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INTEGRATED SOLID WASTE MANAGEMENT: A LIFE CYCLE ASSESSMENT

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ABSTRACT

An amount of 30, 000 tonnes per day is expected to be accumulated in Malaysia in the near year 2020. In order to manage this increasing volume of solid wastes, the waste management technologies have to be further integrated between one and another. A life cycle assessment is an environmental management tool to project and compare the environmental impacts of a product or a service from the initial stage until the final stage of the product's or the service's life-cycle. Life cycle assessment checks every part in a system in which the input such as raw materials and energy and the output such as products including the emissions of air, water and residuals of the system are calculated in order to project the existing environmental impacts resulting from the system's activities. This paper discusses the application of the technique as a tool to predict the integrated solid waste management system impacts towards the environment. The environmental effect analysis on the case study has found that the practiced management scenario i.e. integrated solid waste management is able to solve issues related to the reduction of world's energy resources and raw materials. However, a little impact has been given by the system with regards to the rise of the global warming effects due to the transportation and material processing activities. The improvement of the integrated solid waste management system in future is required in order to reduce the environmental burden that produced the global warming effects.

Keywords: waste collection, central sorting, recycling process, thermal treatment, composting, landfill.

INTRODUCTION

Integrated approach managing solid wastes from the point of accumulation to the point of disposal. This management system combines wastes collection and sorting processes with other management options such as recycling, thermal treatment and ground burial. The advantage of each technology is that each one is able to recover precious resources like raw materials or energy source from wastes. On the other hand, the disadvantage of each technology is the possibility of emissions that will pollute the environment.

The process of choosing appropriate technology management to be applied is crucial because managing wastes requires the relevant database. The function of the database is to prove that wastes have the potential to become a valuable source of energy and to facilitate predictions regarding the effects of emissions that are present in the methods used (Othman *et al*., 2009). For that reason, Life-Cycle Assessment is a best technique that can be used to analyse solid waste management technology selection that practices integrated approach. The technique is able to produce data to be used in predicting the environmental effects exist due to activities generated by the integrated solid waste management.

In order to enhance the management effectiveness, focus must be given in upgrading the existing non-sanitary landfill sites and in building more technologically-enhanced management facilities such as disposal sites, exchange stations, central sorting, recycling centres and others. At present, some waste management companies in Malaysia have taken measures in creating an integrated management system. For example, there is a waste company that has taken an integrated approach in managing wastes from the point of accumulation and it continues with the following list of order: technological option for waste collection, central sorting (material recovery facilities and refuse derived fuel sorting facilities), thermal treatment and landfill(Environmental Impact Assessment, 2004). There is also waste management company that has taken these approaches i.e. waste collection technology, recycling centres, thermal treatment using incinerators and landfill (Siphon, 2007). As for the solid waste management approaches carried out in other waste management company include the options of waste collection, central sorting (material recovery facilities), recycling centres, composting centres and landfill (Hing, 2007). However, some waste management companies has been planning to further upgrade the effectiveness of its integrated solid waste management by suggesting the concept of energy production from the wastes of landfill gas and refuse derived fuel burning (Tsuing, 2007).

Life-Cycle Assessment is an environmental management tool utilized in projecting and comparing the environmental impacts of a product or a service from the intial until the final stage (from cradle to grave) of the product's or the service's life-cycle (White *et al*., 2007). This technique scrutinise every part of a system (the product or the service) and then let the consumers to modify any part that can contribute to the reduction of energy usage, the production of wastes and emissions. The implementation of this technique is divided into four stages namely the goal and scope definition stage, the inventory stage, the impact analysis stage and the assessment or interpretation stage (McDougall and Hruska, 2000). The advantage of this technique as a tool to manage the environment is due to its holistic nature in evaluating the system's environmental impacts. This technique also allows the impacts from each part in the system to be compared. The LCA technique is suitable to be applied in projecting the existing site impacts while managing solid wastes with its various management options.

In brief, LCA is divided into two parts i.e. the product's life-cycle and the waste's life-cycle. The life-cycle of a product starts from the point of manufacturing the product from the earth's raw materials until the production of the usable product. The life-cycle of a waste begins when a product has lost its values to the consumers and is converted into garbage until it is returned back to earth using the landfill technique. At present, the LCA technique has been applied by many countries in assessing their solid waste management system whether using an integrated or an individual way. The technique has given an opportunity on the selection of various suitable waste management techniques to be compared and then to be considered in achieving certain solid waste management strategies. For that reason, this paper highlighted LCA technique as environmental tools to measure the environmental effects produced by the integrated solid waste management system.

METHODOLOGY

In brief, the research methodology is divided into five i.e. field study, data collection, LCA model development, computer calculation development and impact analysis study. The field study listed the waste component facilities in the study area such as waste collection, central sorting, recycling plant, and thermal treatment plant and landfill disposal site. Data collections which are the input and the output of the waste facilities component system are obtained. Normally, it is done by listing down the life cycle inventory for each waste component facilities. The listing will project the burdens of waste management technique toward the environment. The LCA model is design by considering the applied waste management concept including selecting a suitable technology as a sub-system for a chosen system. Computer calculation model is built using excel spreadsheet as the database. The impact analysis will be carried out based on the result obtain from the database. The result will then been interpret and evaluate.

In this study, the inputs of the system are 500 tonnes/day solid waste, raw material and energy such as diesel usage for transportation activities and electricity energy for processing activities. The output of the system is recovery material such as secondary raw material and energy and emission due to the processing and transportation activites.

RESULT

Table-1, Table-2 and Table-3 shows the life cycle analysis on the integrated solid waste management in case study districts. Briefly, with reference to Table-1, the generated calculation has found that 2380.54 kg of the emissions is produced by the transporting activities from the waste accumulation areas to the central sorting facilities in which 2380 kg from the emissions is the air emissions and 0.54 kg is the water emissions. As shown in Table-1, the total emission produced by the activities of transporting wastes from central sorting facilities to the recycling plant, RDF plant, composting plant and disposal sites is 1208.5 kg in which 1208.3 kg is the air emission and the remaining 0.2 kg is the water emission.

Table-1. Emission from the transportation activites due to the practice of integrated solid waste management in case study district.

	Transportation	
Sub-system	**Water**	**Air**
Waste collection	0.54kg	2380kg
Central sorting	0	132.0kg
Recycling process	0	104.1kg
Thermal treatment	0	152kg
Composting	0	16.2kg
Landfill	0.2kg	804kg
Total	0.74 kg pollutant	3588.3kg pollutant

In refer to Table-2, the emissions produced from the processing activities at the central sorting facilities are the water emission i.e. 117.9 tonnes of the mixture of leachate and washing wastewater and 67.5 tonnes per day for residuals. The turnover materials such as plastics, ferrous metal and non-ferrous metal, compost materials and others produced by the central sorting are 185.6 tonnes per day while the source of energy in the form of RDF pellets is 153 tonnes per day as stated in Table-3. The emission produced from the processing activities at the recycling processing plant consists of the water emission with 290 tonnes per day for wastewater from washing activities and 8.1 tonnes per day for residuals waste. The produced turnover materials which are recycled materials or better known as secondary raw materials are 112.2 tonnes per day. Based on the calculation in Table-2, the emission produced from the processing activities at the thermal treatment plant consists of the air emission of 60, 065 Nm^3/day and 34.2 tonnes per day for residuals waste. Based on the calculation in Table-3, the produced turnover material i.e. electrical energy is

ARPN Journal of Engineering and Applied Sciences

160.5 MW per day. The produced turnover material at composting plant is 73.4 tonnes/day. Referring to Table-2, the emission produced from the processing activities at the composting processing plant consists of air emission i.e. the mixture of CO_2 and H_2O which are 33.1 tonnes/day, 5.98 tonnes/day water emissions and 18.5 tonnes/day residuals waste. The emission produced from the disposal activities at the disposal site is 75,034 liter per day for leachate and 280, 900 m^3/day for landfill gas.

Table-2. Emission from the processing activites due to the practice of integrated solid waste management in case study district.

	Processing		
Sub-system	**Water**	**Air**	**Residual waste**
Waste collection	0	0	0
Central sorting	117.9tonnes/day	0	67.5tonnes/day
Recycling process	290tonnes/day	0	8.1 tonnes/day
Thermal treatment	0	60,065Nm^3/day	34.2tonnes/day
Composting	5.98tonnes/day	33.1tonnes/day	18.5tonnes/day
Landfill	75,034litres/day	280, 900m^3/day	0
Total	488.9tonnes/day leachate, and washing wastewater	60,065Nm^3/day air pollutants, 33.1tonnes/day (CO_2+H_2O) and 280, 900 m^3/day landfill gas	128.3 tonnes/day solid waste to be landfill

Table-3. Recovery material from the practice of integrated solid waste management in case study district.

	Recovery material	
Sub-system	**Secondary raw material**	**Energy**
Waste collection	0	0
Central sorting	185.6tonnes/day	153tonnes/day
Recycling process	112.2tonnes/day	0
Thermal treatment	0	160.5MW/day
Composting	73.4tonnes/day	
Landfill	0	0
Total	185.6tonnes/day secondary raw materials	153tonnes/day Refuse derived fuel (RDF) that produce 160.5MW/day electricity

DISCUSSIONS

The case study conducted in the district has found that the practiced management system technique for solid waste management is based on the integrated waste management concept. The environmental effect analysis on the case study has found that the practiced management technique is able to solve issues related to the reduction of world's raw materials and energy resources as shown in Table-3. This is because the system is based on the concept of converting wastes into secondary raw materials and energy resources. Hence, it can be summed that the practiced management system for integrated system has given a minimum impact towards the reduction of the world's source of energy and raw materials.

The analysis of the effect of pollution on problems such as global warming, eutrophication phenomenon and acidification potentials by the practiced management system has found that in general, the potential resulting effect of pollution is the problem of global warming. This is due to the usage of energy through the waste processing and the transporting activities. However, the existing of pollution control system such as pollutant eliminators in gasses enable to reduce the pollutants emissions to the environment. The existing of waste water treatment plant act as a water pollution control system for wastewater resulted from managing waste activities such as a leachate and washing waste water. As for the control of residuals disposal at disposal sites, it is done by disposing the residuals at sanitary disposal sites for non-hazardous residuals while the hazardous residuals will have to be initially modified before disposing them at the secured landfill sites (Dincer *et al*., 2013).

From the case study analysis, there are some identified weaknesses in the management system that cause the increase of emissions from the activities carried out within the system and hence to give impacts towards the environments. These weaknesses are divided into two parts. The first weakness is the management component facilities which are located within a great distance from one and another. For example the distances between the waste central sorting facility with the recycling plant and the energy generation plant. This weakness has caused the increase of pollutants emissions resulting from the waste transporting activities between the components.

The second identified weakness is there is no interaction between the existing buy back centres in the district with the waste sorting centre. For instance, the re-purchasing centres do not send their obtained recycled materials to the central sorting. This phenomenon has caused an environmental pollution due to the activites carried out by the buy back centres outside the integrated waste management system. The difficulty in predicting and controlling the waste management activities outside the system has made it problematic in forming a mechanism to minimise the effects of such activities towards the environment.

The reduction of environmental burden formed from the usage of energy and raw materials by the practiced management system can be achieved if the system’s activities are improved. The improvement methods that can be carried out are to increase effectiveness and technology in each management system component in the integrated solid waste management system which is economy-friendly and environment-friendly: The reduction in the usage of energy for the waste transporting activities by constructing waste management facilities that are within close proximity is another way to improve the environnmental burden. Interactions between the practiced integrated solid waste management system with the buy back centres in the district by making it compulsory for the re-purchasing centres to send the obtained recycled materials to the central sorting for the purpose of management.

CONCLUSIONS

The best waste management system requires a balance between the economy and the environment and, this system has to be accepted by the society. The best management system also needs interactions between one management facilities with the others. Other than that, the best management system has to be successful in overcoming issues related to the solid waste management and in overcoming the problems of pollution and the lack of the world’s natural resources such as the resources for the natural fuel and the natural raw materials

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