Journal of Engineering and Applied Sciences 12 (Special Issue 3): 6450-6455, 2017
ISSN: 1816-949X

Evaluation of Solid Waste Management Using Material Flow Analysis (MFA) for a Waste Utilization System in Shah Alam

Nurul Qayuum Farahin Saidi and Norashikin Ahmad Kamal
Faculty of Civil Engineering, University of Technology MARA (UiTM),
40000 Shah Alam, Selangor, Malaysia

Abstract: The daily increase in solid waste generation is one of the major issues leading to increasing environmental pollution such as leaking of leachate in landfill percolated groundwater sources. Thus, this study has been carried out to fulfil the following objectives to analyse the final net amount of solid waste generation in the solid waste utilization system identify the interrelationship between solid waste management and cost analysis in operating a solid waste facility in the Shah Alam area and evaluate the current status of solid waste management specifically in the Shah Alam area. The STAN (Substance Flow Analysis, Version 1.1.3) software system generated the Material Flow Analysis (MFA) diagram based on the data collected in this research. The final net weight of solid waste ending up in landfills is 166915.07, 197318.40, 194937.54, 190866.62 and 187306.18 ton for the year 2006, 2012, 2013, 2014 and 2015, respectively. Based on the analysis an increase in reduction activity will affect to the final net weight of solid waste arriving at landfills, generally affecting the costs of managing solid waste. Evaluation of the current status of solid waste management in Shah Alam is in the range of satisfying but improvements are needed its managing system. It is recommended that further study be done with Life Cycle Analysis (LCA) for a better understanding of flow for each element in solid waste management.

Key words: Solid waste management, material flow analysis, solid waste generation, solid waste utilization, element, Malaysia

INTRODUCTION

In the modern era, solid waste generation in every country is increasing. This situation has led to environmental pollution getting worse as nations move towards industrialized status. The quality of water, air and soil are all at risk due to a number of human activities. Soil and groundwater pollution are among the pertinent cases to be highlighted. One source of soil and groundwater pollution is the leaking of leachate from landfills the final disposal sites for solid waste. It has been reported that groundwater at landfill sites in Selangor are seriously contaminated (Taha *et al*., 2011).

Currently, landfilling is the most widespread method for discarding municipal solid waste in Malaysia and the majority of landfill sites are open dumping areas, leading to severe effects on the environment and human health (Lau, 2004). Several landfills in Selangor has been identified as causing pollution in the surrounding soil and groundwater such as at Ampar Tenang (Taha *et al*., 2011). Such landfills are generally open dumps with insufficient liner systems. In future, it is feared that more severe contamination cases will be reported, since there are only a few engineered landfills available in Selangor. This is in addition to the rapid growth of the population. Thus, this study is carried out to fulfil the following objectives to analyse the final net amount of solid waste generation in a solid waste utilization system; identify the interrelationship between solid waste management and cost analysis in operating a solid waste facility in the Shah Alam area and evaluate the current status of the solid waste management specifically in the Shah Alam area.

MATERIALS AND METHODS

The study has been carried out based on the current practice of solid waste management in Malaysia. One major issue is the increase of solid waste generation day by day. This also leads to increasing environmental pollution such as leaking of leachate from landfills that percolates into groundwater sources. Leachate refers to

Corresponding Author: Nurul Qayuum Farahin Saidi, Faculty of Civil Engineering, University of Technology MARA (UiTM), 40000 Shah Alam, Selangor, Malaysia

liquids that contain organic and inorganic constituents that are hazardous to the environment and human health. Additionally, methane gases are also produced from solid waste which can be harmful both to human health and environmental surroundings. Moreover, improper solid waste management such as open dumping sites could lead to an unhealthy environment for local people.

Data collection: The data collected in this study is solid waste data from the Shah Alam city Council, World wide Holdings Landfill Management and also the Department Of Environmental (DOE) for the surrounding areas of Shah Alam city. Data collected for this research study includes:

- The residential population of Shah Alam (capita)
- Amount of solid waste generated (ton/year)
- Rate of recycling activity (%)
- Rate of leachate being treated (%)
- Rate of composting activity (%)
- Rate of biogas generated at landfills (%)
- Estimated cost for municipal solid waste management in Shah Alam city (Ringgit Malaysia, RM)

All the data collected will be the inputs for creation of a flow diagram for MFA using STAN Software. Material Flow Analysis (MFA) is a systematic flow diagram of materials and substances in a system with a defined time and space (Cencic and Rechberger, 2008). The model or diagram produced from MFA usually consists of the processing and flow of goods, substances or materials. Processes in an MFA diagram can be defined as black boxes and flow is usually represented as an arrow connecting all the process involved in a system. In addition, the data imported in the system will be known as input. There are three elements defined in an MFA diagram, i.e., goods, substances and material. Each has a different meaning for each element used (Cencic and Rechberger, 2008). Goods are known as economic elements with a negative and positive value, i.e., drinking water and fuel oils. A substance consists of a chemical element with uniform units, i.e., Nitrogen (N) and Carbon Dioxide (CO_2). Lastly, material sits between goods and substances as an element that can be defined in both categories, i.e., Carbon (C) and wood. STAN Software is freeware that produce by the Vienna University of Technology. This software (in Version 1.1.3) is used to create the MFA diagram according to Austrian Standard ONORM S 2096 (Application in waste management) (Cencic and Rechberger, 2008). Thus, the data in this study will be presented in different yearly boundaries, i.e., 2006 and 2012-2015.

The use of a basic equality equation in calculating the amounts needed in this study research can easily be established even though the data collected contain uncertainties. Corresponding uncertainties will be measured by assuming an even distribution of values using standard deviation of method reconciliation.

MFA establishment: After the MFA diagram is generated based on the data input to the STAN Software it will display all the results and the amounts needed in the system. This study focuses on the final amount of solid waste generated in Shah Alam city within a fixed time frame. All processes and values included in municipal solid waste management will be taken into account for the final result display in the MFA diagram, also known as a Sankey diagram (Cencic and Rechberger, 2008). The exported values in the MFA diagram represent the amount of solid waste prevented from entering a landfill.

RESULTS AND DISCUSSION

This research study has been conducted to generate a MFA diagram for municipal solid waste management of a waste utilization system for a case study in Shah Alam city. This MFA diagram is plotted based on the given data and information from authorities, namely the Shah Alam city Council (SACC), Department of Environment (DOE) and Worldwide Holdings Sdn. Bhd. which are all involved in managing and recording amounts of municipal solid waste for Shah Alam city. Furthermore, solid waste management in Shah Alam city is being improved with the addition of technology implemented for sorting and controlling solid waste generation in the city. In addition, it is important to manage the solid waste properly in order to reduce operating costs.

Analysis of data collection: Figure 1 shows the percentage of recycling activity done in Shah Alam city. In 2006, the recycling rate was only around 5.5%. This value continues to increase because the level of awareness in residents is also increasing. According to Worldwide Holdings Sdn. Bhd. the leachate treatment plant operating at Air Hitam Landfill only collected around 5% of municipal solid waste generated every year. This situation can be interpreted only small amount of solid waste collection being reduced from the overall that being ends up in landfill. The increasing recycling rate for

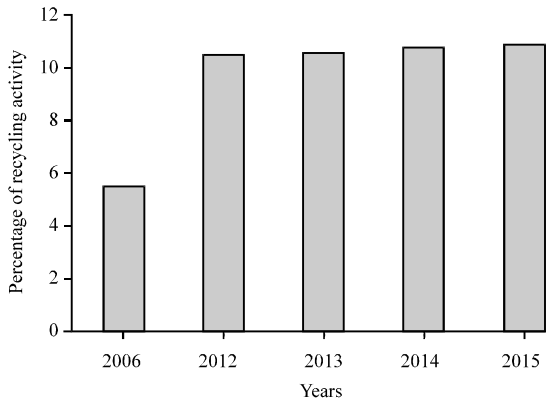

Fig. 1: Percentage of recycling activity for Shah Alam area

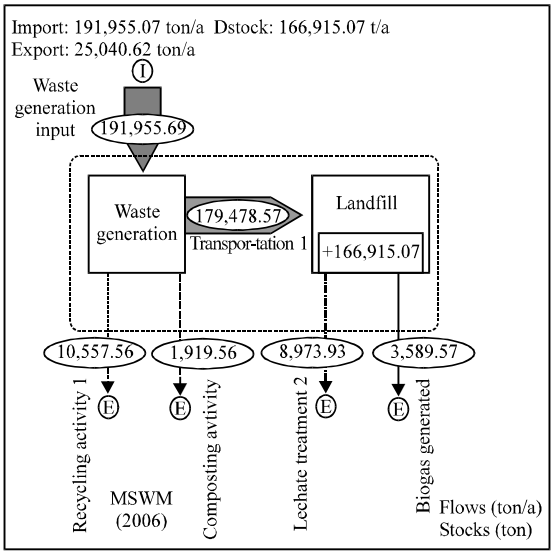

Fig. 2: MFA diagram for MSWM in year 2006

Shah Alam area is positive for solid waste management in this area. From the observation in 2015, the recycling rate reached 10.9% and SACC estimates that it will continue to increase year over year. SACC have also pledged to increase recycling activity within the community to increase the number of Shah Alam residents taking part in recycling activities. Thus, it is important to shows the community regarding to solid waste management and attract the non-government parties to take parts in managing solid waste (Dinie and Mashitah, 2013).

Interpertation of Material Flow Analysis (MFA): Based on the data collected regarding municipal solid waste generation, recycling rate and leachate treatment rate the MFA diagram has been generated via STAN Software. The MFA diagram is defined by 5 different years to evaluate the improvement done for municipal solid waste management specifically in Shah Alam City. Figure 2 shows the analysis of solid waste management in Shah Alam city in 2006 in which the solid waste generated is directly end up at Air Hitam landfill in Puchong. In 2006, the rate of solid waste was 0.90 kg/capita/day. Solid waste was 191955.69 ton/year. Then, the data was imported into the solid waste utilization system with only 5.5% of recycling activity done in at source, 1.0% of composting activity, 5.0% of leachate collected at landfill and 2.0% of biogas generated in 2006 where the remaining will be dumped into the landfill. Moreover, in 2006 there was still no transfer station built to manage solid waste which can reduce the percentage of solid waste dumped in landfills for Shah Alam city. In addition, the cost of municipal solid waste management is still high because of inefficient solid waste management concepts and low level of awareness of recycling activity (Alam and Ahmade, 2013). Eventually, the total amount of solid waste dumped in the landfill is 166915.07 ton after the reduction process. A previous study showed that the value of solid waste dumped in landfill was nearly the same at 147561.96 ton/year (Omar, 2008).

A MFA diagram has been generated in order to analyse the current status of solid waste management in the Shah Alam area. This MFA diagram has produced the amount of solid waste generation in waste utilization system which finally being disposed to landfill. Based on the MFA diagram plotted with complete input data the final amounts of solid waste generated by Shah Alam for selected year 2006, 2012, 2013, 2014 and 2015 are 166915.07, 197318.40, 194937.54, 190866.62 and 187306.18 ton, respectively. In addition, the MFA diagram generated in this study shows the percentage of solid waste ending up at landfills as interpreted from the value change in stock for landfill processes.

Furthermore, each process in solid waste management may also be identified from the MFA diagram in which the processes involved is shown in a block box and solid waste generated is clarified by a red arrow that represents the imported data. The green arrow in the MFA diagram represents the rate of recycling activity. The grey arrow represents the value of leachate treatment done in transfer stations and landfill collection plants. Composting activity is represented by a yellow arrow while the purple arrow represents biogas energy collected from landfill. The arrow in the MFA diagram shows the exported data calculated in this system which is known overall as the amount of reduction of waste from solid waste placed in a landfill.

Other than that the MFA diagram provides a concise explanation of the processes included in the system. In

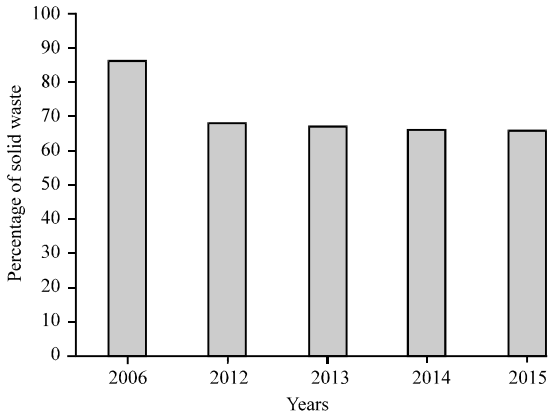

Fig. 3: Percentage of rate for solid waste end up to landfill

this case study, each process is plotted and linked together with a flow that connected the data from started until the end of the process. Upgraded technology should be used by authorities managing solid waste such as Material Recovering Facilities (MRF) which perform sorting activities in order to reduce the solid waste generation dumped to the landfill in the future. Plus, the processes of managing the solid waste can be seen in MFA diagram, giving an initial overview to all the parties to fully understand the solid waste management system. Each process plays a role from the beginning of solid waste generation until the final disposal site which is also related to the costs of managing solid waste.

Figure 3 shows the percentage reduction in the rate of solid waste being dumped in landfills. The year-over-year change has been affected by a decrease in solid waste transported to landfills. This is because of better management of solid waste for Shah Alam city. Plus, the community in Shah Alam has started to realize the importance of managing their solid waste with activities such as sorting in their homes (Alam and Ahmade, 2013) year 2015 the percentage of solid waste ends up at landfill is decrease to 65.3 % which showed the improvement of solid waste management in Shah Alam area. However, there still many improvements needed to reduce the solid waste load of the landfill. Many developed countries such as Japan and Germany that successful in managing their solid waste.

For example, the enhancement of 3R concept that gives a huge impact towards the continuous sustainability for the solid waste management. Plus, 3R implementation should start from the production of waste and play a role in society to separate the waste from the source. Other than that technology related to waste collection and handling also must be designed to suit the separation facility to reduce the amount of waste that will end up at a landfill. By 2020, Shah Alam city may generate a sustainable concept for solid waste management if a better plan is developed. Therefore, it is important to take a look onto the current situation of solid waste management which can trigger the problem and research for its solution.

The calculation on cost analysis regarding of municipal solid waste management in Shah Alam is done by adding all the cost included for the system. If the concept of 3R is implemented in solid waste management it will increase the reducing activity done for solid waste end up at landfill (Johari *et al*., 2014).

Plus, there is a 10-15% reduction of waste going to landfill if the waste separation is conducting at the source. The 3R concept is including reduce, reuse and recycle where in the data collected from Shah Alam city Council only cover the recycling activity done. Therefore, it is shown that the management system in Shah Alam still does not include the sustainability concept of 3R for solid waste management.

Figure 4 shows the example of estimation of 3R activity done with 10% that generally make the reducing activity increase and the solid waste ended at landfill become decrease. The decrease of solid waste ended at landfill means a reduction in costs for managing solid waste in the Shah Alam area. The lesser the solid waste ended at landfill the lesser the cost for operating the solid waste management (Johari *et al*., 2014).

Thus, the interrelationship between proper solid waste management with cost analysis can be proven in terms of activities that will generally reduce solid waste ending up in landfills and affect the costs of managing solid waste. Hence, it is also important to increase activity in reducing and reusing material in production which will have a direct effect on solid waste production.

In addition, a higher level of awareness in the community is also needed in order to implement better solid waste management including an understanding of the solid waste management system. Plus, the implementation of laws regarding to solid waste separation at the source (Act 672) is one of ways to achieve successful management of solid waste. All parties involved in managing solid waste can create a better system of solid waste management in future, covering all sustainable concepts in terms of the environment, society and the economy.

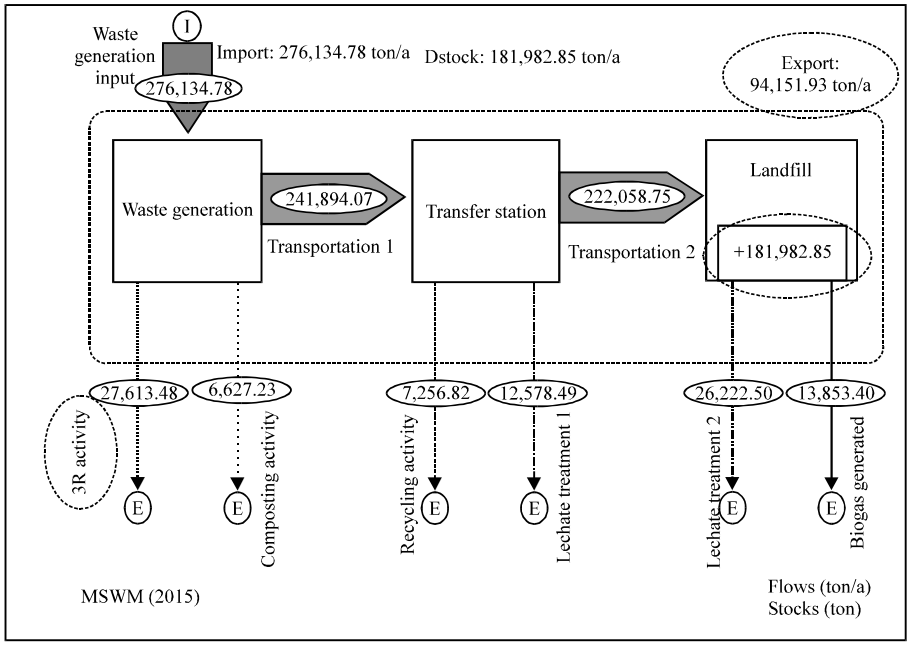

Fig. 4: Example of MSWM with implementation of 3R concept

CONCLUSION

In this research study has achieved its objective based on the examination of solid waste management via. MFA tools. The objective of this study is to analyse the net amount of solid waste generation in Shah Alam area using MFA for the selected years of 2006 and 2012-2015. The final amount of solid waste generated has been measured after taking into account the percentage reduction of solid waste being dumped to landfill. The amounts of solid waste finally end up to landfill are 166915.07, 197318.40, 194937.54, 190866.62 and 187306.18 ton for each year, respectively.

The second objective of this study is to identify the interrelationship between solid waste management and cost analysis in operating solid waste facilities in the Shah Alam area. It has been proven from the analysis done in this study that increasingly reduced activity will generally affect the final net amount of solid waste ended at landfill, thus give an effect towards the cost in managing solid waste. Starting from the solid waste generation by the community in Shah Alam, until the final stage of solid waste at disposal site, the cost will be affected by how much solid waste will enter a landfill. In addition, the construction of a transfer station itself can reduce the cost of transportation, distance and time needed to managing daily solid waste. In a nutshell, the uses of Material Flow Analysis (MFA) as a tool with STAN Software can create an overview for understanding the evaluation of a solid waste system. The findings of this study show that the management of solid waste in the Shah Alam area is satisfactory based on Shah Alam City Council (SACC) records and previous studies indicating that the management of solid waste is in the range of satisfying but still need improvements in managing solid waste. Hence, the need of upgrading technology on management of solid waste can be establish with proper planning of management in the system. Thus, increasing solid waste generation is one of concerning factors in managing solid waste management for a given area.

With the use of MFA as a tool the processes involved in solid waste management can be trace out and the implementation of plan can be conducted. For environmental surroundings it is important to conduct calculations for each process to ensure that the environment will be protected from pollution created by solid waste. Hence, the use of MFA in extracting the process and flow in waste utilization system is necessary for better decision making in planning the management of solid waste in the case study area.

RECOMMENDATIONS

It is recommended that further study be done with Life Cycle Analysis (LCA) for a better understanding of flow for each element in the solid waste management. MFA tools are known as a method to establish an inventory for a LCA tools. Thus, LCA can serve as an

impact assessment of MFA results. In addition, the data collected for each year is predicted from prolong of statistic and graph projection. In this study the data used from Shah Alam City Council (SACC) is in certain years fully recorded by local authorities. It is also recommended to conduct a cost and environmental analysis which can cover the entire sustainability requirement in managing solid waste in area of case study. Hence, this study made may be used as a guideline to determine the proper management of solid waste in Malaysia with addition of knowledge about the use of MFA in evaluating solid waste production. Also, engineers should widen their scope of study to the importance of environmental effects on humans and how to prevent problems concerning the factors of environmental pollution.

ACKNOWLEDGEMENTS

The researchers would like to thank Dr. Norashikin Ahmad Kamal, lecturer from Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM) for her significant contribution and full guidance along the process in completing this study. Words of gratitude are also extended to all individuals and organizations that have made this study possible.

REFERENCES

Alam, P. and K. Ahmade, 2013. Impact of solid waste on health and the environment. Intl. J. Sustainable Dev. Green Econ., 2: 165-168.

Cencic, O. and H. Rechberger, 2008. Material flow analysis with software STAN. J. Environ. Eng. Manage., 18: 440-447.

Dinie, M. and M.D. Mashitah, 2013. Municipal solid waste management in Malaysia: Current practices, challenges and prospect. J. Teknologi Sci. Eng., 62: 99-100.

Johari, A., H. Alkali, H. Hashim, S.I. Ahmed and R. Mat, 2014. Municipal solid waste management and potential revenue from recycling in Malaysia. Mod. Appl. Sci., 8: 37-49.

Lau, V.L., 2004. Case study on the management of waste materials in Malaysia. Forum Geookol, 15: 7-14.

Omar, D.B., 2008. Waste management in the city of Shah Alam, Malaysia. WIT. Trans. Ecol. Environ., 109: 605-611.

Taha, M.R., W.Z.W. Yaacob, A.R. Samsudin and J. Yaakob, 2011. Groundwater quality at two landfill sites in Selangor, Malaysia. Bull. Geol. Soc. Malaysia, 57: 13-18.