogor city. TPA Galuga use control landfill technology, do composting, 3R and also has the leachate water treatment facility. The composting facility was designed to produce compost about 5 – 20 ton per day.

Fig. 1. Final Disposal Site (TPA) Galuga, Cibungbulang, Bogor District

3.2 Alternative of Solid Waste Management System in Bogor City

The most available scenarios of waste management system in Bogor city based on the existing condition were: 1) Collection - transport - landfilling (CTL), 2) Collection Composting (CC). To find the best scenario of waste management system in Bogor city, energy requirement of each process for each scenario was evaluated using LCA.

Screnario 1: Collection - transport - landfilling (CTL)

CTL scenario was analized for four locations of Temporary Disposal Sites which was located at Merdeka Market), Nyi Raja Permas Market, Bogor Market and Jambu Dua Market. Data obtained from field observation and depth interview were tabulated in Table 2.

Table 2. Data of solid waste management system at market in Bogor city

Location/Market	Merdeka	Nyi Raja Permas	Bogor	Jambu Dua
Number of TPS	1	2	1	1
Solid waste Composition (%) 1. Organic 2. Non organic	75 25	80 20	70 30	75 25
Volume of waste (m^3/day)	12	24	8	6
Capacity of truck	8	8	8	8
Total Labour	7	17	4	4
Distance from TPS – TPA (Km)	27	30	30	30
Fuel cost (l/day)	40	40	40	40

Calculation of handling and transportation cost based on the energy requirement for four locations showed in the range of Rp. 8 360 000 to Rp. 20 200 000. This cost must be provided by the local government for solid waste handling according to the scenario of collection to Temporary Disposal Site (TPS) - transporation to Final Disposal Site (TPA) per month for each TPS.

Scenario 2: Collection - Composting (CC)

Composting was designed at the Temporary Disposal Site where located at Traditional market. The assumptions of scenario of CC were: 1) the waste produced from the market was available for composting, 2) cost calculation for composting was only considered for operational cost, and 3) the total organic waste for composting per day was 6 m^3. It was obtained that the total cost for composting per month was Rp. 7 120 000. The income from production of compost was Rp. 3 600 000 per month.

For the scenario of CTL, the local government must provided the budget for solid waste handling and transportation cost of Rp. 8 360 000 to Rp. 20 200 000 per month for each TPS. For the scenario of CC, with the income from compost of Rp. 3 600 000, there was a subsidy of Rp 3 520 000 per month for each TPS must be provided by the local government. This calculation may changes due to the capacity of composting process, total labour or other operational cost. From both scenarios, it was concluded that the scenario of CC was better than that of CTL for solid waste management system in Bogor City. This study only considered the energy and operational cost aspect for the selection of alternatives'scneario for solid waste management system in Bogor City. To obtain the most feasible scenario, the environmental as well as social aspect should also be considered for further study.

4. CONCLUSION AND RECOMMENDATION

4.1, Conclusions

1). This study was conducted to determine the most feasible solid waste management system in terms of its environmental effects which was concern on the use of energy for handling and transportation of solid waste in Bogor city.
2). The results of the study showed that the existing condition for solid waste management in Bogor city followed the step of collection, transportation and landfilling.
3). Two scenarios i.e. collection - transportation - landfilling and collection - composting were evaluated based on the energy requirement during handling and transportation. Four locations of Temporary Disposal Sites (TPS) were used as a sample i.e. Merdeka Market, Nyi Raja Permas Market, Bogor Market and Jambu Dua Market.
4). For the scenario of CTL, solid waste handling and transportation cost were in the range of Rp. 8 360 000 to Rp. 20 200 000 per month for each TPS.

5). For the scenario of CC, with the income from compost of Rp. 3 600 000, there was subsidy of Rp 3 520 000 per month for each TPS must be provided by the local government.
6). It was concluded that the scenario of CC was better than that of CTL for solid waste management system in Bogor City.

4.2. Recommendation

This study only explored the energy use in transportation and process of organic waste as tool for Life Cycle Assessment. To obtain more comprehensive result for LCA approach of waste management system in Bogor city, the environmental and the social aspects should also be considered in the further study.

ACKNOWLEDGEMENT

The author expresses their appreciation for the financial support by The Osaka Gas Foundation of International Cultural Exchange (OGFICE) Research Grant FY 2007/2008 throuh PPLH - IPB

REFERENCES

Aprili PG, Bergonzoni M, Buttol P, Cecchini F, Neri P. Life cycle assessment of a municipal solid waste landfill. Proceedings Sardinia 99. Cagliari, Italy' CISA; 1999.

Barlaz M, Camobreco V, Repa E, Ham R, Felker M, Rousseau C, et al. Life cycle inventory of a modern municipal solid waste landfill. Proceedings Sardinia 99. Cagliari, Italy' CISA; 1999.

Barton, JR., D. Dalley, VS. Patel. 1996. Life cycle assessment for waste management. Waste Manag; 16:35-50.

Dinas Lingkungan Hidup dan Kebersihan Kota Bogor, 2007

Fuertes GJ, Pedraza OB. Life cycle assessment of the energy recovery from solid waste incineration. Proceedings Sardinia 99. Cagliari, Italy' CISA; 1999.

Koller M, Soyez K, Thran D. LCA of residual waste treatment systems with emphasis on the mechanical biological pre-treatment. Proceedings Sardinia 99. Cagliari, Italy' CISA; 1999.

Media Indonesia 7 May 2007, (accessed 3 September 2007).

Ozeler, D. 2001. Life cycle assessment of municipal solid waste treatment methods: Ankara case study, A master of science thesis, METU, Ankara, Turkey.

Rieradevall J, Domenech X, Fullana P. LCA case studies, application of life cycle assessment to landfilling. Int J LCA 1997;2:141- 4.

Schwing E, Jager J. Comparison of waste treatment systems by means of LCA: methodology and consequences. Proceedings Sardinia 99. Cagliari, Italy' CISA; 1999.

Valentini A, Cecchetti G, Mastrogiacomi S. An LCA approach to waste collection systems: a case study in the province of Pesaro and Urbino. Proceedings Sardinia *99.* Cagliari, Italy' CISA; *1999.*

Wheeler P. Commercial and strategic perspectives for anaerobic digestion International directory of solid waste management *200012001.* The ISWA Yearbook; *2000.* p. 76- 84.

Zoethout T. Digestion goes dutch - anaerobic digestion converts city waste to energy", international directory of solid waste management *200012001.* The ISWA Yearbook; *2000.* p. 85-7.