Zagazig J. Agric. Res., Vol. 51 No. (2) 2024 157-169

Plant Production Science

Available online at http://zjar.journals.ekb.eg
http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

STRATEGIES TO MANAGE ELECTRONIC-WASTES IN MALAYSIA: A REVIEW STUDY

Iman S-E.A. El-Gawhari[1*], I.M. Abdel Hameed[1] and F.M. Sami[2]

1. Dept. Nat. Res., Inst. Asian Studies and Res., Zagazig Univ., Egypt

2. Hort. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 23/01/2024; Accepted: 10/03/2024

ABSTRACT: Malaysia occupies a strategic location in Southeast Asia, divided between two regions - Peninsular Malaysia and East Malaysia. The total area of the country is about 330,803 Km^2, located between 3 10 N, 101 42. Uncontrolled disposal of electronic waste can be harmful to human health and the environment because electronic waste contains toxic substances and heavy metals. However, if waste is managed properly, it can become a business opportunity that produces high returns because e-waste also contains valuable materials, such as gold, silver, platinum and palladium. There are problems faced by recovery facilities in achieving the goal of converting e-waste into source material. Issues include the supply of e-waste, the importation and coding of e-waste derived products, and finally the need to develop standards for e-waste treatment technologies to ensure the safety and sustainability of facilities. The issue of electronic waste is becoming an increasingly serious problem because it contains many toxic substances that can seriously harm humans and the environment. This problem is expected to worsen if serious efforts are not made to manage this electronic waste. The current study is an attempt to reduce the risks and solve the problems of electronic waste. For this purpose, use different tools such as LCA, MFA, MCA and EPR. On top of all that, no matter how well the policies are introduced and implemented, the key to success in terms of e-waste management in Malaysia is to develop environmentally designed devices, to properly collect e-waste, recover and recycle materials in safe ways, and dispose of e-waste with appropriate techniques, Preventing the transportation of used electronic waste. Electronic devices to developing countries, raising awareness of the impact of e-waste pollution on both users and manufacturers.

Key words: Malaysia, E-waste, LCA, MFA, MCA and EPR.

INTRODUCTION

In this modern era, the pervasiveness of urban culture advances modern lifestyle and the growing usage of single-use products, have drastically increased the volume of municipal solid waste (MSW) globally. It was reported that 20 years ago, each person out of the then estimated 2.9 billion urban residents generates about 0.64 kg of waste (0.68 billion tons per year). In 2012, this number significantly increased to 1.2 kg per person generated by 3 billion urban residents (1.3 billion tons per year). Further alarming forecasting predicted that by 2025 aggregate MSW per person could exceed 2.2 billion tons with estimated 4.3 billion residents (**Hoornweg *et al.*, 2012**).

Nowadays, technology is increasing fastly that makes the buyers to upgrade their electronic equipment; and this increases consumption, which brings more waste to the environment as the older devices have no more use (**Sivaramanan, 2013**). **Forti *et al*. (2020)** in their study have reported that worldwide approximately 53.6 million tons (Mt) of e-waste are generated during the year of 2019. Furthermore, it is expected to increase and reach 74 Mt in 2030 worldwide. Although, Asia takes place first

* **Corresponding author: Tel. :**+201060733212
E-mail address: emyelgohary.134@gmail.com

position for e-waste production as it contributes a total of 24.9 Mt e-waste production; followed by America (13.1 Mt) and Europe (12 Mt). Nevertheless, China, India, Japan, and Indonesia contribute a total of 10.1, 3.23, 2.57, and 1.62 Mt of e-waste production in 2019; they share totally 70.36% of e-waste production; therefore, these countries are identified as the biggest e-waste generator in Asian continent during the year of 2019.

In 2019, the International Monetary Fund (IMF), in its economic outlook, ranked Malaysia as the 3rd largest economy in Southeast Asia and the 37th largest economy in the world (**World Bank Group, 2018)**. With a healthy economic indicator, e-waste generation in Malaysia is expected to increase in the coming years. The growth in e-waste generation is anticipated worldwide because there is a strong correlation between economic growth and e-waste generation (**Ismail and Hanafiah, 2017)**.

Management of e-waste in Malaysia is still in its infancy and only began in 2005 (**Ismail and Hanafiah, 2019)**. In Malaysia, e-waste is classified as scheduled waste under the code SW 110, "Environmental Quality Regulations 2005" and managed by the Department of Environment (DOE) and the Ministry of Natural Resources and Environment (MNRE) (**Wang *et al.*, 2018).** The primary role of DOE and MNRE is pollution prevention and control through the enforcement of the "Environmental Quality Act 1974" (EQA 1974) (**Aliasi *et al.*, 2014)**. Although there are strategies on e-waste management in place, they do not adequately guide the local consumers or the municipal authorities on how e-waste should be managed, reused, recycled, or disposed (**Wang *et al.*, 2018)**. Subsequent to the listing as e-waste under the "Environmental Quality Scheduled Waste Regulations (EQSWR) 2005", e-waste in Malaysia was reported and managed as municipal solid waste through the Department of Solid Waste Management (DSWM) under the Ministry of Housing and Local Government.

The data related to e-waste generation in Malaysia vary significantly. According to **Azad *et al.* (2017)**, e-waste generation in Malaysia in 2006 was estimated to be 652,909 tonnes, increasing to 706,000 tonnes by 2010 and finally reaching 1.2 Mt in 2020. **Forti *et al.* (2020)** have estimated the e-waste generation to be 364,000 tonnes in 2019.

Strategies and Rules to Manage E-Wastes

A number of countries have developed their own definition of e-waste, but the most widely accepted definition is from a European Union (EU) directive that defines e-waste as "electrical or electronic equipment waste that includes all components, subassemblies, and consumables that are part of the product at the time it is discarded". Basel Convention states that e-waste encompasses a broad and growing range of electronic devices that have been discarded and includes large household devices, such as refrigerators and air conditioners, cell phones, personal stereos, consumer electronics, and computers. On the other hand, Organization for Economic Cooperation and Development (OECD) describes e-waste as any appliance using an electric power supply that has reached its end-of-life.

There is currently extensive research into e-waste management in order to mitigate problems at both the national and international levels. Several tools have been developed and applied to e-waste management including: LCA, MFA, MCA and EPR. The management of e-waste in developed countries has taken a further step forward with the release of a waste electric and electronic equipment (WEEE) directive (Directive 2002/96/EC) that is expected to reduce the disposal of such waste and improve the environmental quality (**EU, 2002**). Research includes the separation of components that could be recycled and the recovery of rare and precious metals. This section summarizes the range of approaches that has been adopted, and points to future developments as shown in Fig. 1.

Life Cycle Assessment (LCA)

Life Cycle Assessment is a tool used to design environmentally friendly electronic devices and to minimize e-waste problems. Since the 1990s considerable research has been conducted on the LCA of electronic devices in terms of eco-design, product development and environmental impacts. The published reviews show the necessity of having more consideration in the design of electronic devices to take account of

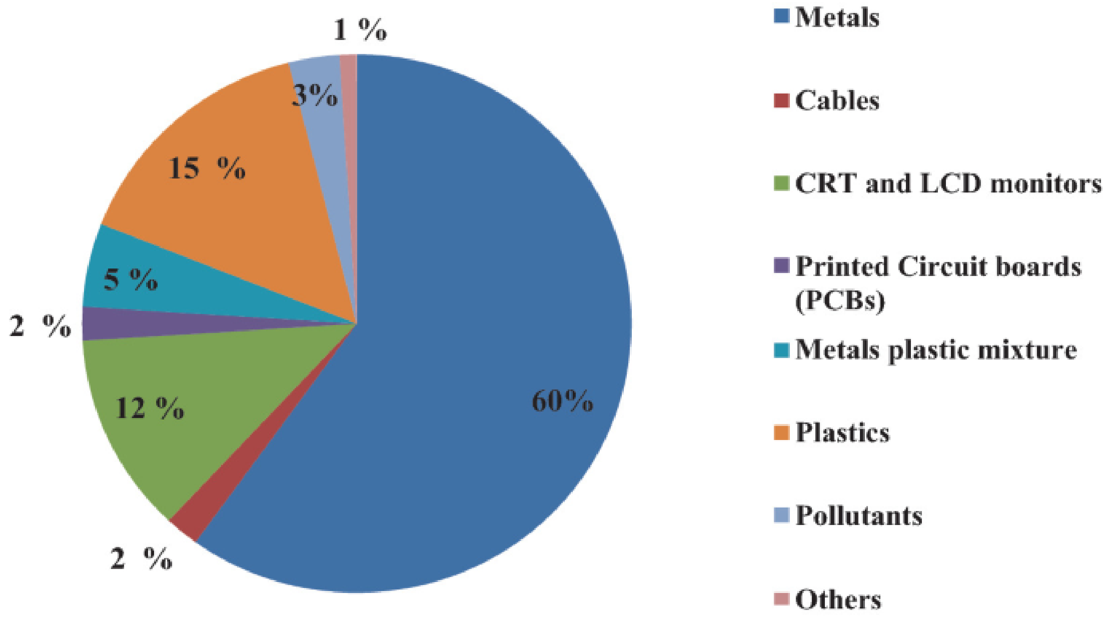

Fig. 1. Waste from electrical and electronic equipment (WEEE) and its specific components

environmental and economic impacts. An environmentally friendly design is a better alternative product and it may in turn appeal to consumers. LCA is a powerful tool for identifying potential environmental impacts to develop eco-design products such as printers **(Pollock and Coulon, 1996),** desktop personal computers **(Kim *et al.*, 2001),** heating and air conditioner devices **(Prek, 2004),** washing machines **(Park *et al.*, 2006),** and toys **(Muñoz *et al.*, 2009)**. It is also a systematic tool to define many environment impact categories such as carcinogens, climate change, ozone layer, ecotoxicity, acidification, eutrophication and land use, to improve the environmental performance of products **(Syafa Bakri *et al.*, 2008)**.

In Asia LCA has been applied to estimate the impact of e-waste and e-waste management. In Korea, **Kim *et al.* (2004)** used LCA to evaluate recycling potentials in terms of environmental and economic factors. The recycling potential in terms of the environmental score showing the highest value was for glass and circuit boards, followed by iron, copper, aluminium and plastic, respectively. In terms of economic score the results showed the highest value was copper, followed by aluminium, iron, plastic, glass and circuit boards. **Choi *et al.* (2006)** studied the practical recycling rate of an EoL personal computer and assessed the environmental impact. Disposal included two scenarios: landfill or recycling. Their results showed that recycling is the most efficient option for disposal. In Taiwan, **Lu *et al.* (2006)** studied the alternatives for notebook computer disposal considering selling to the secondhand market, recycling, incineration and landfill, in terms of environmental and economic aspects. They found that recycling is not a good option due to impacts on the environment from hazardous materials. They emphasised reuse through second hand sales.

In Japan, **Nakamura and Kondo (2006)** used the LCA tool in terms of life cycle cost analysis that compared two scenarios: recycling and landfill for e-waste disposal. They found that landfill disposal saved cost compared to recycling but landfill disposal resulted in higher environmental load and carbon emissions. In India, **Ahluwalia and Nema (2007)** used LCA as a decision making tool for computer waste management. LCA was used to evaluate economic aspects, perceived risk and environmental impacts. The results showed the optimal life cycle of a computer desktop was observed to be shorter by 25% than the optimized cost and the optimized value of computer waste impacts to either the environment or any perceived risk to the public .

In Thailand, **Apisitpuvakul *et al.* (2008)** studied the environmental impact of fluorescent lamp disposal in several proportions of recycling. They found that increasing recycling rates reduced environmental impacts.

Material Flow Analysis (MFA)

Before the Basel Convention came into force large volumes of ewaste from developed countries were exported for reuse or recycling in developing countries especially China, India and South Africa. MFA is a tool used to study the route of material (e-waste) flowing into recycling sites, or disposal areas and stocks of materials, in space and time. It links sources, pathways, and the intermediate and final destinations of the material.

Material Flow Analysis is a decision support tool for environmental and waste management. This tool can be applied to develop appropriate e-waste management (Table 1). This includes a consideration of the flow of e-waste and its assessment it in terms of environmental, economic and social values. **Shinkuma and Nguyen Thi Minh (2009)** used MFA to investigate the flow of e-waste in Asia. They found that secondhand electronic devices from Japan are reused in Southeast Asia (e.g., Vietnam and Cambodia) while most of the e-waste is recycled in Gangdong Province, China, where improper recycling methods were being used. In addition, **Yoshida *et al.* (2009)** found that the proportion of personal computers sent for domestic disposal and recycling decreased to 37% in fiscal year 2004, while the proportion of domestic reuse and exports increased to 37% and 26%, respectively in Japan. **Steubing *et al.* (2010)** investigated e-waste generation using MFA. Many different methods are being used to estimate possible quantities of e-waste. **Liu *et al.* (2006)** used market supply method which provided data for production and sales in regions, and time for estimation. **Steubing *et al.* (2010)** also used the market supply and survey method to estimate e-waste generation. **Osibanjo and Nnorom (2008)** used surveys to estimate quantities of e-waste. They found that e-waste generation will increase in China, India, Nigeria and Chile. For instance, based on MFA, it was reported that the quantify of e-waste would double from 2005 to 2010 and increase by 70% for obsolete devices by 2020 in China (**Liu *et al.*, 2006**), while it will increase four to five times during 2010–2019 in Chile (**Steubing *et al.*, 2010**). **Streicher-Porte (2007)** used MFA and evaluation of economic values as a tool for system analysis of the Au and Cu that flows from personal computer recycling in India. They found that the concentration of Au and Cu and the high value of these metals resulted in profits for recyclers. It is apparent from the study conducted by **Streicher-Porte (2007)** that coupling of MFA and economic evaluation can be a useful tool when limited data is available and where there is rapid economic growth.

Multi Criteria Analysis (MCA)

MCA is a decision-making tool developed for considering strategic decisions and solving complex multi-criteria problems that include qualitative/quantitative aspects of the problem (**Garfì *et al.*, 2009**). MCA models have been applied to environmental problems, including those of e-waste management, to provide optional e-waste management strategies (Table 1). For example, **Hula *et al.* (2003)** used MCA decision-making methodologies to determine the trade-offs between the environmental benefits and economic profit of the EoL processing of coffee makers. They analyzed a six-step methodology: definition of EoL scenarios, defined product models, development of an EoL evaluation model, formulation of a multi objective problem, solutions for the Pareto set, and construction of EoL strategy graphs for the Pareto set of optimal EoL strategies that minimises environmental impacts and economic cost.

Queiruga *et al.* (2008) used MCA to select the best location for ewaste recycling plants in Spain. Their study was based on quantitative criteria, specifically the economics of warehouse locations. **Rousis *et al.* (2008)** used MCA methodology to examine alternative systems for managing e-wastes in Cyprus. There were 12 alternative management systems which were compared and ranked according to their performance and efficiency. The best option was partial disassembly and forwarding of recyclable materials to the local prevailing market with the remainder deposed at landfill sites. Although, MCA is not widely used for e-waste management, it is commonly used for solid waste and hazardous waste

Table 1. Tools for E-waste management approaches being used or proposed in some countries

Tools	Application	Aspects	Country
Life cycle assessment (LCA)	Recycling e-waste	Environment and eco-nomic	Malaysia
	Recycling of end-of-life of personal computers	Environment and eco-nomic	Korea
	Recycling potentia	Environment and eco-nomic	Korea
	Compare different disposal methods (recycle and non-recycle): case study of fluorescent lamps	Environment	Thailand
	Recycling systems: case study of notebook computers	Environment	Taiwan
	Recycling of end-of-life	Environment and eco-nomic	Japan
Material flow analysis (MFA)	The flow of used personal computers	Recycling system	Japan
	The flow of e-waste	Generation	China
	The flow of e-waste and e-waste trade	Law and environmental pollution	Asia
LCA and MFA	The environmental pollutions	Recycling system	Hong Kong
LCA and MFA	The environmental pollutions	Environment	Singapore
Multi-criteria analysis (MCA)	The environmental of e-waste	Waste hierarchy	Indonesia
	The environmental of e-waste e	Material flow analysis	Philippines
	The solid waste dumping	Waste management	Cambodia

Source: Waleed *et al.* (2018).

management (**Hatami-Marbini *et al.*, 2013**). MCA has been recommended for social response to e-waste management (**Williams, 2005**) and to this end it is a useful tool in combination with other tools being used for E-waste management.

Extended Producer Responsibility (EPR)

EPR is an environment policy approach that attributes responsibility to manufacturers in taking back products after use, and is based on polluter-pays principles **(Widmer *et al.*, 2005)**. EPR approaches to e-waste management at a national scale are summarized in Table 1. Leaders of EPR programs for e-waste management are the advanced nations, including the European Union (EU), Switzerland, Japan and some states or provinces of the United States and Canada. The Organization for Economic Cooperation and Development (OECD) has supported an environmentally friendly program and published a guidance manual for governments **(OECD, 2001)**. In 1991 the EU designated e-waste as a priority waste stream and in 2004 the regulation on WEEE was introduced to take back products for treatment and recycling processes. Directive 2002/96/EC of the European Union on the WEEE Directive developed regulations based on EPR. Legislation establishes the responsibility of producers for downstream e-waste management and leads to end of-life environmentally sound reuse, recycling and recovery of e-waste **(EU, 2002)**. The target recycling rate is between 50% and 75% by weight **(Widmer *et al.*, 2005)**. In 2011, the EU adopted Directive 2011/65/EU of the European Parliament and of the Council of 8 June, 2011, on restrictions of the use of certain hazardous substances in electrical and electronic equipment and this was enforced from 22 July, 2011. All 27 member states must bring it into effect by 2 January 2013 **(EU, 2011)**. Switzerland has been a forerunner in regulation of e-waste management. In 1998 the Swiss Federal Office for the Environment (FOEN) announced the Ordinance ‘‘The Return, the Taking Back and the Disposal of Electrical and Electronic Equipment (ORDEE). Most of them are as non-profit organizations and handle the e-waste stream **(Khetriwal *et al.*, 2009)**. **Khetriwal *et al.* (2009)** studied the Swiss experience in e-waste management .

Japan provided environmental policy on the responsibility for e-waste management in the late 1990s. Japan regulates e-waste by two main laws: the Specified Home Appliances Recycling (SHAR) Law and the Electric Household Appliance Recycling Law, which was promulgated in 1998 and came into force in 2001. SHAR was established to take back e-waste including large household appliances: TV sets, refrigerators, air conditioners and washing machines **(Nnorom and Osibanjo, 2008)**. Another law is the Promotion of Effective Utilization of Resources (LPUR) which deals with personal computers and used batteries **(Ogushi and Kandlikar, 2007)**. The difference between SHAR and LPUR is that the former relies on manufacturers' voluntary efforts whereas the latter enforces compulsory commitments on manufacturers. In 2003 LPUR was revised so that new computer purchasers pay the recycling costs in the product cost as an advanced recycling fee **(Nnorom and Osibanjo, 2008)**. SHAR accepts the principle of EPR, which extends the manufactures' obligation in the entire life cycle of the products.

Thailand is one other non-OECD countries to follow EPR lessons learnt from OECD countries and is striving to develop a policy.

Manomaivibool and Vassanadumrongdee (2011) provide the context of the EPR program for the Thai e-waste policy proposal. They found that EPR is one of the aims in the national integrated strategy for e-waste management.

The Thai e-waste strategy of the Pollution Control Department, Ministry of Natural Resources and Environment in 2007 had five objectives: (1) to manage domestic post-consumer e-waste in a scientific and systematic manner, (2) to establish an efficient and sustainable e-waste management system with cooperation from every sector of society, (3) to reduce hazardous wastes from electronic equipment at the origin and to encourage environmentally friendly design and production, (4) to enhance the competitiveness and negotiation power of the country in international trade and (5) to have nationwide efficient and effective integrated e-waste management by 2017. Thailand uses a product fee system to buy back e-waste. Financial inducement is provided to encourage the end-consumers for e-waste collection to pass material onto the recycling sector. On the other hand, EPR has become a costly arrangement of policy tools while the institutional design of the government fund is rigid.

These factors are widening the range of technology expansion. Buying such products makes it natural for the e-waste to appear (**Kang and Schoenung, 2005**). Nowadays, the e-waste managements all over the world have this assessment to alleviate the dangers of this waste. Much research is done on e-waste all over the world trying to find the most suitable ways of alleviating the dangers of this e-waste.

Some common terms in e-waste management rules are given here; such as (1) Consumer-Any person who uses the electronic and electrical equipment (EEE); (2) Bulk consumer-The bulk users of EEE such as central state government, or central government departments public sectors; (3) Extended Producer Responsibility (EPR)-EPR is a policy strategy in which manufacturers are assigned significant financial and/ or physical responsibility for the treatment or disposal of post-consumer products; (4) Producer-Any individual who manufactures and offers to sell electrical and electronic equipment and its components, consumables, parts, or spares under their own brand, regardless of the selling strategy utilized, such as dealer, retailer and e-retailer; (5) Recycler-Any individual who engages in the recycling and reprocessing of waste electrical and electronic equipment, assemblies, or components and has the facilities described in the rules is referred to as a recycler **(Namias *et al.*, 2013)**.

In industrialized countries, Japan, for example, has laws focusing on Reuse, Recycling, and Recovery. Other countries, such as Canada and Australia, are creating systems based on the same principles as the United States. Electronics and electrical items, as well as their parts, are considered to have reached the end of their useful lives and can be discarded by the owner (customer), the service in charge for an area, a factory manager of a factory, or the manufacturer itself. The establishments are under the supervision of the administration manager. An item of machinery once the user or the above-mentioned agencies have permanently disposed it will be deed. There are four principles in e-waste regulation- protection of the environment, social responsibility, disposal and data protection **(Cucchiella *et al.* 2015)**.

Biotechnological Approach of E-Waste Recycling and Business Opportunities

Biotechnological approaches such as hydrometallurgy and pyrometallurgy are considered as a feasible way for developing a sustainable environment from the e-waste with the help of living micro-organisms. E-waste is the secondary source of metals; therefore, bioleaching is a suitable process for recovering and reusing the metals from waste electrical and electronic equipment. Some cyanogenic bacteria such *Pseudomonas plecoglossicida*, *Pseudomonas fluorescens*, and *Pseudomonas aeruginosa* are being used in bioleaching process for extraction of gold from e-waste. Owing to HCN production, *Chromobacterium violaceum* plays an important role in gold leaching from e-waste under suitable growth conditions (**Ilyas *et al.*, 2021**).

E-waste is emerging as a source of income for the industry and has also opened the door for new jobs. This is because various elements like Au, Pt, Cu, Al, and rare earth metals are present in the e-waste; which is sufficient for recovery (**Ilyas *et al.*, 2021**). However, it can be said that biotechnological recycling of e-wastes is attracting the interest of scientists; as it recovers efficient energy and valuable metals such as gold, silver, platinum, and palladium from e-waste without destroying the environment; these can easily create new business opportunities; and also potent circular economy (**Garlapati, 2016**). Skilled technology and reduction of toxic chemicals and further research on the treatment of these toxic chemicals are needed, so that an affordable and environmentally friendly process can be created. It will attract innovation and business and also eliminate the incentive to dump e-waste.

Techniques of E-waste Management in Developing Countries

Informal recycling

Informal recycling is a common and growing method of e-waste management in developing countries owing to its limited need for technology and infrastructure **(Heeks *et al.*, 2015**). The practice is common in developing countries that have high demand for second-hand electronic equipment and the practice of selling e-waste to informal collectors. However, the method is characterized by numerous environmental and health risks that limits its acceptance (**Deepali *et al.*, 2005**).

The informal recycling procedures involves breaking down of electronic equipment to separate reusable components and recovering valuable metals such as plastic, iron, aluminum, copper using crude techniques (**Tran and Salhofer, 2018**). Usually, untrained workers carry out risky procedures without personal protective equipment. The manual dismantling of gadgets usually involves using tools such as hammers, chisels, screw drivers and bare hands; removal of components from printed circuit boards by heating over coal-fired grills; stripping of metals in open-pit acid baths to recover gold and other metals chipping; melting plastics; burning cables to recover copper; burning unwanted materials in the open air; and disposing unsalvageable materials in fields and riverbanks (**Awasthi and Li, 2017**). Thus, the workers are exposed to harmful substances such as heavy metals, inorganic acid, and polycyclic aromatic hydrocarbons.

Unlike other solid wastes, composition of e-waste is diverse and complex with the hazardous components existing even at microscopic levels. Harmful e-waste substances at both micro and macro levels can leach into the surrounding soil, water and air and adversely affect human health and the ecology. The impacts can be extreme in developing countries where people engaged in informal recycling of e-waste live in proximity to dump sites or landfills of untreated e-waste and work without protection or safeguards. Most workers engaged in these recycling operations are the urban poor, who are unaware of the hazards associated with their work (**Annamalai, 2015**).

Successful e-waste management by recycling demands transition from informal to formal sector with a well-organized structure employing appropriate technology and adequate safety measures (**Akon-Yamga *et al.*, 2021**). Additionally, it requires formulation and strengthening of policies for improved recycling rates, working conditions, and efficiency.

Open dumping, open burning and burial

Most developing countries practice open dumping, burning and burial as methods of dealing with their e-waste. Often, the waste is disposed as mixed waste together with municipal solid waste posing serious health and environmental risks of toxic leachates and emissions (**Ayilara *et al.*, 2020**). Open dumping and burning exposes the general public to long term effects of highly toxic e-waste related mixtures (EWMs), through inhalation, contact with soil and dust (**Borthakur, 2016**), or oral intake of contaminated food and drinking water. The extent of exposure may vary form one developing country to another.

Open dumping in developing countries is also characterized by large quantities of e-waste discarded openly along riverbanks where e-waste is manually disassembled, working pieces repaired and marketed and junks burned openly **(Edwards, 2016**). Villagers living along rivers where piles of e-waste are disposed and burned often use the river water directly for drinking, cooking and washing. Uncontrolled open burning of e-plastics, can generate polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF), which are persistent organic pollutants. These dioxins and furans can enter the body via inhalation, ingestion and skin absorption. Exposure to PCDD/PCDF at elevated levels can lead to chloracne; a severe skin disease, darkening of the skin, and altered liver function.

Reuse/Repair

Repair and reuse of EEE involves rectification of a number of faults within the gadgets and returning them to useful service (**Ben Yahya *et al.*, 2021**). Accordingly, the end of life (EoL) of the product is extended, thereby lowering the rate of disposal as a waste. Objectively, a product reuse focuses on extension of the product life, thus diverting its route from disposal facilities such as landfills. Reuse largely takes the form of repair reconditioning and remanufacturing. Although recycling is the most recommended method of e-waste management, the decision on the most preferred method of managing WEEE should be guided by the most ecological and economic option available (**Kumar *et al.*, 2022**). The consumer decision during the use phase of a product whether to repair, pass to a second user or dispose, affect product life spans and subsequently the rate of e-waste generation (**Borthakur and Singh, 2022**).

There is a growing trend in repair of EEE in developing countries. The repair may be viewed as a way of extending the products life (**Long *et al.*, 2016**), thereby reducing the quantity of WEEE generated in the short-term. In the the EU and other WEEE regulations, the hierarchy for e-waste loop management considers avoidance, re-use of components or parts [25], materials or energy recovery (**Cole *et al.*, 2019**) , and finally appropriate disposal. While most developed countries have not been very keen on repairing WEEE, many developing countries have been attracted to import their obsolete gadgets often dumped to them as second hand equipment.

Repairing/reusing instruments can be a good measure for sustainable waste management because it lowers the manufacturing volume of WEEE thereby reducing the amount of e-waste. A large volume of WEEE such as mobile phones has also created an opportunity for repair and reuse, although it is not realized well in many countries (**Wieser *et al.*, 2015)**. However, changes in product designs, technology, and wireless services often pose difficulties in the repair or upgrade of the equipment.

The Distinctive Features of Each Tool for E-Waste Management

The key to success in terms of e-waste management is to develop eco-designed devices, to properly collect e-waste, recover and recycle material by safe methods, dispose of e-waste by suitable techniques, forbid the transfer of used electronic devices to developing countries, and to raise awareness of the impact of e-waste pollution of both users and manufacturers. This approach is currently used routinely in most developed countries, although developing countries and countries in transition are yet to convince local community to implement such management strategies. In these countries, education of young generation may be one way forward with the management of e-wastes. While there are many tools available for the management of e-waste problems, we focused on LCA, MFA, MCA and EPR given its popularity in some countries.

LCA presents various advantages to support e-waste management. LCA estimates the effects of materials consumption that impacts on eco-design products **(Muñoz *et al.*, 2009)** and product development **(Kim *et al.*, 2001)** and allocates the impacts of the examined product or process of environmental interest **(Belboom *et al.*, 2011)**. It also evaluates the environmental and economic aspects related to the end of life disposal of electronic devices and enables better decision making for e-waste disposals **(Wäger *et al.*, 2011)**.

MFA is largely used in the countries that have large recycling plants such as in China, India and Nigeria to investigate destinations to where e-waste is being exported. MCA is used for decision making in terms of the environmental benefits and economic profit, the best location of e-waste recycling plants **(Queiruga *et al.*, 2008)** and the greatest option for e-waste disposal **(Rousis *et al.*, 2008)**. Although MCA is a useful tool for environmental decision making, it is not widely used for ewaste management. EPR is a tool entirely focussed on policy that and manage the treatment process and this is based on a polluterpays principal **(Widmer *et al.*, 2005)**. EPR is currently available in a number of developed and developing countries including Germany, Japan, India, Switzerland, Thailand, The Netherlands, United Kingdom and some states of Canada and United States. However, adherence to EPR policy varies amongst countries with many developing countries finding it difficult to get the end users to implement this approach to managing e-wastes. Developed countries such as Japan and Switzerland have progressed with the application of EPR and this is well accepted by industries associated with electronic goods.

In general, all the tools are useful for e-waste management. Each environment management tool has a specific information category when applied to e-waste management some of which overlap. The findings indicated that LCA, MFA and MCA overlap with regards to environmental decision making while each tool has a distinctive feature that separates them with EPR which is being used at national scale especially in terms of national policy on polluter pays principal. Thus a combination of either LCA, MFA or MCA with EPR may be the optimal model to promote for the management of e-wastes irrespective of the nature of e-waste problem. Indeed, EPR may be most appropriate for all countries in order to minimize generation of e-waste given that the responsibility for e-waste generated post Basel Convention is passed back to the producers.

E-waste management in Malaysia is governed by the Department of Environment (DOE) within the Ministry of Natural Resources and the Environment. Currently, there are no specific rules or regulations directly related to e-waste management. The Environmental Quality (Scheduled Waste) Regulations 2005 and the Environmental Quality (Prescribed Premises) (Treatment, Disposal Facilities for Scheduled Waste) Regulations, 1989 (control on the collection, treatment, recycling, and disposal of scheduled waste including e-waste). The 'Guidelines for Classification of Used Electrical and Electronic Equipment in Malaysia' was issued by DOE in January 2008 **(Azad *et al.* 2017)**.

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اســتراتيجيــات لإدارة النفــايـــات الإلكتــرونيـــة فــي ماليـــزيـــا: دراســـــة مرجعيــــة

إيمان صلاح الدين علي الجوهري[1] - اسماعيل محمد عبد الحميد[1] - فريد محمد سامي[2]

1- قسم الموارد الطبيعية والبيئية – كلية الدراسات الآسيوية العليا- جامعة الزقازيق - مصر

2- قسم البساتين – كلية الزراعة – جامعة الزقازيق – مصر

تحتل ماليزيا موقعا استراتيجيا في جنوب شرق آسيا، مقسمة بين منطقتين - شبه جزيرة ماليزيا وشرق ماليزيا. تبلغ المساحة الإجمالية للبلاد حوالي 330,803 كيلومتر مربع، وتقع بين 3 10 شمالاً، 101 42 . يمكن أن يكون التخلص غير الخاضع للرقابة من النفايات الإلكترونية ضارًا بصحة الإنسان والبيئة لأن النفايات الإلكترونية تحتوي على مواد سامة ومعادن ثقيلة. ومع ذلك، إذا تمت إدارة النفايات بشكل صحيح، فيمكن أن تصبح فرصة تجارية تنتج عوائد عالية لأن النفايات الإلكترونية تحتوي أيضًا على مواد قيمة، مثل الذهب والفضة والبلاتين والبلاديوم. هناك مشاكل تواجهها مرافق الاسترداد في تحقيق هدف تحويل النفايات الإلكترونية إلى مواد ذات قيمة. وتشمل القضايا توريد النفايات الإلكترونية، واستيراد وترميز المنتجات المشتقة من النفايات الإلكترونية، وأخيرا الحاجة إلى تطوير معايير لتكنولوجيات معالجة النفايات الإلكترونية لضمان سلامة واستدامة المرافق. أصبحت مسألة النفايات الإلكترونية مشكلة خطيرة بشكل متزايد لأنها تحتوي على العديد من المواد السامة التي يمكن أن تضر بشكل خطير الإنسان والبيئة. ومن المتوقع أن تتفاقم هذه المشكلة إذا لم يتم بذل جهود جادة لإدارة هذه النفايات الإلكترونية. الدراسة الحالية هي محاولة للحد من المخاطر وحل مشاكل النفايات الإلكترونية. لهذا الغرض، استخدم أدوات مختلفة مثل LCA، MFA، MCA وEPR. علاوة على ذلك، بغض النظر عن مدى جودة تقديم السياسات وتنفيذها، فإن مفتاح النجاح فيما يتعلق بإدارة المخلفات الإلكترونية في ماليزيا هو تطوير أجهزة مصممة بيئيًا، لجمع المخلفات الإلكترونية بشكل صحيح، واستعادة المواد وإعادة تدويرها بطريقة آمنة. وطرق التخلص من النفايات الإلكترونية بالتقنيات المناسبة، ومنع نقل النفايات الإلكترونية المستعملة. الأجهزة الإلكترونية إلى البلدان النامية، مما يزيد الوعي بتأثير تلوث النفايات الإلكترونية على كل من المستخدمين والمصنعين.

المحكمـــون :

1 - أ.د. أســـــامة محمد عبدالمنعم أستاذ رعاية الحيوان وعميد كلية الزراعة – جامعة الزقازيق.

2- أ.د. جمال الدين مصطفى محمد أستاذ الميكروبيولوجيا الزراعية المتفرغ – كلية الزراعة – جامعة الزقازيق.