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The Industrial Ecology Concept for Municipal Solid Waste Management A review of waste management in Bandung City, Indonesia

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ABSTRACT

The concept of industrial-ecology in waste management re-utilize the potential of waste materials and energy in the waste flow of waste in the waste management system itself. Potential energy and materials are utilized to reduce the problems that arise in a conventional solid waste management by waste retreatment using waste management facilities and change the waste into energy. Using the concept, the results of the research show that based on 2009's data of waste from Bandung, the dumped waste in the source was originally 18% of total waste, now decreased to 6%; previously burned waste of 12% from the total waste decreased to 7%; while composted waste increased from only 4% to 21%. The industrial-ecology concept in waste management has also potential to produce energy. The results of the research show that the net energy from the waste management using industrial-ecology scenario is 370,852 GJ. It is a potential in producing electrical energy equivalent to 103,097 MWh. The change of managed waste volume is also beneficial to the environment. Using the scenario, the global warming potential (GWP) is reduced 77% from originally 996,359,307 Kg CO2Eq to 229,824,066 Kg CO2Eq.

Keywords: ***global warming potential, industrial-ecology, net energy, re-utilize***

1. Introduction

a. Background

Per capita waste production figures generated in Bandung City was 3 liters/person/day in 2009. With a population of 2,335,406 people in the city, the total volume of waste generated in 2009 per day was 7000 m3. Waste percentages according its source for the city are from: settlement 65.56%, market 18.77 %, road 5.52%, commercial area 5.99%, institution 2.81%, and industrial 1.35%. According to a report in 2007 on the recapitulation of waste transportation data per month, transported waste volume for one year was at 2,567.35 m3/day or only approximately 37%.

b. Problems

The limitation of waste management in Bandung is caused by two issues, which are the lack of operational funds for waste management and lack of available land that can be utilized for waste final disposal (landfill). These create on poor waste management by the local government resulting in more carelessly waste dumping and led to environmental problems, such as pollution to water bodies, air pollution, and soil contamination.

The 'Industrial Ecology' is a relatively new concept, often applied by industrial practices. This concept aims to further streamline the processes that occur in industrial systems. As it happens in the ecosystem, the use of materials and energy on an activity, by-products, and even waste are reused for other processes.

A similar purpose is developed in this research. It is expected that using the industrial ecology concept, waste management - particularly in urban areas, can be more efficient in its resources use by reusing materials and energy that are still available in the waste. So they can be used for other process or for other activities, both inside and outside of the waste management system (through recycling and recovery).

A main research questions is how the concept of industrial ecology applies for urban waste management? This brings up further research questions, as follows:

a. How to identify and track materials and energy flows in urban waste management?
b. How to identify materials from the waste that can be reused as raw materials in the waste management system?
c. How to calculate the reduced impact/environmental damage due to the effort of energy recovery from waste material after the application of the industrial ecology concept?
d. What is the cost-benefit analysis of waste management using industrial ecology approach compared to conventional waste management? Benefits for analysis are tangible and intangible benefits as a result of reduced material and energy usage, reduced waste management costs, and reduced environmental problems after the implementation of the industrial ecology concept for the waste management?

c. Research Aims

This study aims to produce a concept of waste management based on industrial ecology to support the implementation of sustainable waste management and environmentally sound. The concept is implemented in the form of eco-design. Prior to reaching the stage of eco-design process, the research should answer the following questions:

a. Prepare a method to track materials and energy in the waste management system.
b. Obtain information about the quantity and quality of materials that can be reused and energy that can be recovered, derived from the overall waste management system.
c. Obtain information on the quantity of pollutant emissions reduction from waste management system before and after the implementation of the industrial ecology concept.
d. Obtain information on the costs and benefits of waste management systems based on industrial ecology compared to the cost and benefits of conventional waste management systems.

d. Benefits of the Research

This research is expected to contribute for science development, producing a concept of industrial ecology and municipal solid waste management and generating a direct benefit which is the concept of more sustainable waste management and environmentally sound that can be implemented by city level waste management.

2. Research Method

This research is an exploratory study, a type of research that will explore an unknown or little known issue - in this case is to explore the application of the industrial ecology concept in municipal solid waste management.

The research uses survey research methods. The research begins with the collection of secondary data regarding waste management system in Bandung City to obtain the functional elements of waste management systems that currently exist along with secondary data collection of energy usage, management cost for each functional element, and direct or indirect participation from communities. The next stage is primary data collection related to the flow of materials and energy in the waste management system. Observations of waste volume and composition in each functional element are the core of this primary data collection. Once all data are collected and well documented, then a life cycle analysis/inventory (LCA) is carried out. This stage is intended to generate potentials that can be reused and to calculate environmental pollution from the existing solid waste management system.

The interpretation of LCA results will be a basis for later eco-design which will then be analyzed for cost and benefits to be compared with the current practiced conventional waste management.

3. Result

The waste management in Bandung City is as follows: Total Waste Production (Ts) of 743,541 tonnes, consisting of waste which is managed at its source by the community of 56% and waste entering to the city waste management system of 44%. Managements at the source are carried out by buried (32%), burned (21%), carelessly disposed (8%), reused (32%), and composting (7%). As for waste entering the city waste management system, it is managed by landfill (80%), composted in TPS$^{(*)}$ and TPA$^{(**)}$ (3%), and recycled by third parties (17%). The waste volume continues to increase according to population and community activities.

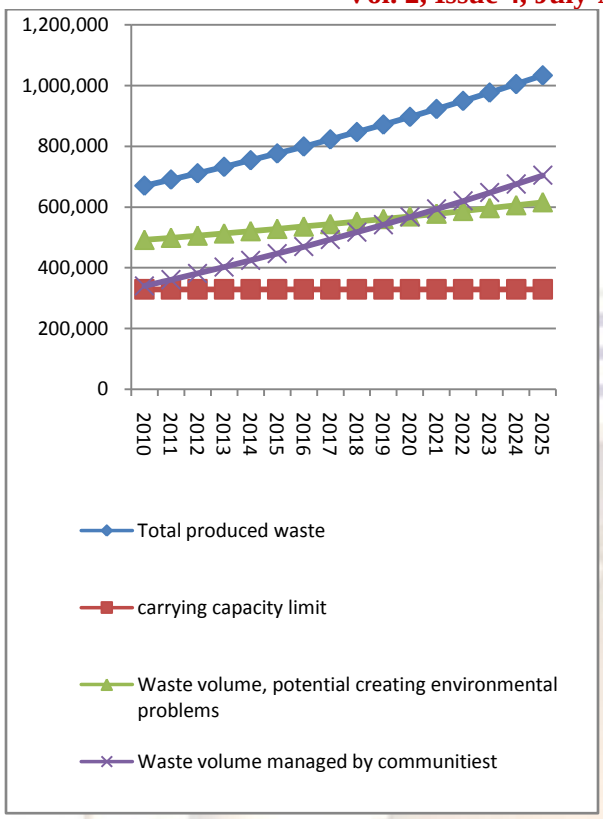

Figure 1. Predicted Waste Volume, Waste Managed by Communities and Waste Potential Creating Environmental Problems

The results of energy and pollutants tracking show that the current waste management in Bandung City (database 2009) use 17,429 GJ/year energy for its operation and there is no functional unit that produces energy. As for environmental pollutant, which is represented by a number of Global Warming Potential (GWP), it generates 996,359,307 KgCO2eq.

Based on the LCA results, those facts and potential problems of the existing waste management are used as basis for determining eco-design for waste management using the industrial ecology (IE) concept as follows:

a. Waste management issues currently.

- The environmental carrying capacity of Bandung City for waste management activities has been exceeded.
- The waste management is still treated as a "cost center".
- Based on the above issues, it is expected to create various environmental impacts as indicated in the above LCI pollutants, where value will increase with the rate of waste generation/capita and population growth rate in Bandung City.

b. Potential, the following are potential materials that can be utilized for recycling or energy recovery from waste in Bandung City.

Potential sources	**Plastic** (Tons/ Year)	**Paper** (Tons/Year)	**Organic** (Tons/Year)
Management at source	41,101	32,196	160,184
City Waste Management System	24,201	12,558	200,821
Total	*65,302*	*44,754*	*361,005*

Based on the above description and potential problems, it is proposed an eco-design of waste management based on ecological industry concept as follows:

- Reducing the amount of waste buried, burned, and carelessly disposed at its source
- Recycling efforts for household plastic for composter container.
- Improving the management of landfill (final disposal))

Through the waste management based on industrial ecology concept, the flow of waste management in the city will be changed to: Total Waste Production 743,541 tonnes, consisting of managed waste at the source of 56% and waste entering to municipal solid waste management system of 44%. Waste at the source is managed through buried 12%, burning 6%, disposed 4%, reused 32%) and composting 46%. Waste entering into municipal solid waste management system will be managed through landfill (final disposal) 7%, composted in the TPS and TPA 3%, recycled by third parties 17%, energy recovery 55% and briquettes making 17%.

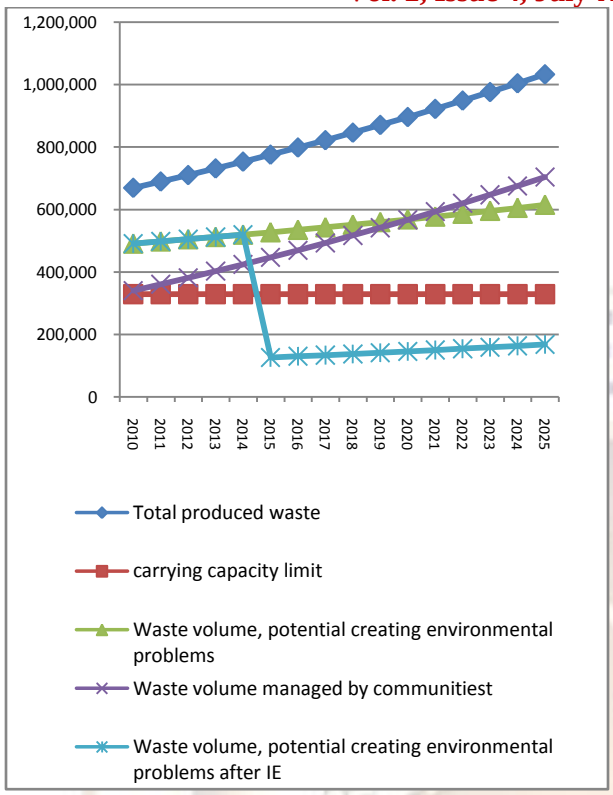

Figure 2.

Predicted Waste Volume, Waste Managed by Communities and Waste Potential Creating Environmental Problems with Waste Management using Industrial Ecology (IE) Concept

Through costs and benefits analysis, with the implementation eco-design, if the tangible benefits only included at a discount rate of 10%, it will result in NPV of IDR 63,876,426,668 and B/C of 1.092 with a payback period of 11 years after the operational period. While if the social benefits are included with the same discount rate, it will generate NPV of Rp.277.789.480.928 and B / C of 1.4 with a payback period of 7 year period after the operational period.

4. Conclusion

The application of ecological industry concept in waste management can be undertaken after an LCA process to determine the material and energy flows in the waste stream, as well as to obtain potential facts and issues of waste management that closely associated with the flow of waste from the source to the landfill (TPA). The LCA result is supported with the survey results of community readiness and understanding of waste management that will be a basis for eco-design for waste management using the industrial ecology concept.

With the eco-design of waste management using the industrial ecology concept, there is a change in waste management pattern at the source and in the municipal waste management system. Uncontrolled disposed waste such as buried, burned, and carelessly disposed of is declining. With the EI-based waste management, generated energy can also be used to supply the waste management system. Similarly to pollution, in particular GWP, it will be decreasing.

The costs benefits analysis results shows, at a certain period, the benefits resulting from the EI-based waste management outweigh the costs - so that can be a basis for policy setting of industrial-based waste management. The policy implementing industrial ecology-based waste management is in line with the Republic of Indonesia Government policy as in the Act 18/2008 on Waste Management that emphasizes the aspect of waste reuse and treats waste as a resource.

Given the important role of LCA in eco-design for waste management using industrial ecology concept, it is advisable to develop the waste LCA software in Indonesian version, based on the real conditions of waste management practices in Indonesia.

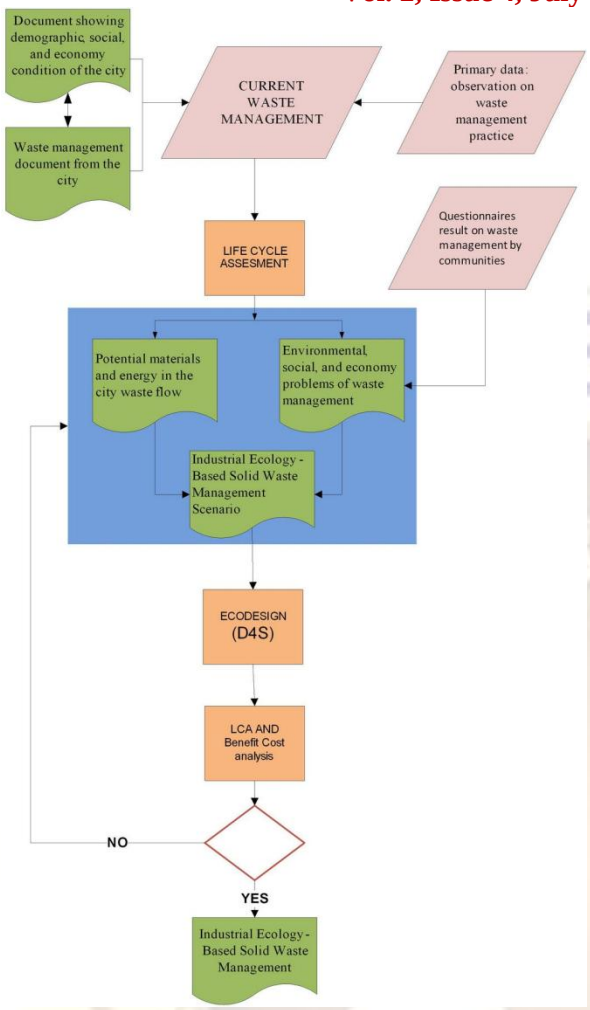

Figure 3 Industrial Ecology-Based Solid Waste Management Model

NOTE:

- *TPS : Temporary disposal site*
- *TPA : Final Disposal site*
- *GWP : Global Warming Potential*

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