International Journal of Technology (2018) 8: 1579-1587
ISSN 2086-9614 

# ASSESSMENT OF COMPOSTING TECHNOLOGIES FOR ORGANIC WASTE MANAGEMENT

Junidah Abdul Shukor[1], Mohd Faizal Omar[1*], Maznah Mat Kasim[1], Mohd Hafiz Jamaludin[2], Mohd Azrul Naim[3]

[1]*School of Quantitative Sciences, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia*
[2]*Faculty of Agro Based Industry, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia*
[3]*Kulliyyah of Science, International Islamic University Malaysia, 25200 Kuantan, Pahang, Malaysia*

(Received: July 2018 / Revised: September 2018 / Accepted: December 2018)

## ABSTRACT

Organic waste disposal in landfills has created various environmental issues, such as greenhouse gas emissions and leachate. Awareness of this issue has resulted in diverting landfill to compost. Thus, there is a need to develop an analytical tool to select the best composting technology. Therefore, this paper reviews a range of assessment steps designed to evaluate specific sustainability criteria (environmental, social, economic, and technical) for organic waste management to select the most suitable composting technology. Due to the complexity of conflicting criteria and alternatives in composting technology, a multi-criteria decision-making (MCDM) technique is suggested to ensure the quality of the decision-making process. As an additional benefit, the synthesis results via the MCDM tool will be more credible when seeking validation by stakeholders.

*Keywords:* Composting; Composting criteria; Decision making; Organic waste

## 1. INTRODUCTION

Organic waste or green waste can be defined as organic material that is easily biodegradable (Kadir et al., 2016). Organic material is derived from natural sources. Essentially, any residual kitchen waste (vegetable peelings, food, tea bags, and egg shells), agro-waste (food and beverage processing waste, dairy products, animal waste, and crops), grass clippings, dried leaves, and timber can degrade naturally (Hartono et al., 2015; Ng & Yusoff, 2015; Kadir et al., 2016). The process of degradation is performed by microbial (fungi, bacteria, actinomycetes, and protozoa) and invertebrate (insects and earthworm) organisms, which digest and break down the organic matter (Basri et al., 2005; Fauziah & Agamuthu, 2009; Kadir et al., 2016).

Due to the ability of organic waste to degrade naturally, dumping it into landfills is the most common waste disposal method. Unfortunately, various studies have indicated the undesirable environmental impacts of using landfills to manage the disposal of organic waste (Manfredi et al., 2009; Fauziah & Agamuthu, 2010). Leachate contamination in surface and groundwater, infestation by pests, and the emission of greenhouse gases are some effects of organic waste disposed into landfills (Manfredi et al., 2009; Fauziah & Agamuthu, 2010). These effects contribute to global warming and environmental pollution.

The awareness of environmental issues has encouraged society to find other alternatives to manage the organic waste disposal process instead of landfills. The composting process can be used for biological decomposition, and this technology has the potential to manage organic

[*]Corresponding author's email: faizal_omar@uum.edu.my, Tel. +604-928-4772, Fax. +604-928-4756
Permalink/DOI: https://doi.org/10.14716/ijtech.v9i8.2754

waste, transform it into valuable agricultural products, and minimize pollution (Basri et al., 2005; Hartono et al., 2015; Kadir et al., 2016). However, several important aspects need to be considered before implement composting technology. These include sources of waste feedstock in terms of quantity (small scale like home composting, medium scale, or large scale composting) and quality (moisture content and nutrient content) (Basri et al., 2005; Fauziah & Agamuthu, 2009; Zabaleta et al., 2014; Hartono et al., 2015; Ng & Yusoff, 2015), technology set-up in terms of site location and area required (Basri et al., 2005; Zabaleta et al., 2014), required operational skill, and capital and operating costs (Basri et al., 2005; Malakahmad et al., 2017). Besides these, the quality of the compost end-product also needs to be taken into consideration (Zabaleta et al., 2014). Most of these aspects or criteria vary with composting technology. Composting can be performed using different methods or systems, such as the static pile system (Ilham & Esa, 2017; Lim et al., 2017), windrow system (Zaini et al., 2015; Ilham & Esa, 2017), in-vessel system (Zaini et al., 2015; Ilham & Esa, 2017; Malakahmad et al., 2017), and vermicomposting system (Fauziah & Agamuthu, 2009).

Therefore, selecting the best composting technology is not a straightforward process. Specific decisions must be made based on these various criteria. The decision maker needs to understand the assessment steps required to make the best decision and to identify the specific weaknesses and strengths of that decision. This procedure can decrease the probability of mistakes and risk during the process planning and execution phases. Additionally, assessment activities will help the decision maker to evaluate each technology proposed so that the optimal alternative can be identified (Zurbrügg et al., 2014; Abdullah, 2015).

## 2. METHODS

This paper critically reviews some assessment steps for decision making when choosing between various courses of action. Each alternative can be viewed from different dimensions that represent various criteria. These criteria can be arranged in a hierarchical manner. Some of these criteria are associated with several sub-criteria. Based on the sustainability of each aspect or criteria, the decision maker can then identify the best tool or method (Triantaphyllou et al., 1998; Zurbrügg et al., 2014).

### 2.1. Assessment Criteria

Assessing the available composting techniques for organic waste management is complex and complicated. While most waste management models consider environmental and economic aspects, very few consider social and technical aspects. The emphasis in social and technical aspects in the decision-making process has developed in recent years (Ghinea & Gavrilescu, 2010). Therefore, to ensure the sustainability of the decision support framework regarding composting technology for organic waste management, all four criteria (environmental, economic, social, and technical) need to be evaluated (Zurbrügg et al., 2014; Zaini et al., 2015; Bababola, 2015; Coelho et al., 2017). Table 1 shows a simplified set of criteria and sub-criteria as a basis of assessment for selecting a suitable composting technology based on previous studies. Alternative criteria and sub-criteria can be determined from many sources, such as an expert in the field, the literature, and secondary information (Samah et al., 2010; Georgiadis et al., 2013).

Table 1 The criteria and sub-criteria description and overview

| Criteria | Sub-Criteria | Description | Solid waste management (Nouri et al., 2014); Waste management alternatives: incinerator, landfill, composting, and recycling. LCA and MCDM (TOPSIS) | Solid waste management (Samah et al., 2010); Waste management alternatives: incinerator, composting, and recycling. MCDM (AHP) | Study Description Food and biodegradable waste management (Bababola, 2015); Waste management alternatives: Anaerobic digestion, incinerator, and composting. MCDM (AHP) | Solid waste management (Louis et al., 2007); Waste management alternatives: landfill, incinerator, composting, and transfer. MCDM | Organic waste composting (Zaini et al., 2015); Waste management alternatives: windrow and in-vessel composting. MCDM (AHP) |
|---|---|---|---|---|---|---|---|
| Environmental *Protecting public health, natural resources, and environmental sustainability* | Odor (air pollution) | Bad odor can cause uncomfortable conditions and attract pest (ecosystem quality) | * | | * | * | * |
| | Pathogens | Easily grow inside the organic waste if treatment process is not properly managed | | | * | | * |
| | Water pollution caused by leachate | Leachate can harm rivers located near the composting area | | * | * | * | * |
| | Water supply for composting process | The distance of centre from water sources, and the weather | | | * | | * |
| | Public health | Effect of process on nearby businesses or residents | * | * | * | * | |
| | Resources | Additional energy requirements | * | | * | | |
| Economy *Costs and benefits needed to use the technology* | Capital costs | Costs for setting up the treatment/management facility | * | * | * | * | * |
| | Operation costs | Costs needed during the composting process | | * | * | * | * |
| | Marketing of end product | The end product can bring profit and added value for customers | | * | * | | * |
| | Recovery rate | Assessed as secondary raw materials | * | | * | | |
| Social *To improve working conditions, earnings, and access to social services* | Authorities | Management group responsible for SWM | | * | * | * | * |
| | Labor | The workers who perform treatment/manage the process onsite | | * | * | | * |
| | Civil awareness | Responsibility and participation in the waste management program | | * | | | |
| Technical *The level and ability of technology applied during the process* | Machine/ equipment | Needed to operate the treatment facility | | | * | | * |
| | Maintenance | Including machine, equipment, and site conditions | | | | | * |
| | Time to complete the process | Duration to complete the process or amount that can be processed | | | * | | * |

*LCA: Life cycle analysis, MCDM: Multi criteria decision-making, TOPSIS: Technique for order preference by similarity to an ideal solution, AHP: Analytic Hierarchy Process, SWM: Solid waste management*

### 2.2. Assessment Tools

In solid waste management, there are several types of decision support frameworks; the most widely used are life-cycle assessment (LCA), cost-benefit analysis (CBA), and multi-criteria decision making (MCDM) (Consultant, 2012; Zurbrügg et al., 2014; Coelho et al., 2017). LCA is an analytical assessment of the environmental performance of products or services over their whole life cycle, including resource consumption, production, utilization, and disposal (Zurbrügg et al., 2014). Therefore, LCA only considers potential environmental aspects when evaluating waste management systems (Allesch & Brunner, 2014; Nouri et al., 2014) and ignores other decision-making options, such as the economic and social effects.

CBA is a monetary valuation method, the main goal of which is to maximize economic efficiency (Zurbrügg et al., 2014). CBA analyzes costs and benefits, including economic aspects, natural resources, and environmental impacts due to waste minimization, waste recycling, and the by-products of waste treatment (Ghinea & Gavrilescu, 2010).

In contrast, assessment via MCDM considers more than just two pillars of sustainability, focusing on environmental, economic, social, and technical aspects (Zaini et al., 2015; Coelho et al., 2017). Because it analyzes multiple conflicting criteria, MCDM is regarded as a complete method and the most effective decision support framework when evaluating existing or potential alternatives (Allesch & Brunner, 2014; Corelho et al., 2017).

### 2.3. Multi-Criteria Decision Making

MCDM is a decision support framework that has the ability to assess and evaluate multiple conflicting criteria (as shown in Table 1) for decision making in organic waste management. MCDM utilizes a multi-level hierarchical structure consisting of objective criteria, sub-criteria, and alternatives for the selection of an appropriate waste management technology. In fact, MCDM provides a convenient, faster way to make the most accurate decision.

One potential MCDM tool that can be applied in the assessment method is the pairwise comparison of each alternative to the others for all proposed criteria. Each MCDM tool uses a different methodology to conduct a pairwise comparison (Martowibowo & Riyanto, 2011). To develop an MCDM model, the following four steps are commonly used:

1. Determine the work objective:
   The goal and scope of the assessment must be defined based on the issues or problems collected from stakeholders, such as the government, operators, citizens, and researchers. There are two types of objective:
   (i) The goal of the overall assessment affects which methodology should be chosen for the evaluation.
   (ii) The objective of the investigation refers to each criteria and sub-criteria.
2. Defining the theoretical framework:
   The theories and research concepts influence the scope of assessment, which can assist with selecting the criteria and alternatives. Details on the issue are gathered by reviewing the literature (books, journals, reports, etc.) and interviewing experts and stakeholders (Samah et al., 2010).
3. Determining the relevant criteria, sub-criteria, and possible solutions or alternatives (Allesch & Brunner, 2014):
   Each key aspect or criterion is broken down into sub-criteria based on experts' and stakeholders' judgements (Georgiadis et al., 2013).
4. Data collection and data processing:
   Each criterion must be evaluated via quantitative or qualitative indicators, and the

experts, decision makers, and stakeholders will act as the evaluators. They will use numerical values to represent the weight or degree of importance of each criterion (Nasrin & Susanna, 2013; Zaini et al., 2015) when assessing the technologies. Sometimes data normalization is necessary for comparability among indicators when presented with different units or scales (Coelho et al., 2017). The results of the data analysis can be presented as a ranking of criteria according to their importance (Nasrin & Susanna, 2013; Zaini et al., 2015).

## 3. RESULTS AND DISCUSSION

Regarding composting technology for organic waste management, various alternatives have been identified, such as the static pile, windrow, in-vessel, and vermicomposting systems. By using MCDM, two or more alternative approaches can be proposed and various angles based on the four key aspects (environmental, economic, social, and technical) can be gathered in order to achieve the assessment objective. The comparison and ranking of alternatives based on criteria and sub-criteria should be analyzed with local stakeholders and experts via qualitative and/or quantitative analysis.

### 3.1. Environmental Aspects

*3.1.1. Air pollution*

Bad odors can cause uncomfortable conditions and attract pests (Zaini et al., 2015). A good composting operation should not generate offensive odors (Kalbasi et al., 2006). Odors result from specific compounds that are produced before materials arrive at the composting site, during composting treatment, or during compost handling and preparation. Bad odors are caused by the high acidity of the compounds, uncontrolled temperatures, aeration, moisture, and bulk density/porosity of compounds during treatment (Ma et al., 2013).

*3.1.2. Water pollution*

Leachate is a dark brown liquid that is released during the composting process when humid compounds are dissolved from the compost. Leachate is rich in soluble nutrients. Therefore, leachate cannot evaporate as steam, but it will drain down towards the ground (Amin et al., 2014). Leachate can harm rivers, lakes, or ponds located near the composting facility (Kalbasi et al., 2006; Zaini et al., 2015).

*3.1.3. Pathogens*

It is very easy for pathogens to grow inside the organic waste if the composting process is not properly managed (Zaini et al., 2015). These bacterial pathogens can be killed during degradation of organic compounds by keeping the temperature in compost systems between 45°C and 70°C (Sunar et al., 2009).

*3.1.4. Public health*

Airborne particles emitted from composting operations, especially from large-scale composting facilities, can impact the health of workers and nearby residents. These airborne particles, also known as organic dust, can come from live or dead bacteria, may be toxins produced by microbes, or can be particles of plant or animal origin. The health effects include respiratory symptoms, mucosal membrane irritation, skin disease, and inflammatory and immune system response (Harrison, 2007; Samah et al., 2010).

*3.1.5. Water supply*

During the composting process, the reactivity of microbes in the composting system cause increased temperatures and decreased moisture content (Rama & Vasanthy, 2014; Anwar et al., 2015; Zaini et al., 2015). Therefore, this process is controlled by adding water (Ilham & Esa, 2017).

## 3.2. Economic Aspects

### *3.2.1. Variable costs*

Variable costs are needed to develop the composting facility (Zaini et al., 2015). including operational costs. These also include the costs needed during the treatment process and depend on the composting technology, transportation costs, and labor costs (Kalbasi et al., 2006; Zaini et al., 2015). The scale of the operation affects the variable costs.

### *3.2.2. Fixed costs*

Fixed costs are the initial investments in the machinery/system, facilities, and equipment needed for waste handling. These costs depend on the types and size of the system (Kalbasi et al., 2006).

### *3.2.3. Marketability*

Composting provides a nature-based business opportunity to generate income from its by-product, bio-fertilizer (Ilham & Esa, 2017). The compost can be applied directly to soil and contains nutrients such as potassium, nitrate, sodium, calcium, magnesium, and chloride to encourage plant growth (Khan & Ishaq, 2011). Therefore, its marketability depends on the volume and quality of compost as well as the consumer demand.

## 3.3. Social Aspects

### *3.3.1. Civil awareness*

Community involvement in waste segregation before disposal is poor (Samah et al., 2010). However, according to Ilham and Esa (2017), some communities in urban areas are aware of this issue and have been practicing waste separation and setting up composting centers within their neighborhoods.

### *3.3.2. Authorities*

A management group must be responsible for the solid waste management (Zaini et al., 2015). Legislation can be used to categorize solid waste in terms of recyclable waste, garden waste, and residual waste, which can modify societal attitudes (Ilham & Esa, 2017).

### *3.3.3. Labor*

Labor includes the workers who oversee the composting process onsite (Zaini et al., 2015). Among others, this study also considered determine what sort of training will be necessary to perform the waste management, law and regulation for works, and occupational safety and health (Bababola, 2015).

## 3.4. Technical Aspects

### *3.4.1. Machinery/Equipment*

The machinery should be easy to use and operate (Zaini et al., 2015). However, the type of machinery depends on composting system, waste capacity, and transportation system to manage waste from residents/businesses to location of centre and also the equipment to handle the compost (Kalbasi et al., 2006).

### *3.4.2. Maintenance*

Maintenance depends on composting system includes any needed aspect troubleshoot for waste management, such as machines and equipment operation, and site conditions management, in order to ensure the composting operation performs safely (Zaini et al., 2015). It involves cost evaluation. There are options to done internally or contract out to a maintenance company especially for machinery, equipment and transportation maintenance.

### *3.4.3. Location*

When determining location, considerations must be made for the distance from the system/facilities to the waste generation site (should involve minimal travel and be convenient for material handling). The area where the system is set up should be away from sensitive water resources such as streams, ponds, and wells. The size of the system should be based on waste capacity and the system set-up location (Kalbasi et al., 2006).

*3.4.4. Duration of processing time*

A shorter period to complete the composting process is preferred in order to reduce large volumes of waste in a shorter time (Zaini et al., 2015). The processing time also affects the operational costs (Kalbasi et al., 2006).

*3.4.5. Processing conditions*

The type of waste affects the quality and quantity of the compost, and it is essential to ensure that the nutrient contents of the compost are valuable for agricultural use (Anwar et al., 2015). Most widely used co-composted materials are animal manures together with agro-waste in order to reduce heavy metals reduction and gain a maximum nutrient content in compost which is suitable for soil amendment.

*3.4.6. Compost quality*

In terms of nutrient contents, phosphorous, potassium, calcium, sulfur, sodium, and magnesium are required for agriculture (Khan & Ishaq, 2011; Rama & Vasanthy, 2014). Different composting methods affect the nutrient status of the compost and its effects on soil content (Kadir et al., 2016).

## 4. CONCLUSION

MCDM can be applied in any discipline to make effective and accurate decisions based on various evaluation criteria. This study focused on how the MCDM approach can be used to choose the best composting technology for organic waste. However, the assessment step (basic step as mention in section 2.3, the four steps commonly used: (1) Determine of work objective; (2) Define theoretical framework; (3) Determine relevant of criteria, sub-criteria, and alternative or possible solution; and (4) Data collection and data processing) is fundamental not specifically for technology selection, but rather expansion knowledge of decision maker system. Using the MCDM system can result in improved outcomes and more comprehensive support for the decision makers. As an additional benefit, the synthesis results made using MCDM will be more convincing and valid to the stakeholders.

## 5. ACKNOWLEDGEMENT

The authors gratefully acknowledge the support and assistance from UUM Collaboration 1+3 Research Grant (S/O Code: 14036) for this research and the cooperation of research teams from IIUM, UMK, and D&Y Coldchain Venture. M.H.J was supported by Niche Research Grant Scheme from Ministry of Higher Education of Malaysia (grant number: R/NRGS/A07.00/00413A/004/2014/000150) and M.A.N was supported by Research Matching Scheme of IIUM (grant number: RMGS17-004-0030).

## 6. REFERENCES

Abdullah, L., 2015. Developing Decision on Suitable Wastewater Treatment Technology using Fuzzy Simple Additive Weighting. *International Journal of Engineering and Technology*, Volume 7, pp. 405–413

Allesch, A., Brunner, P. H., 2014. Assessment Methods for Solid Waste Management: A Literature Review. *Waste Management & Research*, Volume 32(6), pp. 461–473

Amin, M.M., Hashemi, H., Bina, B., Ebrahimi, A., Pourzamani, H.R., Ebrahimi, A., 2014. Environmental Pollutants Removal from Composting Leachate using Anaerobic Biological Treatment Process. *International Journal of Health System and Dissater Management*, Volume 2, pp. 136–141

Anwar, Z., Irshad, M., Fareed, I., Saleem, A., 2015. Characterization and Recycling of Organic Waste After Co-composting - A Review. *Journal of Agricultural Science,* Volume 7, pp. 68–79

Bababola, M.A., 2015. A Multi-criteria Decision Analysis of Waste Treatment Options for Food and Biodegradable Waste Management in Japan. *Environments,* Volume 2, pp. 471–488

Basri, N.E.A., Basri, H., Stentifor, E.I. 2005., An Expert System to Design Composting Facilities for Municipal Solid Waste. *Jurnal Kejuruteraan,* Volume 17, pp. 85–99

Coelho, L.M.G., Lange, L.C., Coelho, H.M., 2017. Multi-criteria Decision Making to Support Waste Management: A Critical Review of Current Practices and Methods. *Waste Management & Research,* Volume 35(1), pp. 3–28

Consultant, S., 2012. Life Cycle Assessment of Organic Waste Management Options. *4CA-00999-00034.* Regional District of Central Okanagan. Available Online at http://slrconsulting.com , Accessed on August 08, 2018

Fauziah, S.H., Agamuthu, P., 2009. Sustainable Household Organic Waste Management via Vermicomposting. *Malaysian Journal of Science,* Volume 28, pp. 135–142

Fauziah, S.H., Agamuthu, P., 2010. Landfills in Malaysia: Past, Present and Future. *In :* 1st International Conference on Final Sinks. Vienna., pp. 1–9

Georgiadis, D.R., Mazzuchi, T.A., Sarkani, S., 2013. Using Multi Criteria Decision Making in Analysis of Alternatives for Selection of Enabling Technology. *System Engineering*, Volume 16(3), pp. 287–303

Ghinea, C., Gavrilescu, M., 2010. Decision Support Models for Solid Waste Management - An Overvierw. *Environment Engineering and Management Journal,* Volume 9(6), pp. 869–880

Harrison, E.Z., 2007. Health Impact of Composting Air Emissions. *BioCycle,* Volume 48(11), pp. 44–50

Hartono, D.M., Kristanto, G.A., Amin, S., 2015. Potential Reduction of Solid Waste Generated from Traditional and Modern Markets. *International Journal of Technology,* Volume 6(5), pp. 838–846

Ilham, J.I.J., Esa, N., 2017. Composting as a Sustainable Method to Minimise Waste at Source in Malaysia. *In*: International Conference on Environmental Research and Technology (ICERT), pp. 225–228

Kadir, A.A., Azhari, N.W., Jamaludin, S.N., 2016. An Overview of Organic Waste in Composting. *In*: MATEC Web of Conferences, 47

Kalbasi, A., Muktar, S., Hawkins, E.E., Auvermani, B.W., 2006. Design, Utilization, Biosecurity, Environmental and Economic Considerations of Carcass Composting. *Compost Science and Utilization,* Volume 14(2), pp 90–102

Khan, A., Ishaq, F., 2011. Chemical Nutrient Analysis of Different Compost (*Vermicompost* and *Pitcompost*) and Their Effect on the Growth of a Vegetative Crop *Pisu sativum*. *Asian Journal of Plant Science and Research,* Volume 1(1), pp 116–130

Lim, L.Y., Bong, C.P.C., Lee, C.T., Klemeš, J.J., Sarmidi, M.R., Lim, J.S., 2017. Review on the Current Composting Practices and the Potential of Improvement using Two-stage Composting. *Chemical Engineering Transactions,* Volume 61, pp. 1051–1056

Louis, G.E., Magpili, L.M., Pinto, C.A., 2007. Multi-criteria Decision Making and Composting of Waste in the Municipality of Bacoor in the Philippines. *International Journal of Environmental Technology and Management,* Volume 7(3-4), pp 351–368

Ma, J., Wilson, K., Zhao, Q., Yorgey, G., Frear, C., 2013. *Odor in Commercial Scale Compost: Literature Review and Critical Analysis*. Department of Ecology State of Washington,

Washington State University, 2013. Available Online at http://cdn.shopify.com, Accessed on May 13, 2018

Malakahmad, A., Idrus, N.B., Abualqumboz, M.S., Yavari, S., Kutty, S.R.M., 2017. In-vessel Co-composting of Yard Waste and Food Waste: An Approach for Sustainable Waste Management in Cameron Highlands, Malaysia. *International Journal of Recycle Organic Waste Agriculture,* Volume 6(2), pp 149–157

Manfredi, S., Tonini, D., Christensen, T.H., Scharff, H., 2009. Lndfilling of Waste: Accounting of Greenhouse Gases and Global Warming Contributions. *Waste Management & Research* Volume 27(8), pp 825–836

Martowibowo, S.Y., Riyanto, H., 2011. Suitable Multi Criteria Decision Analysis Tool for Selecting Municipal Solid Waste Treatment in the City of Bandung. *Journal of KONES Powertrain and Transport,* Volume 18, pp. 273–280

Nasrin, R.K., Susanna, D., 2013. Application of Multi Criteria Decision Analysis in Design of Sustainable Environmental Management System Framework. *Journal of Cleaer Production,* Volume 47, pp 188–198

Ng, C.G., Yusoff, S., 2015. Life Cycle Inventory of Institutional Medium-scaled Co-composting of Food Waste and Yard Waste in Tropical Country. *Sains Malaysiana,* Volume 44(4), pp 517–527

Nouri, J., Omrani, G.A., Arjmandi, R., Kermani, M., 2014. Comparison of Solid Waste Management Scenarios based on Lift Cycle Analysis and Multi-criteria Decision Making (Case Study: Isfahan City). *Iranian Journal of Science & Technology*, Volume 38(3), pp. 257–264

Rama, L., Vasanthy, D.M., 2014. Market Waste Management using Compost Technology. *International Journal of Plant, Animal and Environmental Sciences,* Volume 4(4), pp. 57–61

Samah, M.A.A., Manaf, L.A., Zukki, N.I.M., 2010. Application of AHP Model foe Evaluation of Solid Waste Treatment Technology. *International Journal of Engineering and Techscience*, 1(1), pp 35–40

Sunar, N.M., Stentiford, E.I., Stewart, D.I., Fletcher, L.A., 2009. The Process and Pathogen Behaviour in Composting: A Review. *In*: Proceeding UMT-MSD 2009, Post Graduate Seminar 2009, Universiti Malaysia Terengganu, pp. 78–87

Triantaphyllou, E., Shu, B., Sanchez, S.N., Ray, T., 1998. Multi-criteria Decision Making: An Operation Research Approach. *Encyclopedia of Electrical and Electronics Engineering,* Volume 15(1998), pp. 175–186

Zabaleta,, I., Scholten, L., Zurbrügg, C., 2014. A Decision Support Tool for Selecting Organic Waste Treatment Technologies. *Sandec News,* Volume 15, p. 5

Zaini, N.S.M., Basri, N.E.A., Zain, S.M., Saad, N.F.M., 2015. Selecting the Best Composting Technology using Analytical Hierarcy Process (AHP). *Jurnal Technologi*, Volume 77 (1), pp. 1–8

Zurbrügg, C., Caniato, M., Vaccari, M., 2014. How Assessment Methods Can Support Solid Waste Management in Developing Countries - A Critical Review. *Sustainability*, Volume 6(2), pp. 545–570