早稲田大学大学院 環境・エネルギー研究科

博 士 論 文 概 要 書

論 文 題 目

Analysis and proposals for the development of sustainable municipal
solid waste management methods in developing Asian countries

アジア新興国におけるサステナブルな都市廃棄物
の処理・管理手法の開発に関する分析と提案

申 請 者

Andante Hadi Pandyaswargo

氏　名　　アンダンテ　ハディ　パンディヤスワルゴ

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This study provides the analysis and proposals for the development of sustainable municipal solid waste management (MSWM) methods in developing countries in Asia. In the first chapter, problems were addressed, previous studies on the current MSWM Life Cycle Assessment (LCA) were identified and the structure of the thesis was elaborated.

In the second chapter, strengths, weaknesses, opportunities, and threats of adapting MSWM technologies were identified. The developing Asian countries have organic waste as the biggest fraction of their municipal waste composition. The technologies that have been practiced are including landfilling, composting, RDF, incineration, and small-scale anaerobic digestion. Common waste characteristics are high moisture, low calorific value and mixed collection. This characteristic adds to the challenge of energy and material recovery. As comparison, analyses of the current status of the developed European countries were also provided. The result was that the composting is widely practice and effective in minimizing the amount of waste going to the landfill. Due to the complexity of environmental issues caused by inappropriate MSWM and LCA study is necessary

To select the appropriate methodology for LCA study, several LCA methodologies such as the Eco-Indicator 99 and Eco Point, are compared in the third chapter. The emission factors of each methodology were applied on two scenarios. The first scenario is the baseline scenario consisting of landfill gas capture for energy recovery and composting. The second scenario is the proposed scenario consisting of landfill gas capture and anaerobic digestion. The comparative analysis showed that all methods (ELP, Eco-Indicator 99, and EP) select the scenario with anaerobic digestion (AD) as the best CO_2, CH_4, SO_2, NO_x, and solid waste avoidance option. Eco-indicator has similarities with ELP in terms of approaches, which is the panel survey. On the other hand, Eco Point is politically driven. The three methodologies gave different figures but similar conclusion in terms of the total value comparison. EP put emphasize on waste disposal (500 unit), where it is only 1 unit in ELP and 0 unit in eco-indicator. Since all of the methodology proposes the scenario with AD, a SWOT analysis of the feasibility of AD

implementation was offered. The conclusion of the SWOT analysis was that the technology may not be feasible at the moment but might be feasible in the future when waste are properly separated at source.

For further analysis, the fourth chapter applied ELP on three scenarios tested on three developing Asian countries. The three scenarios proposed includes incineration, anaerobic digestion and the three countries are India, Indonesia and China. The result shows that the environmental impact and risk of failure of the scenario incorporating composting is considered as medium compared to the other options (incineration and anaerobic digestion). This scenario also offers significant amount of energy recovery potential from the sanitary landfill.

Since composting was found to be the currently feasible method, economic assessment was conducted in the fifth chapter to improve the system's economic performance. Cost Benefit Analysis was performed for different capacities of composting using real data from Indonesia, China, and Sri Lanka. This chapter aimed at finding the optimum scale of municipal waste composting using several economic feasibility tools such as NPV, BCR, and estimation of amortization period. As an effort to investigate the influencing factors of the financial feasibility of organic content from the municipal waste in developing Asian countries, the most challenging part of this study was data collection because often plant managers are reluctant to give the real figure of costs and benefits due to confidentiality issue. However, site visits and continuous communications maintained were able to solve the problem. The results of this chapter showed that the medium scale (51 TPD) composting plant has better opportunity to be financially feasible; waste input and product quality are more controllable, there is possibility to gain benefit from CER and project can make use of the existing landfill complex and transportation. When quality could be enhanced such as by manually separating organic waste done in Bali or pelletizing the waste in Bekasi, market acceptance might be increased. With good market acceptance, Bali composting plant was predicted to be able to sustain itself even without benefit from CER. The other strategy done was an agreement by the Bantar Gebang plant with the department of agriculture where significant amount of the

product is used for plantations. Government and institutions role especially in providing investment cost of the small scale composting plant, and in addition, tipping fee in to the large scale composting plant are significant in determining the economic feasibility of the plant. Awareness of the governmental policy makers to these findings and their effort to alter their policy framework accordingly will lead to more sustainable municipal waste management the developing Asian countries. Moreover, better soil condition, sustainable agricultural production, and new job opportunity are only few of additional benefits from a sustainable municipal waste composting plant.

On the sixth chapter, Environmental Load Point (ELP) method was tested with different approaches to find the most appropriate impact category weighting system. Two approaches were used, the first one was Analytical Hierarchical Process (AHP) and the second one was text mining. Each of the methodology has its own advantages and disadvantages. The advantages of AHP approach is, results reflect the respondent past experiences and future expectation based on their knowledge and experiences. The disadvantages of AHP approach is, results represent limited number of sample group risk of subjectivity. The advantage of Text-mining is, results reflect a wide perspective from the national or regional trends and interest. However, it only represents a limited period of time. Risk to capture only Occasional / temporary hypes or events occurring in the particular year. AHP is the more applicable approach for projects that require long term consideration and where using results from a group of people as representative is acceptable whereas text-mining is the more applicable approach for projects where long term considerations are not vital but require a national / regional perspective. The study of this chapter was followed by the application of ELP with AHP approach to Indonesia, China and Thailand. Since Text mining highlights the problem of disposal, it may be used in the future studies related to waste management.

Future work planned to follow up this study includes the social life cycle assessment (SLCA) and the research on the feasibility on applying Extended Producer Responsibility (EPR) in the developing Southeast Asian countries. The use of text mining weighting approach is recommended.