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LIFE CYCLE ASSESSMENT STUDY FOR MANAGING ELECTRONIC WASTE USING LANDFILL TECHNOLOGY

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ABSTRACT

Electronic waste has become a serious environmental issue due to its rapid growth in volume and its hazardous content. As a new addition to the waste stream, the emergence and rapid increase of electronic waste demands an inclusive management system. The management of electronic waste using landfill technology will pose significant amount of problem for environment and human health. Toxic substances from electronic waste dumping at the landfill site may be found in various type of emission such as leachate and landfill gas from landfill site. This study aims to evaluate the environmental impact produced by management of the electronic waste using landfill technology. In this study, a life cycle assessment technique will be used to evaluate the impact of the management of electronic waste using landfill technology. The methodologies of this study are field study, data collection, model development of landfill system, computer calculation development and impact analysis study. The inputs of the system are management of 700 tonnes/day of electronic waste, which were generate from residential, commercial and industrial premises. The fuel usage for transportation activities are 1,069.44 liters per day. The energy usage for processing activities at secured Landfill site are 2,800 liters per day for diesel usage and 2.33 MW/day for electricity usage The results of this study shows that there is no recovery material produced from the landfill. The emissions produced from the processing activity in the landfill system are 583.1 tonnes/day of leachate as well as 2,249,100 m3/day landfill gas. The landfill system produces 59.19 kg water pollutant and 866.9 kg air pollutant. The finding of the study shows that, landfill technology unable to recover world raw materials such as plastics, metals, glass and others. In addition, the emissions such as water and air emission also generated from the system. To minimize the impact of Landfill Technology for managing electronic waste, pollution control facilities such as air pollution control and water pollution control is essential to eliminate the pollutant from released to the atmosphere and water bodies.

Key words: Emission, Life Cycle Inventory, Transportation, Landfill, E-waste.

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1. INTRODUCTION

Globally, the ownership of electric and electronic equipment growing along with the increase of a country's economic factor [1], [2]. Therefore, the volume of obsolete electronic equipment will increase and this makes electronic waste as one of the fastest growing waste streams in the world [3]. One factor which create the rapid growth of electronic waste is the fastest innovation on the electrical equipment especially information technology and telecommunication. Computer manufacturers competing intensely in terms of innovation, the raw processing power of computers is rapidly increasing, resulting in a large number of machines becoming obsolete in increasingly short periods of time [4]. Study conducted by Zhang, Schnoor and Zeng, (2012) and Yu *et al.*, (2010) pointed out that when there is an enhancement of technology; the lifespan of equipment will decrease. In United State of America for example, the life span of computers was four to six years in 1997, but by 2005 had drastically reduced to less than two years [7]. There have several studied had been conducted to estimate the growth of electronic waste in several countries in the world. Most of the study found that most of the electronic waste recently been generated by information technology equipment and telecommunication equipment followed by consumer equipment such as television and refrigerator [8], [9]

Specifically, electronic waste defined in European Union (EU) Directive as electrical and electronic equipment waste that includes all components, subassemblies, and consumable that are part of the product at the time it is discarded [10]. Basel Convention declares that electronic waste encompasses a broad and growing range of electronic devices that have been discarded and includes large household devices, cell phones, personal stereos, consumer electronics and computers [11]. On the other hand, Organization for Economic Cooperation & Development (OECD) states that electronic waste as any appliance using an electric power supply that has reached its end of life[12]. In Malaysia, electronic waste has defined by the laws as waste from the electrical and electronic assemblies containing components such as accumulators, mercury-switches, glass from cathode-ray tubes and other activated glass or polychlorinated biphenyl capacitors, or contaminated with cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese or polychlorinated biphenyls' [13].

To ease the process of electronic waste management, electronic waste has been categorized into ten categories as stated in Table 1. Based on this categorization, several scholar such as Duan *et al.*, (2009) and Kiddee, Naidu and Wong, (2013) reflect only category 3 which is Information Technology and telecommunication equipment as well as category 4 which is consumer equipment are from this list as electronic waste, leading to an clarification of electronic waste. However, the popular of studies in e-waste interpret e-waste as a term encompassing a wide and growing range of electronic and electrical devices, which have been thrown away by their owners [2], [16], [17]. As per ten categories listed, Widmer *et al.*, (2005) Kiddee, Naidu and Wong, (2013) agreed that Categories 1 – 4 account for almost 95% of electronic waste generated in Europe. The category of electronic waste generated is very diverse and differs in product across different categories. For an example, in Australia, the largest category was ICT with an accumulation nearly 51% which greater than household equipment [19]. While in China recorded large household as the highest discarded item with nearly 78 million [17]. In Malaysia, it has been recorded in 2014, the mobile phones and television being the largest e-waste categories had been obsolete [20].

Table 1 The ten categories of e-waste [10]

No	Category	Label
1	Large Household Appliances	Large HH
2	Small Household Appliances	Small HH
3	Information Technology and Telecommunication Equipment	ICT
4	Consumer Equipment	CE
5	Lighting Equipment	Lighting
6	Electrical and electronic tools (with the exception of large scale stationary industrial tools)	E & E Tools
7	Toys, and leisure and sports equipment	Toys
8	Medical devices(with the exception of all implemented and infected products)	Medical Equipment
9	Monitoring and control instruments	M & C
10	Automatic dispensers	Dispensers

The composition of e-waste contains more than 1000 different substances that fall under hazardous and non-hazardous category including ferrous and nonferrous metal, plastic, glass, wood and other items [21]. Some of the components become hazardous after they end up in landfill. The toxic compound such as lead, cadmium, chromium, mercury and arsenic [22]. Not only that, from the electronic waste it is possible to recover a precious metal which most of the frequently recovered are steel with rate amounted 50% [23]. Those hazardous and valuable materials need a further recycling and recovery process in order to recover it from the bulk electronic waste.

Electronic waste content is a substantial environmental issue due to its toxicity [18]. There are numerous types of trace elements in electronic waste such as platinum, silver, gold, and titanium which are precious materials, while some are both precious and hazardous such as copper, mercury, lead and cadmium [24], [25]. The contradiction between environmental and economic worth of electronic waste has made electronic waste management an intimidating challenge (Bhat et. al., 2012). The toxic rudiments in e-waste may be released to the environment in various ways. Usually, the main factor is from inappropriate disposal of e-waste, where e-waste is commonly disposed together with municipal solid waste and over in non-hazardous landfill or being incinerated [26]. E-waste that containing heavy metals, brominated as well as chlorinated flame retardants that had been dumped into the soil able to give potential impact to the environment [27]. In these occurrences, the toxic elements in e-waste may enter the soil and contaminate the groundwater, or enter the atmosphere as toxic fumes if burning is used as a way of disposal [21]. In the United States of America, it is assessed that 70% of mercury and cadmium pollution, and 40% of lead pollution in landfills are affected by leakage of e-waste [28]. Besides that, by implemented the improper recycling and recovery technique, the releasing of toxic substances may harm the air, soil and water [9]. The hazardous substances also have the possible to enter the environment through probable leakage in the process of movement of e-waste from one country to another [11].

If electronic wastes are disposed or recycled without proper supervision, its impact towards the environment and human health are predictable [29] According to Norazli *et al.*, (2015) the main weakness of landfill technology is the presence of pollutants that are released to the environment. For that reason, the objective of this paper is to evaluate the environmental impact produced by management of the electronic waste using landfill technology. In this study, a life cycle assessment technique will be used to evaluate the impact of the management of electronic waste using landfill technology. Basically, the life cycle assessment technique can be used to predict the burden and impacts towards surroundings from the beginning until the end of the waste management system.

2. METHODOLOGY

In brief, the research methodologies of the study are field study, data collection, model development of landfill system, computer calculation development and impact analysis study. The field study lists the waste component facilities in the study area such as waste collection and landfill disposal site as well as effluent treatment plant. Data collections which are the input data and the output data of the waste facilities component system are obtained. Normally, it is done by listing down the life cycle inventory for each waste component facilities. In this study, the input of the system is 700 tonnes/day electronic wastes which were generated from residential, commercial and industrial premises. Others input such as raw material, energy such as petrol and diesel usage for transportation activities and electricity energy for processing activities is stated in Table 1 and Table 2. The output of the landfill technology system are recovery material such as secondary raw material and energy as well as emission that generated from the processing and transportation activity as stated in Table 3, Table 4 and Table 5. Specifically, the listing will predict the burdens of waste management technique toward the environment. Next, designed development model by considering the applied waste management concept including selecting a suitable technology as a sub-system for a chosen system as shown in Figure 1 and Figure 2. Computer calculation model is built using excel spreadsheet as the database. The impact analysis will be carried out based on the results obtained from the database. The result will then be interpreted and evaluated.

3. RESULTS AND DISCUSSION

Figure 1 and Figure 2 illustrate the model development for each sub-system of the Landfill system. The sub-systems considered in this study were waste collection facilities and landfill facilities. There is also effluent treatment plant that had been considered in this study. Referring to Figure 1 and Figure 2, the electronic waste generated from residential, commercial and industrial premises will be directly sent to the secured landfill.

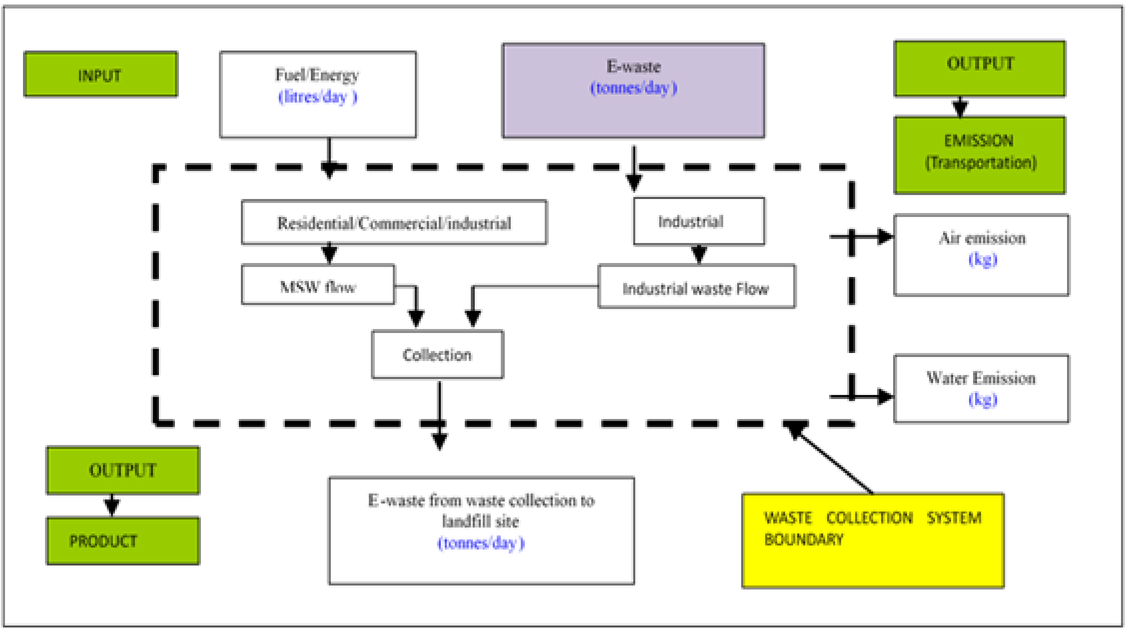

Figure 1 Life Cycle Inventory Model for electronic waste collection

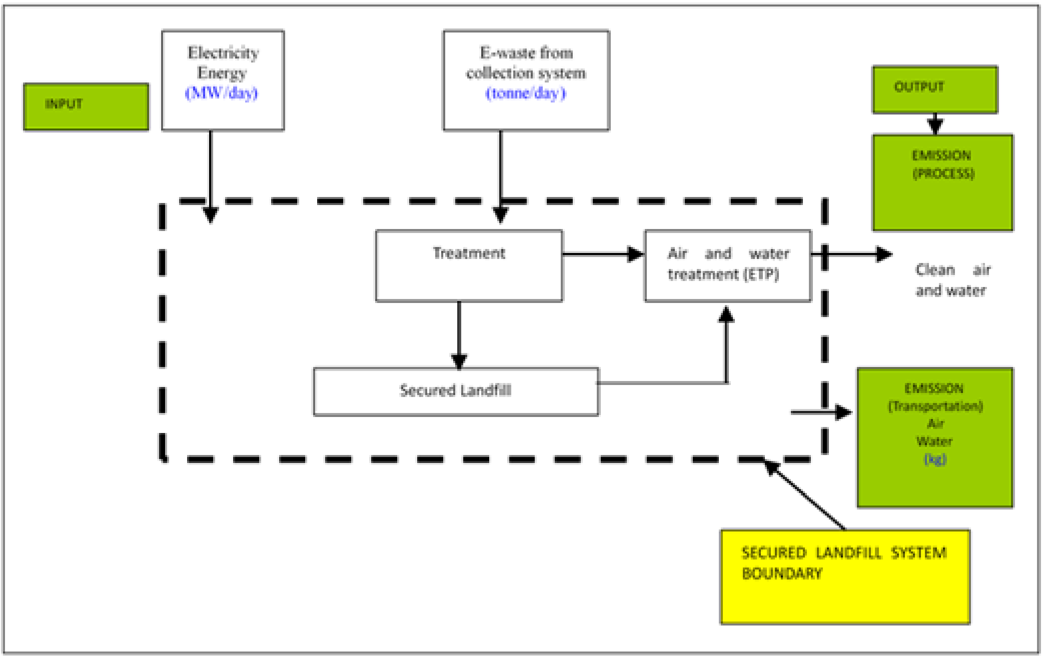

Figure 2 Life Cycle Inventory Model for secured landfill

Table 1 and Table 2 summarize the input data such as fuel usage for transportation activities as well as water usage and energy usage for processing activities in the landfill system for each landfill sub-system. Table 3, Table 4 and Table 5 summarize the output data such as emission from the processing activities and transportation activities as well as secondary raw materials from the landfill system for each landfill sub-system. Referring to Table 1, prediction of the fuel usage for transportation activities are 1,069.44 liters per day. In this option, the route of transportation activities is from source of electronic waste that have been produced such as residential, commercial and industrial premises direct to the secured landfill site. The prediction of the energy usage for processing activities at secured Landfill site are 2,800 liters per day for diesel usage and 2.33 MW/day for electricity usage as stated in Table 2.

Table 2 Fuel usage for transportation activities in the Landfill system for electronic waste

Sub-system	Transportation	
	Petrol	Diesel
Waste collection	0	1,069.44 liters/day
Secured landfill	0	0
TOTAL	0	1,069.44 liters/day

Table 3 Raw material and Energy usage for processing activities in the Landfill system for electronic waste

Sub-system	Processing		
	Raw material	Electricity	Diesel
Waste collection	0	0	0
Secured landfill	0	0	2,800 liters/day
Effluent Treatment Plant (ETP)	0.25 tonnes/day	2.33 MW/day	0
TOTAL	0.25 tonnes/day	2.33 MW/day	2,800 liters/day

Briefly, with reference to Table 3, the generated calculation found that 353.1 kg of the emission are produce by the transporting activities from the accumulation areas to the landfill site in which 330.49 kg from the emission is the air emission and 22.61 kg is the water emission. With reference to Table 4, the generated calculation found that the emissions produced from the landfill activities at the landfill site are 865 kg air emission, 59.19 kg water emission for 700 tonnes per day electronic waste. From the calculation, the processing activities at the disposal site will produce 2,249,100 m3 of landfill gas per day and 583.1 tonnes of the leachate per day. For effluent treatment plant, the emission comes from the usage of the electricity energy in which the whole emission is the air emission with the prediction value of 1.9 kg. However, prediction of the sludge waste produce from the effluent treatment plant is 1.17 tonnes per day. For Landfill system, there is no recovery material such as secondary raw material and energy recovery produced as stated in Table 5

Table 4 Emission from the transportation activities in the Landfill system for electronic waste

Sub-system	**Transportation**	
	Water	**Air**
Waste collection	22.61 kg	330.49 kg
Secured landfill	0	0
TOTAL	22.61 kg pollutant	330.49 kg pollutant

Table 5 Emission from the processing activities in the Landfill system for electronic waste

Sub-system	**Processing**		
	Water	**Air**	**Residual Waste**
Waste collection	0	0	0
Secured landfill	59.19 kg and 583.1 tonnes/day	865 kg and 2,249,100m^3/day	700 tonnes/day
Effluent Treatment Plant (ETP1)	0	1.9 kg	1.17 tonnes/day
TOTAL	59.19 kg pollutant and 583.1tonnes/day leachate	866.9 kg pollutant and 2,249,100 m^3/day landfill gas	701.17tonnes/day electronic waste to be landfill

Table 6 Recovery material in the Landfill system for electronic waste

Sub-system	**Recovery material**	
	Secondary raw material	**Energy**
Waste collection	0	0
Secured landfill	0	0
TOTAL	0	0

As a whole, the emissions produced from the processing activity in the landfill system are 583.1 tonnes/day leachate and 2,249,100 m3/day landfill gas. The leachate and landfill gas generated by the landfill system able to produce 59.19 kg water pollutant and 866.9 kg air pollutant that will pollute the environment. Therefore, the air pollution control and water pollution control is necessary to minimize the impact of the landfill technology in managing electronic waste.

4. CONCLUSION

There had been a lot of study that showed impacts of pollutant towards the environment and human health. This study shows the impact of the presence of pollutants especially to the soil, water bodies and atmosphere. In essence, there is an urgent need to manage electronic waste in the integrated and sustainable manner. The best management practice should include the recycling for raw material and energy recovery from electronic waste in order to reduce the volume of electronic waste to be dumped at the landfill. The practice should concomitant with the aim that able to save world raw material and world energy source.

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REFERENCES

[1] J. Yu, E. Williams, M. Ju, and C. Shao, "Managing e-waste in China: Policies, pilot projects and alternative approaches," Resour. Conserv. Recycl., 2010.

[2] W. K.-Y. Lau, S.-S. Chung, and C. Zhang, "A material flow analysis on current electrical and electronic waste disposal from Hong Kong households," Waste Manag., 2013.

[3] I. C. Nnorom and O. Osibanjo, "Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries," Resources, Conservation and Recycling. 2008.

[4] J. Sohaili, S. K. Muniyandi, and S. S. Mohamad, "A Review on Printed Circuit Board Recycling Technology," J. Emerg. Trends Eng. Appl. Sci., 2012.

[5] K. Zhang, J. L. Schnoor, and E. Y. Zeng, "E-waste recycling: Where does it go from here?," Environ. Sci. Technol., vol. 46, no. 20, pp. 10861–10867, 2012.

[6] J. Yu, E. Williams, M. Ju, and C. Shao, "Managing e-waste in China: Policies, pilot projects and alternative approaches," Resour. Conserv. Recycl., vol. 54, no. 11, pp. 991–999, 2010.

[7] A. Borthakur, "Generation and Management of Electronic Waste in India: An Assessment from Stakeholders' Perspective," J. Dev. Soc., 2015.

[8] V. K. Soo and M. Doolan, "Recycling mobile phone impact on life cycle assessment," in Procedia CIRP, 2014.

[9] Q. Song, Z. Wang, J. Li, and X. Zeng, "Life cycle assessment of TV sets in China: a case study of the impacts of CRT monitors," Waste Manag., vol. 32, no. 10, pp. 1926–36, Oct. 2012.

[10] EU Directive, Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), no. June. 2012, pp. 38–71.

[11] Basel Convention, Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. 2010.

[12] F. Suja, R. Abdul Rahman, A. Yusof, and M. S. Masdar, "e-Waste Management Scenarios in Malaysia," J. Waste Manag., 2014.

[13] DOE, "Guideline for the Electrical and Electronic Equipment in Malaysia," Jabatan Alam Sekitar, 2010. [Online]. Available: www.doe.gov.my.

[14] H. Duan, M. Eugster, R. Hischier, M. Streicher-Porte, and J. Li, "Life cycle assessment study of a Chinese desktop personal computer," Sci. Total Environ., 2009.

[15] P. Kiddee, R. Naidu, and M. H. Wong, "Electronic waste management approaches: An overview," Waste Manag., 2013.

[16] I. C. Nnorom and O. Osibanjo, "Electronic waste (e-waste): Material flows and management practices in Nigeria," Waste Management, vol. 28, no. 8. pp. 1472–1479, 2008.

[17] F. O. Ongondo, I. D. Williams, and T. J. Cherrett, "How are WEEE doing? A global review of the management of electrical and electronic wastes," Waste Management. 2011.

[18] R. Widmer, H. Oswald-Krapf, D. Sinha-Khetriwal, M. Schnellmann, and H. Böni, "Global perspectives on e-waste," Environmental Impact Assessment Review. 2005.

[19] G. Davis and S. Herat, "Electronic waste: The local government perspective in Queensland, Australia," Resour. Conserv. Recycl., 2008.

[20] J. A. Kalana, "Electrical and Electronic Waste Management Practice by households in Shah Alam , Selangor , Malaysia," Int. J. Environ. Sci., vol. 1, no. 2, pp. 132–144, 2010.

[21] Y. Barba-Gutiérrez, B. Adenso-Díaz, and M. Hopp, "An analysis of some environmental consequences of European electrical and electronic waste regulation," Resour. Conserv. Recycl., vol. 52, no. 3, pp. 481–495, 2008.

[22] S. B. Wath, P. S. Dutt, and T. Chakrabarti, "E-waste scenario in India, its management and implications," Environ. Monit. Assess, 2011.

[23] A. Fornalczyk, J. Willner, K. Francuz, and J. Cebulski, "E-waste as a source of valuable metals," Arch. Mater. Sci. Eng., 2013.

[24] M. Bigum, L. Brogaard, and T. H. Christensen, "Metal recovery from high-grade WEEE: A life cycle assessment," J. Hazard. Mater, 2012.

[25] K. Zhang, Y. Wu, W. Wang, B. Li, Y. Zhang, and T. Zuo, "Resources , Conservation and Recycling Recycling indium from waste LCDs : A review," "Resources, Conserv. Recycl., vol. 104, no. 100, pp. 276–290, 2015.

[26] R. Rajarao, V. Sahajwalla, R. Cayumil, M. Park, and R. Khanna, "Novel Approach for Processing Hazardous Electronic Waste," Procedia Environ. Sci., vol. 21, pp. 33–41, 2014.

[27] H. Taghipour, Z. Amjad, M. A. Jafarabadi, A. Gholampour, and P. Norouz, "Determining heavy metals in spent compact fluorescent lamps (CFLs) and their waste management challenges: Some strategies for improving current conditions," Waste Manag., 2014.

[28] S. Sthiannopkao and M. H. Wong, "Handling e-waste in developed and developing countries: Initiatives, practices, and consequences," Sci. Total Environ., 2013.

[29] N. Othman and R. M. A. Kamaruddin, "PREDICTION OF ELECTRONIC WASTE DISPOSALS FROM," J. Teknol., vol. 10, pp. 1–6, 2015.

[30] Norazli Othman, Nurul Aini Osman, Shreeshivadasan Chelliapan and Roslina Mohammad, Life Cycle Assessment: A Comparison Study on the Various Electronic Waste Management Option. International Journal of Civil Engineering and Technology, 8(8), 2017, pp. 1177–1185.

[31] S. Kiran Kumar and Dr. S. Siddiraju, Effect of Steel and Polypropylene Fiber on Mechanical Properties of Concrete. International Journal of Civil Engineering and Technology, 7 (3), 201 6 , pp. 342–346

[32] O. Norazli, M. Roslina, A. B. N. Ezlin, M. Y. M. Noor, A. Technology, and U. Teknologi, "Developing an Integrated Electronic Waste Management Approach in Malaysia," vol. 1, no. 1, pp. 5–13, 2015.