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Review Article

e-Waste Management Scenarios in Malaysia

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e-Waste, or electronic waste, disposal that is uncontrolled can be harmful to human health and the environment because e-waste contains toxic substances and heavy metals. However, if the waste is properly managed, it can become a business opportunity that produces high returns because e-waste also contains valuable materials, such as gold, silver, platinum, and palladium. The government of Malaysia wants to ensure the safe, effective, and economically beneficial management of e-waste in Malaysia. Management approaches have included law enforcement and regulation and the promotion of e-waste recovery activities. e-Waste of no commercial value must be disposed of at sites/premises licensed by the Department of Environment (DOE), Malaysia. To date, 18 full recovery facilities and 128 partial recovery facilities that use various available technologies have been designated for the segregation, dismantling, and treatment of e-waste. However, there are issues faced by the recovery facilities in achieving the goal of converting e-waste into a source material. The issues include the e-waste supply, the importation of e-waste derived products and coding, and finally the need to develop the criteria for e-waste processing technologies to ensure the safety and the sustainability of the facilities.

1. Introduction

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" [1]. 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 & Development (OECD) describes e-waste as any appliance using an electric power supply that has reached its end-of-life [2].

In 2012, the total e-waste generated in Malaysia was approximately 10–15% of the total generated scheduled waste, and its value is expected to increase when the collection of household e-waste is fully implemented. A major reason for the rapid generation of e-waste is the high rate of obsolescence in the electronics market. Most electronic goods have very short lifespans and are routinely replaced every two years by either discarding or exporting to developing countries as second-hand merchandise.

In Malaysia, hazardous waste management programs were begun in 1989 because the rapid development in industrial activities generated various waste products and materials. The effective implementation of policies and strategies is required to minimize the environmental and health risks caused by such complex hazardous wastes.

e-Waste is listed as scheduled waste under the Environmental Quality (Scheduled Wastes) Regulations 2005. These regulations stipulate that no person is allowed to dispose of any e-waste into landfills, e-waste must be recycled and recovered at prescribed or licensed premises, and disposal must take place at prescribed premises only and must be carried out in an environmentally sound manner. Malaysia through its Department of Environment (DOE) has issued licenses to 18 full recovery facilities and 128 partial recovery facilities

Table 1: e-Waste categories according to the EU directive [3, 4].

Number	Category	Label
1	Large household appliances	Large HA
2	Small household appliances	Small HA
3	IT 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, leisure, and sports equipment	Toys
8	Medical devices	Medical devices

to convert various kinds of e-waste into source materials. Various available technologies have been designated for the segregation, dismantling, and treatment of the e-waste.

2. e-Waste Sources

Sources of e-waste are divided into those from the industrial sector as well as the household and institutional. The e-waste from the industrial sector includes electrical and electronic assemblies, whilst the household and institutions produce e-waste from the used and end-of-life electrical and electronic equipment.

2.1. e-Waste Categories and Compositions. According to the definitions in the Directive 2002/96/EC of the European Parliament and of the Council (January 2003) [3], e-waste consists of the ten categories listed in Table 1.

Of the eight categories listed, Categories 1–4 account for almost 95% of the e-waste generated in Western Europe (see Figure 1). Figure 2 shows examples of Category 3 (ICT).

The composition of e-waste is very diverse and differs in products across different categories. It contains more than 1000 different substances that fall under the "hazardous" and "nonhazardous" categories, including ferrous and nonferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete and ceramics, rubber, and other items. Iron (Fe) and steel constitute approximately 50% of e-waste, followed by plastics (21%), nonferrous metals (13%), and other constituents. Nonferrous metals consist of metals such as copper (Cu), aluminum (Al), and precious metals, such as silver (Ag), gold (Au), platinum (Pt), and palladium (Pd). The presence of elements such as lead (Pb), mercury (Hg), arsenic (As), cadmium (Cd), selenium (Se), and hexavalent chromium and flame retardants beyond threshold quantities in e-waste classifies it as hazardous waste [5].

Most e-waste is composed of a mixture of metals, particularly Cu, Al, and Fe, that are attached to, covered by, or mixed with various types of plastics and ceramics [6]. Large household appliance items, such as washing machines and refrigerators that are mostly composed of steel may contain fewer potential environmental contaminants than lighter e-waste items, such as laptops and computers, which may contain high concentrations of flame retardants and heavy metals [7].

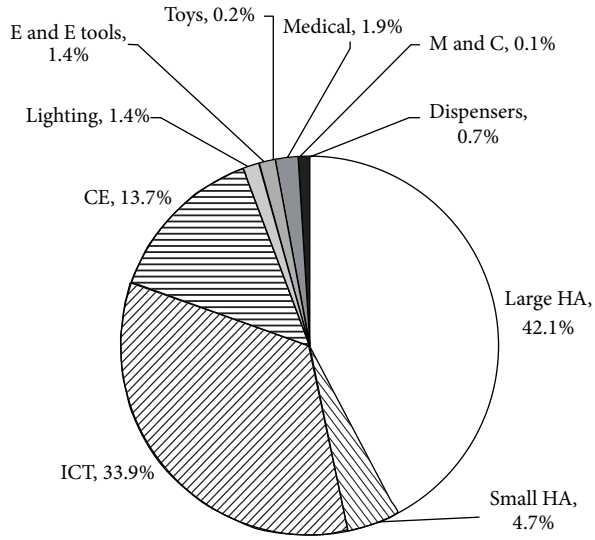

Figure 1: Composition of e-waste for Western Europe [5].

Table 2: Quantity of e-waste generated by the industrial sector in Malaysia [10].

Number	Year	Quantity of e-waste (metric tons)
1	2009	134,035.70
2	2010	163,339.80
3	2011	152,722.04
4	2012	78,278.05

Virtually all e-waste contains certain valuable components or base materials, especially Cu. Platinum group metals are included in electrical contact materials because of their high chemical stability and conductance of electricity. The precious metal concentration in printed circuit boards is more than tenfold higher than that of commercially mined minerals [8]. Some contaminants, such as heavy metals, are used in the manufacture of electronic goods, whereas others, such as polycyclic aromatic hydrocarbons (PAHs), are generated by the low-temperature combustion of e-waste. The burning of insulated wire, which typically occurs in open iron barrels, generates 100 times more dioxins than the burning of domestic waste [7, 9].

2.2. Quantity of e-Waste in Malaysia. In Malaysia, the classification of e-waste is based on the "Guidelines for the Classification of Used Electronic and Electrical Equipment in Malaysia" that was published by the Department of Environment in 2008. The gross quantity of e-waste from the industrial sector in Malaysia based on sources of generation is shown in Table 2.

3. Environmentally Sound Management of e-Waste

In Basel Convention, Environmentally Sound Management (ESM) of waste means taking all practicable steps to ensure

(a) (b)

Figure 2: Example of e-waste in Category 3 (ICT): (a) used mobile phones and (b) used monitors.

that hazardous wastes or other wastes are managed in a manner that will protect human health and the environment against the adverse effects that may result from such wastes, whilst Organization for Economic Cooperation & Development (OECD) defines ESM as a scheme for ensuring that waste and scrap materials are managed in a manner that will save natural resources and protect human health and the environment against adverse effects that may result from such waste and materials.

3.1. Acts and Regulations in European Union (EU). The EU has not carried out specific work on ESM but has indirectly addressed it through many EC directives and regulations related to waste and environmental protection that include managing waste in an environmentally sound manner as an underlying principle. Hence, a set of EC directives and regulations, which are legally binding, contributes to the implementation of the ESM principle [11].

Table 3 summarizes the recommended general ESM components identified through reviews of the existing guidelines from the Basel Convention, OECD, EU directives, Partnership for Action on Computing Equipment (PACE), Mobile Phone Partnership Initiative (MPPI), Basel Action Network (BAN), and Basel Convention Regional Centre for South East Asia (BCRC-SEA).

3.2. Environmental Quality (Scheduled Wastes) Regulations 2005 of Malaysia. In Malaysia, the release of the Environmental Quality (Scheduled Wastes) Regulations 2005, which replaced the revoked Environmental Quality (Scheduled Wastes) Regulations 1989, has classified e-waste as a scheduled waste under the code SW110, while the specified e-waste, such as waste from lead acid batteries, batteries containing heavy metals and fluorescent lamps, are coded as SW102, SW103, and SW109, respectively.

Because of this classification, any treatment of e-waste is regulated and must be carried out at a licensed on-site treatment facility, and the disposal of e-waste must be performed at the only prescribed premise, Kualiti Alam Sdn. Bhd. Because Malaysia is one of the parties to the Basel Convention, the export or import of e-waste is strictly prohibited, which is stipulated in Article 4, paragraph 1(a) and 1(b) in the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal:

(a) Parties (refer to the country) exercising their right to prohibit the import of hazardous waste or other waste for disposal shall inform the other Parties of their decision pursuant to Article 13 (Transmission of Information);

(b) Parties shall prohibit or shall not permit the export of hazardous waste and other wastes to the Parties that have prohibited the import of such waste, when notified pursuant to subparagraph (a) above.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal lists hazardous waste, mentioned in paragraph 1(a) of Article 1, as waste that belongs to any category contained in Annex I (Categories of Wastes to be Controlled), unless they do not possess any of the characteristics contained in Annex III (List of Hazardous Characteristics). Wastes listed in Annex VIII are also characterized as hazardous pursuant to paragraph 1(a) of Article 1.

4. Assessment of e-Waste Scenarios

4.1. e-Waste Management in Developing and Developed Countries. In India, e-waste is a major issue resulting from the generation of domestic e-waste and from waste that is imported from developed countries. India's electronics industry is one of the fastest growing industries in the world [13]. In 2005, India's Central Pollution Control Board developed guidelines for the environmentally sound management of e-waste in India; however, e-waste is not regulated at the present time. The Ministry of Environment and Forest, as part of the Environmental Protection Act of India, has enacted the "e-waste (Management and Handling) Rule" of 2011 that was to take effect on May 1, 2012.

The rule mandates producers to be responsible for the collection of e-waste and the financing of collection systems according to an extended producer responsibility concept. The rule clearly defines the responsibilities of the producers,

Table 3: Summary of ESM components recommended by the existing guidelines [12].

Component	ESM criteria for facilities	Example of requirements for facilities
Compliance with legal requirements	(i) Comply with conditions or standards (environmental and emissions) required by the country, region, international treaty, and so forth (ii) Obtain approval and licenses from the appropriate authorities of the national or local government	(i) Implementation of pollution prevention measures to ensure legal compliance (ii) Implementation of required actions to obtain the license (e.g., environmental impact assessment (EIA)) (iii) Continuous implementation of the above required action for the periodical renewal of license
Introduction of Environmental Management System (EMS)	Establishment of policies or goals for the EMS on a voluntary basis, introduce the EMS to facilities, and manage operations based on the EMS	(i) Acquisition of ISO14001 or other ESM certification by the third party organization, or introduction of a similar management system and its continuous implementation (ii) Ensuring commitment from top management
Identification of hazards or risk	Identify hazards or risks to the environment	Utilization of a Material Safety Data Sheet (MSDS) or laboratory results identifying the risks or hazards in facilities (hazardous substances or appropriate packaging, etc.)
Occupational safety and health	Avoid exposures to unacceptable occupational risks in working environments	Ensuring occupational health and safety of employees (providing equipment for personal protection, cleaning of the working place and sanitary management, periodical medical checks, etc.)
Awareness and competency of staff	Enable workers to understand the hazards or risks of hazardous waste and handle it in an appropriate manner	Awareness raising and capacity development of employees (through seminars or in-house training, etc.)
Monitoring, recording, reporting	Collect and maintain records of information such as the material flow or emission status (exhaust gas or effluent) and report information to the appropriate authority	(i) Development of procedures for monitoring and allocating staff and equipment for monitoring (ii) Development of procedures for record keeping (iii) Periodical reporting to the appropriate authority
Emergency response	Capable of considering unexpected situations that can create negative effects on the environment	(i) Development of an emergency response plan (ii) Sharing of the above plan among facility employees and local authorities
Secure financial resource	Access to a financially stable resource that can accommodate unexpected situations (such as an accident or closure of the facility)	Ensuring access to a financial resource or having financial instruments (e.g., insurance)
Ensure downstream ESM	Ensure ESM in downstream recycling chain or destination country	(i) Maintaining contracts with recyclers in the downstream chain (ii) Maintaining contracts with exporters and all shipping documents

collection centers, consumers, or bulk consumers, dismantlers and recyclers [14]. e-Waste dealers, refurbishers, dismantlers, recyclers, and collection centers are required to register with the relevant State Pollution Control Board (SPCB) or Pollution Control Committee (PCC). The liability on the consumer has also been fixed in the form of a requirement to dispose of e-waste by taking it to authorized dealers and collection centers.

Bulk consumers are at liberty to auction their waste with the restriction that they may only auction it to authorized collection centers, dismantlers, or recyclers or to the collection services offered by the producers. The rules assign all responsibility for ensuring enforcement to the respective SPCB or PCC. Every institution registered by the authorities has to submit an annual report to the appropriate SPCB or PCC [15].

In 2009, Thailand generated approximately 80,000 tons/year of e-waste that contained approximately 20,000 tons/year of electrical and electronic goods. Thai-land also suffers from issues stemming from a lack of general awareness of e-waste, incomplete databases and inventories related to e-waste, a lack of environmentally sound management practices, and a lack of specific laws and regulations for e-waste. To address these issues, the government of Thailand passed the National Strategic Plan on Integrated Management of WEEE (WEEE Strategic Plan) in July 2007. The strategy, which was approved by the Cabinet on 24 July 2007, is a 10-year road map [16].

Japan has formulated two laws concerning e-waste production in Japan: the Law for the Promotion of Effective Utilization of Resources (LPUR) and the Law for Recycling Specified Kinds of Home Appliances (LRHA). The LPUR covers personal computers and small-sized batteries, whereas the LRHA is concerned with televisions, refrigerators, washing machines, air conditioners, and clothes dryers. While the LPUR encourages manufacturers to voluntarily assist

e-waste recycling to reduce the generation of waste, the LRHA imposes more compulsory obligations on the consumers and manufacturers. When disposing of home appliances, consumers are required to pay for the cost of transportation and recycling [15].

Manufacturers are responsible for establishing proper e-waste recycling facilities and are required to achieve compulsory recycling rates that include 70% for air conditioners, 60% for refrigerators, and 65% for washing machines. An amendment to the Law for the Effective Utilization of Resources took place on July 1, 2006, that mandates that manufacturers provide material content declarations for certain categories of electronic products sold after July 1, 2006. Manufacturers and importers are required to label their products and provide information on the content of lead, mercury, chromium VI, cadmium, Polybrominated biphenyls (PBB), and Polybrominated Diphenyl Ethers (PBDE). The importers of electronic products must also meet the Design for Environment (DfE) criteria, which are also required for domestic manufacturers [16].

In the 1980s, the policy in Germany of incinerating municipal solid waste faced increasing public opposition as waste volumes continued to grow to a point where the country was facing a waste disposal crisis. To overcome these challenges, the German government adopted the Packaging Ordinance following consultations with industry and consumers. This ordinance imposed significant packaging take-back and recycling obligations on the industry. Specifically, the ordinance established a requirement for retailers, rather than producers, to either take back packaging from consumers at retail shops or participate in a national collective system for packaging collection and recycling. Recognizing the significant challenges associated with collecting used packaging at retail shops, the retail, consumer goods and packaging industry established a voluntary organization—the "Duales System Deutschland" (DSD)—to collectively conduct their joint packaging management responsibilities under the ordinance [17].

The DSD organization established a packaging recycling and collection system across all of Germany that operated in parallel with the municipal waste collection system, hence its name meaning the "dual" system. Collection and processing from households and small businesses is physically undertaken by service providers operating under contract to the DSD, and the recycling of used packaging is provided by the DSD without directly charging consumers. However, to finance their activities, the DSD charges license fees to producers that sell package goods (in practice, packers and fillers) using the well-known "Green Dot" trademark as a way of proving that appropriate license fees have been paid [16].

4.2. e-Waste Management Issues in Malaysia. e-Waste in Malaysia is handled by the licensed recovery facilities. However, there are issues faced by the recovery facilities in achieving the goal of converting e-waste into a source material. From the visit and survey made to these facilities, the common issues are summarized as below.

4.2.1. e-Waste Supply. The issue of lacking e-waste supply is brought up at all full recyclers visited. This seems to be the main challenge faced by all large plants, as it relates to production of the plants, thus income to the plants. In Malaysia, many full recyclers are not able to operate at full capacity due to lack of e-waste. However, the recyclers have been diligent in investing, purchasing only the necessary shredder and grinder, and have been able to recover their investment costs. Also competition has led to stiff competition during bidding for wastes. Many full recyclers spend an inordinate amount of time and resources preparing for bids.

The recyclers alleged that there are too many full recyclers. Some allege that the recycling licenses have been issued without considering the amount of e-waste available. Also there are allegations that the e-waste has been illegally processed by illegal backyard operators without proper facilities. A few of the operators allege that much e-waste has been exported, with lack of checks at the customs attributing to e-waste getting through.

4.2.2. Importation of e-Waste Derived Products and Coding. Any full recyclers hold contract for e-waste processing for manufacturers with plants located in other countries, such as Campuchea, where labour is still cheap. In such a situation if parts from the waste are no longer coded as waste, but as metal scrap and metal mixture, there would be greater opportunity for full recyclers to grow.

Ingots lower in gold content are currently exported by certain full recyclers for refining, for example, to Japan. For equipment, such as a washing machine or a printer, only a small weight fraction of it is the electronic part comprising mainly the motherboard, plus several connectors, and so forth. Only the electronic part contains the precious metals recovered by e-waste recyclers, the rest are metal and plastic casings, wires, and so forth. Partial recyclers would isolate the electronic parts and, rightly, sell these to full recyclers for processing in a physic-chemical-thermal processes. As it is now, the whole equipment is classified as SW110 Waste and the electronic parts remain as SW110 waste. There is need for greater clarity on coding, as the metal and plastic parts are no longer wastes but become feed for metal smelters and plastic recyclers, while the electronic parts become feed for physic-chemical-thermal processes.

4.2.3. Criteria for e-Waste Processing Technologies. In Malaysia, e-waste is collected and treated only at licensed facilities by the Department of Environment. By the end of February 2013, 18 full and 128 partial recovery facilities of e-waste had been licensed to perform the recovery process of precious (gold, silver, and platinum) and valuable (copper, aluminum, and nickel) metals. These facilities are also expected to simultaneously handle the hazardous elements found in e-waste, such as heavy metals (cadmium, lead, mercury), to prevent them from polluting the environment and risking human health and manage the recyclable items, such as plastic and glass.

Wastewater and sludge are primarily generated from processes of chemical dissolution, electrowinning, electrolysis,

Table 4: Types of certification awarded to e-waste recovery facilities in Malaysia.

Number	Recovery facility	ISO 9001:2008	ISO 14001:2004	Responsible recycle (R2) practice	OHSAS 18001:2007	Others
1	A	—	Yes	—		—
2	B	—	Yes	—		—
3	C	Yes	Yes	—		—
4	D	—	Yes	—		—
5	E	Yes	Yes	In progress		—
6	F	—	Yes	—		—
7	G	Yes	Yes	—		—
8	H	Yes	Yes	—		—
9	I	Yes	Yes	—	Yes	—
10	J	Yes	Yes	—	—	—
11	K	Yes	Yes	Yes	—	—
12	L	Yes	Yes	—	—	—
13	M	Yes	Yes	—	Yes	MS 1722
14	N	Yes	Yes	—	—	—
15	O	—	—	—	—	—
16	P	—	—	—	—	—

precipitation, and scrubbers. Sludge generated from wastewater treatment plants at the e-waste recovery facilities is categorized as a scheduled waste and coded SW501. The generated sludges are then sent to Kualiti Alam for proper disposal. The residue gas is treated using either a dust collector (mainly for the dust from crushing and grinding processes) or gas scrubber (vapor/gas from stripping and refining processes).

The existing technologies in use are conventional dismantling, crushing, grinding, air separation, or wet separation via jigging, chemical extraction, electrowinning, and thermal refining. Most equipment is similar to conventional mineral extraction equipment used in the mining industry and this equipment can be bought or fabricated in the country. Crushing, grinding, and air separation can be noisy and dusty, although there are technologies which are less noisy and dusty in use.

Chemical and thermal processes also pose a significant threat. Chemical extraction processes in use can emit chemical odors (usually of acids) although there are technologies with efficient vapour extraction and with cyanide detectors, whilst thermal refining processes are usually in open spaces, which may pose danger of metal vapours to workers, notably of lead, mercury, and so forth.

Destruction of, and metal recovery from, carbon ray tubes is a residual problem, as the tubes contain mercury vapours and yield leaded glass for which there is scarce demand; yet the carbon ray tubes are no longer in production. There remain only residual carbon ray tubes to be destroyed.

Since chip technologies are changing into those with smaller sizes, with thinner layers of precious metals, as such, the conventional physical separation processes of grinding or jigging may no longer be able to recover the precious metals.

Therefore, there is a need to categorise the technologies in use according to criteria of environmental performance, technological performance, and economics.

4.3. Certifications. To meet international standards for the e-waste industry, most e-waste recovery facilities have applied for certification through an accreditation process such as from the International Organization for Standardization (ISO). Certification includes requirements for quality, the environment and the occupational health and safety management system. Table 4 lists several types of certification that have been awarded to licensed e-waste recovery facilities.

ISO 9001:2008 sets out the criteria for a quality management system. The standard is based on a number of quality management principles that incorporate a strong customer focus, motivation and action of top management, the process approach, and continual improvement. By having this certificate, the facilities ensure that customers will receive consistent, good quality products and services, which can prove beneficial to business. ISO 14001:2004 sets out the criteria for an environmental management system and requires e-waste facilities to map out a framework for an effective environmental management system. These criteria can also provide assurance to facility management and employees, as well as to external stakeholders, that the facility's environmental impact is being measured and improved.

Some facilities were also awarded the International Standard (OHSAS 18001:2007) or Malaysia Standard (MS 1722) for occupational health and safety management systems. These facilities can use the awards to demonstrate their commitment to safeguarding the welfare of employees and others from workplace injuries and illnesses, as well as to meeting OSH legal requirements. One facility was awarded the Responsible Recycling Practices Standard (R2) certification from a third-party agency; this certification is recognized by the Environmental Protection Agency (EPA) and it includes a set of voluntary principles and guidelines designed to promote and assess responsible practices for electronics recyclers. The management system is accountable for practices affecting worker health and safety, security,

the environment, and the downstream management, both domestically and internationally, of end-of-life electronic material and equipment.

5. Conclusion

Malaysia has adopted measures such as collecting information about the generation of e-waste, providing regulations and measures, and permitting only licensed facilities to perform treatment and recovery of e-waste. However, more drastic measures are required to ensure that all e-waste is collected, treated, and recovered by licensed facilities. Criteria should also be established mandating that the technologies are environmentally sound and do not produce deleterious effects to the people involved in handling the e-waste. In summary, the criteria for Environmentally Sound Management (ESM) must be provided and implemented for use at all levels of the management of e-waste.

Disclosure

This paper is written based on a consultation study for the Department of Environment (DOE) Malaysia.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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