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Environmental Assessment of Municipal Solid Waste Disposal Options in Malaysia

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Abstract: The Malaysian inhabitants has been growing at a rate of 2.4% per annum or about 600,000 per annum since 1994.So, the municipal solid waste (MSW) generation also increases, which makes MSW management vital. In 2003, the average amount of MSW generated in Malaysia was 0.5–0.8 kg/ person/day. And, by the year 2020, the quantity of MSW generated was estimated to have increased to 31,000 tons. Currently, landfilling is the only method used for the discarding of municipal solid waste in Malaysia, and the majority of the landfill sites are open dumping areas, which causes severe environmental and social threats. So, the aim of this study is taking into account the present condition of disposal options in Selangor state regarding environmental point of view. Life cycle Analysis is a method which is used to consider disposal methods. In this Article life cycle assessment tool is used to weigh up different treatment scenarios with Eco-indicator (Europe 99) methodology which is applied to model different scenarios. Research, showed that all scenarios has a high amount of different potential impacts, Otherwise analysis illustrated first scenario which is the existing condition of Malaysian disposal method, is not preferable than others because of its high contribution on climate change , respiratory organics and carcinogens. Scenario 3 also has high impacts on respiratory inorganic, ecotoxicity and acidification. In addition, second scenario has the average impacts and its situation is between S1 and S3. However, environmental impacts of disposal methods could be considered by decision makers in future and it should be completed by different solid waste management methods and defining different scenarios in the country to introduce the most environmentally and economic method to the authorities.

Key words: Environmental Analysis, Municipal solid waste, disposal methods, life cycle assessment.

INTRODUCTION

The major proportion of MSW in Malaysia is generated by Selangor with a population of almost 5 million in 2009 and a production of 3,923 tons daily.

Municipal waste is in general disposed by landfilling or incineration and only a small proportion of the MSW stream (about 2%) is recycled or treated by biological composting (Chen, 2005). Also, in Selangor, All the MSW collected by the waste collectors from defined areas are disposed in an open dump landfill .The management of the landfill includes the monitoring and leveling of waste. The landfill is an open-dump that lacks any lining system and leachate collection pond. The waste management system in Selangor state is basically under the responsibility of three main authorities which cover areas of Kuala Lumpur, Rawang, Sepang and Banting, Hulu selangor and township of Kajang.

One of the authorities is the consortium appointed by the Ministry of Housing and Local Government to provide waste management services in the central region of Peninsular Malaysia. It serves 6.1 million people over a total area of 72 388 km^2 in the central and eastern regions of Malaysia covering state of Selangor, Pahang, Terengganu, Kelantan, and cities of Kuala Lumpur and Putrajaya.

Another authority is located approximately 20 km to the south- east of Kuala Lumpur. The area generally constructed of hilly landscape with valleys fanned near the rivers, including Sungai Langat, Sungai Bangi, Sungai Semenyih and Sungai Chua. Kajang has a population of 189,400 people with major activities include commercial, education and agricultural.

As part of 'Vision 2020', the government of Malaysia looking for developing the environmental protection and integrate the existing solid waste management system. Recycling is still at an infant stage in Malaysia; nonetheless, with increasing environmental awareness, the government is starting to support waste recycling by drafting policies and suggesting support to private waste management companies. It is also importing technologies from Japan and some European countries, in trying to provide a conductive environment for technology sharing.

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Literature:

Review Studies on modeling of solid waste management systems were started in the 1970s and were increased with the development of computer models in 1980s. While models in the 1980s were generally based on an economic perspective (Gottinger, 1988), models that included recycling and other waste management methods were developed for planning of municipal solid waste management systems in the 1990s (MacDonald, 1996).

Models developed in recent years have taken an integrated solid waste management approach, and included both economic and environmental analyses. Models have included linear programming with Excel-Visual Basic (Abu Najm And El Fadel, 2004), Decision Support Systems (Fiorucci *et al*, 2003), fuzzy logic (Chang and Wang, 1997) and Multi Criteria Decision-Making techniques (Hokkanen and Salminen, 1997).

Environmental LCA is a system analysis tool. It was developed rapidly during the 1990s and has reached a certain level of harmonization and standardization. LCA studies the environmental aspects and potential impacts throughout a 'product' life (i.e., cradle-to-grave) from raw material acquisition through production, use and disposal. This is done by compiling an inventory of relevant inputs and outputs of a system (the inventory analysis), evaluating the potential impacts of those inputs and outputs (the impact assessment), and interpreting the results (the interpretation) in relation to the objectives of the study (defined in the goal and scope definition at the beginning of a study). LCA is currently being used in several countries to evaluate treatment options for special waste fractions (Bauman and Tillman, 2004; Bore *et al*, 2007; Winkler and Bilitewski, 2007; Borghi *et al*, 2007; Ozeler and Yetis, 2006). So, in the study, LCA methodology is used to analyze and to evaluate different alternatives for Malaysia. Therefore, SimaPro7 (2006) software has been applied to model waste disposal scenarios.

Methodology:

Doing LCA on solid waste management methods in order to evaluate different methods of waste management for Malaysia is a new subject. Now a days in Malaysia some of industries are doing LCA in order to have sustainable products, whereas no institutes and solid waste management companies emphasize on LCA to consider environmental impacts of their disposal options. The comparison is done by Simapro 7.2 as a software in order to considering environmental impacts by open dump and sanitary landfill in Malaysia .This evaluation was conducted according to TSE EN ISO 14040 (1996). According to TSE ISO 14040, an LCA comprises four major stages: goal and scope definition, life cycle inventory, life cycle impact analysis and interpretation of the results

Goal and Scope:

The aim of this study is to select a suitable waste disposal option for Malaysia by evaluating from an environmental point of view alternatives. The results of the study would be helpful for the Metropolitan Municipality of Malaysia. The functional unit of this study was the average total tonnage of MSW generated per year for the period of 20 years design life of landfill based on 2,257 ton per day generated in the Federal Territory of Kuala Lumpur. In this study, In order to do an analysis on different solid waste management methods in Malaysia 3 alternative scenarios to the current waste management system in Selangor were defined, and these scenarios were evaluated by the means of LCA.

The first one is based on the present condition of waste management technology which is 97% open dump and 3% sanitary landfill. The second one is 50% of household waste dispose in open dump and 50% in sanitary landfill. The third scenario is 100% household waste dispose in sanitary landfill.

System Boundary:

The system of the study started with collection of MSW from residential areas and includes waste treatment alternatives (open-dump and sanitary landfill) of waste. A life cycle analysis of transportation was not considered.

Life Cycle Inventory:

The total life cycle inventory model for landfill consists of the inventory of energy consumption, air emissions and water emissions during the phase of landfill construction, operation, closure and post-closure care. However, in this study only landfill operation, leachate gas emission and leachate generation are modeled. Also, the data for life cycle inventory was gathered from actual applications in Malaysia, literature and the database of the SimaPro7.

Regarding energy consumption, fuel (diesel) and electricity consumption during landfill operation modeled to estimate the energy consumed in term of Kwh of electricity and the amount of fuel (diesel) for managing one ton of solid waste in landfill. The electricity consumption during landfill operation was the electricity consumed for lighting of administration building, garbage site, and operation of weighbridge and leachate treatment plant.

Diesel consumption is the amounts consumed by landfill machineries to place, spread and compact the waste, and transport, spread of daily, intermediate and final cover.

The estimation of the quantity of landfill gas generated from landfill was modeled using the triangle gas production model (Tchobanoglous *et al*, 1993).

Landfill leachate is characterized by high contents of organic and inorganic compounds, the content of a wide range of toxic substances and high variability (Filipkowska, 2005). The leachate quantity generated from landfills was estimated using water balance method (Tchobanoglous *et al*, 1993).

The BOD concentration in the leachate was modeled by assuming that BOD concentration started at high concentration and diminished over time as the waste aged. The COD concentrations were calculated using BOD/COD ratio of landfill leachate. And other pollutants in landfill leachate are assumed constant through landfill design life.

Regarding energy consumption between open dumps and sanitary landfill, it is obvious that sanitary landfill consumed more energy than open dump. The energy consumed by sanitary landfill was 7.31E+04 GJ per year, 3.01E+04 GJ more than open dump. The high consumption of energy by sanitary landfill was due to facilities used by sanitary landfill such as leachate treatment plant, site lighting and administration building that are not available at open dump.

By considering air emissions between open dumps and sanitary landfills, the highest CH4 emission was emitted by open dump with the amount of 5.63E+06 kg per year. While, sanitary landfill emitted more CO2 (fossil) and N_2O than open dump with the amount per year of 1.38E+07 kg and 1.84E+02 kg, respectively, for other air emissions such as HCl, HF, NH_4, NOx, SOx and total metals, sanitary landfill was emitted more than open dump except for total HC and total NMVOC. The high emissions of HCl, HF, NH_4, NOx, SOx were due to the process of electricity generation and the production and use of diesel fuel. As for the emission of total HC and total NMVOC, the emissions of these compounds were due to decomposition process of organic matter in landfill (Abdul nasir, 2007).

Open dump had the overall highest output of water emissions for all parameters studied except PO4 as compared to sanitary landfill. BOD and COD emitted per year by open dump were 4.42E+06 kg and 1.19E+07 kg, respectively, while sanitary landfill emitted 8.84E+04 kg of BOD and 2.38E+05 kg of COD. However, sanitary landfill emitted higher PO4 with 1.34E+02 kg per year as compared to 9.34E+00 kg by open dump. The high emission of PO4 is due to the high consumption of electrical energy and diesel fuel.

RESULTS AND DISCUSSION

Life cycle impact assessment of the solid waste disposal options has been done by the Eco-indicator method. Three different impact area like human health, ecosystem quality and resource depletion is considered by this method as a damage oriented end point analyzing tool (Pre consultants, 2001).

Eco-indicator methods has the alternative to analyze environmental load under three impact areas and eleven different impact categories like carcinogens, respiratory organics, respiratory inorganic, climate change, radiation, ozone layer, eco-toxicity, acidification/eutrophication, land use, minerals and fossil fuels. In this study, the focus is on 3 impact categories included by the Eco-indicator (Europe 99) method. Climate change, Acidification, and Eutrophication are described below.

- Climate change, the characterization model developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterization factors. Factors are expressed as Global Warming Potential for time horizon of 100 years (GWP100), in kg carbon dioxide/kg emission (Goedkoop and Oele, 2004).
- Acidification, the major acidifying pollutants are SO2, NOx, HCl and NH3. What acidifying pollutants have in common is that they form acidifying H+ ions. A pollutant's potential for acidification can thus be measured by its capacity to form H+ ions. The acidification potential is defined as the number of H+ ions produced per kg substance relative to SO2 (Bauman and Tillman, 2004).
- Eutrophication is a phenomenon that cans influence terrestrial as well as aquatic ecosystems. Nitrogen (N) and phosphorus (P) are the two nutrients most implicated in eutrophication. Eutrophication potentials are often expressed as PO_4^{-3} equivalents (Bauman and Tillman, 2004). In the inventory, impacts are analyzed by different effect categories then damage assessment has been measured by human health, ecosystem and resource categories. Then the impact values are normalized based on regional perspectives. In this study European value has been considered and normalization and weighting value are given bellow.

Table 1: Normalization and weighting for Europe 99 method.

Normalization/weighting set	Damage categories	Normalization	weighting
Europe EI 99 E/A	Human Health	64.7	400
	Ecosystem Quality	1.95 E-4	400
	Resources	1.68E-4	200

Source: Pre Consultant (Pre consultant, 2008).

Source: Pre Consultant (Pre consultant, 2008) Eco-indicator has the option to analyze eleven different impact categories however, in the study LCA model has been developed based on emissions for average total tonnage of MSW generated per year data in Malaysia .So, the results have been showed with ‘no impact’ value for radiation, ozone layer, land use, mineral and fossil fuels.

Figure 1, shows the graph of the different disposal options. Regarding characterization chart, scenario 1 which is the existing condition of disposing solid waste in Malaysia has the higher impact in carcinogen, respiratory organic and climate change. And, scenario 3 which is assumed that 100% of solid waste disposes to sanitary landfill has the considerable impact on respiratory organic, ecotoxicity and acidification/eutrophication. Therefore, third scenario which is defined 50% of waste disposes in open dump and 50% dispose in sanitary landfill has the lower potential impact in carcinogens, respiratory organics and climate change. In addition, it has a higher impact on respiratory organics compare to scenario 3. But, the impact of scenario 2 on ecotoxicity and acidification/eutrophication is higher than scenario 1 especially on ecotoxicity .Although regarding scenario 3, scenario 2 is lower in the two mentioned potential impacts.

Characterization results show the contribution of emissions in different impact categories. Since the model is developed from the average emission value of the disposal options, therefore, the model is restricted to describe the consequences of the diverse waste streams.

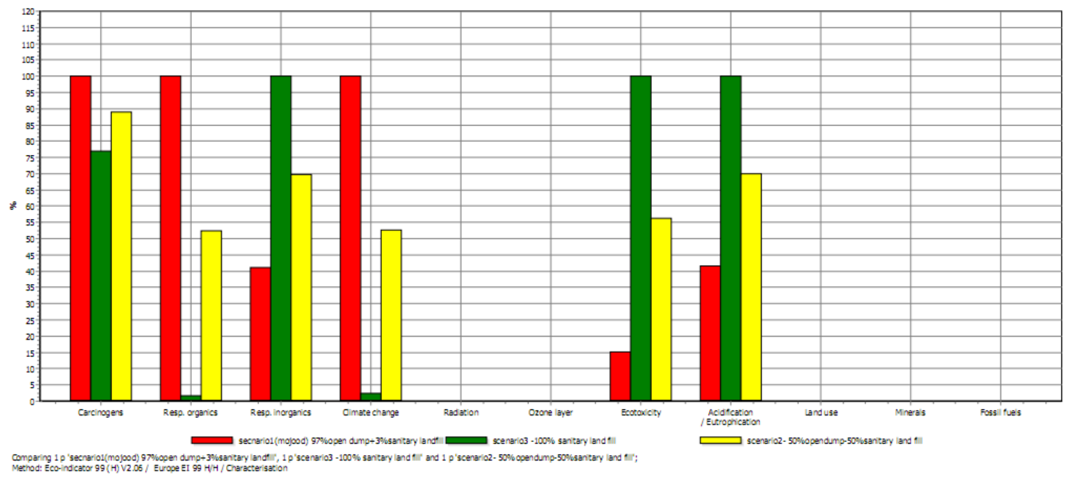

Fig. 1: Comparative LCA characterization results of three disposal scenarios.

Normalized and Weighting:

Results Figure 2 shows the normalization graph of the three scenarios .Normalization graph shows that climate change is the significant impact category in regional perspective. In addition scenario 1 which is the existing condition of disposal and scenario 2 which is 50 % open dump and 50 % sanitary landfill and are the 2 disposal scenarios that contribute in climate change respectively. And scenario 3 has the lowest impact in climate change. Methane and carbon dioxide emission from scenario 1 and 2 are mainly responsible for climate change impact.

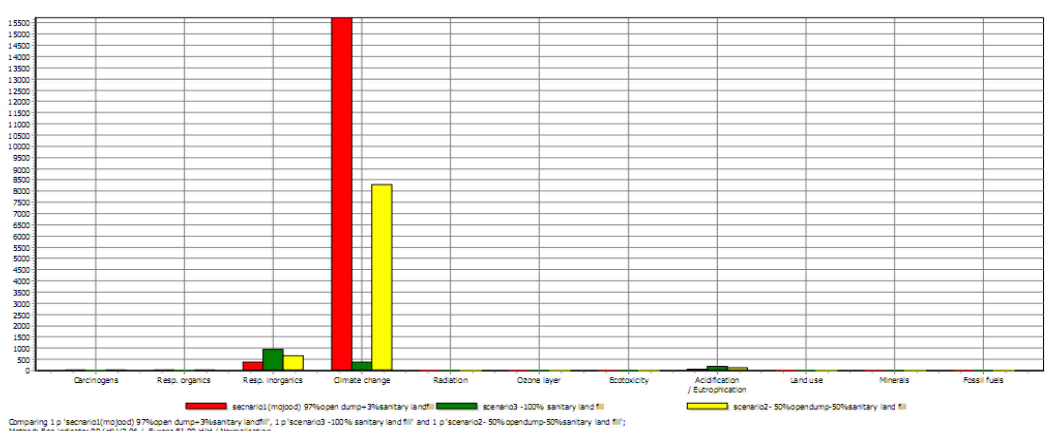

Fig. 2: Normalization graph for three disposal scenarios.

Conclusion:

In this article life cycle assessment tool is used with Eco-indicator (Europe 99) methodology to weigh up different treatment scenarios .Analysis illustrated that all scenarios has a high amount of different potential impacts. In addition, first scenario which is the existing condition of Malaysian disposal method is not a preferable method than others because of its high contribution on climate change, respiratory organics and carcinogens.

In this study, waste management alternatives were investigated from only an environmental point of view. But, in future different solid waste management methods should be consider to compare environmentally and economically to introduce to the MSW authorities. And, it might be supported with other decision-making tools that consider the economic and social effects of solid waste management. By adopting the use of LCA as part of the waste management decision making process countries can avoid the risk of making serious long-term environmental mistakes by rigid adherence to the hierarchy. Instead a Life Cycle data based decision making process will ensure that future investment in waste management will be reflected in overall environmental improvements.

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REFERENCES

Abdul Nasir, A.A., 2007. The ingenieur Life cycle Inventorization between open dumps and sanitary landfills.,volume 34,June-August.

Abou Najm, M., M. El-Fadel, 2004. Computer-based interface for an integrated solid waste optimization model. Environmental Modelling and Software, 19: 1151-1164.

Boer, J., E. Boer, J. Jager, 2007. LCA-IWM: A decision support tool for sustainability assessment of waste management systems. Waste Management, 27: 1032-1045.

Borghi, A., L. Binaghi, M.G.M. Borghi, 2007. The application of the environmental product declaration to waste disposal in a sanitary landfill. International Journal of LCA, 12(1): 40-49.

Bauman, H., A. Tillman, 2004. The Hitch Hiker's Guide to LCA . Studentlitteratur AB, Sweden.

Chang, N., S.F. Wang, 1997. A fuzzy goal programming approach for the optimal planning of metropolitan solid waste management systems. European Journal of Operational Research, 99: 303-321.

Chen, C.C., 2005. An Evaluation of Optimal Application of Government Subsidies on Recycling of Recyclable Waste, , Polish Journal of Environmental Studies, 14(2): 137-144.

Filipkowska, U., 2008. Effect of Recirculation Method on Quality of Landfill Leachate and Effectiveness of Biogas Production, Polish J. of Environ. Stud., 17(2): 199-207.

Fiorucci, P., R. Minciardi, M. Robba, R. Sacile, 2003. Solid waste management in urban areas development and application of a decision support system. Resources Conservation and Recycling, 37: 301-328.

Goedkoop, M., M. Oele, 2004. Effting S. SimaPro Database Manual Methods library. PRe ´ Consultants, Netherlands.

Gottinger, H.W., 1988. A computational model for solid waste manage- ment with application. European Journal of Operational Research, 35: 350–364.

Hokkanen, J., P. Salminen, 1997. Choosing a solid waste management system using multi criteria decision analysis. European Journal of Operational Research, 98: 19-36.

MacDonald, M., 1996. Solid waste management models: a state of the art review. Journal of Solid Waste Technology and Management, 23(2): 73-83.

Ozeler, D., U. Yetis, 2006. Demirer G.N. Life cycle assessment of municipal solid waste management methods: Ankara case study. Environment International, 32: 405–411.

Pre consultants, 2008. Sima Pro 7, Amersfoort, The Netherlands.

Pre Consultant, 2001. Eco-indicator 99: A damage oriented method for life cycle impact assessment, methodology report, 22nd June 2001, Netherlands.

Tchobanoglous, G., H. Theissen, S.A. Vigil, 1993. Integrated Solid Waste Management: Engineering Principles and Management Issues. McGrow-hill, International edition, Singapour.

Winkler, J., B. Bilitewski, 2007. Comparative evaluation of life cycle assessment models for solid waste management. Waste Management, 27: 1021-1031.