REVIEW PAPER

CURRENT WASTE GENERATION OF E-WASTE AND CHALLENGES IN DEVELOPING COUNTRIES: AN OVERVIEW

Nur Sumaiyyah Supian*, Gautam Lalit Shah & Mohd Badruddin Mohd Yusof

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Malaysia

*Corresponding Author: *maya_viaxzey89@yahoo.com*

Abstract: The rapid growth of information and telecommunication technology ((ICT) in many developing countries has led to the improvement in the capacity of computers but simultaneously decrease the product lifespan which contribute to increase amount of e-waste. This paper reviews management issues related to electric and electronic waste (e-waste) as well as challenges faced by developing countries particularly China, India, Jordan, Tanzania, Philippines, Korea, Thailand, Brazil and Malaysia. Amongst the issues include awareness of institution and government, overall management and financing problem. From the review in selected developing countries, it can be concluded that the awareness of public towards e-waste management is low. Most consumers were not aware of the proper way to treat e-waste and for government and institution commitments were low as strict and consistent enforcement were lacking. Informal sector plays a major role while low-cost machinery and manual segregation was prominent. Systematic policy and regulation of e-waste management in developing countries needs to be enhanced to achieve best practices in e-waste management. Lack of financial support further exacerbated the challenges in these developing countries, as proper treatment requires a high capital and maintenance costs.

Keywords: *Challenges, developing countries, e-waste, issues, waste generation*

1.0 Introduction

Development in information and communication technology (ICT) is essential for a country's economic and social improvement (Schluep *et al.* 2013). Over the last two decades, the number of consumers and electric and electronic equipments has increased continuously. The exponential evolution of e-waste may further be worsened by a decrease in the lifecycle of existing devices as a result of the rapid innovation of products with new features. According to Ongondo *et al.* (2011), e-waste was generated 20-50 million tonnes worldwide and Asian continentals contributed 12 million tonnes. Many innovations of electric and electronic equipments resulted lifespan of products such as computers, laptops, smart phones and other gadget decreased. According to

Osibanjo and Nnorom (2007), the lifespan of computer at workplace approximately 2 to 3 years while at home (3 to 5 years).

Furthermore, other electric and electronic equipments had their own lifespan depending on the type of device, market growth conditions, age group of consumer, and cultural behavior. For example, average lifespan for refrigerators was 7.7 years, washing machine (7.6 years), televisions (7.3 years), air-conditioner (6 years) and mobile phone (2.4 years) (Jang, 2010). Mostly in Asian continental, the e-waste was treated in backyards or small workshops using primary methods i.e., manual disassembly and open burning (Osibanjo and Nnorom, 2007). Manual disassembles of discarded e-wastes were popular in China because of low labour cost (Liu, e*t al.*, 2010). However, some parts of e-waste contain some valuable material. Figure 1 shows metal fraction in electric and electronic equipments.

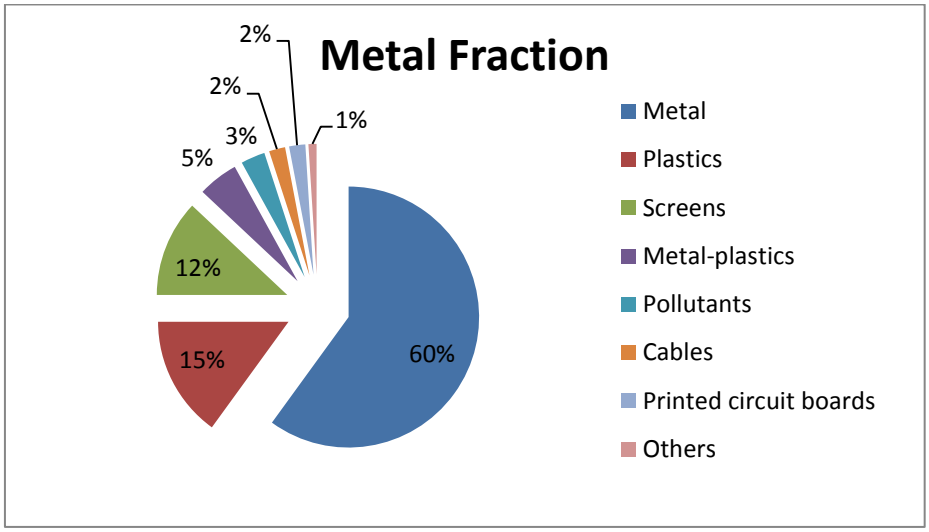

Figure 1: Metal fraction in electric and electronic equipments (Herat and Agamuthu, 2012)

2.0 Current Waste Generation in Several Developing Countries

India is one of the countries that are facing e-waste problem. Most of the e-waste treatment carried out by backyard operations (Gidarakos, *et al.*, 2012). Furthermore, India is one of the destinations for imported e-waste from other developed countries. Every year, it is estimated 50,000 tonnes imported into India's industry and there were 30% of discarded and obsolete of personal computer (PC) generated between 2007 and 2011 (Ongondo, *et al.*, 2011). Despite that, India still does not prescribe any regulation from production of e-waste until recovery in order to sustain their overall environment sustainability (Rathore *et al.*, 2011). According to Herat and Agamuthu (2012),

computer wastes generations in India were estimated about 41 to 152 million units by 2020. Besides that, the annual growth rate of e-waste in India is approximately to 7 to 10%. This circumstance happened because 80% of India's market more into service and commercial in computer and information technology (IT) hardware (Dwivedy and Mittal, 2012).

China is the world's largest exporter of electric and electronic goods. In 2009, computers wastes were about 12 million units and increased more than 70 million units in 2010. There were three major sources contributed to produce e-wastes in China such as households, offices (businesses, institutions and government) and the original equipment manufacturers (OEMs) (Ongondo, *et al.,* 2011). Furthermore, around 1.33 billion populations in China were estimated to produce 1.1 million tonnes of e-waste. Rapid advanced technologies as well as shorter lifespan of electronic also can contribute to the e-waste stacks (Li, *et al.*, 2012). Currently, 60% of e-waste sold to private individual collectors and processed by informal sector (Zeng, *et al*., 2013). Material Flow Analysis (MFA) is a tool to ease environmental management. According MFA, there was e-waste quantity generation increase by two times between 2005 and 2010 in China (Kiddee, *et al.*, 2013).

Meanwhile in Thailand, the number of computers in households increased more than fourfold, from 0.8 to 4.5 million units (Manomaivibool and Vassanadumrongdee, 2011). Thailand has been known one of the largest manufactures because around 2000 electric and electronic manufactures (Herat and Agamuthu, 2012). In this context, e-waste generation of computer was expected to reach 7.5 million units by 2020 and for industrial e-waste, has been estimated to be around 11,000 tonnes per year (Manomaivibool and Vassanadumrongdee, 2011). Meanwhile in Brazil, production of computers was the most popular sector (Araújo, *et al.*, 2012). The Brazilian population represents about 191 million people and the predicted number of people anticipated to own computer will also increase. From this situation, we can predict at least 10 years ahead, the quantity e-waste production in Brazil would be greater if it is not treated properly (Oliveira, *et al.*, 2012).

In Malaysia, e-waste generation is recorded by the Ministry of Natural Resources and the Environment in the annual Environmental Quality Report (EQR) every year. Based on Environmental Quality Report, e-waste generation has been recorded at 134,036 metric tonnes in 2009, while for 2010 (163,340 metric tonnes), 2011 (152,722 metric tonnes) and 2012 (78,278 metric tonnes). Electric and electronic equipments were recovered at off-site recovery facilities. In 2009 there were 138 recovery facilities has been recorded, while in 2010 (153), 2011 (158) and 2012 (153). Table 1 below shows e-waste generation in selected developing countries. Developing countries may have a large opportunity of health risk from improper handling of e-waste which emits e-waste's chemical such as mercury, brominated flame retardants (BFRs), polycyclic aromatic hydrocarbon (PAHs), thus penetrate into air, groundwater as well as soil. Since

e-waste was made of a multitude of sophisticated blends of plastics and metals, the affects were way greater to the environment (Frazzoli, *et al.*, 2010).

Table 1: E-waste generation in selected developing countries by e-waste category

Country	E-waste generation (tonnes per year)	Category
India*	1.95 million	Computers
China**	1.1 million	Computers and other electronic goods
Korea***	2.6 million	Refrigerator, washing machine, televisions
Tanzania****	9500	Computers
Jordan*****	23400	Household appliances

*(Dwivedy and Mittal, 2012);**(Ongondo, *et al.*, 2011);***(Jang, 2010);
**** (Schluep, *et al.*, 2011);*****(Fraige, *et al.*, 2011)

3.0 Challenges

There were several challenges faced by developing countries such as awareness of public, overall management issue and financing problem. Rapidly developing technology all over the world has led to increase e-waste volumes especially in developing countries. This was because of the growth of urbanization is much more in developing countries than the develop countries in last three decades (Khatib, 2010). Majority of untreated discarded e-wastes were lead to the landfills (Gaidajis, *et al.*, 2010). E-waste differs chemically and physically from residential and industrial waste. It contains both dangerous and valuable materials that required special treatment to avoid environmental pollution. Other than that, phenomenon of modern technologies in electric and electronic appliances proportional to the increasing of electric and electronic volume in recovery centers.

Fortunately from positive perspective, modern and innovative technologies can act as a solver to reduce e-waste volume. For example, consumer tended to choose lightweight personal computer (PC) which weight 1 to 3 kg and equipped with Liquid Crystal Display (LCD) screens instead of the older Cathode Ray Tube (CRT) (Gaidajis, *et al.*, 2010). Figure 2 below shows example of several challenges and situation in developing countries while Table 2 shows challenges faced by others developing countries and solutions.

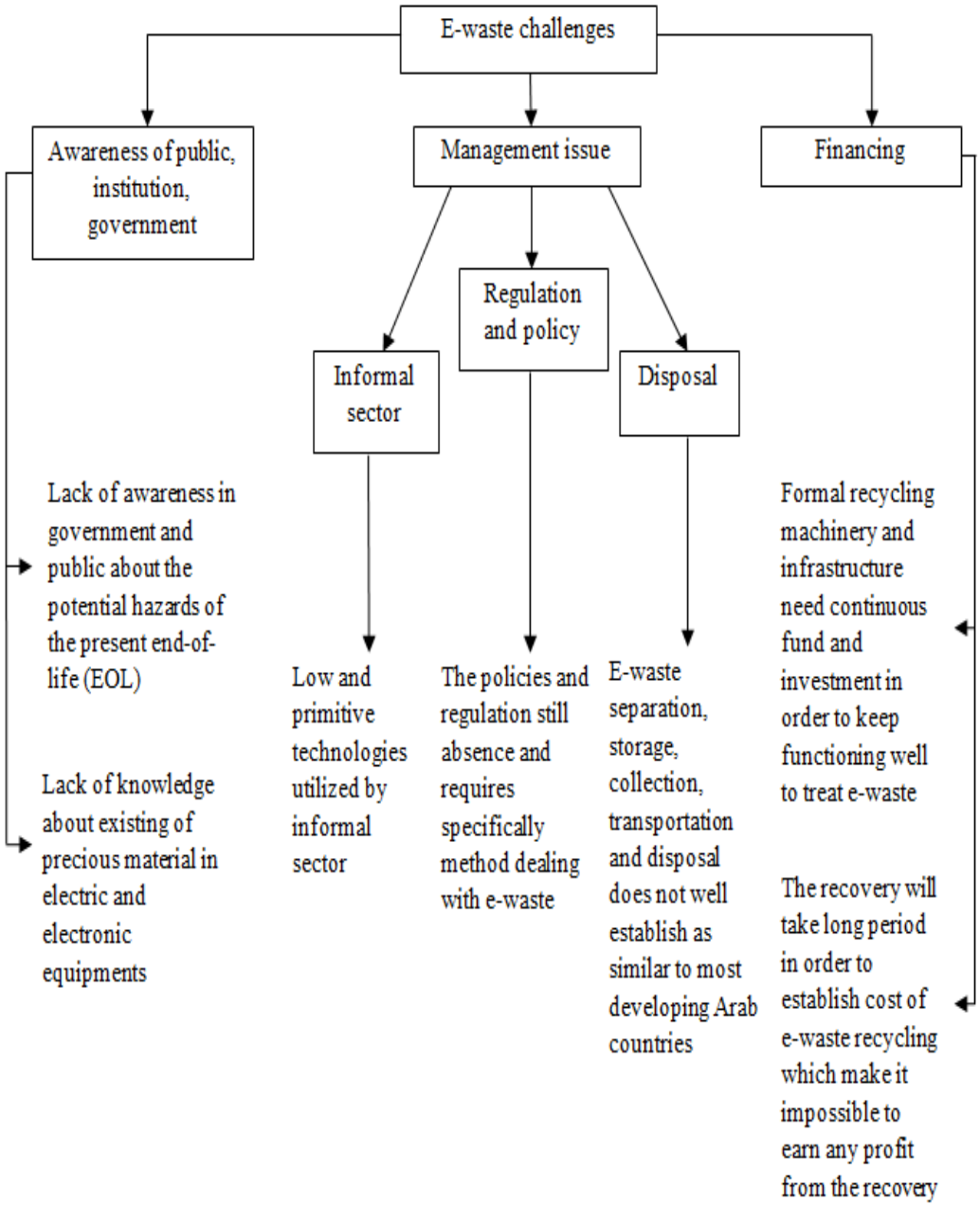

Figure 2: Example of several challenges and situation in developing countries

Table 2: Example of challenges faced by others developing countries and solutions

Issues	Country	Solution
Awareness of public	Jordan Tanzania	Educating people the side effect of e-waste by targeting the different social class (Fraige, *et al.,* 2011); (Schluep, *et al.,* 2011)
	China	Guiding people to use green appliances and electronic equipment through advertisement and media (Zhu, *et al.,* 2012)
Management issues	Nigeria	Introducing state-of-the-art to formal recycling facilities to achieve major efficiency (Osibanjo and Nnorom, 2007)
	Korea	Implementing extended producer responsibility (EPR) and put more effort in cost-effective recycling technologies (Jang, 2010)
Financing problem	Mexico	Implementing deposit-refund scheme whereby manufactures need to pay deposit for waste recovery and processing their product (Garcia, 2012)
	Spain	Establish the Producer' Registration Observatory to avoid unregistered manufacturer do illegal work and control free-riding in Spain (Queiruga, *et al.,* 2012)

3.1 Awareness of Public, Institution and Government

Different educational background indicates different behavior of environmental awareness. In developing countries, crude recycling activities has been involved in industrial for a long time and the effect to the environment was very critical. This situation happened because of the lack of awareness in government and public about the potential hazards of the present end-of-life (EOL) management e-waste in developing countries (Osibanjo and Nnorom, 2007).

Furthermore, e-waste became a crucial problem as to the improvement of living standards in developing countries. Some high-class residential areas tended to choose packaged products cause the increasing of recycle materials (Dhokhikah and Trihadiningrum, 2012). In Philippines, 80% discarded e-waste are assumed to be landfilled because recycling was too new for them (Peralta and Fontanos, 2006). Meanwhile in Tanzania, lack of knowledge and low awareness on the existence of precious metals in the electric and electronic equipments were critical. As a result, there were no formal sectors which specifically in e-waste field (Schluep, *et al.*, 2011).

3.2 Management Issue (Informal Sector, Collecting, Disposal, Regulation, Policies)

In developing countries, e-waste mostly processed by informal sector under the primitive method. General flows of e-waste shows in Figure 3. Informal sector activities in developing countries were very active in e-waste recycling chain. Valuable and

precious material contained in e-waste stream was their passion to involve passionately (Pariatamby and Victor, 2013). Countries such as Ghana and Nigeria which faced second hand equipments and illegal waste shipment reveal a large organized informal sector (Schluep, *et al.*, 2013). Low and primitive technologies utilized by informal sector in developing countries which result in major environmental impacts and low of material recovery (Herat and Agamuthu, 2012). Collection of e-waste was starting point of the general flow. Unfortunately, most of waste management in Brazil was led to landfill and selective trash collection was a new phenomenon in Brazil (Araújo, *et al*., 2012). Meanwhile in Nigeria, young children earned $2 a day by collecting electric and electronic components. Some private companies in Sri Lanka were refused to collect e-waste without official government's enforcement on collecting and treatment of e-waste (Mallawarachchi and Karunasena, 2012).

Policies and regulation were very important in order to achieve a systematic plan. Unfortunately the policies and regulations in many countries were remaining silent in developing countries. Despite that China has a lot of laws and regulations, the existing laws and regulation did not specifically explaining the whole life cycle of electric and electronic equipments and lack effective enforcement and supervision (Ongondo, *et al*., 2011). Meanwhile in Jordan, e-waste separation, storage, collection, transportation and disposal not established well as similar to most developing Arab countries. Furthermore, the existing laws in Jordan also limiting its management and did no stated clearly about responsibilities and obligation for stakeholder (Fraige, *et al.*, 2011).

Furthermore, lack of structured policy for collection and recycling in Brazil were led to the large volume of e-waste although there were varieties of individual involved (Oliveira, *et al*., 2012). Meanwhile in Tanzania, formal collectors were nowhere to be found. Municipalities of Kinondoni, Ilala and Temeke were responsible to collect e-waste and city of Dar es Salaam received the e-waste from the three municipalities. According to Schluep, *et al.* (2011), Kinondoni was estimated to generate 2026 tonnes of waste per day but only collected 954 tonnes. It was due to participate of informal sector in collecting process and illegal dumping areas. No regulation and policy specifically of e-waste has been created yet in Cambodia. All the activities of e-waste management such as separation, collection, recycling and exportation were handling by formal and informal sector. They were using manual method to treat e-waste and low technology to dismantle during e-waste treatment (Sothun, 2012).

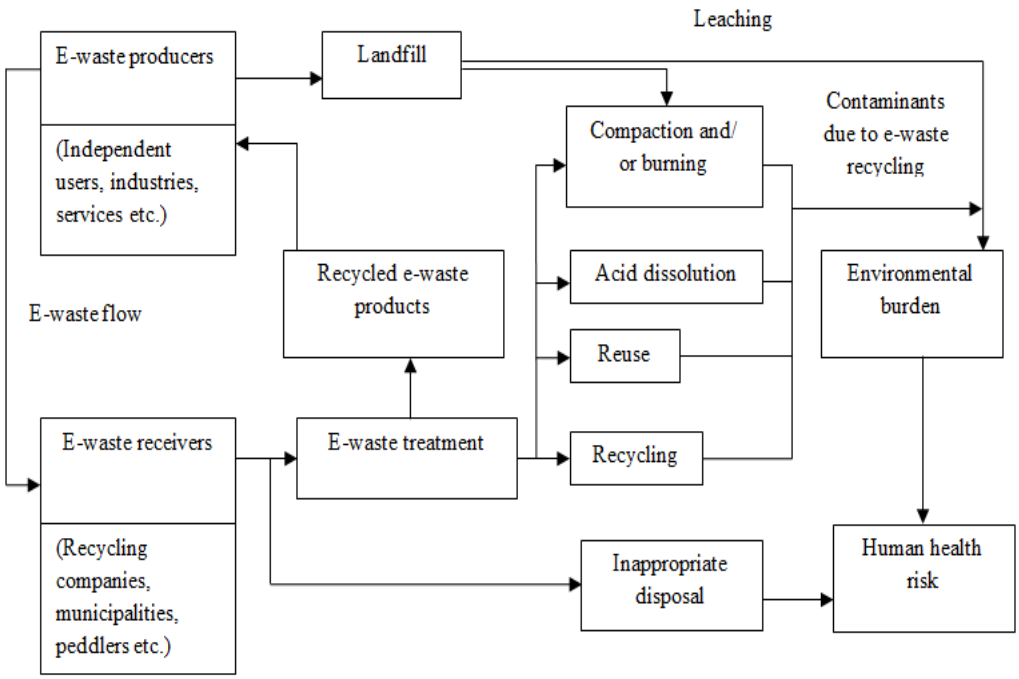

Figure 3: General flow of e-waste (Gaidajis, *et al.*, 2010)

3.3 Financing

Sufficient fund is one of the main major obstacles in developing countries. Allocation of money to e-waste management could help to increase for effectiveness system. Furthermore, formal recycling machinery and infrastructure need continuous fund and investment in order to keep functioning well to treat e-waste (Herat and Agamuthu, 2012). In Thailand, the policy proposal offers to invest money into e-waste collection of formal sector to compete with informal sector. But in present, the problem happened when authorized treatment facilities (ATFs) found the opportunities in the offers and take it for granted.

Therefore, a serious interest needs to focus more on financial inducement rather than economic instrument in Thailand (Manomaivibool and Vassanadumrongdee, 2011). In China, the recovery would take a long period to establish cost of e-waste recycling which made it impossible to earn any profit from the recovery itself (Wang e*t al.*, 2010). According to Yu *et al.* (2010), recycling in China was supported by government subsidy. However, insufficient subsidy was discontinued because recycling a large volume of e-waste was unbearable. Other than that, foreign companies and importers were not interested to invest in e-waste recycling in China because lack of central

management and need a large amount of money to make in international e-waste trading (Yu, *et al*., 2010).

4.0 Conclusion and Discussion

Growths of innovative and advanced technologies such as computer, smart phones, laptop, and gadget were led to the rise of e-waste generation in developing countries and become a crucial problem. Under current situation, the level of awareness from public, institution, and government related to e-waste were low. The circumstances occurred because most of them did not know how to manage e-waste properly. Campaigns and activities related towards sustainable and greener world need to be intensified in order to attract people joined. Furthermore, the existing of informal sector should be taking into an account since they were most active in e-waste management in developing countries. Government and industrial sector should be worked together to have a win-win situation regarding of e-waste and avoid any mistrust. E-waste activities such as collection, storage, treatment, and disposal need to be specific in order to handle a systematic and effective management. All parties who are involved in e-waste management process need to clarify one or two day per week as an e-waste collecting from consumer and industry. A fund need to set up from tax authority and electric and electronic producers to help e-waste management activities went smoothly.

5.0 Acknowledgements

The authors wish to thank all of the members of the research team and others who participated in the study.

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