COMPARATIVE ASSESSMENT ON HOUSEHOLD E-WASTE MANAGEMENT IN THREE CITIES IN MALAYSIA

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KUALA LUMPUR

2021

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY (ENVIRONMENTAL MANAGEMENT)

INSTITUTE OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
UNIVERSITI MALAYA
KUALA LUMPUR

2021

UNIVERSITI MALAYA
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Name of Degree: **MASTER OF TECHNOLOGY (ENVIRONMENTAL MANAGEMENT)**

Title of Dissertation ("this Work"):

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COMPARATIVE ASSESSMENT ON HOUSEHOLD E-WASTE MANAGEMENT IN THREE CITIES IN MALAYSIA

ABSTRACT

Electronic waste or E-waste is a relatively new waste stream that is fast growing because of the increased production of electronic items with short lifespans. Like other developing countries, Malaysia is also facing problems of managing E-waste. Although research have been carried out on industrial E-waste, however, E-waste from households has not been adequately studied. Thus, this study is intended to assess the current E-waste management and recycling practice among the public in three major cities in Malaysia, namely Putrajaya, Shah Alam, and Petaling Jaya. A questionnaire survey was the main method used to collect data from 1200 respondents from the three cities. From the Material Flow Analysis (MFA) 23,033 kg per year (at a rate of 19.19 kg per capita) of E-waste was generated from the study areas, from which only 15.89% was recycled. The public in Putrajaya generated the lowest amount of E-waste (17.99 kg per capita) compared to that in Petaling Jaya and Shah Alam. 33% of public generally kept their E-waste at home or sell to scrap dealers rather than sending it to recycling centers. 88.96% of electronic items was recorded as stocks (153.73 kg per capita) and air conditioner was the largest stock at 59,235 kg (28.38%). Pearson correlation revealed a significant but positively weak correlation ($r = 0.067$, $p < 0.05$) and a significant regression equation was found as well [F (1,1198) = 5.416, $p < 0.05$), with an R^2 of 0.005 between knowledge and practice on E-waste management and recycling among the public in the three cities. From One-way ANOVA and Bonferroni Post Hoc test, significant differences among the three cities were observed in level of public knowledge [F (2,1197) = 12.886, $p < 0.05$], and practice [Welch's F (2,770.49) = 119.79, $p < 0.05$] on E-waste management and recycling. However, significant variations were only observed in E-waste management and recycling practices among the public between 31 to 40 age group, higher learning education, and higher income level. According to the public opinion, inadequate facilities, lack of awareness and education, insufficient recycling centres, and public ignorance towards E-waste management were the main reasons behind the unsuccessful recycling program in the study areas. Law enforcement, frequent programs on public awareness, incentives or gifts, and closer proximity of recycling centre will enhance the E-waste recycling in the study areas. The findings of this study can be utilised by the policy makers and other stakeholders so that effective steps can be taken to increase the performance of recycling among the public.

Keywords: E-waste, Electric and electronic waste management, Recycling, Knowledge, Practice

PENILAIAN PERBANDINGAN PENGURUSAN E-SISA RUMAH TANGGA DI TIGA KOTA DI MALAYSIA

ABSTRAK

Sisa elektronik atau E-sisa ialah aliran sisa baru yang semakin berlambah kerana peningkatan pengeluaran barang elektronik yang mempunyah jangka hayat yang pendek. Seperti negara-negara membangun yang lain, Malaysia juga menghadapi masalah dalam menguruskan E-sisa. Walaupun banyak kajian telah dilakukan terhadap E-sisa industri, sisa elektronik dari isi rumah kurang diben penekanan. Oleh itu, kajian ini telah dijalankan untuk menilai pengurusan dan kitar semula E-sisa di kalangan orang ramai di tiga bandar utama di Malaysia, iaitu Putrajaya, Shah Alam, dan Petaling Jaya. Tinjauan soal selidik adalah kaedah utama yang digunakan untuk mengumpulkan data dari 1200 responden dari tiga bandar ini. Dari Analisis Aliran Bahan (MFA) 23,033 kg per tahun (pada kadar 19.19 kg per kapita) E-sisa dihasilkan dari kawasan kajian, dari mana hanya 15.89% darinya dihantar untuk kitar semula. Orang awam di Putrajaya menghasilkan jumlah E-sisa terendah (17.99 kg per kapita) berbanding di Petaling Jaya dan Shah Alam. Sebanyak 33% orang awam menyimpan E-sisa mereka di rumah atau dijual kepada peniaga barangan terpakai berbarding dengar jumlah yang menghantar E-sisa ke pusat kitar semula. 88.96% barangan elektronik dicatatkan sebagai stok (153.73 kg per kapita) dan penghawa dingin dicatat sebagai stok terbanyak 59,235 kg (28.38%). Pekali korelasi Pearson yang signifikan diperolehi memberikan positif tetapi lemah ($r = 0.067$, $p < 0.05$) dan persamaan regresi yang signifikan juga dijumpai [F (1,1198) = 5.416, $p < 0.05$), dengan R^2 of 0.005 di antara pengetahuan masyarakat dan amalan pengurusan kitar semula E-sisa. Menurut ujian ANOVA Sehala dan Bonferroni Post Hoc, wujud perbezaan yang ketara di antara ketiga-tiga bandar dari segi pengetahuan orang awam [F (2,1197) = 12.886, $p < 0.05$], dan praktik amalen [Welch's F (2,770.49) = 119.79, $p < 0.05$] pengurusan dan kitar semula E-sisa. Walau bagaimanapun, variasi yang ketara hanya diperhatikan dalam amalan pengurusan dan kitar semula E-sisa di kalangan orang ramai yang berumur antara 31 hingga 40 tahun, kumpulan pendidikan tinggi, dan kumpulan tahap pendapatan yang lebih tinggi. Menurut pandangan orang awam, kemudahan yang tidak mencukupi, kurangnya kesedaran dan pendidikan, pusat kitar semula yang tidak mencukupi, dan ketidakpedulian masyarakat terhadap pengurusan E-sisa adalah sebab utama kegagalan program kitar semula di kawasan kajian. Penguatkuasaan undang-undang, program kitar samula kepada kesedaran masyarakat, insentif, dan jarak pusat kitar semula akan meningkatkan kitar semula E-sisa di kawasan kajian. Hasil kajian ini dapat dimanfaatkan oleh penggubal dasar dan pihak berkepentingan yang lain untuk mengambil yang langkah efektif untuk meningkatkan kadar kitar semula di kalangan masyarakat.

Kata kunci: E-sisa, Pengurusan sisa elektrik dan elektronik, Kitar semula, Pengetahuan, Amalan.

ACKNOWLEDGEMENTS

At first, I would like to thank almighty Allah for His grace and mercy bestowed in my life. Special thanks go to my both supervisors, Prof. Dr. Agamuthu Pariatamby and Associate Prof. Dr. Fauziah Binti Shahul Hamid whose blessings and insightful guidance help me to complete my dissertation.

I would like to thank also to all the individual respondents in the study areas those who gave me their special time to perform at questionnaire survey and government officials as well for their guidance and information.

Special name mentioned of Mr. Sufian (the community Secretary of Precinct 9, Putrajaya), Mr. Mazlon (the government official and Secretary of Surau Al-Husna Recycling Centre, Section 20, Shah Alam), Miss Nor Azah Masrom (DOE official, Putrajaya), Miss Norhidayah Jamaluddin (T-pot electrical and electronics Sdn Bhd, Shah Alam), Pavel Ahmed and Nargis Akter whom I would like to thank as well.

My Sincere thanks to my MTech course mates Khairah, Khairiyah, Hanieh, Diba, Sara, Kelly, Mehran, Farhana and my UM-Solid Waste Lab mates (Awal, Chen, and Aziz) for their incredible support.

At the end my gratitude goes to my parents, my sister Johora Kulsum, my brothers Mamunul Haque and Dr. Mahfuzul Haque for always believing in me and helped to fulfil my dreams. Without their support and encouragement, it wouldn't be possible.

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LIST OF ABBRIVIATIONS

APC : Air Pollution Control

AGC : Attorney General's Chambers of Malaysia

ANOVA : Analysis of Variance

BAN : Basel Action Network

BRF : Brominated flame retardants

CFC : Chlorofluorocarbon

COP : Conference of Parties

CRT : Cathode Ray Tube

CSR : Corporate Social Responsibility

DOE : Department of Environment

DOSM : Department of Statistics, Malaysia

EC : European Commission

EEE : Electrical and Electronic Equipment

EOL : End of Life

EPA : Environmental Protection Agency

EPR : Extended Producers Responsibility

EQA : Environmental Quality Act

EQSWR : Environmental Quality (Schedule Waste) Regulation

ESM : Environmentally Sound Management

EU : European Union

IC : Integrated circuit

ICT : Information and Communication Technology

IT : Information Technology

JICA : Japan International Cooperation Agency

LPUR	:	Law for the Promotion of effective Utilization of Resources
LRHA	:	Law for Recycling specified kinds of Home Appliances
MAR	:	Microsoft Authorized Refurbishers
MBSA	:	Majlis Bandaraya Shah Alam
MBPJ	:	Majlis Bandaraya Petaling Jaya
MFA	:	Material Flow Analysis
MNRE	:	Ministry of Natural Resources and Environment
MOEJ	:	Ministry of Environment Japan
MPPI	:	Mobile Phone Partnership Initiatives
MRF	:	Material Recovery Facilities
MSW	:	Municipal Solid Waste
NGO	:	Non-governmental Organisation
NSES	:	National Strategy for E- waste Stewardship
OECD	:	Organisation for Economic Co-operation and Development
PACE	:	Partnership on Computing Equipment
PAYT	:	Pay-As-You-Throw
PAHs	:	Polycyclic Aromatic Hydrocarbons
PBB	:	Polybrominated Biphenyls
PBDE	:	Poly-Brominated Diphenyl Ethers
PC	:	Personal Computer
PCB	:	Polychlorinated Biphenyls
PCDD	:	Polychlorinated Dibenzofurans
PEWOG	:	Penang Environmental Working Group
PIKOM	:	*Persatuan Industri Komputer Malaysia* (National ICT Association of Malaysia)
POPs	:	Persistent Organic Pollutants

PRO	:	Producer Responsibility Organisation
RoHS	:	Restriction of the use of certain Hazardous Substances in EEE
SEPA	:	Swedish Environmental Protection Agency
SPSS	:	Statistical Package for Social Science
StEP	:	Solving the E-Waste Problem
SVTC	:	Silicon Valley Toxics Coalition
TBP	:	Take Back Program
UN	:	United Nation
UNEP	:	United Nation Environmental Programme
UNDP	:	United Nation Development Programme
USEPA	:	United States Environmental Protection Agency
UNU	:	United Nation University
WEEE	:	Waste Electrical and Electronic Equipment
WtE	:	Waste to Energy

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Managing solid waste is a challenging task for many countries in the world. This is because of its high amount due to high consumption from the increasing population, rapid urbanization and development and changing lifestyle (Tiep at al., 2015; Malik et al., 2015). Most of household E-waste is often discarded with the municipal garbage and dumped into landfills, or openly incinerated which give rise to with serious environmental consequences (Alias et al., 2014). Fazeli et al. (2016), in a recent review on Waste to Energy, highlighted that the growing economy of Malaysia has contributed to the environmental burden levied by high energy consumption and high-volume of waste generation (Fazeli et al., 2016). Shumon et al. (2014) also mentioned that rapid economic growth, together with the massive urbanization has caused a significant increase in the consumption of Electrical and Electronic Equipment in Malaysia, leading to a major threat to the environment and the country's sustainable economic growth (Shumon et al.,2014).

Electronic waste (E-waste), which is also known as Waste Electrical and Electronic Equipment (WEEE) or end of-life electrical and electronic products, includes all components, sub-assemblies and consumables such as small and large household appliances, IT and telecommunications equipment, automatic dispensers and lighting equipment that are considered unwanted or obsolete by users (Wang, 2017; Kahhat et al., 2008). It should be noted that the United States Environment Protection Agency (USEPA) considers the commonly used term "E-waste" to be reserved for used electronics and recognizes the inherent value of these materials that can be reused, refurbished or recycled to minimize the actual waste that might end up in a landfill or improperly disposed in an unprotected dump site, either in US or abroad (USEPA, 2017).

WEEE or E-waste is one of the fastest growing waste streams in the world (Afroz et al., 2013; Nnorom & Osibanjo, 2008; Jain, 2008; Cui & Forssberg, 2003), with a growth rate of 3% to 5% per year (Afroz et al., 2013; Mohan et al., 2008). That is three times faster than that of general waste (Agamuthu & Dennis, 2013). Moreover, according to USEPA (2011), the global E-waste generation increased annually from 5% to 10% where only 5% of that amount is being recovered (Shamim et al., 2015; USEPA, 2011). In developed countries, there are more than 900 types of EEE enlisted (Wang et al., 2013; Shevchenko et al., 2019). The United Nations projected that by 2020 (StEP, 2009; Shevchenko et al., 2019), the volume of obsolete computers will increase by 500% and the number of used mobile phones will be 18 times higher in India and seven times higher in China in comparison to 2007 (StEP, 2009; Shevchenko et al., 2019).

Managing E-waste is a challenging task, not only due to the increasing volume, but more importantly because of its hazardous nature (Akhter et al., 2014). The Municipal solid waste contains 1% - 3% hazardous wastes, including E-waste (Herat & Agamuthu, 2015). And the rapid increase in the quantities of E-waste is currently an emerging environmental issue which is destined to continue unabated for some time (Agamuthu & Dennis, 2013). Malaysia is now facing the rapidly growing problem of E-waste generated from households, business entities, and institutions. The estimated E-waste in Malaysia was about 652,909 tonnes in 2006, leading to an increase of about 706,000 tonnes in 2010 and expected to be 1.2 million tonnes in 2020 (Azad et al., 2017; Agamuthu & Victor, 2011). According to the Global E-waste Monitor Report (2017), Malaysia generated 250,000 tonnes of E-waste per year, at a rate of 7 kg /per inhabitant. Household and industries are the two main sources of E-waste in Malaysia (Global E-waste monitor report, 2017). According to the Department of Environment of Malaysia (DOE) E-wastes are classified as schedule wastes that must be handled, recycled, and disposed by authorized licensed contractors (Herat & Agamuthu, 2015). However, most of the contractors provide facilities for industrial E-wastes but not for households. Hence, there are no proper facilities for handling household E-wastes (Herat & Agamuthu, 2015).

In view of the growing E-waste problem, the Malaysian government has regulated the Environment Quality (Schedule wastes) Regulation since 2005.The aim is to prevent the public from disposing any E-waste in landfills. While the industrial sector has widely practiced this, it is not happening at the household level (Babington et al., 2010; Ho et al., 2013). The Department of Environment (DOE) carried out a project from 2011 to 2018 on household E-wastes in Peninsular Malaysia with the collaboration with the Japan International Cooperation Agency (JICA) (JICA, 2014; 2018). The prior objectives of this project were to develop a collection model and prepare the legal/regulatory/policy framework for household E-wastes (JICA, 2014; 2018). According to JICA (2018), the estimated household E-waste generation was about 114,400,00 units in 2017, to be increased to about 143,140,000 units in 2020 and 229,490,00 units in 2025 (JICA,2018). Based on previous findings, besides the six household electronic items noted earlier, it was proposed that the list be expanded to include the fluorescent tube, rechargeable batteries, and 18 types of small electronic items (JICA, 2018). DOE has submitted to the Attorney General's Chambers of Malaysia (AGC) a new E-waste management regulation which incorporates the "Extended Producers' Responsibility (EPR)" for reviewing (JICA, 2014; 2018).

In terms of potential pollution, E-waste is one of the most problematic waste streams as it contains more than 1000 substances, including heavy metals and plastics (Gubanova, 2014; Shevchenko et al., 2019). About 70% of the mercury and cadmium in U.S. landfills originates from the E-waste (Tanskanen, 2013; Shevchenko et al., 2019). There is a concern that a significant proportion (23%) of E-waste generated in developed countries ends up in developing countries for recycling, predominantly by informal sectors that are not regulated (Seeberger et al., 2016; Sthiannopkao & Wong, 2012). It is even more unfortunate that these developing countries are the primary destination for E-waste dumping because they have insufficient recycling and disposal technologies and facilities, lack of occupational and environmental pollution control (Seeberger et al., 2016; Shumon et al., 2014; Sthiannopkao & Wong, 2012).The United Nations Environmental Program (UNEP) predicted that improper management of hazardous waste in developing countries will result in serious consequences due to its sharp increase the next 10 years (Shumon et al., 2014; UNEP, 2010).

Malaysia's household recycling system is still at an early stage (Kalana, 2010). Moreover, the E-wastes generated by households are still beyond the control of the authorities. John et al. (2010) revealed that only 5% of the waste recycled by material recovery facilities in Malaysia was collected from households. It is apparent that E-waste recycling efforts from households is still very poor as there is no obligation among the householders to recycle (Tiep et al., 2013; 2015). To enhance the recycling practice among the public, DOE has launched the E-waste recycling program. Though some voluntary activities on a small scale have been seen (Shumon et al., 2014), the program appears to be rather disorganized. Hardly any announcement or information has been published regarding systematic management and handling of E-waste.

In many countries, studies have been conducted on public knowledge, attitude and practice regarding recycling to reveal that large-scale adoption of recycling depends on public attitude and behaviour (Echegaray & Hansstein, 2016). Shorofi & Arbon (2017), and Mangiri et al. (2017) also revealed that socio- economic characteristics have a great influence on public knowledge, attitude and practice (Shorofi & Arbon, 2017; Mangiri et al., 2017). Sivanthanu (2016) in his study on E-waste knowledge and attitude in India, stated that there is a significant relationship between public awareness and willingness to practice E-waste recycling. Socio-economic factors were also considered in evaluating the factors that affect E-waste recycling (Sivanthanu, 2016).

Besides socio-economic factors, individual knowledge is an influential factor to the success of recycling programs (Bortoleto et al., 2012). Public with higher education has a great influence on recycling rate as shown in the study of Wang et al., (2016). Kibert (2000) found a significant relation between gender and knowledge whereas the research of Rinmik (2010) showed otherwise. Tabernero et al. (2015), Saphores et al. (2012) and Siddique et al. (2010) observed a positive relationship between age and recycling rate whereas the research of Gaeta at al. (2017) and Jaoko et al. (2016) showed opposite results (Tabernero et al., 2015; Saphores et al., 2012; Siddique et al., 2010; Gaeta at al., 2017; Jaoko et al., 2016).

Recent research on E-waste management in Malaysia has focussed on developing a model or strategy for effective E-waste collection and recycling system (Jayaraman et al., 2019; Ismail & Hanafiah, 2019; Kang et al., 2020; Yang et al., 2019; Al-Rahmi et al., 2018; Jaibee et al., 2015; Alias et al., 2014), on related policies (Osman et al., 2016; Askari et al., 2014; Victor & Agamuthu, 2013), and treatment technologies (Othman et al., 2017; Norazli et al., 2015). However not much attention has been paid to studying the knowledge and practice of household E-waste management and recycling. Without proper awareness and willingness of the public to join the recycling efforts, government initiatives, whether through policy or campaign, will not be successful.

1.2 Problem statement

There are many challenges associated with the current E-waste management in Malaysia. The absence of a standard definition of E-waste, rapid growth of E-waste generation, and dominance of informal recycling sectors in E-waste trading are among the major challenges, followed by the lack of infrastructure to collect, segregate and handle the non-prohibited hazardous components of E-waste. The lack of awareness and knowledge on E-waste management and recycling amongst the public are also the major concern that need to be mentioned.

In Malaysia, MSW contains 3% - 5% hazardous waste which includes E-waste (Kasapo, 2010). The increasing use of electrical and electronic items by individuals has led to tremendous accumulation of E-waste. E-waste is chemically and physically distinct from municipal and industrial wastes as it may contain potential environmental contaminants (Robinson, 2009). Hence, E-waste consists of much complex material and most of the informal recyclers in developing countries lack necessary tools and technologies to handle it effectively without causing severe consequences to human health and the environment.

Knowledge is such an important tool that influences all phases of consumers' decision making and impacts public's recycling behaviour (Yoke et al., 2019; Alba & Hutchinson, 1987; Burcks, 1985). Insufficient knowledge influences their behaviour, often leading to confusion and to avoiding situations which they do not like (Yoke et al., 2019). Hence, it can be seen that very often, the reason behind public not adopting recycling behaviour is due to the lack of knowledge (Yoke et al., 2019). Thus, a good recycling knowledge should be able to increase the level of awareness and lead high public participation in recycling activities (Babaei et al., 2015).

Furthermore, socio-economic status of the public may play a very significant role in the success of E-waste management and recycling. Only a few studies have focussed on public knowledge and practice of E-waste management and recycling and their relationship with socio-economic groups (Mahat et al., 2019; Lin et al., 2018; Ali et al, 2017; Akil et al., 2015; Tiep et al., 2015; Malik et al., 2015; Akhter et al., 2014; Afroz et al., 2013; and Kalana, 2010) in Malaysia. It is hoped that the outcome from this study will help the authorities and municipalities to strengthen their existing policies and current campaigns/programs to adopt safer and sound recycling practices by targeting groups or areas with low recycling rates.

Although there have been a few initiatives provided by the authorities to recycle household E-waste, most of them have received lukewarm responses from the public. Therefore, a proper implementation of 3R technology is necessary to help change the current recycle scenario in the country. In view of this, there is a need to have a thorough understanding of this issue, to raise awareness and to ensure the involvement of all the stakeholders in society to participate in recycling.

1.3 Objectives of the study

The aim of this study is to assess the management and recycling of household E-waste practice among public in three cities (Putrajaya, Shah Alam and Petaling Jaya) in Malaysia. The specific objectives of this study are:

1. To analyse the current generation and disposal methods of household E-waste through Material Flow Analysis (MFA).

2. To assess the relationship between current level of knowledge and practice and their differences among public towards E-waste management and recycling.

3. To compare the existing household E-waste management and asses the public awareness on E-waste management in the three study areas.

4. To recommend improvements by addressing issues related to household E-waste management.

1.4 Study design

To achieve the main aims and objectives of this study, an overall study design had been conducted. The conceptual framework of the study is given below (Figure 1.1). According to framework, the research problems were notified to determinate the research objectives, and further the research method designed for data collection from the study areas. Field observation and sampling were performed before to conduct the questionnaire survey for primary data collection. The secondary data was collected from different journals, official websites, books and newspapers etc. The collected data was analysed using different analysing tools (SPPSS, STAN and MS excel). After that, it discussed briefly with suggesting the favourable recommendation for improvement according to the objectives.

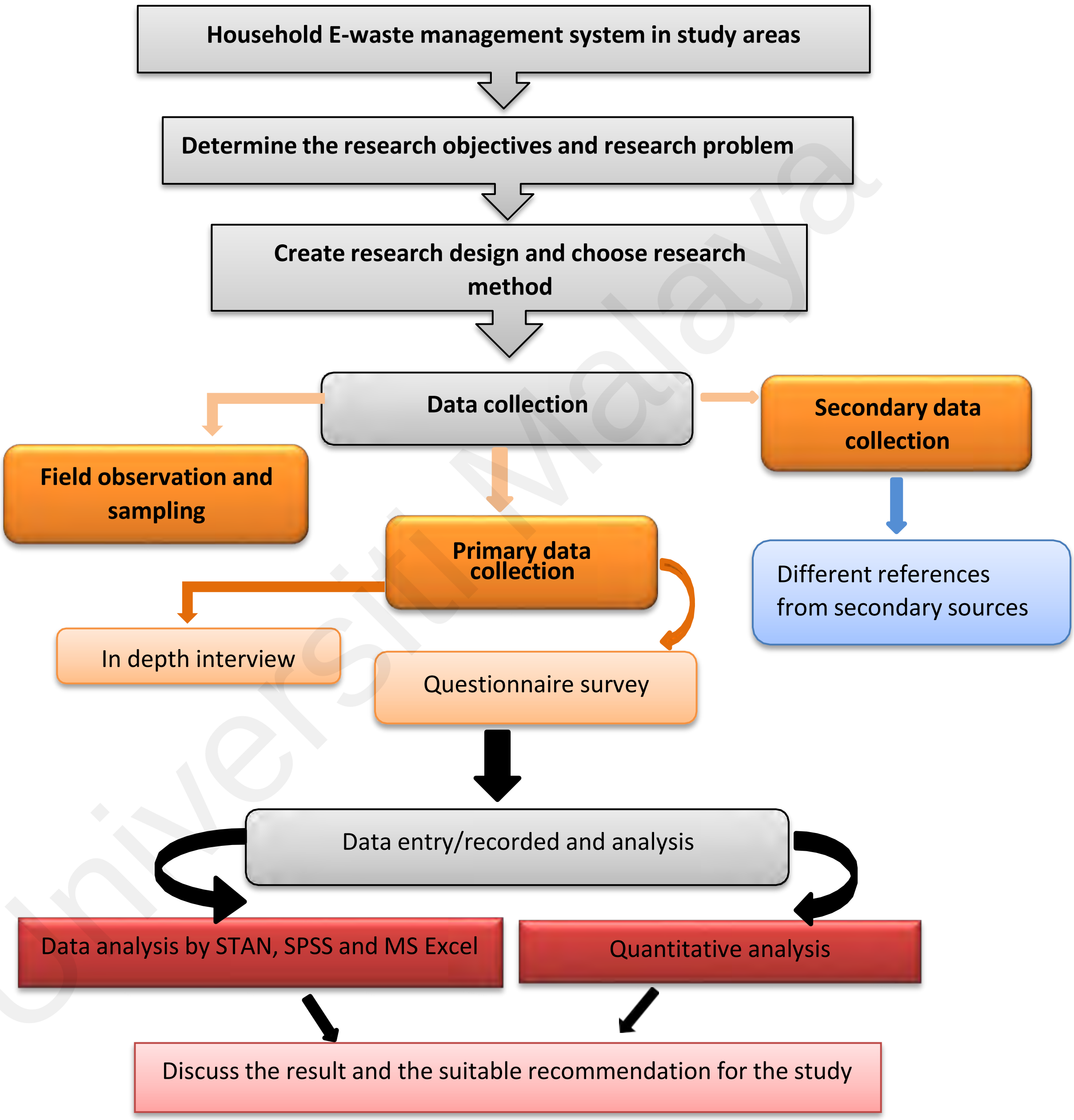

Figure 1.1: The conceptual framework of the study

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of E-waste

According to various sources, there is yet to be a standard definition of electronic waste or for short, 'E-waste' (Alias et al., 2014; Widmer et al., 2005; Terazano et al., 2006; Lepawsky and McNabb, 2009). However, E-waste is often misunderstood and classified only as computer and related IT equipment (Jaibee et al., 2015; Jain et al., 2011). Hence, very often, the definition of E-waste overlaps with that of the Waste from Electrical and Electronic Equipment (WEEE). Broadly defined, E-waste includes computers, cell phones and accessories, and discarded domestic appliances that use electricity such as air conditioners, microwave ovens, tube lights and other electronic consumer items at their end of life (EOL) (Alias et al., 2014; Sthiannopkao & Wong, 2012). On the other hand, Organization for Economic Cooperation & Development (OECD) describes E-waste as any appliances using an electric power supply that has reached its end of life (Suja et al., 2014; Alias et al., 2014). E-waste may contain hazardous substances such as lead, mercury, PCB, asbestos and CFC's that pose risk to human health and the environment (Askari et al., 2014). The Basel Action Network (BAN) defines E-waste as "a wide and developing range of electronic appliances, such as refrigerators, air-conditioners, cell phones, stereo systems and consumable electronic items to computers discarded by their users".

Several countries have developed their own definitions of E-waste but most have accepted the definition from a European Union (EU) directive (2012/19/EU) that defines E-waste as electrical or electronic equipment waste that includes all components, substances, and consumables that are part of the product at the time it is discarded (Osman et al., 2015; Suja et al., 2014; Mohan, 2008).

There is no specific definition of E-waste in Malaysian domestic regulations (Tiep et al., 2013). According to the guidelines for classification of used Electrical and Electronic Equipment (EEE) in Malaysia, E-waste is defined as "Waste from electrical or electronic appliances that consist of components such as accumulators, mercury-switches, glass from cathode-ray tubes and other activated glass or polychlorinated biphenyl-capacitors; and components contaminated with cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese or polychlorinated biphenyl" (Soo et al., 2013; DOE, 2010).

E-waste is commonly defined as 'used' electrical and electronic assemblies categorized as scheduled wastes (SW110) in the first schedule of Environment Quality (Scheduled Wastes) Regulation 2005, administered by the Department of Environment (DOE) (Tiep et al., 2015; DOE, 2008). But this regulation does not deal directly with E-waste from household. Recently a definition of 'Household E-waste' has been officially which states,

"Household E-waste" means electrical and electronic waste that comes from household, commercial, institutional, and other sources which because of its nature is similar to that from households (DOE, 2015).

2.2 Classification of E-waste

Sources of E-waste are divided into those from the industrial sector, as well as, the household and institutions. 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 (Suja et al., 2014).

E-waste has been categorized into three categories namely large household appliances such as refrigerators and washing machines, IT and telecommunication equipment such as PCs, monitors and laptops and consumer equipment such as televisions and DVD players (Jaibee et al., 2015; Pinto, 2008). Moreover, according to the EU directive council (2003) E-waste consists of ten categories because of its diverse composition (Table 2.1).

Table 2.1: E-waste categories according to the EU Directives (Suja et al., 2014)

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

More than 1000 different substances fall under the hazardous and non-hazardous categories, where iron (Fe) and steel constitute 50% of E-waste, followed by plastics (21%), nonferrous metal (13%) and other constituents. It also contains certain valuable components or base materials, especially Copper (Cu), Platinum group metals are included in electrical contact materials because of their high chemical stability and electrical conductance (Betts, 2008).

Three most used criteria or systems for categorizing waste are based on level of toxicity and risk, chemical composition, and source of generation.

1. The first system, based on level of toxicity and risk, divides waste into two groups of hazardous and non-hazardous waste.

2. The second system, based on chemical composition, divides waste into inorganic or organic/ microbiological waste; and

3. The third system, based on the source of waste generation, divides waste into municipal, industrial, clinical, agricultural, commercial, and construction and demolition waste (Williams, 2005).

E-wastes are chemically and physically distinct from municipal and industrial wastes as they may contain potent environmental contaminants (Robinson, 2009). The problem is exacerbated by the fact that E -wastes consist of complex materials and most of those who recycle on an informal basis in developing countries lack the necessary tools and technologies to handle them effectively to prevent severe consequences to human health and the environment.

2.3 Household E-waste management and recycling practices in the global context

2.3.1 Household E-waste management and recycling practices

Modern and advanced technologies that attract consumers with latest gadgets play a very large role in increasing the rate of E-waste generation. This is because when the products are no longer up to date, they are mainly discarded with very few are re-sold or recycled and most become undocumented E-waste. According to the latest estimation from Solving the E-waste Problem (StEP) initiative, the worldwide annual E-waste production was 48.9 million metric tonnes in 2012 and 65.4 million metric tonnes in 2017 (Seeberger et al., 2016; StEP, 2014). The estimated annual growth rate of E-waste was 5 to 10% globally (EPA, 2011).

The Global E-waste Monitor report (2017) claims that the global E-waste generation in 2016 was around 44.7 million metric tonnes (Mt) or 6.1kg per inhabitant(inh) in comparison with the 5.8 kg per inh in 2014 (Global E-waste Monitor report, 2017; Balde et al., 2017; Shevchenko et al., 2019). It is even more daunting that the estimated E-waste generation will exceed 46 million metric tonnes in 2017 and the expected 'growth' for 2021 is 52.2 million metric tonnes or 6.8 kg/inh with the annual growth rate of 3 to 4% (Global E-waste Monitor report, 2017; Balde et al., 2017; Shevchenko et al., 2019) (Figure 2.1). As per the Global E-waste Monitor report (2017), only 20% (8.9 Mt) of E-waste was reportedly collected and recycled in 2016 while approximately 1.7 Mt were dumped into residual waste by higher-income countries and likely to be incinerated or land-filled. The rest, i.e. 80% remain undocumented, dumped, traded or recycled under inferior conditions (Global E-waste Monitor report, 2017).

Figure 2.1: Global E-waste generation (Source: Global E-waste Monitor report, 2017)

By far the largest amount of E-waste (18.2 Mt) was generated in Asia, followed by Europe (12.3 Mt), the Americas (11.3 Mt), Africa (2.2 Mt), and Oceania (0.7 Mt) (Global E-waste Monitor report, 2017; Balde et al., 2017; Shevchenko et al., 2019). But according to Balde et al. (2017), the E-waste collection rate in Asia was only 15% due to its importation from other countries while it generates approximately 40.7% of global E-waste (Balde et al., 2017; Shevchenko et al., 2019). On the contrary, Oceania was the highest E-waste generator per inhabitant (17.3 kg/inh), with only 6% of E-waste being collected and recycled (Global E-waste Monitor report, 2017). Europe was the second largest generator of E-waste per inhabitant with an average of 16.6 kg/inh but it also had the highest collection rate of E-waste (35%) globally (double that of the Americas) and about one-third of Europe's total E-waste generation was managed and recycled properly

(Global E-waste Monitor report, 2017; Balde et al., 2017; Shevchenko et al., 2019) (Table 2.2).

Table 2.2: E-waste generation and collection per continent (Global E-waste monitor report, 2017)

Indicator	Africa	Americas	Asia	Europe	Oceania
Countries in region	53	35	49	40	13
Population in region (millions)	1,174	977	4,364	738	39
WG (kg/inh)	1.9	11.6	4.2	16.6	17.3
Indication WG (Mt)	2.2	11.3	18.2	12.3	0.7
Documented to be collected and recycled (Mt)	0.004	1.9	2.7	4.3	0.04
Collection Rate (in region)	0%	17%	15%	35%	6%

The E-waste flow was higher in developing countries, since 80% of E-waste was exported by developed countries to developing countries which were older and less eco-friendly, but re-usable (Kiddee et al., 2013). One of the main reasons is that the imported E-waste from developed countries can be processed at a low labour cost in developing countries (Shumon et al., 2014). The volume of cheap and short- lifespan electronic items are increasing in developing countries, leading to the high amount of E-waste generation, limited safeguard policy and unsafe disposal of electronic products. Strong evidences have been found regarding extensive occupational and environmental contamination in informal recycling sectors, particularly in China, India, Nigeria, Ghana, and other developing countries where E-waste recycling has boomed in the past two or three decades (Seeberger et al., 2016).

2.3.1.1 European Countries

The first E-waste management in European countries came into force in February 2003 under the WEEE Directive (Directive 2002/96/EC) where WEEE provided free-of-charge collection schemes to consumers to increase the recycling and reuse rate. It was revised to tackle the fast-increasing waste stream and came into effect in February 2014 (EC, 2018; DOE, 2018). It included the provision of national E-waste collection points and processing systems, which enable the proper disposal and treatment of E-waste (Global E-waste Monitor report, 2017). The revised WEEE Directive has broadened its coverage to include all electrical and electronic equipment (Agamuthu & Herat, 2015). Recently the European Commission (EC) adopted the “WEE package” which has a common methodology for the calculation of the weight and quantity of WEEE (EC, 2018).

Country wise, Germany generated 1.9 Mt of E-waste in 2016, which is the highest quantity in Europe; Great Britain and Russia generated 1.6 Mt and 1.4 Mt, respectively (Global E-waste Monitor report, 2017). Norway generated the highest quantity of E-waste per inhabitant in Europe (28.5 kg/inh), followed by Great Britain and Denmark (each 24.9 kg/inh) (Global E-waste Monitor report, 2017). However, other countries are still catching up with Northern Europe, whose collection rate, at 49%, is the highest in the world (Global E-waste Monitor report, 2017). The EU WEEE directive stated in their report that over the last three years, the annual collection rate of E-waste was 45% of the average volume of EEE (Electronic and Electric Equipment) placed on market (Shevchenko et al., 2019). Only a few countries managed to achieve a rate higher than 65% with the principality of Liechtenstein and Bulgaria having the highest E-waste collection rates (111.9% and 105.2%, respectively) (Shevchenko et al., 2019). Over the last few years, Scandinavian countries have shown a consistently increase in E-waste collection (Shevchenko et al., 2019; EUROSTAT, 2018).

Switzerland was the first country in the world to develop and implement a formal and well-organized E-waste management system for the collection, transportation, recycling /treatment, and disposal of E-waste (Shuman et al., 2014). The country’s legal and operational framework was based on the EPR (Extended Producer Responsibility) model, where manufactures and exporters are committed to the physical and financial responsibilities of an environmentally- sound handling, recycling, and disposal of E-waste (Shuman et al., 2014). In the case of Finland, the government encourages recycling of small household E-waste items by treating them differently from the large items. Focusing on interaction between the consumers and the local authority in Netherland, a significant reduction of small household E-waste items has been occurring in the household waste streams by introducing a pay-as-you-throw (PAYT) system (Agamuthu & Herat, 2015).

2.3.1.2 United States of America

According to statistics, the United States generated the highest amount of E-waste - 6.3 million metric tonnes in 2016 which works out to be 19.4 kg per/capita and the E-waste collection was 1.4 Mt, which is 22% of the total E-waste generation (Global E-waste Monitor report, 2017). The U.S. Environmental Protection Agency (EPA) (2016) stated that only 3 categories of electronic products data were included in the report, namely video products (CRT, TV's, VCR, DVD's and laserdisc etc.), audio products (audio systems, CD's, CD players, MP3 players, portable headset, home radios etc.) and information products (cordless/corded telephone, cell phone, answering machine, fax machine, desktop, laptop, tablet, e-reader, keyboard and mouse). Certain audio components were excluded due to unavailability of data. Thus, though the collection rate of the products was low, it would rise to 70%, if we consider other products not covered by EPA's scope (EPA, 2016). However, the recycle system of the U.S. varied according to states. This disparity occurs because U.S. still does not have an effective legislation on E-waste management of the national level, and individual states' legislation covers only approximately 85% of total US population (Global E-waste Monitor report, 2017). About 25 states, including Puerto Rico and Washington DC have consumer tack-back law and 17 states including New York have landfill ban legislation (mostly for CRT) while almost 15 states, including Alabama, Ohio, and Massachusetts, still do not have any legislation on E-waste (Global E-waste Monitor report, 2017).

2.3.1.3 Asian countries

In 2016, the total E-waste generation in Asia was 18.2 Mt, with China generating 7.2 Mt, the highest E-waste (by volume) in Asia and the whole world (Global E-waste Monitor report, 2017). Japan and India generated annually 2.1 Mt and 2 Mt of E-waste, respectively. The top four Asian giant economies, Cyprus (19.1 kg/inh), Hong Kong/ China (19 kg/inh), Brunei and Singapore (around 18 kg/inh each) had the highest E-waste generation in 2016 (Global E-waste Monitor report, 2017). About 72% of the total population in Asia is covered by national legislation on E-waste since the two most populous countries in Asia (China and India) have E-waste rules (Global E-waste Monitor report, 2017). In East-Asia, the official collection rate is close to 25%, whereas in other sub-regions, such as Central and South Asia, it is still 0%, likely leaving most of the E-waste to be managed by the informal sector (Global E-waste Monitor report, 2017).

2.3.1.3.1 India

India's electronics industry is one of the fastest growing industries in the world (Suja et al., 2014). And due to its burgeoning population, E-waste generation in India is estimated to exceed 260 million tons per year by 2047 (Rasmi & Fasila, 2017). The domestic generation of E-waste was 2 million tonnes in 2016, and in addition, the country imported E-wastes from the developed countries (Global E-waste Monitor report, 2017). The Indian Rajya Sabha Secretariat (2011) stated that India's Ministry of Environment and Forest (MoEF) chose to place legal liability for reducing and recycling on producers for the first time under the E-waste (Management and Handling) Rules 2011 which form part of the Environment Protection Act. According to the Extended Producer Responsibility (EPR) concept, it is mandated that producers are responsible for the collection and financing of systems. Further amendment to this rule came in 2015, which resulted in the E-waste (Management) Rule in 2016. The main feature of this rule is the EPR. The amended rule has provisions for Producer Responsibility Organisations (PROs) and Deposit Refund Scheme under EPR. The fact that India has adopted such a law is also a positive example of on-going discussions on regulation of electronic wastes in other developing countries (Global E-waste Monitor report, 2017; Bob et al., 2016) Most of the E-waste recycling operations in India are conducted by the informal sector though the formal sector is also getting involved in some major cities (Bob et al., 2016). More than 1 million people are involved in manual recycling operations, however, most of them lack awareness about the health and environmental impact of informal E-waste processing (Bob et al., 2016).

2.3.1.3.2 China

China plays a key role in the global EEE industry due to the high demand for electronic products by its expanding consumer base (Awasthi et al., 2016). Moreover, a high volume of E-waste is imported from other countries as well (Yamamoto, 2010). The total amount of E-waste estimated in 2016 was 7.2 million tonnes and expected to reach 11.7 million tonnes by 2020 and 27 million tonnes by 2030 (Zeng et al., 2017; Awasthi et al., 2016). This E-waste mainly includes air conditioners (26%), televisions (24%), computers (14%), refrigerators (12%), washing machines (7%), printers (9%) and fluorescent lamps (7%) (Li et al., 2015). In January 2015, a new Catalogue of WEEE Recycling (Batch 2) was issued and extended to cover another nine categories of WEEE. These 'new' WEEE categories will increase the amount of governmental scrutiny of the recycling industry (Awasthi et al., 2016; Zeng et al., 2015). China also has a strong EEE manufacturing industry which plays a key role in the refurbishment, reuse, and recycling of E-waste. Both formal, as well as, informal activities are involved in the collection system (Awasthi et al., 2016). The formal E-waste recycling industry has shown considerable growth in treatment capacity and quality. 18% of the E-waste generated has been documented to have been collected and recycled in recent years (Awasthi et al., 2016). The Chinese government has issued E-waste management related laws, regulations, standards, and technical guidance over the past decades but the various studies suggest that there is no specification about the implementation and enforcement (Bob et al., 2017).

2.3.1.3.3 Japan

Japan has formulated two laws concerning E-waste production. One is a Law for the Promotion of effective Utilization of Resources (LPUR), which focuses on enhancing measures for recycling goods and reducing waste generation (Chung & Suzuki, 2008). The other is a Law for Recycling specified kinds of Home Appliances (LRHA), which imposes certain responsibilities related to the recycling of used home appliances on manufacturers and consumers (Chung & Suzuki, 2008). LPUR covers personal computers and LRHA covers four electronic items, i.e. television, refrigerator, washing machine and air conditioner (Chung & Suzuki, 2008). The enactment of both the laws was direct responses to the scarcity of waste disposal site and increased cost of waste disposal (Bob et al., 2017). Consumers are required to work together with retailers to ensure the collection of their WEEE. A ‘recycle fee’ has been introduced as a pre-treatment fee, to which consumers need to agree with. Additionally, consumers are often charged with transportation fees, but this depends on the retailer’s discretion (Shuman et al., 2014; Suja et al., 2014; Chung & Suzuki, 2008). This is supported by Bo & Yamoto (2010) stating that the main mechanism of reinforcing E-waste recycling in Japan is collection through recycling tickets where recycling is carried out after full dismantlement at recycling plants (Bo & Yamoto, 2010). Both legislations place compulsory obligation upon manufacturers (Bob et al., 2017).

2.3.2 E-waste treatment technologies

2.3.2.1 Landfilling

Landfilling is a common disposal method for E-waste which cannot be reused or recycled. Most of the discarded electronic items either end up in landfills or are burnt openly. The process of landfilling must be carried out carefully. Trenches have to be made to bury the E-waste after excavating the soil. To collect and transfer the E-waste to the treatment plant, a clay or plastic leachate basin, made impervious with liner has to be installed first.

The number of landfills keeps increasing in both developed and developing countries as the world moves towards zero waste. The growing number of landfills without proper treatment facilities for E-waste is a major concern as it inadvertently gets mixed with other wastes (Kasapo, 2013; Kiddee et al., 2013). As noted previously, landfilling is not an environmentally sound technique to dispose of E-waste. Toxic chemicals (like lead, mercury, cadmium, and acids) from E-waste can percolate through the soil into ground water that can severely impact the environment and the nearby communities (Kasapo, 2013, Askari et al, 2014). The waste degradation in landfills is a very complicated process and it takes a long-time to be completed (Kasapo, 2013, EMPA, 2009). Regulations has been imposed in many European countries, Japan, South Korea, Taiwan and several U.S. states to prevent E-waste from being dumped to landfills (Shamim et al., 2015). Despite these measures, in the U.S. and Australia, almost half of the E-wastes is dumped into landfills. It is estimated that between 10% to 20% of discarded computers penetrate the landfills of Hong Kong (Askari et al, 2014; Sivaramanan, 2013).

2.3.2.2 Incineration

Incineration is a controlled combustion technique to treat E-waste in which waste is burnt at high temperatures (900-1000ºC) in a specially designed incinerator. While it is a very useful method to reduce the volume of waste, it is also associated with generating and dispersing pollutants and toxic substances through gas emission into the air (Kasapo, 2013; Chandroth, 2009). Heavy metals are the byproduct of this process and can bio-accumulate in the food chain especially in fish. Cu in the circuit boards and cables acts as catalysts for dioxin formation when flame retardants are incinerated. It generates highly toxic polybrominated dioxins and furans when exposed to low temperature. PVC that is commonly found in E-waste becomes highly corrosive when it is burnt and induces dioxin formation (Askari et al., 2014; Chandroth, 2009).

Currently, incineration is the most advanced WtE (Waste to Energy) technology with over 1400 plants in operation all over the world. The latest generation of incinerators are equipped with advanced air pollution control (APC) (Dang et al, 2019). Pyrolysis and gasification are the new advanced technologies. Pyrolysis operates in the absence of oxygen. Hence, without burning occurring, the substances are transformed into fumes, oils and charcoal. However, in the gasification process, the substances are converted into fume, ash and tar in the limited presence of air (Dang et al, 2019; Sivaramanan, 2013). Through these two processes, the formation of dioxin can be minimized and it is possible to integrate with high-efficient energy recovery devices. Despite this, it is still less applied on a commercial scale (Dang et al., 2019).

2.3.2.3 Acid bath

The acid bath method is used for extracting Cu from E-waste (Sivaramanan, 2013). The circuit board is soaked in sulphuric, hydrochloric or nitrite acid solutions for 12 hours to dissolve the Cu (Sivaramanan, 2013). Acid baths can also be used to extract gold and silver and also to dissolve lead. However, acid baths are not without dangers - the hazardous acid mixed with water finds its way to the local water resources (Sivaramanan, 2013).

2.3.2.4 Recycling and recovery

Recycling is the safest method which includes industry wide systems for E-waste collection (Sivaramanan, 2013). It includes a sequence of activities for the collection of used, unused, or reused waste items. It is done by sorting and processing the recyclable items into raw materials and manufacturing them into new product (Sreenivasan et al., 2012). The first step in the process of recycling is called manual dismantling. This enables the recovering of valuable, reusable and recyclable components like glass, plastic, iron, and precious metals, as well as, hazardous components like CFCs, PCB, Hg switches, LCD, CRT-glass, which need to be treated separately (Jaibee et al., 2015). After carrying out the dismantling process, the dissembled equipment can be sorted easily by reclaiming the reusable parts and reducing the separation effort in the recovery process (Kasapo, 2013). For reducing the size of the recyclable materials, shredding can be performed as part of the mechanical shredding process. For example, to remove the ferrous metals from the shredded E-waste magnetic belt, for non-ferrous metals (aluminum, Cu). Eddy-current separation is generally used while for plastics, it is usually gravity or density separation (Jaibee et al., 2015; Kasapo, 2013).

For the material recovery or extraction process, pyrometallurgical and hydrometallurgical processes are commonly used in the formal industry. Pyrometallurgical process happens to be a conventional method to recover non-ferrous metal, precious metals and other metals from E-waste. It has number of treatment options like smelting in a plasma arc furans or blast furnace, sintering, melting and a high temperature gas reaction, though all are supported in thermo-physical separation phase of the metal. A physical sorting and dismantling are required for industrial E-waste pyrometallurgical process before the smelting process to maximize the energy efficiency per tonne of produced value metal (Jaibee et al., 2015; Kasapo, 2013; Ilkanoon et al., 2018). Hydrometallurgical processes consist of a series of acidic and caustic leaching that requires small sized grains of solid materials to increase the yield of metals. Electrolysis technique is used for metal recovery too and it is a special refinery process which is applied if any impurities are found in the waste (Jaibee et al., 2015; Kasapo, 2013). Cui & Zhang (2008), in evaluating both techniques, stated that hydrometallurgical processes have certain benefits and merits in comparison to the pyrometallurgical process in terms of point of predictability and control. On the other hand, the pyrometallurgical process is economical and eco-efficient compared to the hydrometallurgical process from the perspective of maximizing the recovery of precious metals (PMs) (Cui & Zhang, 2008; Ari, 2016). Hydrometallurgical operations in the E-waste recycling industry are only functioning at a limited commercial scale because of the lack of improvement of other metal extraction techniques (Cui & Zhang, 2008; Ilkanoon et al., 2018; Ari, 2016).

2.3.3 Trans-boundary movement and international regulation on E-waste management

The high volume of E-wastes generated from different countries and regions annually are not treated within the countries themselves. Despite the existence of agreements and conventions for controlling trans-boundary traffic and trade of E-waste, a large portion of WEEE is illegally exported from developed countries (USA, Canada, Australia, Europe, Japan and Korea) to developing countries like China, India, Bangladesh and Pakistan where the disposal facilities are cheaper and environmental standards and laws are poorly enforced or less strict (Alias et al., 2014; Shamim et al., 2015; Ilankoon et al., 2018) (Figure 2.2).

Figure 2.2: Trans-boundary movements of E-waste (Source: Laha,2015)

However, it should be noted that the recycling and recovery activities are performed by the informal sectors in most receiving countries (Alias et al., 2014). Within the East Asia and Pacific region**,** China is the main destination for illegal export of E-waste despite having stringent laws since 2000 (Ongondo et al., 2011). It is estimated that 80% of E-waste is shipped to Asia (including India) where 90% of it exported to China (Ongondo et al., 2011). Meanwhile, the existence of restriction to export certain hazardous substances related to electronic devices, created an alternative trans-boundary route to the countries of West Africa (StEP Annual Report, 2015/16). According to Olowu (2012) and Kasapo (2013), it is estimated that about 40% of E-wastes from Europe is solely exported to Asia and Africa. However, other estimations suggest that 25-75% of second-hand goods are shipped into Africa and about 75% to 95% of non-functioning computers were exported to Nigeria (Kasapo, 2013; Olowu, 2012). Besides, Greenpeace has noted that E-waste of common electronic brands of USA, Japan, and Europe namely Sony, Philips, Nokia, Microsoft, Canon, Dell and Siemens have been shipped to Ghana (Kasapo, 2013).

2.3.3.1 International legislation and initiatives in E-waste management

Some international legislation and initiatives have been summarised with key features that have emerged for E-waste management by some international organisations and agencies (Ilankoon et al., 2018). Most of these regulated initiatives have been adopted by certain European countries (Shamim et al., 2015).

2.3.3.1.1 Basel Convention

The Trans-boundary movements of hazardous wastes and the disposal of global WEEE are controlled by the Basel Convention. The main aim of this convention was to protect the environment and human health from the adverse effects of hazardous and toxic waste generation, its management, trans-boundary movements and waste disposal (Agamuthu & Victor, 2011). It was enforced on 5th May 1992 and till 2010 the convention had been ratified by 178 nations. At the sixth meeting of the conference of parties (COP), convened in 2002, the issue of E-waste recycling was recognized as one that needed urgent and in-depth supervision, especially in the Asia Pacific regional countries (Shamim et al., 2015). The Mobile Phone Partnership Initiatives (MPPI) were launched for (i) better product stewardship, changing consumer behaviour, promoting best reuse, refurbishing, material recovery, recycling and disposal and (ii) political and institutional support for environmentally sound management (Agamuthu & Victor, 2011). At the ninth meeting of COP (2006), the Nairobi declaration on the Environmentally Sound Management (ESM) for Electrical and Electronic Waste was adopted by all parties to strengthen the program further. The secretariat of the Basel Convention developed a pilot project on ESM of E-waste products in consultation with some selected countries and regional Centers like Basel Convention Regional Centre in China (BCRC China), Basel Convention Regional Centre for South East Asia (BCRC-SEA), and Secretariate of the

Pacific Regional Environment Program (SPREP). In the Basel Convention, E-wastes are classified under ANNEX VIII (A1180, A1190, A1150) and ANNEX IX (B1110) (Shamim et al., 2015; Herat & Agamuthu, 2012; BAN, 2012; Agamuthu & Victor, 2011).

In June 2008, Partnership for Action on Computing Equipment (PACE) was adopted to provide a new and innovative approach to address the issues related to used and End-of-Life (EOL) electronic devices. A technical guideline on transboundary movements of E-waste, in particular to distinguish between E-waste and non-E-waste was released by the Basel Convention in July,2011 which is still in draft form (http://basel.int/cop10/data/COP10-INF/documents/i05e.pdf) (Agamuthu & Victor, 2011). The second hand WEEE items and E-waste scrape which are exported for recycling are not regulated by the Convention because it cannot ban a country's right to export E-waste entirely (Alias et al., 2014; Shamim et al., 2015; Ilankoon et al., 2018). Hence, the exportation of secondhand electronic devices from developed to developing countries that have not ratified the convention continues through legal loopholes and concealed operations. Annually two million secondhand televisions are exported to the Philippines, of which approximately 400,000 units are shipped from Japan (Kiddee et al., 2013). As a result, informal recycling and open burning activities have intensified in nearby dumpsites in Manila (Kiddee et al., 2013).

2.3.3.1.2 The European Unions' WEEE Directive

The first WEEE directive was enforced in February 2003 to increase the rate of E-waste recycling and reuse. This created a collection scheme for consumers where they could turn in their WEEE free of charge. Despite having extensive legislation, in just a few years of implementation, it faced some difficulties. According to the directive, less than half of collected E-wastes was treated and reported. The European Directive PE-CONS 2/12 enforced on 15 August 2018 categorized all EEE into six groups instead of 10 categories as E-waste processing is facing problems (EU Directives, 2020; Shamim et al., 2015). Under the second directive legislation (RoHS Directive-2002/95/EC), there is a restriction on using some hazardous substances in EEE like heavy metal, PBBs, and PBDEs. These should instead be substituted with safer alternatives (European Commission, 2017b).

2.3.3.1.3 The StEP (Solving the E-waste Problem)

The StEP initiative started in 2004 at Berlin with the aim to evaluate the issues related to E-waste and create a dialogue to discuss about it. The StEP is led by The Institute for the Advanced Study of Sustainability of the United Nation University (UNU) and has 51 members from amongst businessmen, organizations, governments, non-governmental organizations and academic institutions from all around the world. The focus of the StEP initiative is on the areas of policy, redesign, recycle, reuse, knowledge management and capacity building (Kasapo, 2013; Nnorom & Osibonjo, 2008; StEP, 2015/16; 2018; Ilankoon et al., 2018).

2.3.3.1.4 The G-8 3Rs initiative

The G-8 3Rs initiative was introduced by Japan in 2004 during G-8 summit and was formally launched in 2005 at the Tokyo Ministerial Conference on the 3R initiative. The objectives are to shift the global consumption and production pattern towards the development of a sound material- cycle society (EPA, 2016; UNCRD-3R Initiative, 2017).

2.3.3.1.5 National strategy for E- waste stewardship (NSES)

In July 2011, a tri-organizational taskforce implemented the 'National Strategy for E-waste Stewardship' (NSES), a unified framework to evolve electronic stewardship as the basis of design improvement of electronic devices. It meant to enhance the management of discarded and used electronic equipment in a sustainable manner, to protect human and environment health from harmful effects that are associated with improper handling and unplanned disposal of E-waste, and to promote new and innovative technologies in the future (Shamim et al., 2015; Ilankoon et al., 2018).

2.4 Household E-waste management in Malaysia

Malaysia is a fast-developing country with a population of 32 million (DOSM, 2017). Therefore, by 2020, Malaysia is destined to become a major electrics and electronics producer and consumer. This will in turn lead to E-waste generation (Osman et al., 2015) which is most unfortunate as E-waste management in Malaysia is still in its infancy (Alias et al., 2014). Since household E-wastes mostly end up in the informal sector, no proper data has been captured by the authorities on the actual quantity of household E-waste generation in Malaysia. Based on a published project report on an inventory of E-waste in Malaysia, funded by the Ministry of Environment Japan (MOEJ), the total amount of discarded E-waste was projected to increase by an average of 14% annually, and by the year 2020, a total of 1.17 billion units or 21.38 million tons of E-waste will be generated (DOE, 2009; Haron, 2015). Televisions and mobile phones are among the largest contributors of E-waste in terms of volume and units (Figure 2.3).

On the contrary, based on the Malaysia E-waste inventory project report 2008, the amount of E-waste generation predicted is 1,120,000 tons by 2020. The amount of E-waste generated by Malaysia in 2014 was 232,000 metric tonnes (StEP, 2014). This amount showed an increment of only 12.065 metric tonnes as compared to 2008 (Babington et al., 2010). Therefore, it is not possible to reach the estimated total of 690,827,529 metric tonnes of E-waste within 14 years, that is, between 2006 and 2020 (Osman et al., 2015).

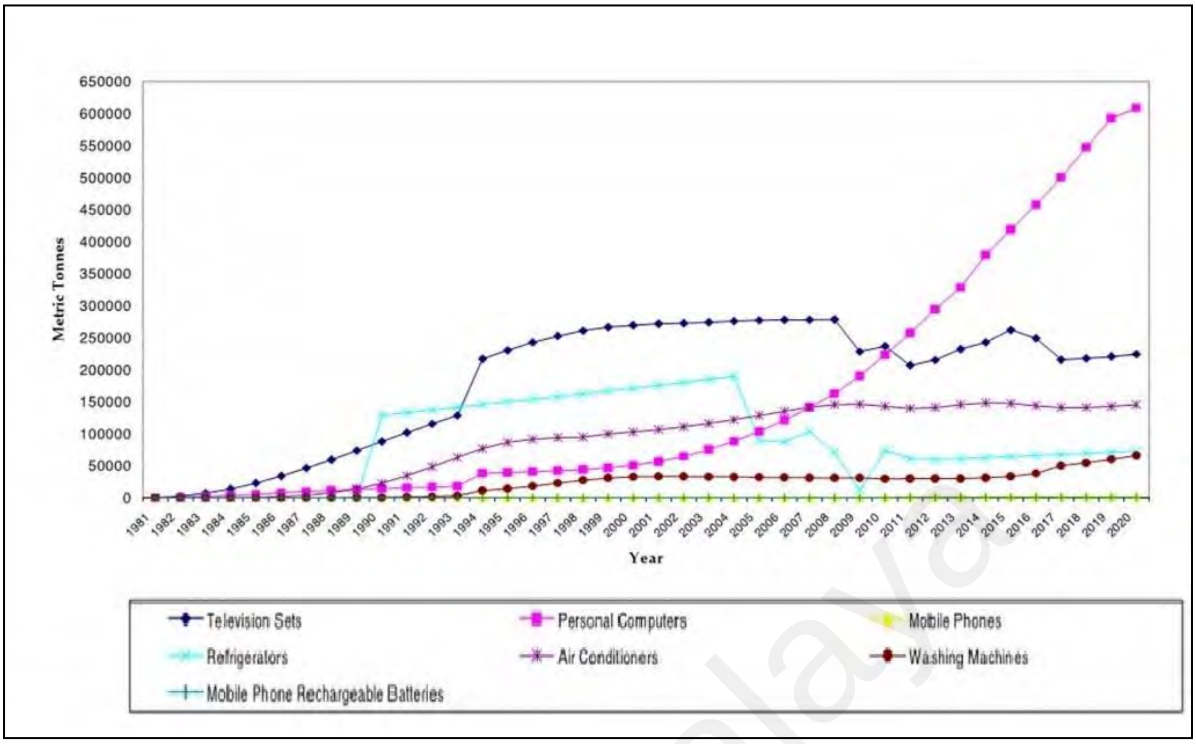

Figure 2.3: Future projection of WEEE generation in Malaysia (in metric tonnes) (DOE, 2017)

Currently, there is no proper segregation mechanism or disposal system to encourage the public to recycle and discard E-waste. As such, most of the E-waste ended up in landfills. Besides that, many existing facilities are unable to process E-waste due to the constraints in space and handling (EQR, 2006). The continued generation of E-waste over time, together with a lack of structured mechanism of institutional framework and inadequate infrastructure, results in improper E-waste management (Kalana, 2010). In Malaysia, although E-waste comes from industrial, household and business centres, a proper E-waste management has only been implemented in the industrial sector (Osman et al., 2015; Kalana, 2010; Jaibee et al., 2015).

In 2009, DOE had licenced 351 scheduled waste off-site recovery facilities which include 138 full material recovery facilities (MRFs) scattered all over the country (Shuman et al., 2014). E-waste is currently collected by different means from households and sent to three different streams, namely partial and full recovery facilities, and informal recycling. Partial and full recovery facilities are the formal streams that treat wastes. These facilities prevent unwanted mixing and landfilling with other wastes. On the other hand, informal recycling streams do not have proper treatment facilities for hazardous wastes (Shuman et al., 2014) (Figure 2.4). DOE has also placed hundreds of recycling bins in public places nationwide with the aim of educating and enhancing public awareness about proper disposal and recycling of E-waste (Alias et al., 2014).

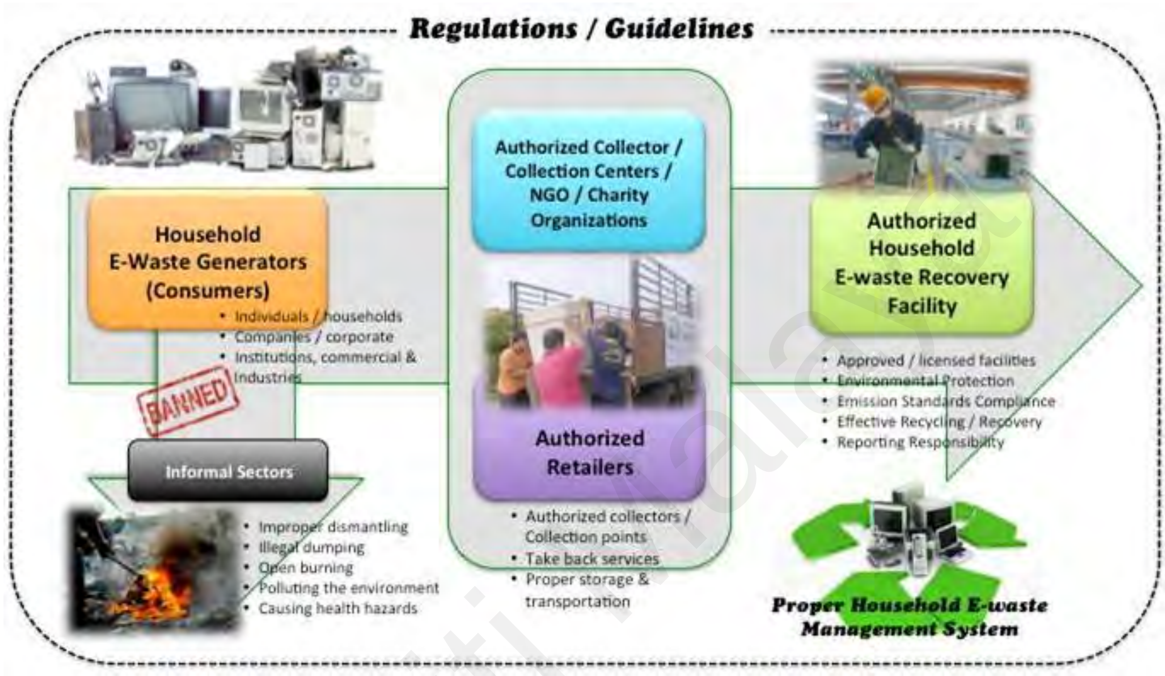

Figure 2.4: Current E-waste management system approved by DOE (DOE, 2018)

2.4.1 Laws and Regulation of E-waste management in Malaysia

Unlike handling traditional municipal wastes, managing E-waste is very different (Duan et al., 2011). Policies for management differ from the policies which apply to traditional waste types because E-waste stream contains highly toxic substances, which endangers both health and environment (Guo et al., 2010; Askari et al., 2014). In Malaysia, all environmental issues are regulated by the DOE (Jaibee et al., 2015; Osman et al., 2015). The main roles of DOE are to prevent, control and abate pollution through the enforcement of the Environmental Quality Act 1974 (EQA1974) (Bakri et al., 2004; Osman et al., 2015). Under EQA 1974, the Environmental Quality (Scheduled Waste) Regulation 1989 (EQSWR, 1989) applies the ‘cradle to grave’ concept of waste management where the generation, storage, transportation, treatment and disposal of scheduled wastes are strictly regulated (Shahnor et al., 2011). The EQSWR (1989) was later replaced by the Environment Quality (Scheduled Waste) Regulation 2005 where categorization of scheduled waste was based on the types rather than sources or origin of the waste (Arora, 2008; Kalana, 2010; Shahnor et al., 2011).

E-waste which is categorized under SW110, are already regulated by the Environmental Quality (Scheduled Wastes) Regulations 2005. But this regulation does not deal with E-waste from households (Jaibee et al., 2015; Osman et al., 2015). Ever since E- waste has been analysed as containing hazardous substances such as lead, mercury, and cadmium, it has become an issue because of its inappropriate system of management (Kalana, 2010). That is why all disposal of E-wastes is strictly prohibited from landfills or waterways, and all recycling, recovery and disposal activities must only be performed in environmentally sound manner or in prescribed premises (Alias et al., 2014; Suja et al., 2014). In 2008, a set of guidelines acknowledged as the Guidelines for the classification of Used Electrical and Electronic Equipment, which identified the characteristics and components of E-waste was published by DOE (DOE, 2008; Osman et al., 2015). Currently these guidelines only distinguish between E-waste and non-E waste. It also specifies the export and import criteria of used electrical and electronic components that are not categorized as non-E waste. Waste categorized as E-waste is not allowed to be imported without the approval of the Basel Convention (DOE, 2008; Kalana, 2010; Jaibee et al., 2015). However, these guidelines do not provide any information on how to manage E-waste at the end of the products' lifespan (DOE, 2008; Kalana, 2010).

2.4.2 Current initiatives about managing Household E-waste in Malaysia

Malaysia has also implemented the extended producer responsibility (EPR) concept which was initiated voluntarily by a few multinational electronics firms such as Motorola, Nokia, Dell, Apple, and Hewlett-Packard as part of their corporate responsibility policy

(Alias et al., 2014; Agamuthu, 2011). Besides that, DOE has established a collection and recycling system for household E-waste. For a start, the public can send their E-wastes, limited to used mobile phones, mobile phone batteries and their accessories, computers and their accessories, as well as television sets to the E-waste collection centres. The solid waste concessionaries or local authorities are responsible for managing the collection from these E-waste centres (JICA, 2018; DOE, 2012; Tiep et al., 2015).

Another initiative involved a pilot E-waste management and awareness program which was set up by federal government administrative centre of Putrajaya to collect end-of-life mobile phones, batteries and accessories. It involved setting up collection bins in government offices, universities, shopping complexes and telecommunication companies (Arora, 2008; Babington et al., 2010). Based on previous initiatives, JICA carried out a pilot project in Penang from 2011 to 2013, known as 'The project for Model Development for E-waste collection, segregation and transportation from households for recycling" in collaboration with DOE. The aim of the project was to develop an E-waste collection model for household items that could be used to make a countrywide drive after test running the model (Shumon et al., 2014). Based on this, DOE is currently in the midst of establishing a proper management mechanism of household E-waste, including legal framework and guidelines for development which aims to regulate the involvement of stakeholders in the entire flow of E-waste. To this end, DOE and JICA initiated another Technical Cooperation (TC) project from August 2015 through January 2018 to develop nationwide regulatory framework and mechanism to channel household E-waste to formal collection and recycling.

Currently, E-waste Alam Alliance is a follow-up of a pilot project of JICA and DOE where a framework of managing E-waste attempted. The project was carried out in six states in Malaysia namely Perak, Selangor, Federal Territories (Kuala Lumpur and Putrajaya), Melaka and Johor (DOE, 2013). According to Osman et al. (2015), through this initiative, the formal framework and management for hazardous E-waste will be developed. The three drafted guidelines in this project are: (i) on collection, storage, handling, and transportation of household E-waste in Malaysia, (ii) reporting for household E-waste recycling and (iii) household E-waste recycling (Figure 2.5).

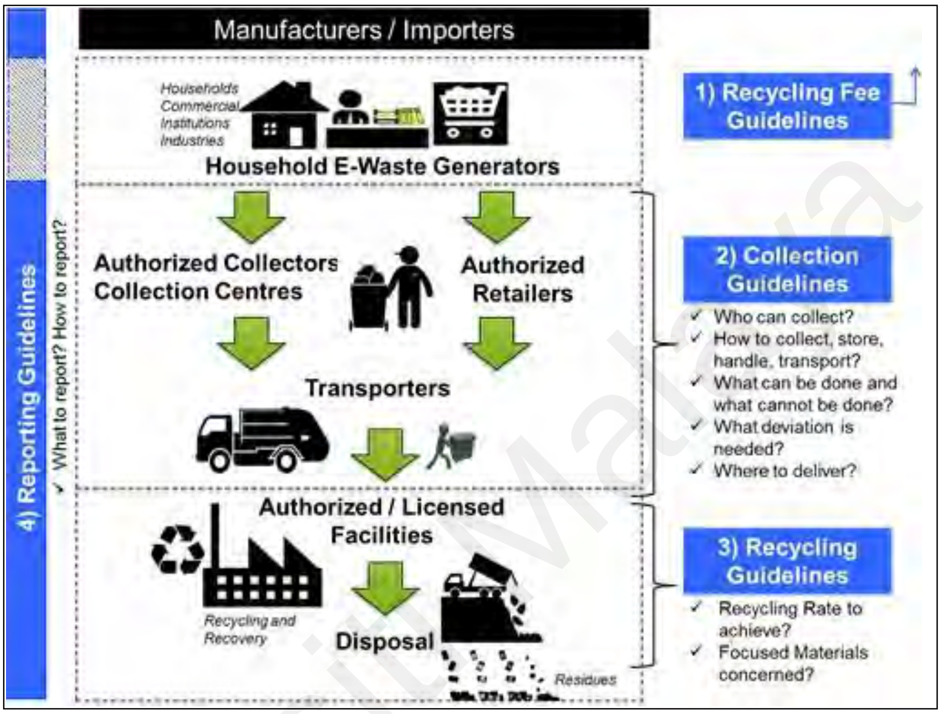

Figure 2.5: Guidelines framework on regulation of household E-waste management and recycling (DOE, 2017)

There have been two pilot projects carried out since August 2017 under these three guidelines. The project's new mechanism for household E-waste collection and reporting will come under the first and second guidelines of the drafted regulations. Local companies like T-Pot Recycling Sdn Bhd., Shan Poornam Sdn Bhd, SWM Environment, Alam Flora Sdn Bhd. and international companies like Toshiba are participating in this project and in a similar one on household E-waste recycling (DOE, 2017).

On the other hand, a substantial number of EEE producers in Malaysia have also initiated a small-scale program known as the Take Back Program (TBP) to reduce the number of WEEE from being discarded in landfills. In fact, the proper disposal program for E-waste was promoted by the Ministry of Science, Technology, and Innovation

(MOSTI). Some of the major EEE manufacturers like Panasonic Malaysia, Motorola (M) Sdn. Bhd, Nokia Malaysia, Dell Malaysia, and HP-Compaq have already associated with this program (DOE, 2009). However, these programs and facilities have been found to be insufficient in their ability to reach the public and their effectiveness remains elusive. The fact remains that many people are still storing their E-waste at home. It is believed that a major concern about the Take Back Program in Malaysia is the availability and accessibility of such programs. Generally, the public is not well informed of such programs by the companies and the restriction to certain areas only. Hence, members of the public who intend to participate in the program may be hindered due to lack of information and convenience (Tiep et al., 2015). Though E-waste recovery systems are widespread in many developed countries, they have only recently been implemented in Malaysia. There are currently 153 E-waste recovery facilities in Malaysia with 128 facilities conducting partial recovery, and the remaining 25 performing full recovery (Shumon et al., 2014; The Star, 2012). These recovery centres collect and treat computers, audio-visuals, mobile phones, white goods, and other products that may contain valuable elements and substances suitable for reclamation. Most of Malaysia's E-waste management is centred in the state of Penang (Shumon et al., 2014).

However, most of the projects received lukewarm response from the public due to their poor awareness of E-waste management issues and their consequences (Hicks et al., 2005; Pinto, 2008; Abul Hasan, 2010; Babington et al. 2010; Kalana, 2010; Lim and Haw, 2011). The Extended Producer Responsibility (EPR) has been emphasised globally to tackle the E-waste problem. Many developed countries have successfully implemented EPR with varying models, while developing countries which are trying to follow the same footsteps are facing some challenges. Most of the Tack Back schemes around the world concentrate only on computers and mobile phone (Agamuthu & Herat, 2015). According to Resmi & Fasila (2017), recycling and reuse through refurbishment can also be a systematic technique to deal with E-waste. Certain devices like mobile phones and PCs are discarded due to advancement in technology. Such devices can be used again with a touch of renovation, provided they meet the quality standards. Refurbishment can help provide a secondary market, selling renovated products at a lower price (Resmi & Fasila, 2017).

2.4.3 Trans-boundary movement in Malaysia

Malaysia has been one of the parties of the Basel convention since 1993 where the export and import of E-waste is strictly prohibited (Suja et al., 2014). Therefore, as a requirement of EQA1974, before the shipping consignment enters into Malaysia, a prior written approval is needed from the Director General of DOE for the trans-boundary movement of scheduled waste. The E-wastes are enlisted as code A1180 and code A2010 under list A of Annex A2010 under the list A annex VIII (DOE, 2010; Kasapo, 2013; Alias et al., 2014). The prescribed policy for Used Electrical and Electronic Equipment (UEEE) are as follows (DOE, 2010):

I) Under the provision of the Environmental Quality (Scheduled Wastes) Regulation 2005, if the used electronic item does not match the definition, it is not contaminated with any scheduled waste (SW 110).

II) The age of the equipment and its' components must be five (5) years or less from the date of manufacturing.

III) Importation is prohibited for the purpose of material recovery and disposal.

IV) The cooling equipment should not be contaminated with CFCs and HCFCs.

V) The UEEE should be protected from damage during transport, loading and unloading.

VI) The receiving facility must fulfill the EQA, 1974 and its relevant regulations.

Malaysia will only allow exportation of hazardous material from other countries if the local recovery facilities are not able to carry out such activities (Othman et al., 2017;

DOE, 2008). However, the signatory status did not stop Malaysia from importing E-waste for recycling and recovery activities as like China, India, Pakistan, Vietnam, Nigeria and Ghana, because Malaysia is the transit point for global movement of E-waste (Alias et al., 2014). Moreover, Malaysia too is the end point for some trans-boundary movement of E-wastes.

2.5 The impact of improper E-waste management

2.5.1 The environmental impact

A recent study in Iran showed that almost 10,000 tonnes of imported household batteries were discarded with MSW and dumped in sanitary landfills where high percentages of mercury, cadmium, lithium, nickel, arsenic, and other toxic and heavy metals were observed (Ferronato & Torretta, 2019; Zand & Abduli, 2008). Severe impact on the atmosphere is also caused by the disposal of heavy metal in landfills (Zeng et al., 2017; Pan & Li, 2016). E-waste can be disposed in landfills through incineration process, but the practice is considered as conviction (Zeng, et al., 2017). The consequences lead to the release of toxic gases into the atmosphere (Zeng et al., 2017; Azad et al., 2017; Shamim et al., 2015; Kiddee et al., 2013). In developing countries, E-waste is disposed of mostly in open dumpsites and burnt without following proper guideline (Mmereki et al., 2016). The concentration of heavy metal was clearly observed in well water and soil during a study of the open dumpsites in Lagos state (Nigeria) and Tijuana (Mexico) (Olafisoye et al., 2013; Nava-martinez et al., 2012). In Lagos, the presence of Pb and Ni was found at significant levels in the well and tap water which correlates with metal input from leachates, resulting from the dumping of WEEE in the dumpsites (Olafisoye et al., 2013). It should be noted that the concentration of heavy metal decreased when the sampling distances increased from the dumpsites (Olafisoye et al., 2013).

Many studies have encountered the presence of toxic substances in the soil, water, air, and vegetation of nearby recycling sites. Findings shown that agricultural soil at nearby

E-waste processing sites in China, was highly contaminated with heavy metals (the particles migrated through air) (Fu et.al., 2008), PDBEs (Wang et al., 2011), and PCBs and PDBEs (Fu et al., 2011). These contaminants were also found in vegetables (Wang et al., 2011) and animals (e.g. apple snails) (Fu et al., 2011).

The informal and open burning in the recycling process of plastic E-waste releases harmful dioxin, brominated flame-retardants, and furans (Zeng, et al., 2017; Seeberger et al., 2016). Solder is removed from the circuit boards through open burning or soaking them in acid baths to strip them for gold or other metals (Shamim et al., 2015). These acid baths are then dumped into surface water which severely impacts the fresh water ecosystem (Shamim et al., 2015). Despite the banning of E-waste for its uncontrolled acid leaching, and being considered as illegal in Guiyu, China, its presence was identified during field sampling. As a result, the rivers have been considerably ‘enriched’ with heavy metals (Cd, Co, Cu, Ni, Pb, and Zn) (Shamim et al., 2015). Pradhan & Kumar (2014) revealed in their study that heavy metals were found in the surface soil, local ground water, and native plants of the informal E-waste processing area in Mandoli, Delhi, India (Pradhan & Kumar, 2014).

Some pollutants such as PCDD/Fs, PCBs, PBDs, PAHs, cadmium, chromium, lead, and arsenic have been identified in atmospheric particles in and around the E-waste dismantling areas in China (Shamim et al., 2015). In Vietnam, the concentration level of PCBs and PDBEs in the air of residences within the E-waste processing area was observed to be much higher (100-1800 and 620-720 pg/m^3) than the control area (Tue et al., 2012).

2.5.2 Health impact

Most people are unaware about the negative impact of the rapidly increasing use of electronic devices (Rai, 2012). Many researchers have found the association between E-waste exposures and the higher level of chemicals and metals in human-derived biological samples (Shamim et al., 2015; Wen et al., 2008). A large number of the studies have succeeded in drawing a link between human health impact and the contribution of pollutants from E-waste processing (Shamim et al., 2015). As more E-waste is placed in landfills, exposure to environmental toxins is likely to increase, resulting in elevated risks of cancer and developmental and neurological disorders (Bhutta et al., 2011).

Informal recycling sectors in developing countries often use convenient locations to recycle E-waste with simple tools and methods (Seeberger et al., 2016). The pollutants generated from informal E-waste processing and handling brings about toxic and genotoxic effect on the human body. It threatens not only the health of the workers but also the future generation (Quiang, 2009). It has been reported that more than 75% of people involved in E-waste activity are suffering from one or the other diseases that can be directly attributed to the unsafe recycling of E-waste (Sing et al., 2019). Individuals who directly engage with E-waste recycling with poor protection bear the consequences of skin contact with harmful substances, the inhalation of fine and coarse particles and congestion of contaminated dust (Seeberger et al., 2016; Shamim et al., 2015; Chi et al., 2011).

The chemicals that are released from E-waste into the environment can accumulate in the human body through different ways. Contaminated air and dust inhalation are believed to be one of the most important pathways. Major research findings include the potential adverse health effect by E-waste exposure leading to disruption of thyroid hormones (Shamim et al., 2015; Zheng et al., 2010), reduction of lung function (Zheng et al., 2013; Shamim et al., 2015), bring about adverse pregnancy outcomes (stillbirth, preterm birth, low birth weight, lower Apgar scores), reduced child weight and height (Yang et al., 2013; Shamim et al., 2015), and impaired neurodevelopment (neonatal behaviour, child temperament, and cognitive function) (Seeberger et al., 2016; Shamim et al., 2015), mental health issues, cancer, and end organ diseases (Shamim et al., 2015; Grant et al., 2013; Xu et al., 2012).

Heavy metal in blood due to chromium exposures in neonatal, impact the thyroid hormone, and lungs of children. Research showed that about 80% of children in Guiyu, China suffers from respiratory diseases have high risk of leukaemia and high concentration of lead in blood (Lucier & Gareau, 2019; Shamim et al., 2015; Tsydenova et al., 2011; Sepulveda et al., 2010). Neurological, respiratory, digestive, and bone problems are very common among the workers and their families (Lucier & Gareau, 2019). Due to the existence of numerous recycling sites in the Guiyu region, the levels of chromium concentration are very much higher which impacts on the health of new-borns and children who reside in the adjacent areas of recycling sites (Xijin et al., 2015). Zheng et al. (2013) stated that children who live in E-waste processing sites in China are affected by lower pulmonary functions and oxidative damage due to Mn and Ni exposure. An increasing concentration of heavy metals was observed in the soil adjacent to an informal recycling shop in Bangalore, India (Sing et al., 2019). As a result, the presence of heavy metals was reported in the hair sample of the workers (Sing et al., 2019; Zheng et al., 2013; He et al., 2009). High concentration of Fe, Sb, Pb, and arsenic in urine were found among workers of an E-waste processing site in India (Asante et al., 2012). The average levels of PCBs reached 1700 ng/g lipid weight in human milk samples collected from women living nearby a solid waste dump in Kolkata, India, while in the reference site, the concentration was as a low as 60 ng/g lipid weight (Devanathan et al., 2012).

2.6 Public behaviour regarding E-waste management and recycling

2.6.1 Knowledge and practice

Schratz (2016) and Babaei et al. (2015) stated that knowledge should be combined with acquiring experiences and a basic undertanding or awareness of the environmental problems. Knowledge also includes facts, information, description or skills acquired through experience or education (Schratz, 2016 ; Babaei et al., 2015). On the other hand, practice is an action that is based on public knowledge and attitude towards the issue. According to Haron (2015), knowledge and education can change public behaviour towards E-waste recycling. Several studies have indentified the lack of environmental knowledge as one of the prior obstacles to the implementation of environmental education (Dung et al., 2017; Haron, 2015; Pulkkien, 2003; Lee & Wiliams, 2001).

Studies have also shown that knowledge generally influences pro environmental attitudes, which in turn motivates environmentally responsible consumer behaviour (Yoke et al., 2019; Kollmuss & Agyeman, 2002; Szechy et al., 2013). Similarly, Ibrahim (1999) stated in his study that information and knowledge about recycling were both important predictors in recycling behaviour. Jekria and Daud (2016) also believed those who concerned about environmental issues tend to have positive attitudes towards recycling behaviour (Yoke et al., 2019). According to Makmattayan (2003), knowledge on environmental impact of E-waste recycling has a positive relationship with recycling practice. Those who show a greater knowledge along with concern about the environmental impact of recycling tend to participate willingly on waste minimization (Oskamp et al., 1991). Yuan et al. (2019) reported that people who have knowledge about environmental impact of waste management are willing to take part in recycling activities (Yuan et al., 2019). But the overall success of waste minimization relies on the waste handling pattern and attitude as well. The greater involvement in waste recycling reflects greater knowledge about the importance and impact of such a practice (Ali et al., 2017).

Based on the findings of Kelana (2010), Jaibee et al. (2015) and Sumaiyyah et al., (2015), it appears that the knowledge about the disposal of E-wastes is still low in Malaysia and due to this, Malaysians do not practice recycling but disposed their E-waste with MSW or store it at home (Kelana, 2010; Jaibee et al., 2015 & Sumaiyyah et al., 2015). These results are consistent with the findings of Tarawneh & Saidan (2013) in

Jordan, as well as, Okeyo & Odoh (2014) in Anambara, Onitsha, and Africa. However, positive results were observed in the study of Huang & Deng (2006) in Ningbo, China where the public happen to possess knowledge in terms of recycling. Hence, they practice waste segregation and disposal according to materials by following the labeling on the containers, just like in the Philippines (Barloa et al, 2016).

According to Mahat et al. (2019), knowledge about E-waste disposal among the public of Selangor is very high (within the range of 3.34 to 5 of mean value) in the context of environmental, social, and economic aspects which support the results of Bortoleto et al., (2012). According to Alias et al. (2019), the behavior of people in Kundasang, Sabah showed a similar orientation regarding knowledge about waste management but in terms of practice of waste disposal, it was still very low (34.2%) (Alias et al., 2019).

2.6.2 Public awareness

Awareness can be defined as the understanding in context of one's own self-activities in comparison with other activities (Dourish & Bellotti, 1992). According to several studies (Schwartz, 1976; Eckman & Walker, 2008; Mahat et al., 2019) awareness is based on public knowledge, practice and attitude, and knowledge is the key factor (Salerno & Santoro, 2014). Yuan et al. (2019) stated that awareness and knowledge are very important in influencing public participation in recycling activities. In terms of environmental awareness, despite having knowledge about the environment, many people failed to make a commitment to their awareness. This reflects the irresponsible attitude towards knowledge (Yuan et al., 2019; Stark,1990). Ibrahim & Babayemi (2010) agreed that education can play a vital role to raise awareness about environmental problems and it is necessary to collect baseline data about their awareness on environmental problems among young people and attitude towards waste management as part of their learning (Dung et al., 2017). Proper environmental education can help to change the attitude and awarenss towards envionmental issues (Momoh & Oladebeye, 2010).

Tiep et al. (2015); Lin et al. (2018) and Yuan et al. (2019) agreed that lack of awareness about the increased generation and environmental impact of E-waste among Malaysians impact the government's current recycling programs (Tiep et al., 2015; Lin et al., 2018; Yuan et al., 2019). However, Malik et al. (2015) showed the significant relationship between public awareness and attitude towards waste management program indicating the high involvement of public in recycling programs (Malik et al., 2015). It can be seen in the studies of Afroz et al. (2014) and Akter et al. (2012), that the public in Kuala Lumpur, Malaysia was aware of the environmental consequences of E-waste (Afroz et al, 2014; Akter et al., 2012). Furthermore, the E-waste management awareness among the public of Selangor has become better (Mahat et al., 2019) and is similar to that of the people of Kundasang, Sabah, Malaysia (Alias et al., 2019). However, Sumayyiah et al. (2015) and Ho et al. (2015) argue that the awareness about the proper treatment of E-waste among public and the local authority are still low. The lack of financial backing for the promotion of waste minimization/recycling shows unawareness about the existing issues of waste management among the public (Ali et al., 2017). Shah (2014) suggests that greater awareness is essential among the public for an effective E-waste collection and enhanced recycling rate (Akter et al., 2013).

2.7 Concept of 3R

The waste hierarchy (3Rs) has been used as a framework for the development of waste management policy and it was established in helping the government to achieve sustainable development goal in waste management (Sreenivasan et al., 2012). El-Haggar (2007) explained the waste management concept that was based on a level of hierarchy known as 3Rs (Oyenuga & Rao, 2015; El-Haggar, 2007). Basically, it is the classification of the waste management options (reduction, reuse, recycling, recovery, and disposal) to minimize their environmental impacts and prevent the waste from entering dumpsites or landfills (Kasapo, 2013; Raina, 2010; Hashim, 2011). EU defines waste hierarchy as relating to recycling, reuse, and reduction behaviour of public towards waste management. The waste hierarchy emphasised the 3R policies with the involvement of the community by raising awareness which have momentarily been adopted by developed countries (Ahmadi, 2017).

Firstly, the concept emphasises reducing the volume of the waste from the waste stream or source reduction before recycling. When a product with a long-life span can used more than once, it helps to reduce the quantities of waste generation and offsets the production of the new products. Source reduction not only helps to minimize the costs of product manufacturing, waste disposal and handling but also saves environmental resources, and reduces pollution and toxic (Ahmadi, 2017). Recycling is another strategy of waste management which is combined with waste collection, segregation, and processing the waste with a productive value (Ahmadi, 2017) (Figure 2.6).

Figure 2.6: 3Rs concept (Ahmadi, 2017)

2.8 Extended Producer Responsibility (EPR)

Extended Producer Responsibility (EPR) is an environmental policy approach that is based on polluters-pay principles which featured responsibility to manufacturers in taking back the products once discarded by consumers (Ismail & Hanafiah, 2020; Gupt et al., 2015). The OECD defines EPR as a policy approach under which a significant responsibility (financial or physical) is given to producers to handle and discard post customer products. To prevent wastes at the source, the product design should promote the environment and support the achievement of public recycling and materials management goals. Assigning such responsibility to producers could in principle provide incentives. Within the OECD, the trend is towards the extension of EPR to new products, product groups and waste streams such as, electronics and electrical appliances (OECD, 2001; Borthakur et al., 2019).

In the early 1990s, the EPR policy emerged in academic circles (Shamim et al., 2015). The EEE Directive announced by EU in 2003 incorporated EPR as a basic principle to be followed by both EU member states and those outside Europ (Pathak & Ojasvi, 2019; Borthakur et al., 2019). In the literature, various aspects of E-waste management based on EPR have been investigated, from the trends and evolution of EPR applications and the designation and implementation of EPR to the operation of the EPR models and their development trends (Ismail & Hanafiah, 2020).

The main idea of EPR is to incentivise the producers for designing products in a way that waste management cost is kept at a minimum and they are financially responsible for this process (Shevchenko et al., 2019). EPR demands a design strategy promoting "cradle to cradle" responsibility by taking account the upstream environmental impacts inherent in the selection, mining extraction of materials, and during the production process, the health and environmental impact on workers and surrounding communities and downstream impacts during use together with the recycling and disposal of the products

(Kasepo, 2015; EPR Working Group, 2008). EPR was mostly applied for packaging waste. Currently around the world, the concentration is on EPR policies for electronic and electrical products. (Shamim et al., 2015). The concept of product take-back based on EPR has been proven to be practicable, thus it is becoming progressively popular especially in Europe, where several countries favour an EPR based E-waste policy (Ismail & Hanafiah, 2020; Borthakur et al., 2019; Zhou et al., 2017; Shamim et al., 2015). Some emerging economies like China, India and Indonesia have started to develop EPR programs though they are not fully implemented yet. South-East Asian countries such as Malaysia and Thailand are also embarking on the path towards EPR for E-waste, though these initiatives generally rely on voluntary participation of producers (Shamim et al., 2015).

2.9 Material Flow Analysis (MFA)

To investigate the flows and stocks of materials or environmental pollutants in a defined system, Material Flow Analysis (MFA) is the most favourable analytical tool used extensively in resource management, waste management and environmental management (Islam & Huda, 2019; Makarichia et al., 2018; Millwared-Hopkins et al., 2018; Zang et al., 2017). It is a systematic assessment approach for the flow of the materials and supplies which are defined by space and time. MFA can be carried out at both level of substances and level of goods (Marick et al., 2019) and the outcomes can be measured by simple material balance comparing all inputs, stocks, and outputs of the procedure (Islam & Huda, 2019).

After the enactment of the Basel Convention, MFA was applied for studying the route of material (E-waste) flows from the developed countries to developing countries for reuse, recycling (especially recycling or disposal areas), and stocks of the materials (Kidde et al., 2013). In developing countries, E-waste is considered as a profitable good by the consumers which is why the strict regulations for illegal channels and dumping by developed countries are not followed (Islam & Huda, 2019). According to Shinkuma & Nguyen (2009), some South-East Asian countries like Cambodia and Vietnam reused the second-hand electronic devices that were imported from Japan. Later, these electronic items were recycled in China in an improper way (Shinkuma & Nguyen, 2009; Kiddee et al., 2013). MFA has been used for E-waste evaluation (Lin et al, 2019; Mishima et al, 2016; Ismail & Hanafiah, 2020), generation of E-waste (Tran et al., 2018; Wang et al., 2018; Ismail & Hanafiah, 2020) and efficiency of E-waste management systems based on collection and recycling rates (Gurauskiene & Stasiskiene, 2011; Kim et al., 2013; Parajuly et al., 2017; Ismail & Hanafiah, 2020). Several methods were used as well to quantify E-waste such as market supply method (Lee et al., 2006; Jain & Sareen, 2006; Steubing et al., 2010; Kiddee et al., 2013) and survey method (Osibanjo & Nnorom, 2008; Steubing et al., 2010; Kiddee et al., 2013). It has been projected that E-waste would double from 2005 to 2010 and obsolete devices will increase by 70% in China (Liu et al., 2006; Kiddee et al., 2013) and during 2010-2019, it will increase four to five times in Chile (Steubing et al., 2010; Kiddee et al., 2013). In Malaysia, a study was conducted where MFA, considered as a decision support tool for planning and sustainable solid waste management, was used to get a precise understanding of the reason behind the increasing waste output in the system. The outcome of the study indicates a lack of strategic policy and management which is a major hindrance to successful sustainable development in Malaysia (Shah et al., 2015; Siti, 2012).

CHAPTER 3

METHODOLOGY

3.1 Study area(s)

This study was conducted in three cities namely Shah Alam, Petaling Jaya, and Putrajaya (Figure 3.1 & Table 3.1). The three cities were chosen because they are currently participating in E-waste Alam Alliance Malaysia organized by Department of Environment (JICA, 2014; 2018). The outcome of the study could reflect the progression and shortcomings of the initiative regarding public involvement and awareness towards E-waste management and recycling program undertaken by the government. By studying these cities, it would be possible to come up with a role model for other cities that want to replicate the program or to develop their own household E-waste management program.

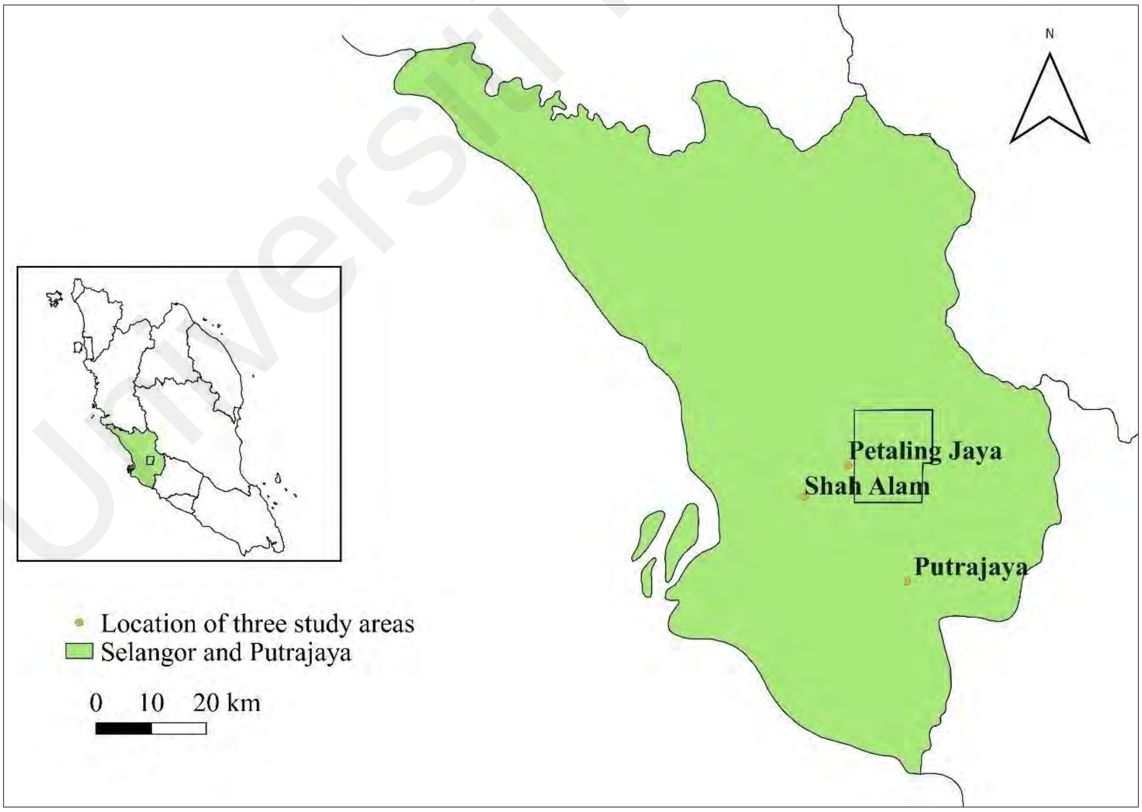

Figure 3.1: The study areas

Table 3.1: The study areas

No.	Cities name	Coordinates	Area (km^2)	Population
1	Shah Alam	3°4'24.636″N,101°31'12.738"E	290.3	650,000
2	Petaling Jaya	3°05′N, 101°39′E	97.2	619,925
3	Putrajaya	2.9430952°N, 101.699373°E	49	103,700

3.1.1 Shah Alam

Shah Alam is the capital city of Selangor state with an area of 290.3 km^2 and the total population is 650,000 (MBSA, 2019). It borders Subang Jaya, Klang and is also near to Putrajaya and Cyberjaya (MBSA, 2019). The city is divided into three major parts consisting of 56 sections and it has a similar urban layout like Petaling Jaya or Subang Jaya where housing areas occupy most of the city (55.2 km^2) (Wikipedia, 2019).

3.1.2 Petaling Jaya

The population of Petaling Jaya is about 619,925 with an area of 97.3 km^2 (MBPJ, 2019). The whole city is divided into several sections which are subdivided into smaller zones. Some sections have their own names, for instance SS1 is also known as Kampung Tunku, while other sections are grouped together, such as SS6 and SS5 are part of Kelana Jaya (Wikipedia, 2019).

3.1.3 Putrajaya

The Federal Territory of Putrajaya is located 25 km south of Kuala Lumpur with an area of 49 km^2. The population of this city is about 103,7003 (DOSM, 2019).

3.2 Target group(s)

3.2.1 Public

Since the population in the study areas were heterogeneous (with different city, gender, age, ethnicity, income level, occupation and accommodation level), a total of 400 respondents were chosen from each study area by using stratified random sampling to give each member an equal opportunity of being selected. For this, the target population comprised those aged between 18 to 40 years above of both gender, different ethnicity, education level, income level, and occupation (Plate 3.1 A & B). They were selected because they are the major consumers of electronic products and are willing to spend money on consumer gadgets (Kalana, 2010; Tiep et al., 2015).

(A) **(B)**

Plate 3.1 (A & B): Public participation in questionnaire survey

The sample size of population was calculated using Yamane (1967) formula based on 95% confidence level. The calculation formula of Yamane is given as follows (Equation 3.1),

$$\boldsymbol{n} = N/(\mathbf{1}+N\,\boldsymbol{e}^2) \qquad \text{(Eqn.3.1)}$$

Where, n = the sample size, N = the size of the population, e = the error of 5%. According to the sample size table (Appendix A), for fulfilling the questionnaire survey the sample size would be 400 respondents from each study areas (Table 3.2). Since, more than 300 to 500 of sample size is considered suitable in any type of research by many researchers (Alias et al., 2019).

Table 3.2: Selected sample size for performing questionnaire survey in the study areas

No.	Cities name	Population	Sample size
1	Shah Alam	650,000	400
2	Petaling Jaya	619,925	400
3	Putrajaya	103,700	400
	Total	1,373,625	1200

3.2.2 Target E-waste(s)

Table 3.3 shows the eight electronic items which were selected to quantify the generation of E-waste in the study areas. These items were also the target items (except stereo equipment) under the E-waste collection program of DOE.

Table 3.3: Targeted E-waste items in the study areas

No.	Target E-waste(s)
1	Mobile Phone
2	Laptop
3	Desktop
4	Television
5	Refrigerator
6	Washing Machine
7	Air Conditioner
8	Stereo equipment (CD's & DVD's)

3.3 Data collection

3.3.1 Primary data collection

Questionnaire survey and interview were the main tools for primary data collection. English language was the prime language been used to prepare the questionnaire by taking consideration of respondents' age and occupation; hence Bahasa Malayu was used as well but in socio-demographic section only. The questions were designed based on the previous studies (Kasapo, 2015; Alavi et al., 2015) which focused on the generation and disposal methods of targeted Household E-wastes by public and their knowledge and practice on E-waste management were also investigated. Additionally, some web survey questionnaires also considered for the moderation of questionnaire. The survey was conducted going door to door, local restaurants, shopping areas, and with the assistance of local community officials as well to distribute the questionnaire to the community members. The pilot survey was administrated from 10th December 2018 to 28th December 2018 on 30 respondents from the study areas to notify the problems and to understand the public participation on the survey. The actual questionnaire survey was conducted on 11th January 2019 to 11th July 2019.

3.3.1.1 Public survey questionnaire

The questionnaire was divided into five sub-sections (from A to E) comprising 64 questions (Appendix B). Both close-ended and open-ended questions were included to assess: i) the respondent's electronic products usage rate, ii) the respondent's participation in waste generation, iii) the respondent's participation in waste segregation and, iv) the respondent's participation in recycling. Similarly, Likert scale questions were used to measure the practice and knowledge on E-waste management and recycling among the public.

Section A included data on gender, race, age, occupation, education level, income (per month), accommodation types, number of family members etc. Section B focus on the overall practice regarding the waste segregation program. Section C covered E-waste generation, collection and disposal methods practiced by public. The questions in Section D, were designed to evaluate the public knowledge of E-waste management and recycling. They also included questions on environmental issues, waste management related policy and economic aspects. Likert scale questions were given at the end of Sections C & D to assess the two hypotheses of the study. This part consisted of eight statements based on knowledge and practice of E-waste management and recycling among the respondents. To assess the knowledge variable, the five-point likert scale ranged from Strongly Agree (SA), Agree (A), Disagree (DA), and Strongly Disagree (SDA) to Not Sure (NS) was employed. For the practice variable, the scale ranged from Strongly Practiced (SP), Moderately Practiced (MP), Fairly Practiced (FP), Not Practiced (NP) to Not Sure (NS). In Section E, respondents were asked for their recommendations to improve the current E-waste management services.

3.3.1.2 Interviews with relevant officials

Face to face interviews were also conducted with the government officials to understand the government's views and initiatives taken towards the betterment of the E-waste management program, related policies, and regulations (Plate 3.2).

Plate 3.2: Interview with the government official

3.3.2 Secondary data collection

The secondary data were collected from previously published and unpublished research papers, newspapers, books, and related websites. Data were also gathered from sources such as the E-waste inventory project report in Malaysia, the Environmental Quality Report (EQR) from DOE, Malaysia, and the annual publication of *IMPAK* magazine by DOE, Malaysia.

3.4 Reliability tests

3.4.1 Reliability test for questionnaire

In this study, the questionnaire was distributed to 30 respondents to evaluate the reliability of the tool. Cronbach's alpha test was applied for ensuring each question of the questionnaire measured the same attributes. The test scored 0.87, which is well above the acceptable reliability score.

3.4.2 Reliability test for knowledge and practice variables

To examine the reliability of the dependent variables (Knowledge and Practice) of this study, Cronbach's Alpha was used to evaluate the score of the results. For reliability coefficient, both knowledge and practice variables had an alpha value of 0.7 approximately, which supports further analysis.

3.5 Data analysis and modelling

3.5.1 Material Flow Analysis (MFA)

The STAN software was used to create the MFA model (by items and by city separately) to measure the E-waste streams that ended in different sectors by using different disposal methods. A total of eight electronic items as listed in Table 3.3 were selected to calculate the E-waste flow in the study areas.

3.5.1.1 Mass balance equation

The calculation of MFA is based on a simple mass balance equation where the mass of all inputs into a process equals the mass of all outputs of this process plus a storage term that considers accumulation or depletion of materials in the process (Burnner et al.,2005) (Equation 3.2).

$$\sum \mathbf{m}_{\mathbf{input}} = \sum \mathbf{m}_{\mathbf{output}} + \sum \mathbf{m}_{\mathbf{storage}} \qquad \text{(Eqn. 3.2)}$$

3.5.1.2 Measuring the uncertainty of E-waste flow

It is known that MFA results are influenced by the method and the quality of the data used (Patrecio et al. 2015). Uncertainty analysis should be included in all descriptive MFA case studies, implying quantification of material balance in a specific region (Patrecio et al. 2015). But, the majority of related studies did not address the measurement errors associated with the database, or with the applied model (Patrecio et al. 2015). However, the STAN software allows researchers to use the uncertainty of the materials (Patrecio et al. 2015). In this study, uncertainty of the E-waste flow was also measured.

3.5.1.3 'Use and consumption' method to estimate the public E-waste generation and disposal

To investigate the potential generation of E-waste, the European Environmental Agency suggested several methods, such as time step method, the market supply method, the carnegie method, and other approximation methods (Alavi et al. 2015). In this study, the simple "use and consumption" method was applied because of insufficient research about the study areas. To estimate the contribution of an item to annual E-waste generation in the study areas, it was calculated by Equation 3.3 (Alavi et al. 2015, Robinson, 2009).

$$\mathbf{E=MN/L} \qquad \text{(Eqn. 3.3)}$$

Where, E (kg/year) is the quantity of E-waste generated, M (kg) is the weight of the items, N is the number of e-products units in use, L is the average lifetime of the product.

3.6 Statistical analysis

Statistical Package for Social Science (SPSS) software (Version 22.0) was used for data analysis. All the variables were coded and then inputted into the SPSS spreadsheet. By using descriptive analysis, the mean and standard deviation were measured for the variables. The data were summarized into frequency tables, graphs, charts, and percentages. A cross-tabulation method was also used to compare two or more relevant variables. Pearson correlation coefficient was used for testing the relationship between knowledge and practice variables. Moreover, One Way ANOVA was performed to examine the differences in knowledge and practice variables between different socio-economic groups. Bonferroni and Games-Howell post-hoc test also was performed to compare within groups. Microsoft Windows Excel, 2010 was also used to simplify the interpretation of the multiple response questions and graphical presentations of the data. For mapping and projection of the study areas, QGIS (version 3.4.2) was used.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Demographic /Socio-economic characteristics of three cities

Out of 1200 respondents, 55.1% were females and 44.9% were males; 74.8% were Malay, followed by 14.30% Chinese, 10.30% Indians and 0.50% others (Table 4.1). These proportions represent the population in the demographic statistics of 2019 (DOSM, 2019).

Table 4.1: Demographic/Socio-economic characteristics of the respondents from the three cities

Basic information	Group	Number of populations	Proportion of total (%)	Sample average	
				Mean	S.D
Gender	Male	539	44.90%	**1.55**	**.498**
	Female	661	55.10%		
Race	Malay	898	74.80%		
	Chinese	172	14.30%	**1.37**	**.685**
	Indian	124	10.30%		
	Others	6	0.50%		
Age	<20 years	238	19.80%		
	20-25 years	348	29.00%	**26.95**	**7.474**
	25-30 years	194	16.20%		
	30-35 years	228	19.00%		
	35-40 years	112	9.30%		
	>40 years	80	6.70%		
Occupation	Student	424	35.30%		
	Businessman	110	9.20%	**2.47**	**1.219**
	Service holder	348	29.00%		
	Others (Part time/ Freelance job)	318	26.50%		
Income (per month)	<RM 1000	140	11.70%		
	RM 1001-2000	268	22.30%		
	RM 2001-3000	198	16.50%	**1877.82**	**1569.82**
	RM 3001-4000	136	11.30%		
	>RM4000	180	15.00%		
	No income	278	23.20%		
Level of education	School graduate/ SPM / STPM	320	26.70%		
	Undergraduate	578	48.20%	**2.09**	**.9**
	Postgraduate/Masters/PhD	182	15.20%		
	Others (Diploma)	120	10.00%		
Types of accommodation	Bungalow	112	9.30%		
	Apartments/Condominium	494	41.20%	**2.46**	**.745**
	Terrace house	522	43.50%		
	Others	72	6.00%		

As for the age groups, the highest proportion (29%) of the respondents were between 20 to 25 years, followed by the 19.8% respondents of below 20 years old, and 19% of 30 – 35 years. As for education level, 48.2% were undergraduates, 26.7% were SPM/STPM school leavers, 15.20% postgraduate and 10% were diploma holders. The respondents' socio-economic characteristics of three study areas were also tabulated in Appendix C. The average members per household in the three study areas were 4 each for Putrajaya, Shah Alam and Petaling Jaya (Table 4.2), which is in line with the national demographic projection (4 members per household) (DOSM, 2019).

Table 4.2: Average members in a household in the three cities

	Putrajaya	Shah Alam	Petaling Jaya	Average
Average members per household	4.00	4.43	4.45	**4.29**

4.2 Material Flow Analysis (MFA) for household E-waste in three cities

4.2.1 Total number of electronic items owned and E-waste generated by the public

The total number of electronic items owned by the respondents in the three cities in 2019 amounted to 208,711kg per year (9061 units) (Table 4.3).

Table 4.3: The quantities of Electronic items owned and E-wastes generation by the public in three cities (Electronic item wise)

Name of EEE items	No. of EEE items owned by the public (1200)	Average EEE items owned[a] by the public	Weight of the EEE items[1] (kg)	Lifetime of the EEE items[2] (Years)	EEE Items owned[b] by the public (1200) (kg/year)	WEEE generated[c] by the public (1200) (kg/year)	WEEE generated by the public (in percentage)	EEE stock[d] by the public (1200) (kg/ year)	EEE stock by the public (in percentage)	WEEE kg per capita
Mobile Phone	3124	2.61	0.1	2	312.40	156.2	0.07	156.2	0.07	0.13
Laptop	913	0.76	3	3	2739	913	0.44	1826	0.87	0.76
Desktop	215	0.18	25	8	5375	671.87	0.32	4703.13	2.25	0.56
Television	1149	0.96	30	8	34470	4308.75	2.06	30161.25	14.45	3.59
Refrigerator	1100	0.92	45	10	49500	4950	2.37	44550	21.35	4.13
Washing Machine	984	0.82	50	8	49200	6150	2.95	43050	20.63	5.13
Air Conditioner	1077	0.90	60	12	64620	5385	2.58	59235	28.38	4.49
Stereo equipment (DVD's and CD's)	499	0.42	5	5	2495	499	0.24	1996	0.96	0.42
TOTAL	**9061**				**208711.40**	**23033.83**	**11.04%**	**185677.58**	**88.96%**	**19.19**

[1 & 2] JICA, 2014; Agamuthu & Herat, 2012; Gaidajis et al., 2010

Note: [a]Average EEE items owned by the public = Total items owned by public (in sample size population) / total sample size population
[b]EEE items owned by the public (kg/year) = Number of items owned by the public× weight of the item
[c]WEEE generation (kg/year) = Items owned by the public (in kg) / lifetime of the item (years)
[d]EEE stock (kg/year) = EEE Items owned by the public (kg/year) - WEEE generated by the public (kg/year)

Mobile phones were the highest (3,124 units) electronic products used by the public with an average usage of 2.61 per household. The usage rate (3.04 per household) recorded in Taizhou, China was higher than the current results (Chi et al., 2014). With regards to the usage of air conditioners, an average value of 0.9 per household was recorded. This was lower than those reported in Macau (2.64 per household) (Song, 2012) and Taizhou, China (1.74 per household) (Chi et al., 2014). The usage of laptops per household was expectedly higher (0.76) than that of desktops (0.18) possibly because of the high and lucrative marketing initiatives launched by giant electrical companies which made the products more affordable to the consumers. Likewise, modern lifestyle might have contributed to the higher usage of laptops than desktops. On comparison, current results agreed with those of Song (2012); Chi et al. (2014) and Kalana (2010). The number of DVD and CD players (0.42 per household) was higher than that of Chi et al. (2014) (0.2 per household). The possession of electronic appliances varied among the public in the three cities as well. Publics in Petaling Jaya recorded the highest value of 71,909 kg per year followed by Shah Alam (71,841 kg per year) and Putrajaya (64,962 kg per year) (Table 4.4).

Table 4.4: The quantities of electronic items owned and E-wastes generation by the public (city wise)

Name of the cities	EEE items owned by the public (1200) (kg/year)	WEEE generated by the public (1200) (kg/ year)	WEEE generated by the public (in percentage)	WEEE in kg per capita	EEE stock by the public (1200) (kg/year)	EEE stock by the public (in percentage)	EEE stock in kg per capita
Putrajaya	64961.6	7197.05	3.45	17.99	57764.55	27.68	144.41
Shah Alam	71841.2	7912.23	3.79	19.78	63928.98	30.63	159.82
Petaling Jaya	71908.6	7924.55	3.80	19.81	63984.05	30.66	159.96
Total	**208711.4**	**23033.83**	**11.04%**	**19.19**	**185677.58**	**88.96%**	**154.73**

In terms of the average weight of the electronic items, the total annual E-waste generated by the respondents in three cities was 23,034 kg per year. This value presented only 11.04% of E-waste generated from the total EEE items owned by the respondents. About 19.19 kg per capita of E-waste was generated from the three cities. That was higher than Malaysia's E-waste generation in kg per capita (11.1) reported in 2019 (Global E-waste Monitor Report, 2020). Countries like China (7.2 kg per capita) and India (2.4 kg per capita) were recorded lower E-waste generation than the three cities due to their huge range of population (Global E-waste Monitor Report, 2020). Developed countries like USA (21), Great Britain (23.9), Japan (20.4), Denmark (22.4), Canada (20.2) were generated most in kg per capita attributed by higher income, advancement of the technologies in EEE, and social progress (Global E-waste Monitor Report, 2020).

Among the eight electronic items reported in the three cities, the highest E-wastes generated were from washing machines (6,150 kg) and air conditioners (5,385 kg). These values were lower than those documented for air conditioners (3,125 tonnes) in Ahvaz, Iran and washing machines (3,055 tonnes) in Macau (Alavi et al., 2015; Song, 2012). The rise in the E-waste accumulation may be related to the advancement of technologies in EEE (Electrical and Electronic Equipment) and the public behaviors towards EEE usage. Based on the survey, the public own different types of electronic products with some having more than one of the items. As such, it resulted with high accumulation of E-waste. The highest E-waste was generated in Petaling Jaya 7,925 kg per year at 19.81 kg per capita, followed by Shah Alam (19.78 kg per capita) and Putrajaya (7,197 kg per year at 17.99 kg per capita). On the other hand, the E-waste generated in cities like Ahvaz, Iran (9,952 tonnes), Macau (6,655 tonnes), Tamil Nadu (13,486 tonnes), Gujrat (8,994 tonnes), Pune (4,573 tonnes), Mumbai (1,20,000 tonnes), Delhi (98,000 tonnes) and Bangaluru (92,000 tonnes), India, were comparatively higher than those reported in the current three study areas (Alavi et al., 2015; Song, 2012; Reena et al., 2011; Sivathanu, 2016; Garg & Adhana, 2019). The lowest E-waste generated was from mobile phones (156 kg). Additionally, 5,385 kg and 4,950 kg of E-wastes generated from air conditioners and refrigerators respectively which was 44.83 % of the total E-waste generation in the three cities.

A total of 185,678 kg per year at 154.73 kg per capita of the stockpiled EEE items was measured which means about 88.96% of electronic items were remained as stock in the three cities. As for number of items, air conditioners were the largest stockpiled (59,235 kg per year), followed by refrigerators (44,550 kg per year), washing machines (43,050 kg per year), and televisions (30,161kg per year). However, light weighted items such as mobile phones (156 kg per year), laptops (1,826 kg per year), and stereo equipment (1,996 kg per year) constituted the smallest amount of the stocks. Public in Petaling Jaya possessed the highest stockpiles of 63,984 kg per year as compared to Shah Alam (63,928 kg per year) and Putrajaya (57,765 kg per year). Moreover, 159.96 and 159.82 kg per capita of EEE stock were recorded for each Petaling Jaya and Shah Alam, accordingly while Putrajaya recorded 144.41 kg per capita.

4.2.2 The disposal methods of E-waste by the public

In the current study, there were no secondary data sources available to support the calculation of the household E-waste flow in the three study areas. Figures 4.1 and 4.2 show the preferred methods of disposal for obsolete electronic items.

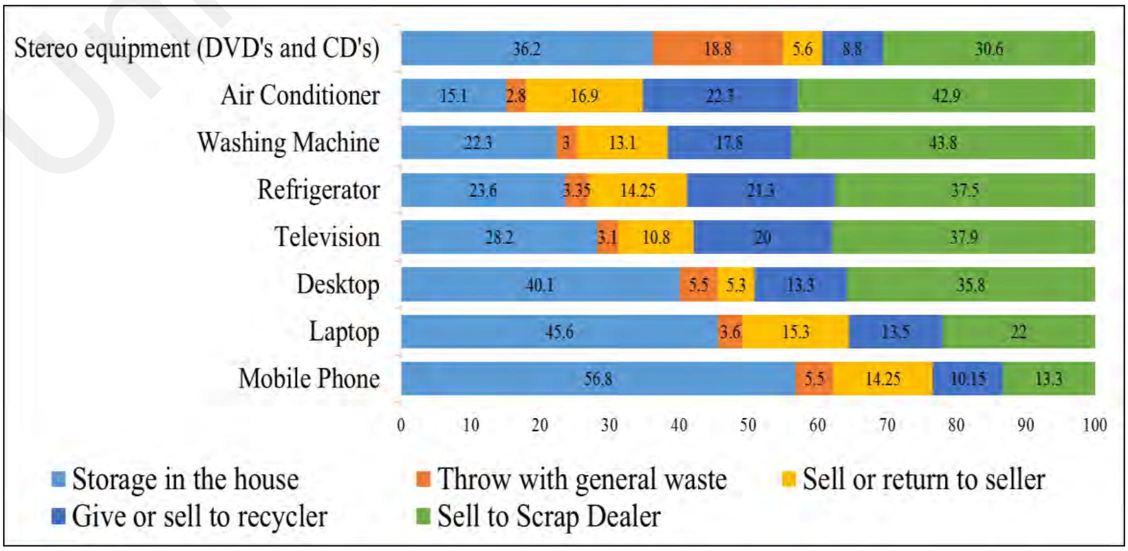

Figure 4.1: The disposal methods of WEEE by the public in percentage (item wise)

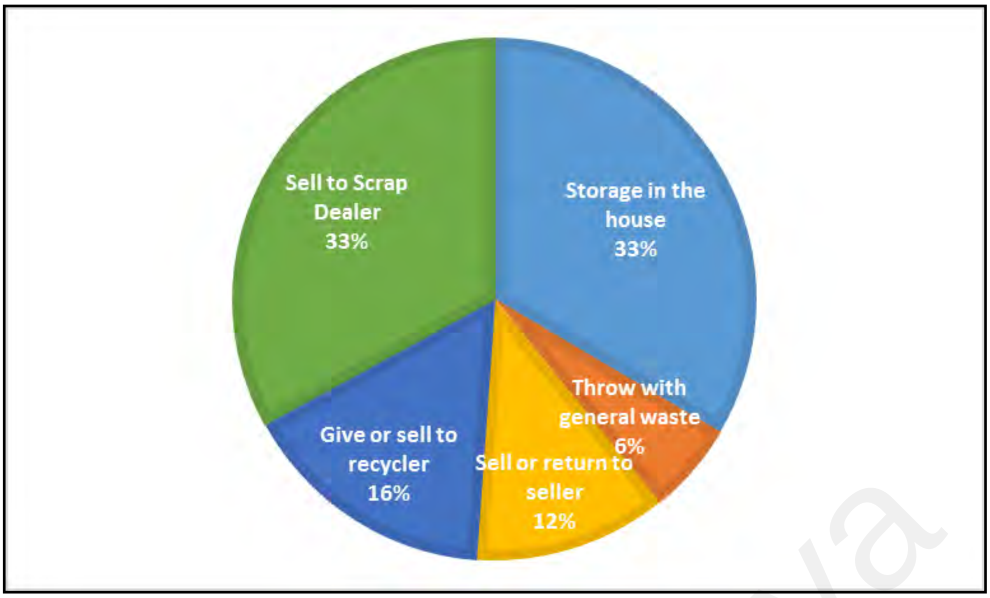

Figure 4.2: Disposal options of WEEE opted by the public (in percentage)

The results revealed that the public either stored their electronic items in the house (33.49%) or gave/sold to scrap dealers (Plate 4.1) (32.98%). This practice was similar in the three cities, as well as, the findings of Kelana (2010).

Plate 4.1: General practice among public who stored the un-usable electronic appliances

Conversely, in other researches were conducted in Selangor (Mahat et al., 2019) and Melaka (Tiep et al., 2015), the results revealed that the most preferred disposal methods by the publics were either selling to the scrap dealers (25%) or donating (35%) the obsolete electronic items. However, results from Pune, India revealed that publics were interested more in exchanging their old electronic items to a new one (32%) as also reported among the public in Selangor (Mahat et al., 2019; Bhat & Patil, 2014). In the current results, mobile phones (56.80%) and desktops (45.60%) was the highest the electronic items stored by public. On the contrary, air conditioners (42.90%) and washing machines (43.80%) were sold to scrap dealers. However, Islam et al. (2016) and Yang et al. (2019) showed that public in Beijing, China preferred to store most of their mobile phones and personal computers at home.

Due to the inadequate facilities for waste segregation, most of the electronic items ended up in the landfills. Additionally, in most cases, authorities could not fully implement recycling schemes to encourage the residents to do so. Only 15.89% of the generated E-waste was given away or sold to recyclers as there was no sufficient take back scheme for consumers. Items like televisions, refrigerators, and air conditioners were commonly sold to recyclers as they have high recycling value than other electronic items. Thus, the practice of giving or selling the electronic items to the recyclers was highest in Putrajaya (18.53%), followed by Shah Alam (15.51%) and Petaling Jaya (13.64%). Contrastingly, the percentage recycling this research is comparatively lower than those in Shah Alam (Kelana, 2010) and Selangor (Mahat et al., 2019). On the other hand, current results are higher than those observed in Melaka (Tiep et al., 2015) and Kuala Lumpur (Afroz et al., 2013).

In Beijing, public recycled up to 42% of their electronic items, meanwhile, in Onitsha, Nigeria, a significant number of the public reportedly throw their obsolete electronic items along with the general waste (Wang et al., 2011; Nduneseokwu et al., 2017). This study revealed that the obsolete electronic items which are thrown along with general waste totalled 5.71%, and this was found to be the lowest rate as compared to other cities. This discarding method was observed to be lowest (4.43%) in Putrajaya and highest in

Shah Alam (6.92%). However, Afroz et al. (2013) showed that 34% of the respondents in Kuala Lumpur reused their electronic items instead of disposing it with the general waste (30%).

In Table 4.5, different E-waste streams were calculated from the total generated E-waste (23,034 kg) based on the disposal methods opted by public. According to this, a total of 7,597 kg (32.98%) of obsolete EEE were given or sold to scrap dealers by public. It was found that donating or selling practices to the recyclers were rather unpopular among the public in the study areas where 3,660 kg (15.89%) of obsolete EEE ended up in the recycling streams. Some electronic companies have allowed consumers to either sell or return older products and replace them with new ones. However, this was rarely reported as only 2,750 kg (11.94%) of obsolete EEE was seen in this waste stream. Furthermore, 7,714 kg (33.49%) of obsolete EEE was stored in the house. The fact that a significant number of items was stored rather than disposed using efficient means, indicates the lack of awareness on the importance of disposal of obsolete EEE. On the other hand, some consumers kept unused or broken EEE for years before reselling or disposal (Tiep et al., 2015).

Table 4.5: Estimation of E-wastes that end in different disposal options (kg/year)

WEEE generated	Stored in the house	Throw with general wastes	Sell or return to seller	Give or sell to recycler	Sell to Scrap Dealer
23033.83	**7714.03** (33.49%)	**1312.93** (5.70%)	**2750.24** (11.94%)	**3660.07** (15.89%)	**7596.56** (32.98%)

The average lifetime of the stored obsolete EEE after primary use was reported to be 1.5 years as presented in Table 4.6. According to the result, 4,277 kg of E-waste was generated with 3,437 kg of stockpile form the electronic items that been stored for 1.5 years.

Table 4.6: Estimation of E-wastes that had been stored after primary use (kg/year)

Stored obsolete EEE in the house	Average lifetime of stored obsolete EEE (years)	E-waste from stored obsolete EEE	Stock from stored obsolete EEE
7714.03	**1.45**	**4277.37**	**3436.66**

The stored obsolete EEE (4,277 kg) after primary use, which ended up in different disposal options was presented in Table 4.7. Based on current results, 2,951 kg (69%) of E-waste was sold to scrap dealers, while 781 kg (18.25%) of E-waste was mixed with MSW. Meanwhile, 312 kg (7.3%) of E-waste ended up with recyclers and 233 kg (5.45%) of E-waste was sold or returned to take-back companies.

Table 4.7: Estimation of the E-wastes from the different disposal options that opted by public after primary use of obsolete EEE (kg/year)

Stored E-wastes after primary use	Throw with general wastes	Sell or return to seller	Give or sell to recycler	Sell to Scrap Dealer
4277.37	**780.62** (18.25%)	**233.12** (5.45%)	**312.25** (7.3%)	**2951.39** (69%)

In addition, A total of 2,094 kg of E-waste estimated from before and after primary usage of obsolete EEE were disposed into MSW stream, which would end up in the landfills or dumpsites. And 1,989 kg of E-waste would be remained as stock in the landfills or dumpsites while 105 kg of contaminants from the E-waste would be released to the environment. The surface and ground water are especially polluted by this contaminated leachate which can lead to human health hazards (Shumon et al., 2014; Tiep et al., 2013). The life cycle assessment of E-waste recycling system in Malaysia indicated that 700 tonnes/day of E-wastes were collected from industrial, commercial, and household premises (Othman et al., 2017 & 2018), while about 472 tonnes/day of secondary raw materials were recovered from recycling (Othman et al., 2017 & 2018). Moreover, about 19.26 kg of waste water with 8,872 tonnes/day of leachate, 28.1 kg air pollutants with 731.80 m^3/day of landfill gas, and 228 tonnes/day of residual E-waste were emitted as residues from the E-waste recycling systems (Othman et al., 2017 & 2018).

The overall E-waste generation and disposal practice of the public in three study areas are presented through Material Flow Analysis (MFA) models in Figure 4.3 and 4.4. These models are created based on eight electronic items and three cities separately to show the existing E-waste flow system. According to the results, 208.71 t/a of EEE items has used by the public from which a good amount of EEE items is remain in stock in the system (191.1 t/a). Only 17.61 t/a of E-wastes disposed by practicing both formal and informal disposal methods and most of E-waste goes to scrap dealers' stream (10.55 t/a) as it was more profitable to public than recycle (3.97 t/a) and give back to seller (2.98 t/a).

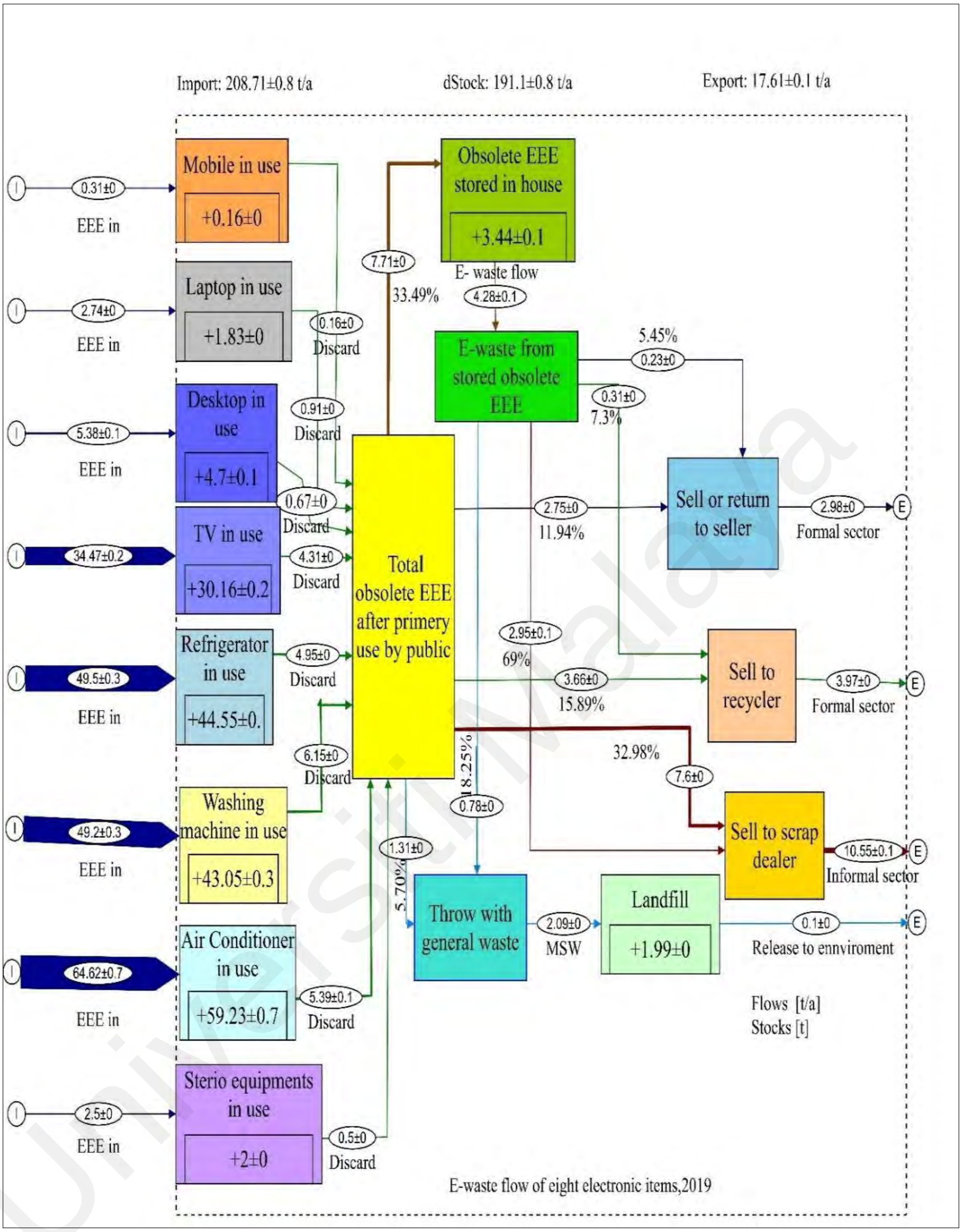

Figure 4.3: Household E-waste flow of eight electronic items

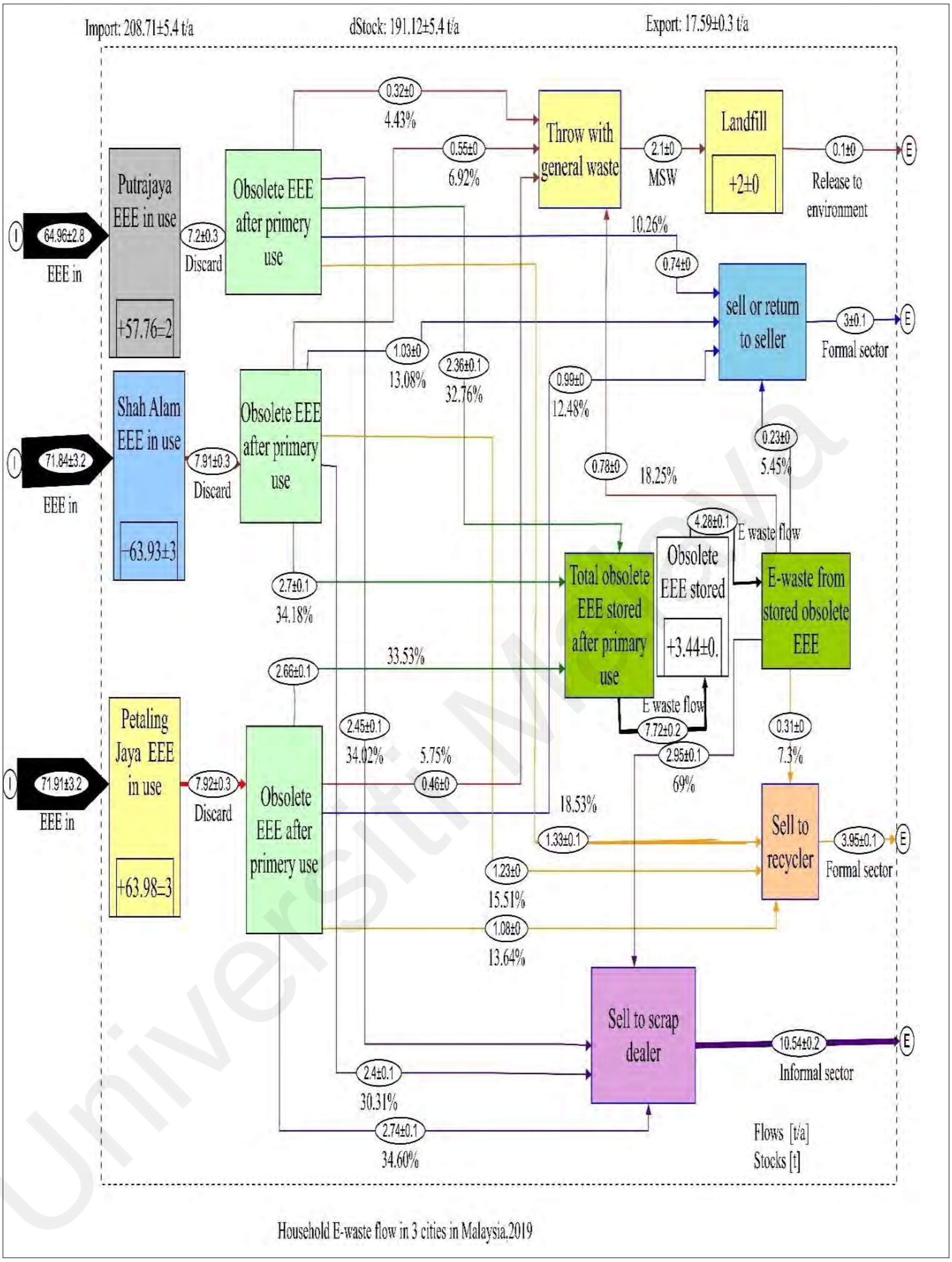

Figure 4.4: Household E-waste flow (city wise)

4.2.3 Monetary value of generated E-wastes in three cities

A market survey among authorized E-waste recyclers/traders i.e. those who buy obsolete household electronic items from consumers showed that price of items varied depending on the condition, usage year and specification of the electronic devices. In addition, some recyclers/traders have offered a fixed price according to unit(s). To estimate the value of the E-waste items, E-waste purchasing price was adopted from the value of Buy-back centre in Putrajaya and the purchasing price offered in the pilot project on E-waste in Penang (JICA, 2014) (Appendix D). Compared to other countries, it was found that the recovery price offered in Malaysia for E-waste recycling is less than those of the cities of Beijing, Shanghai, Fujian, Anhui, and Jiangsu in China, and the prices vary from high unit price (US$ 106.92) for air conditioners to lowest (US$ 0.46) unit price for televisions (Li et al., 2015). In Macau, the recovery price for a PC was US$9.04 while for washing machines it was US$5.98 (Song, 2012). According to a study by Tsai (2019), the recycling returns in Taiwan for heavy weight items like washing machines, air conditioners and refrigerators, ranged from US$ 6 - US$ 24.41, while for items like television, the range was US$ 0.96 - US$ 1.38 (Tsai, 2019).

From the current findings, the estimated annual price for household E-waste by the respondents was worth RM 12,082 (US$ 3020.05) (Table 4.8). Petaling Jaya and Shah Alam accounts for the largest portion of the total E-wastes and have the estimated values of RM 4154.81 (US$ 1038.70) and RM 4093.31 (US$ 1023.33), respectively (Table 4.9). The annual estimated value of the stockpiled generated electronic wastes indicated a potential side income for the public. However, sometimes people prefer to give away to recyclers/scrap dealers for free in order to get rid of the waste as it occupies space in the house.

Table 4.8: Monetary value of annual generation of E-waste (by items) in three cities

Name of the item(s)	E-waste generated by public (1200) (unit)	Estimated value	
		Malaysian Ringgit (RM)	US Dollar
Mobile Phone	1562	6248	1562
Laptop	304	1064	266
Desktop	27	270	67.5
Television	144	720	180
Refrigerator	110	550	137.5
Washing Machine	123	1230	307.5
Air Conditioner	99	1800	450
Stereo equipment (DVD's and CD's)	100	200	50
Total	2460	12,082	3020.5

Table 4.9: Monetary value of annual generation of E-waste (city wise)

Name of the city(s)	E-waste generated by public (1200) (unit)	Estimated value	
		Malaysian Ringgit (RM)	US Dollar
Putrajaya	785	2459.64	614.91
Shah Alam	831	4093.31	1023.33
Petaling Jaya	844	4154.81	1038.70

4.3 Overall knowledge and practice on E-Waste management system among public

4.3.1 Knowledge and Practice on E-waste recycling among public

It was observed that 55% of the total respondents knew about E-waste recycling, whereas 45% have no idea. In contrast, 64% of the respondents do not practice E-waste recycling (Figure 4.5). In a similar research in Shah Alam, 57% of the respondents were knowledgeable about E-waste, while 43% have no idea what E-waste entails (Kalana, 2010). Findings by Kasapo et al. (2015) revealed corroborated results where 60% of the respondents did not know about E-waste. Moreover, the study conducted in University Technology, Malaysia concluded that knowledge about E-waste among publics in the University was 'severely low' although an exact figure has not been reported (Yousuf, 2008; Kasapo et al., 2015). According to Shah et al. (2015), Material Flow Analysis (MFA) on E-waste showed that 55% of the respondents were not practicing recycling at all.

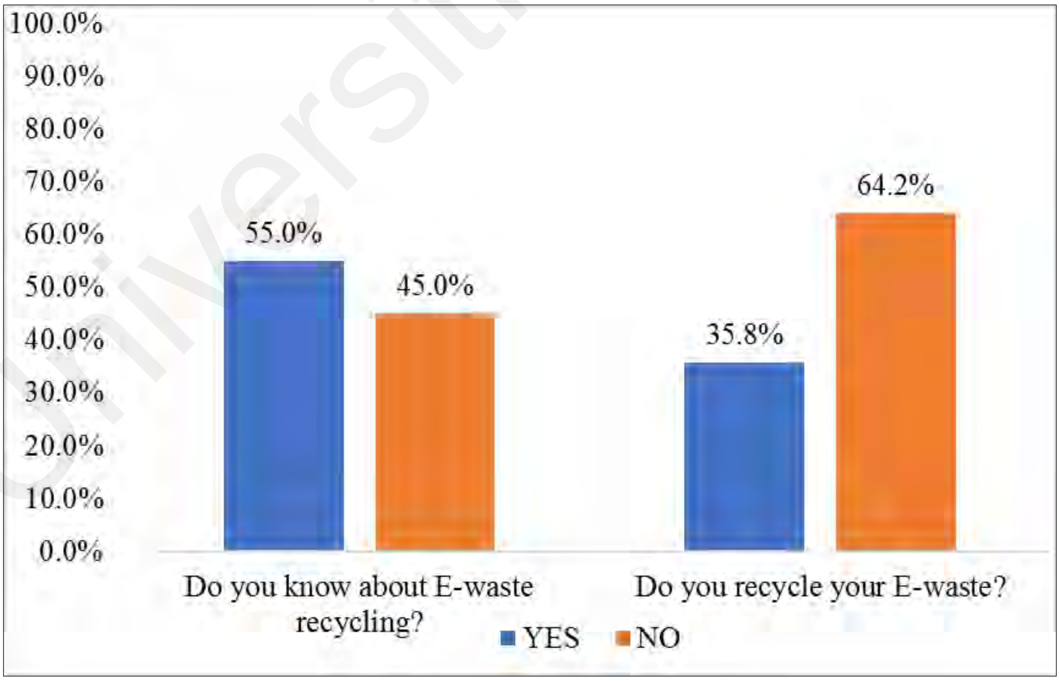

Figure 4.5: Public knowledge and practice about E-waste recycling

In Figure 4.6, inadequate facility (18.8%), authority should be responsible (18.6%), time constraints (18.3%), insufficient recycling bins (13.2%), and distance of the recycling centres (11.6%) were the main reasons given by the public for not practising E-waste recycling. Besides, 7.7% of the public store their electronic items as they have many rooms in their home and 7.8% do not care about the recycling.

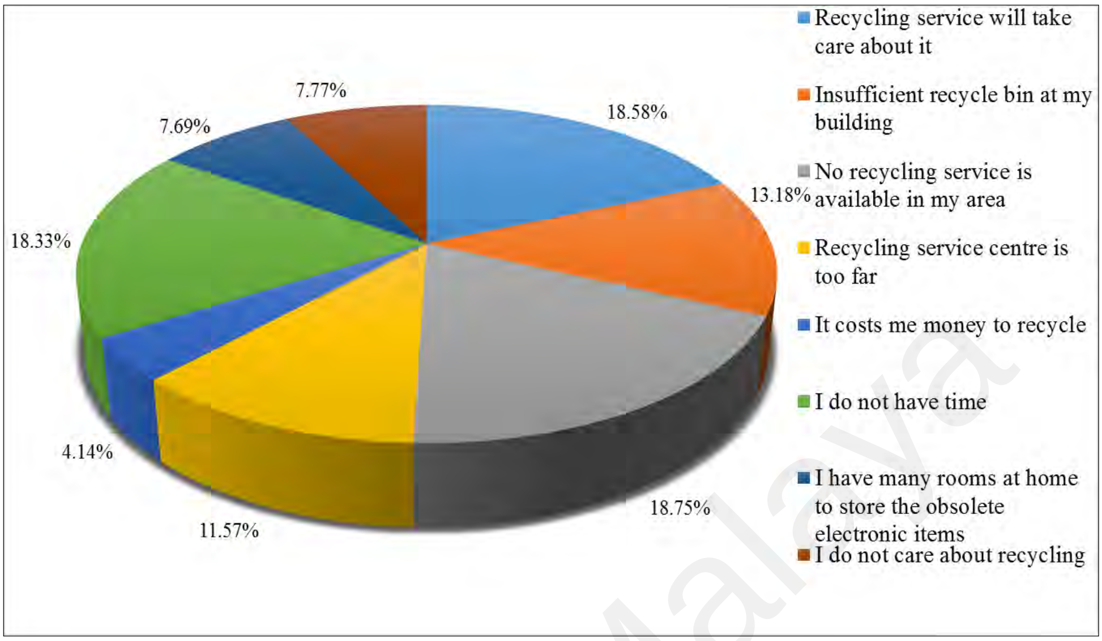

Figure 4.6: Reasons for not recycling E-waste (by the public)

In terms of public response on the current E-waste management and recycling services, about 59.8% of the public were unaware of the location of the nearest recycling centre in their premises although they mentioned some of the recycling companies such as Alam Flora, T-Pot recycling centre, Shan Poornam, Aeon, Samsung, Kualiti Alam, etc. Most of the respondents (71.3%) were unaware of the presence of E-waste bin in their premises. However, about 28.7% of them knew about it, out of which 12.8% were aware of its location in the commercial areas. Regarding the use of E-waste bin, 65.5% have not used it while 34.5% have used it. Despite the knowledge about the location of recycling centres, about 59.3% did not send any item for recycling. On the other hand, about 78.8% of the public did not know about any program/campaign/project on E-waste recycling conducted by the authorities (Table 4.10). Overall, public in Putrajaya responded better result than the public in Shah Alam and Petaling Jaya on current E-waste management and recycling services.

Table 4.10: Public response on current E-waste management and recycling services

		Total (in percentage)	Name of the area		
			Putrajaya	Shah Alam	Petaling Jaya
Do you know any E-waste bin available at your area?	Yes	28.7%	43.5%	26.5%	16.0%
	No	71.3%	56.5%	73.5%	84.0%
Do you use bin for E-waste?	Yes	34.5%	35.8%	33.0%	34.8%
	No	65.5%	64.3%	67.0%	65.3%
Do you know about the nearest recycling centre at your area?	Yes	40.2%	50.5%	43.8%	26.3%
	No	59.8%	49.5%	56.3%	73.8%
Have you sent any item for recycling?	Yes	40.8%	55.0%	40.0%	27.3%
	No	59.3%	45.0%	60.0%	72.8%
Do you know any company who collect E-waste at your area?	Yes	26.5%	35.0%	30.5%	14.0%
	No	71.5%	63.0%	66.5%	85.0%
	No answer		2.0%	3.0%	1.0%
Any Project /Program/ Activity/Campaign on recycling at your area?	Yes	21.2%	34.0%	21.5%	8.0%
	No	78.8%	66.0%	78.5%	92.0%

This agreed with the previous study where the mean value of all respondents indicated that most of the respondents were not involved in any environmental activities (Shah et al., 2015). In a previous study, Malik et al. (2015) stated that accessibility of E-waste collection centres in residential areas can influence the participation of a community in the recycling activity. They further asserted that the greater the distance of the recycling centre, the less chances for a better recycling activity (Malik et al., 2015). Table 4.11 & 4.12 depict the respondents' answer from open-ended questions on obsolete electronic items that they usually sent the recycling centre and the recycling campaign/project/program on recycle that conducted by the authorities at their area.

Table 4.11: The electronic items normally sent to recycling centre by the public

Electronic items that sent by public in recycling centre	% agreed
• Batteries	3.0%
• Computer accessories (CPU, motherboard)	3.1%
• Laptop	1.7%
• Television	2.5%
• Electronic toys	0.7%
• Radio, hand phone	1.4%
• Washing machine	0.3%

Table 4.12: Recycling programs/projects/campaigns organized in respondents' areas

Name of the project/ campaign/program on recycling in the study areas	% agreed
• 3R by Ministry of Housing and Local Government, Malaysia	1.7%
• MCMC by Jabatan Telekom Malaysia	1.3%
• Program Kitar Semula by MBPJ, MBSA & PPJ	3.0%
• Take Back with AEON	4.0%
• Recycling Day by Ministry of Housing and Local Government, Malaysia	0.7%

4.3.2 Public knowledge on environmental consequences of improper disposal of E-waste

With regards to public opinion on the necessity of E-waste recycling, about 38% of the respondents believed that it is necessary to recycle E-waste to reduce environmental pollution. Meanwhile, 29% addressed their concern about human health related issues. 17% of them affirmed their awareness on the economic benefits of E-waste recycling, while 15% felt that it would increase the aesthetic view of the city (Figure 4.7).

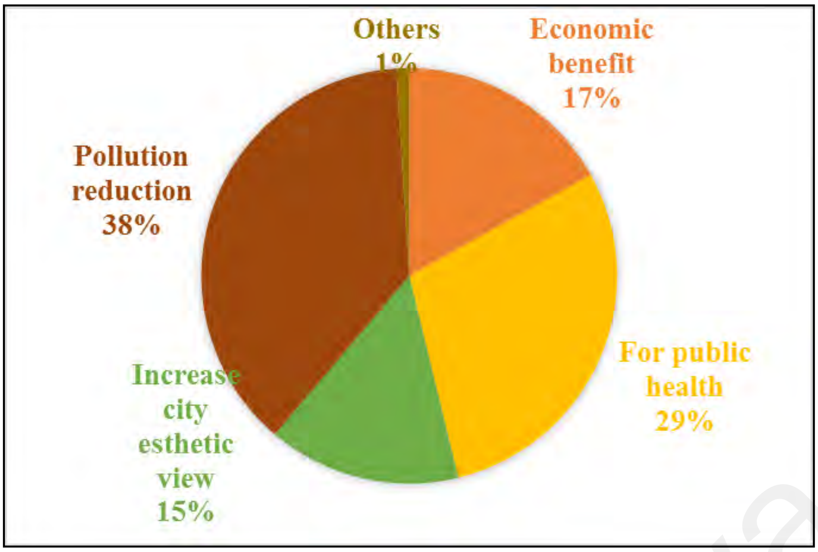

Figure 4.7: Public opinion on the importance of E-waste recycling

Zeng et al. (2017) and Jana & De (2015) asserted that awareness of the environmental consequences of E-waste results in minimizing environmental pollution and the negative impacts on the human health. Moreover, it was further stressed that visual pollution can also affect the quality of life and well-being of communities. In addition, it will reduce the economic and aesthetic appeal (Zeng et al., 2017; Jana & De, 2015). With respect to the knowledge of the presence of hazardous substances in E-waste, about 76.4% of the respondents confirmed having the knowledge, while 22.8% have no idea about it (Figure 4.8).

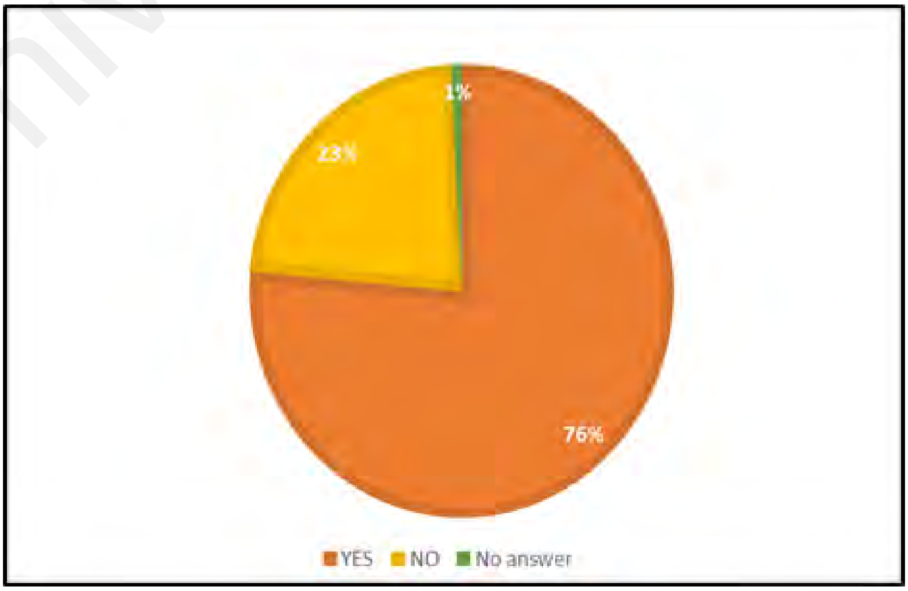

Figure 4.8: Public knowledge on the presence of hazardous substances in E-waste

55% of the respondents were conversant with the harmful impact of improper disposal of E-waste, while 44.30% were ignorant when asked about the consequences of improper disposal of E-waste (Figure 4.9).

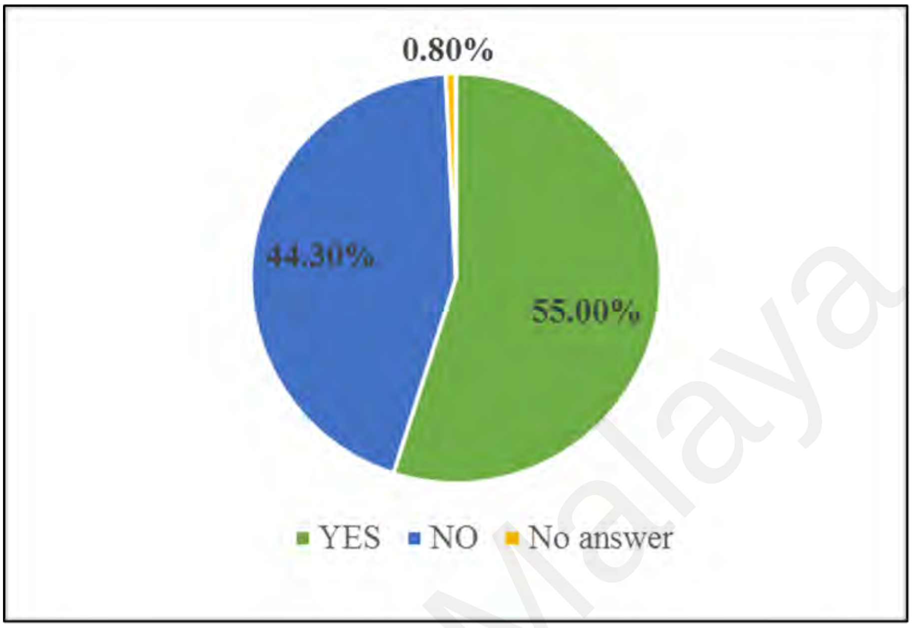

Figure 4.9: Public knowledge on the consequences of improper disposal of E-waste

Contrastingly, Kasapo et al. (2013) showed reverse results where 60% of the respondents did not know about the environmental hazards that may result from improper disposal of E-waste. However, in agreement with the current findings, Akter et al. (2014) reported that 56% of the respondents were aware that electronic equipment can create environmental problems and health hazard. In a related instance, Cristina & Brian (2019) revealed that almost 80% of the children in Guiyu, China suffered from respiratory problems as a result of improper disposal of E-waste imported from the USA.

The collected responses from the open-ended questions were summarized in Tables 4.13 and 4.14. The hazardous substances in E-waste were listed together with the environmental issues resulting for improper disposal of E-wastes.

Table 4.13: Public response on the presence of hazardous elements in E-waste

Presence of hazardous elements in E-waste	% agreed
• Lead	4.3%
• Mercury	8.3%
• CFC	2.2%
• Heavy Metal	2.7%
• Lithium	3.0%
• Toxic Chemicals	9.7 %
• Cadmium	0.3%
• Arsenic	1.2%
• Radioactive elements	2.3%

Table 4.14: Public response on the environmental issues caused by unplanned disposal of E-waste

Environmental issues caused by unplanned E-waste	% agreed
• Water Pollution	8.5%
• Soil Pollution	8.3%
• Air Pollution	2.7%
• Ground water poisoning	1.3%
• Radiation exposer	1.3%
• Health Hazard	2.5%
• More rubbish adding to environment	1.7%
• Illegal dumping	2.8%

Kalana (2010) stated that instead of been aware of the environmental consequences due to the unplanned disposal of E-waste, most of the publics in Shah Alam were ignorant, highlighting the limited environment associated knowledge on E-waste among the public. As such, more initiatives on awareness need to be undertaken. In similar study by Islam et al. (2016) in Bangladesh, only 9% of the households were aware about the health and environmental impacts of E-waste, while 12% do not think WEEE was a major environmental problem (Islam et al., 2016). This is rather similar with the findings of this study.

4.3.3 Public knowledge about economic benefit of E-waste recycling

Public response on the commercial value of E-waste revealed that 62.4% of the respondents knew about the commercial value of the obsolete electronic items (Figure 4.10).

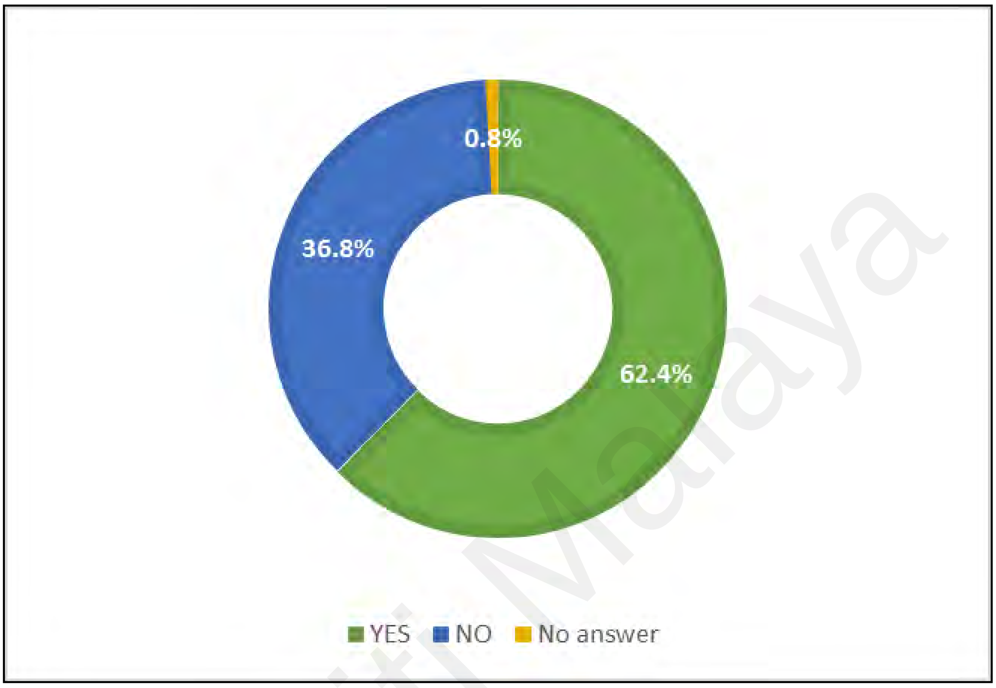

Figure 4.10: Public response about the commercial value of E-waste

Many of the respondents (37%) tend to sell their E-wastes to scrap dealers rather than the E-waste contractors (21%) (Figure 4.11), to earn more profit. Current outcome is consistent with the study by Kalana (2010) in Shah Alam, Malaysia, where about 19% of the respondents preferred to give away their E-waste to scrap dealers rather than sending them to recyclers, as scrap dealers offered higher price. It should be mentioned that recycler's price usually depends on the type of EEE, weight, and condition of the waste (Kalana, 2010).

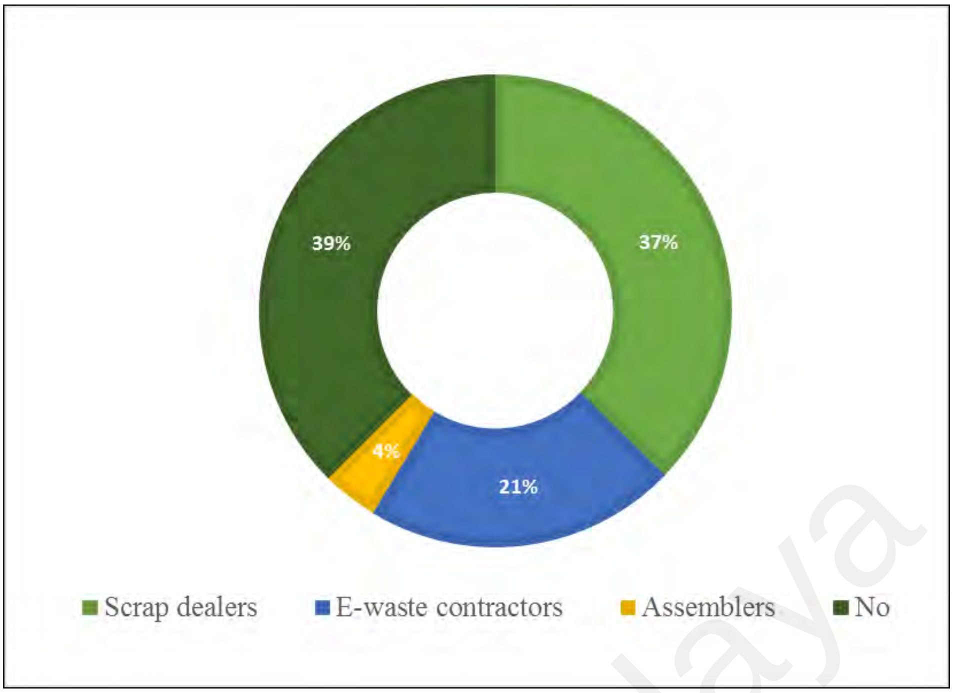

Figure 4.11: The preferred way among public to sell their obsolete electronic items

These were also some of the influencing factors that make households store their E-waste and wait for buyer with a better price. However, according to Jaibee et al. (2015), majority of the respondents asserted that they kept their E-waste because of the values. This is also consistent with those carried out in Finland where the storage of small electronic devices at home was largely because of the high residual value as claimed by the owners (Shevchenko et al., 2019; Ylä-Mella et al., 2015; Tanskanen, 2013). In similar instances, about 73% of respondents in Spain and more than half of households in Thailand stored their electronic devices at home largely because they thought that the items are still valuable (Shevchenko et al., 2019; Bovea et al., 2018; Manomaivibool & Vassanadumrongdee, 2012). In China, 47.1% of obsolete mobile phones were stored at home because used mobile phones are usually sold through the informal sector for cash-back (Shevchenko et al., 2019; Yin, Gao & He., 2014).

On the willingness to pay for E-waste recycling, most of the public (73.3%) in the study areas are not willing to pay for the E-waste recycling. 25.5% were willing to pay, while 0.8% were undecided (Figure 4.12).

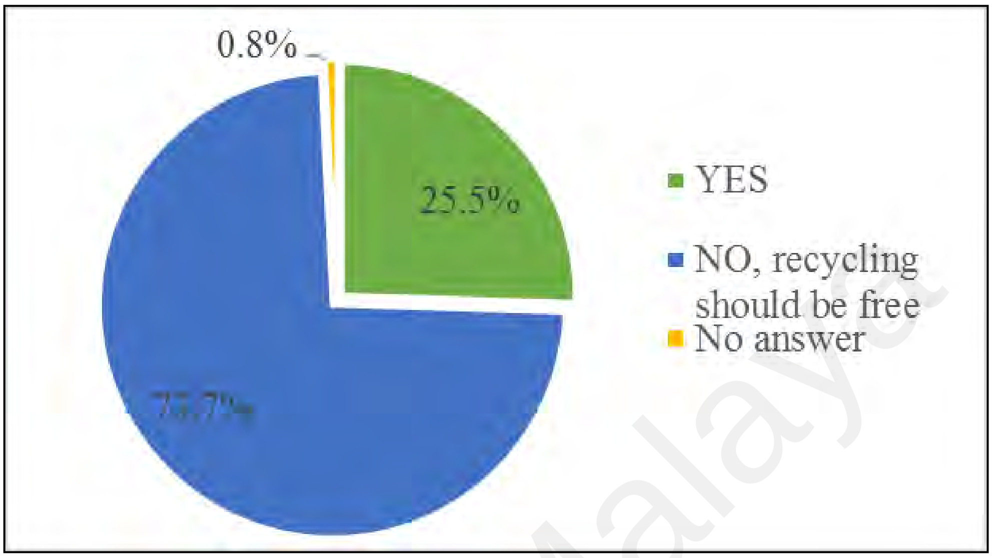

Figure 4.12: Public willingness to pay for E-waste recycling

Other findings also disclosed that public were not willing to pay for their E-waste recycling similar to that observed in this study. Public prefer to sell the items for some economic gains (Islam et al., 2016; Kalana, 2010). On the contrary, Wang (2011) showed that 22.57% of the respondents in Beijing city, China is willing to pay to recycle their E-waste, particularly if there are mandatory laws and regulations.

68.8% of the respondents showed willingness to pay for E-waste disposal as long as it is reasonable and affordable. 11.8% of them thought that the E-waste occupies more space in the house, while 7.8% believed that it will help to reduce the visual disturbance. Some of them (24.8%) expressed that they have no problem paying for the recycling if it will help in waste minimization and improve both human and environmental health (Figure 4.13). These responses proved that people were concerned about the environmental consequences resulting from the improper disposal of E-waste.

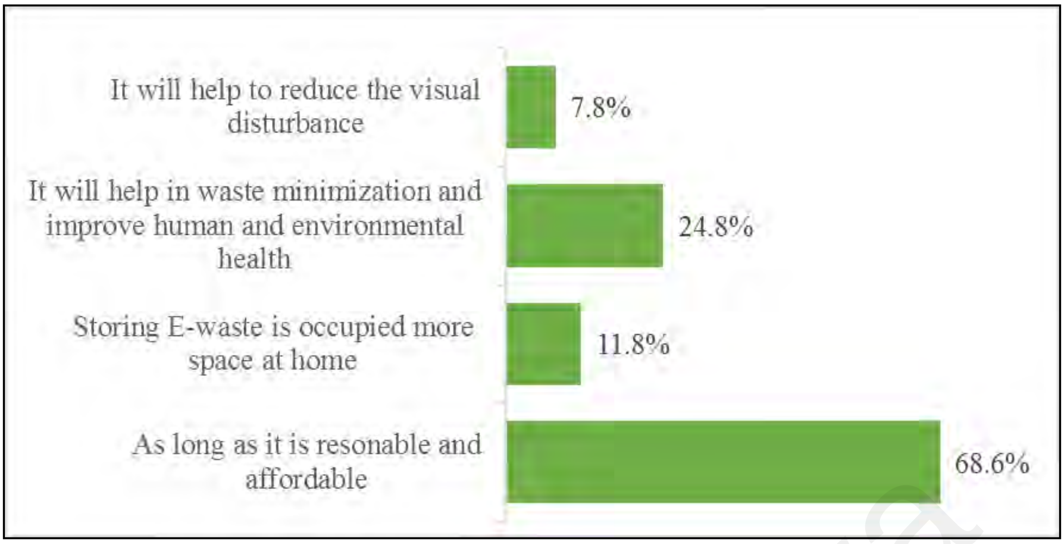

Figure 4.13: Reasons behind the public willingness on paying for E-waste recycling

Contrastingly, in a study conducted by Yuan et al. (2019), majority of the households preferred to get back some money instead of paying the recycling fees to the licensed collectors to discard the E-waste properly (Yuan et al., 2019). Similarly, according to Gao & He (2014), 28.5% of consumers preferred to receive bonus by selling their waste phones (Gao & He, 2014). Afroz (2013) also showed that most of the households were willing to dispose their E-waste if the government provide free service to collect the E-waste. Therefore, government should also hire more licensed collectors to collect and dispose E-waste. Current results revealed that economic incentives such as Deposit Refund System will improve proper return of E-waste, especially for small WEEE.

4.3.4 Public knowledge about E-waste management related policy and regulation

As for public knowledge on E-waste related policies and regulations (Figure 4.14), the combined overall knowledge of the public was 43%. About 42% of the respondents know about the policies, while only 15% have a good knowledge about the policies and regulations. In support of the current results, Bhat & Patil (2014) also revealed that 17% of the respondents in Pune city, India knew about India's policy for E-waste management. However, 48% were not aware of the related policies, while 35% have no idea of what the policies were all about (Bhat & Patil, 2014)., which concurs with the findings from this study.

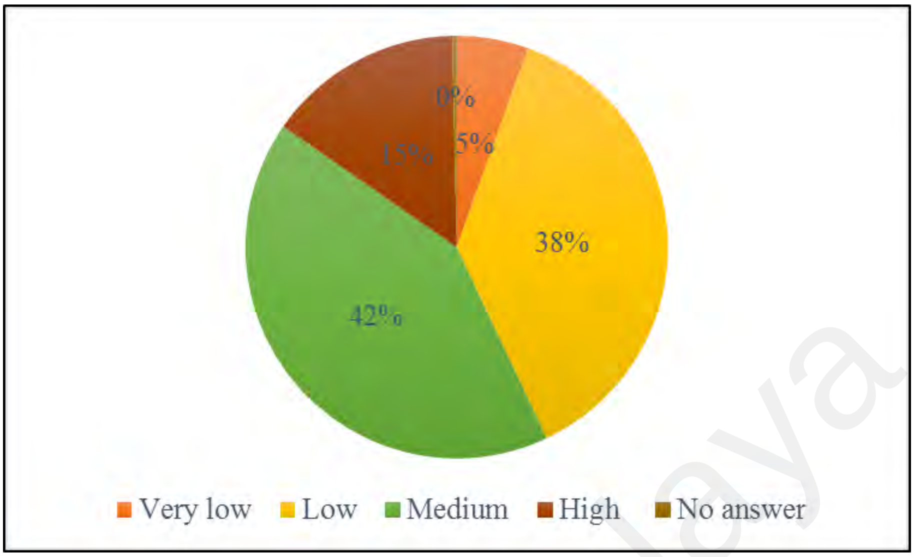

Figure 4.14: Public knowledge on E-waste management related policies and regulations

About 68% of the respondents agreed that there was a gap between legislation and the current E-waste management system (Figure 4.15), which was claimed to be the main reason behind the current unsuccessful E-waste management program. Meanwhile, 32% disagreed with the statement.

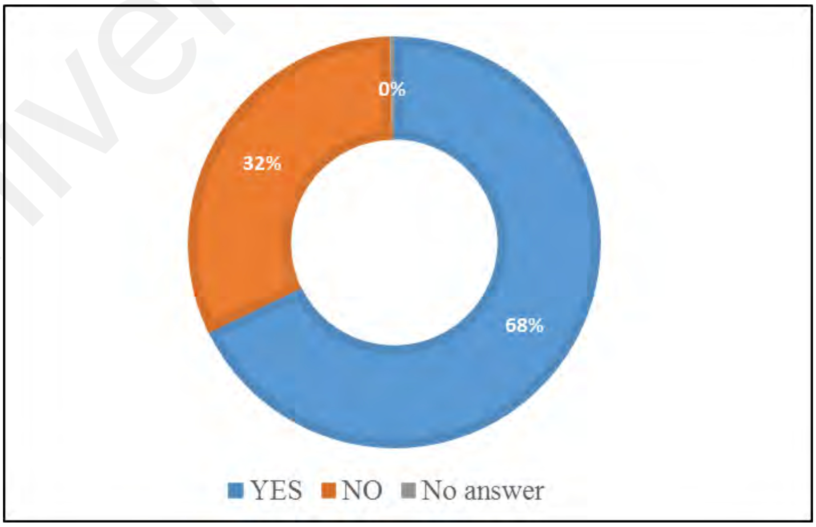

Figure 4.15: Public response on the statement on 'legislative gap is the reason of current unsuccessful E-waste management'

Public knowledge on whether Environmental Quality (Schedule wastes) Regulations (EQSWR, 2005) covered the current E-waste management, 55% of the respondents expressed that they have no knowledge about it, while 36% felt that EQSWR (2005) partially covered it. Only 9% agreed that the current E-waste management was fully covered by EQSWR, 2005 (Figure 4.16).

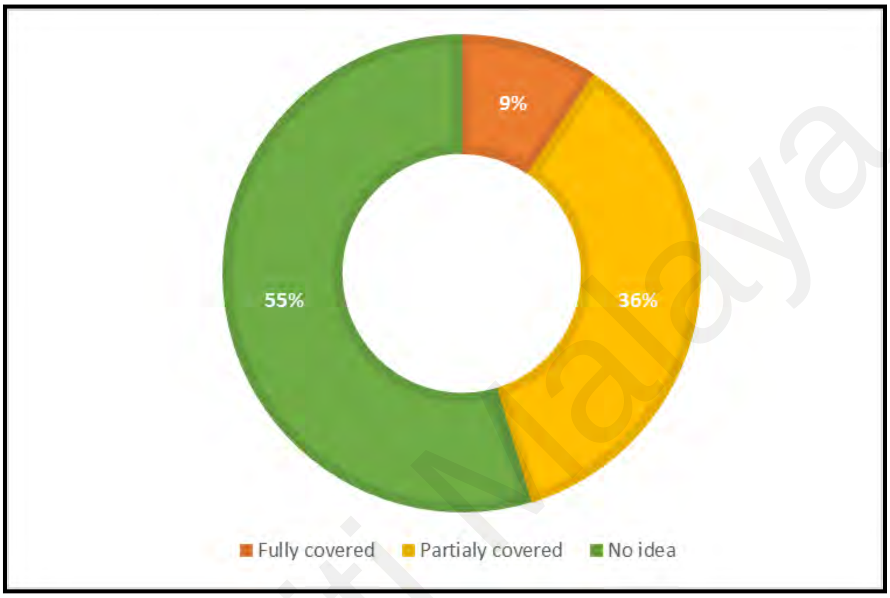

Figure 4.16: Public knowledge about Environment Quality (Schedule Wastes) Regulations (EQSWR, 2005)

On whether law enforcement can change the current practice of E-waste recycling, 72% of the total respondents agreed that legal enforcement would help to change the current practice of E-waste in Malaysia, 27% claimed that law enforcement will not change the current practice, while 1% of the respondents were undecided (Figure 4.17).

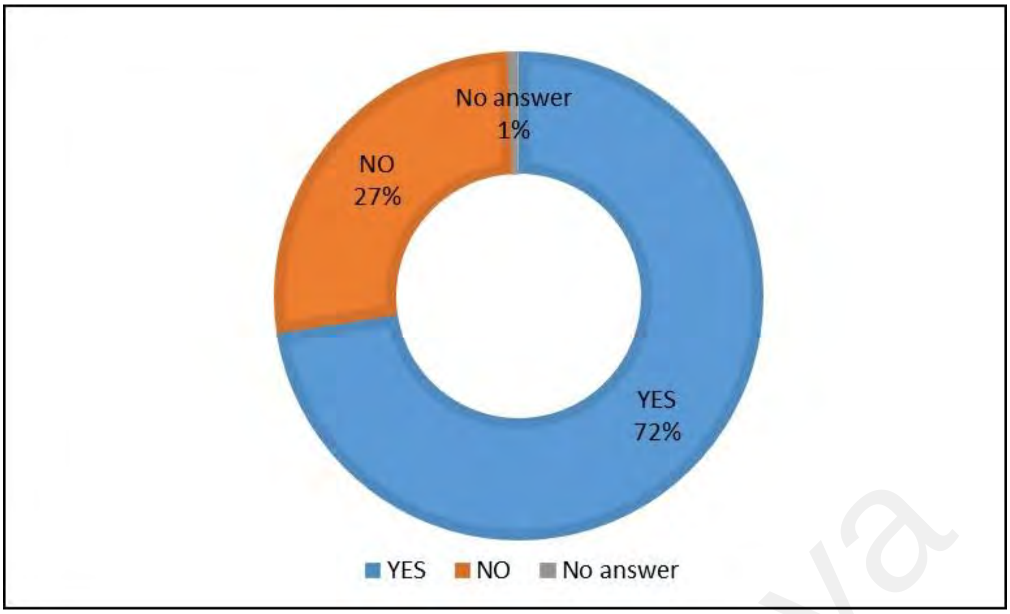

Figure 4.17: Public response on the statement of 'The enforcement of law can change the current practice of E-waste recycling'

In support of the respondents that agreed that enforcement will change the current E-waste recycling practice, Yuan et al. (2019) stressed that E-waste recycling can be achieved through law enforcement using appropriate guidelines. However, due to the absence of appropriate regulations on E-waste recycling in Malaysia, efforts to achieve effective E-waste management has been hindered (Yuan et al., 2019; Tiep et al., 2015). Akil et al. (2015) revealed that 24% of public in Iskandar, Malaysia believed that sanctions should be put in place, while majority (70%) showed their willingness to participate without any legal action (Akil et al., 2015). This is showed the contrast result with the findings from this study.

4.3.5 Waste segregation practice

According to the current study findings, the practice of waste separation among the public was very low. Public did not separate their E-waste from the general waste. The waste was heterogeneous as it consists of various mixed items (Plate 4.2 & 4.3).

Plate 4.2: Medical waste mixed with the general wastes.

Plate 4.3: Electronic toys also found together with the general wastes.

Majority of the public (60.1%) did not practice waste segregation that the overall waste separation was very low (39.9%). On the other hand, current findings indicated that due to the available, easily accessible and better waste segregation facilities, the public from Putrajaya practiced more waste segregation (44.9%) than those in Shah Alam (29.2%) and Petaling Jaya (25.9%) (Table 4.15). Corroborated results (52.9%) were reported by Malik et al. (2015). Akil et al. (2015) reported that 37% of public in Iskandar, Malaysia was practiced waste separation and 26% of them had never separated their waste. Meanwhile, only 11% of the public seldom separate their waste (Akil et al., 2015).

Table 4.15: Waste segregation practice in the study areas

		Name of the areas							
		Putrajaya		Shah Alam		Petaling Jaya		Total	
Do you separate your wastes?	**YES**	215	44.9%	140	29.2%	124	25.9%	479	**39.9%**
	NO	185	25.7%	260	36.1%	276	38.3%	721	**60.1%**

4.3.5.1 Types of waste commonly segregated by public

In this study, 11% of electronic appliances were usually sorted out by public from the study areas apart from other recyclable wastes (Figure 4.18). On the contrary, Cheng et al. (2017) resulted that 0nly 1% of total respondents from Putrajaya (4 out of 400) were segregated their electronic wastes and small electronic appliances which was their least major segregated solid waste (Cheng et al., 2017).

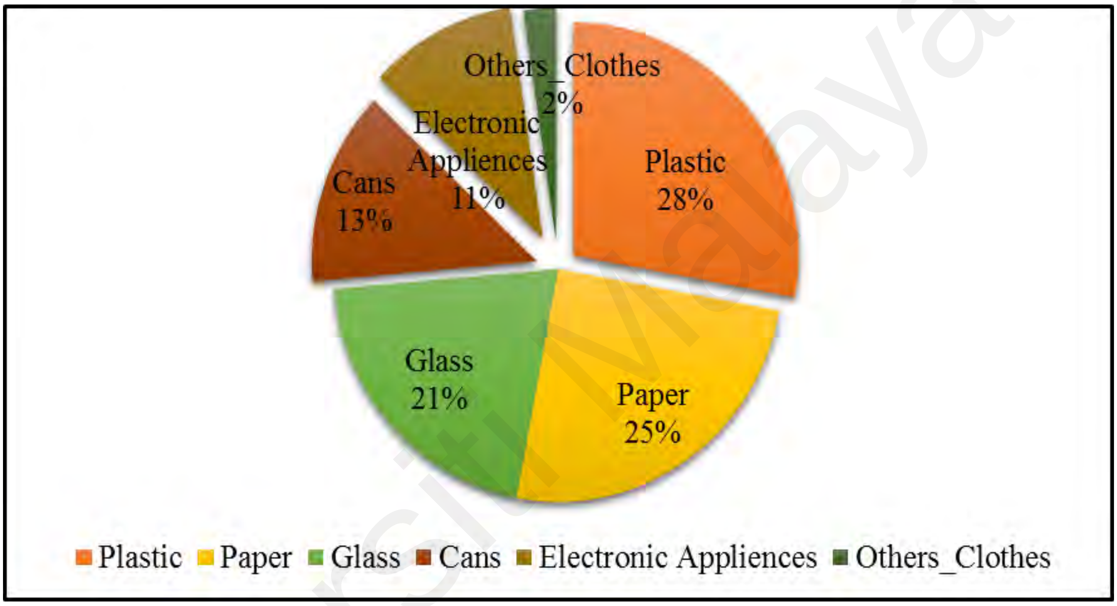

Figure 4.18: Types of waste that the public segregate

4.3.5.2 The reasons why public did not segregate the wastes

The most frequent reasons given by the respondents for not practicing waste segregation were time constraints (24%), laziness (13%), habit of throwing with other wastes (7%), and insufficient recycle bins (5%) (Figure 4.19). However, some households claimed that some of the waste collectors do not collect the waste separately even if they segregate their waste.

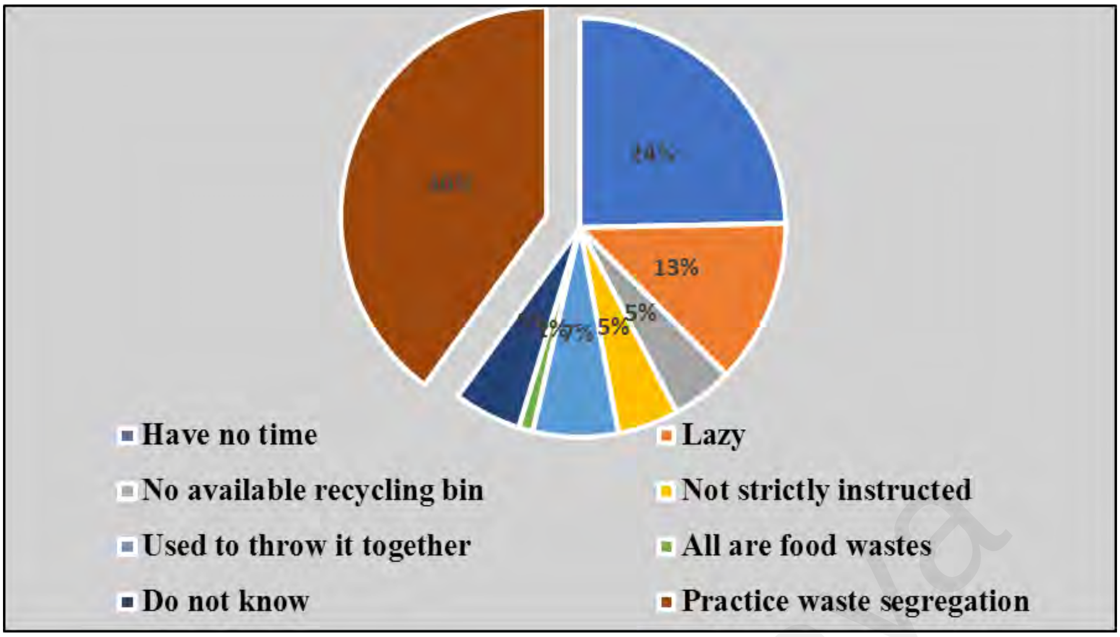

Figure 4.19: Respondents' reasons on not to segregate their wastes

On the issue of public opinion on non-cooperation with the current waste segregation program, a significant number (46%) of the public in the study areas explained that lack of awareness among people about waste segregation program was the prime reason for not practicing waste segregation, whereas others (23.3%) expressed their dissatisfaction about the program that is currently being operated by the authority. They also thought that lack of education (23.3%) about waste segregation among the public was behind the failure of the program (Figure 4.20). These results are in line with the previous study conducted in Shah Alam by Ali et al. (2017) where 58% of the respondents were not aware of the waste minimization program organized by the local authorities in their area.

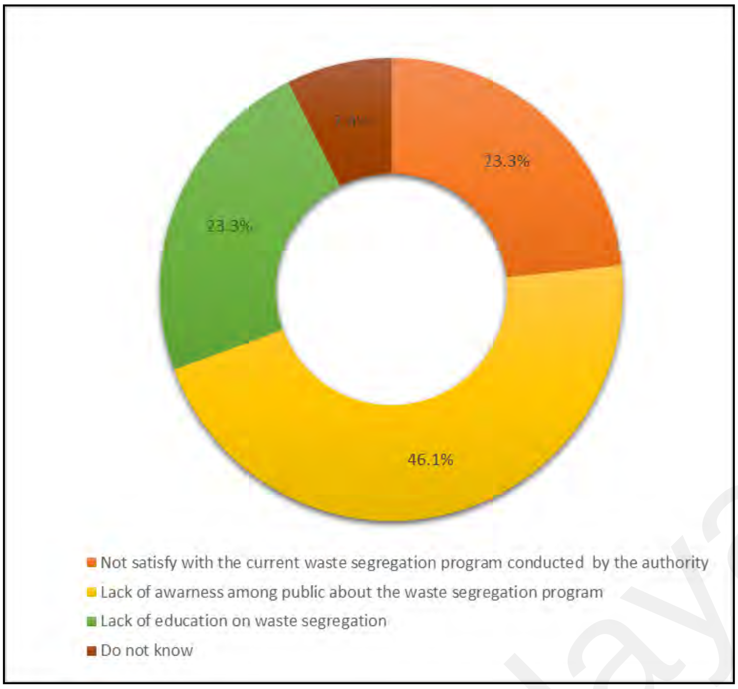

Figure 4.20: Public opinion on the cooperation of current waste segregation program

4.3.6 Small electronic items that discarded into the general wastes by the public

In Figure 4.21, batteries were the highest number of item (22.3%) discarded in the MSW stream. However, other small electronic items like electronic toys, CD's, computer accessories, cartridges, TV remote controls and broken kitchen equipment have reportedly been discarded into their MSW bin.

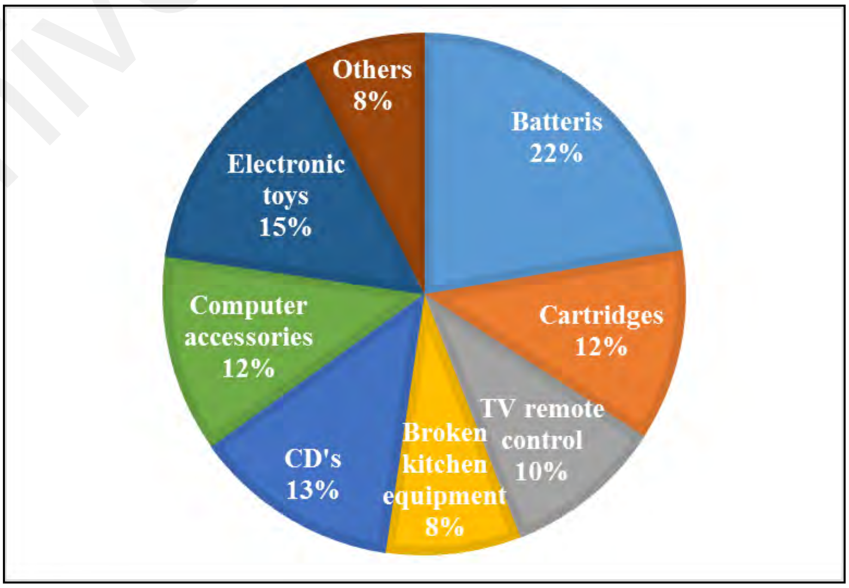

Figure 4.21: Small electronic items thrown with MSW by the public (in percentage)

The disposal of batteries into MSW was highest in Shah Alam (23.6%), followed by Petaling Jaya (22.0%) and Putrajaya (21.3%). Moreover, 14.7% of computer accessories was discarded with general waste by the public in Shah Alam. On the other hand, highest number of electronic toys (17.7%) was disposed by the public in Petaling Jaya while 12.7% of cartridges disposal into MSW was recorded in both Putrajaya and Shah Alam. (Figure 4.22).

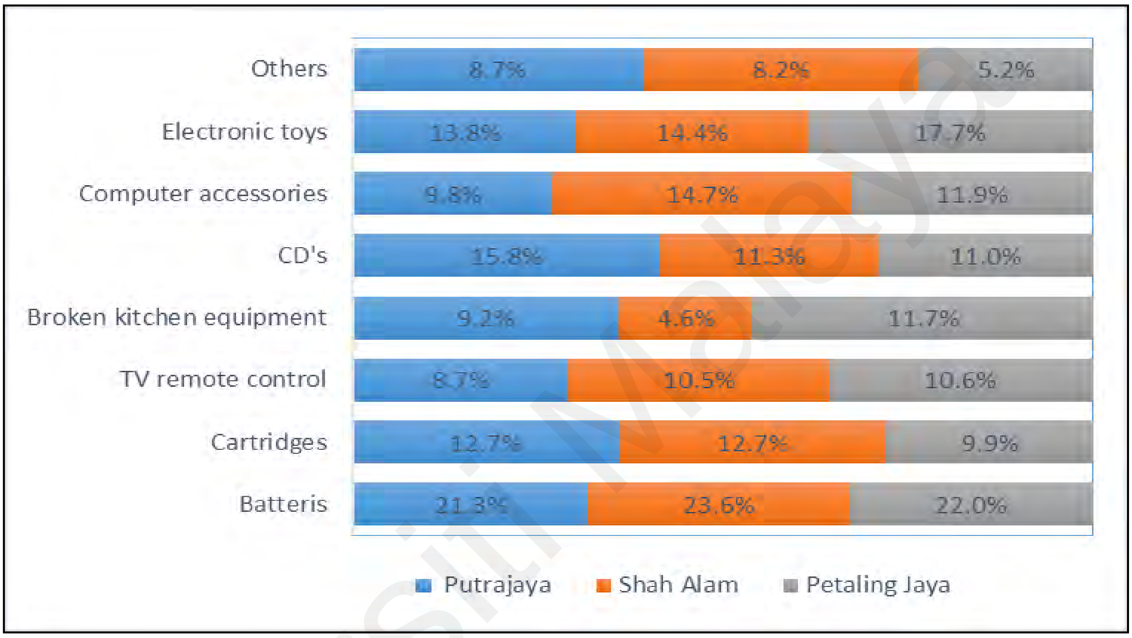

Figure 4.22: Small electronic items discarded into MSW stream by public (city wise)

4.3.6.1 Reasons behind the disposal of electronic items by the public

In this study, publics were asked to give reasons for disposing their electronic items. 'Malfunction during use' was the primary reason given which accounted for 32%, while 'lifespan elapsed' and 'Products being outdated' constituted 23% and 22%, respectively. Additionally, majority of the public (13%) disposed their old electronic items because of the high cost of repairs. However, 8% of them disposed it due to the cheaper price of the new products and a very few respondents (2%) donated their old electronic items to others (Figure 4.23).

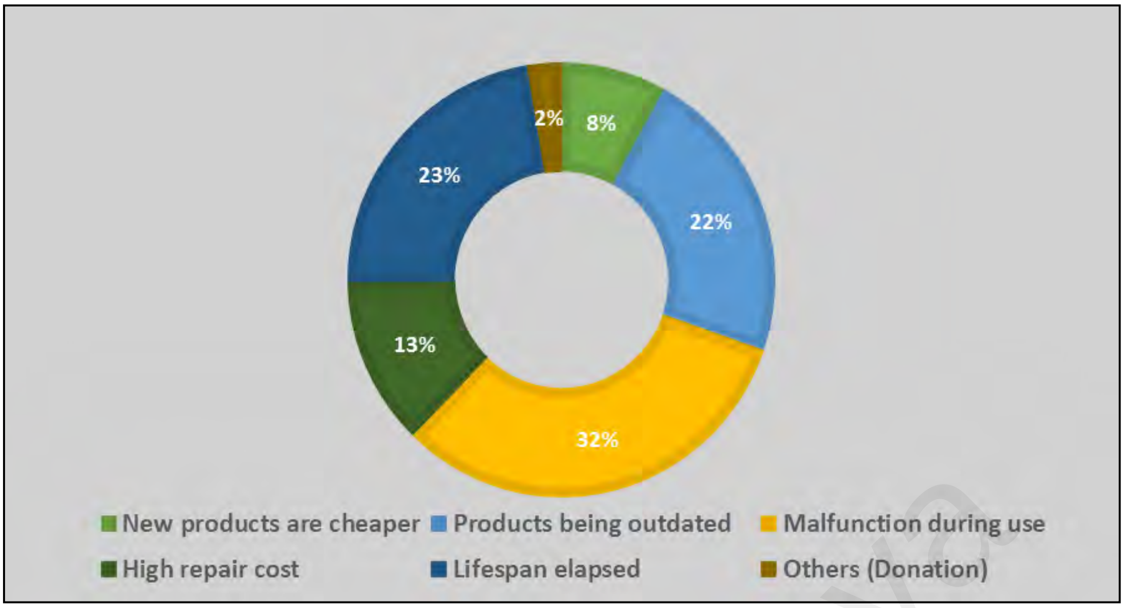

Figure 4.23: Reasons behind discarding the electronic items by the public

Similar findings by Kalana (2010), showed that about 48% and 46% of the respondents disposed their electronic items because of malfunction and lifespan elapsed. As highlighted by Kalana, (2010), due to the increasing affordability of new products and technological advancement, it is easier to buy a new product rather than repair the outdated one. In comparison with the study by Tiep (2015) in Melaka, Malaysia showed that 'high repair cost' (40%) and 'the item being outdated' (35%) were the major reasons given for abandoning electronic items by households rather than malfunction (20%), cheaper new product (15%), and lifespan elapsed (15%) (Tiep, 2015). In another study, Islam et al. (2016) stated that 22.24% of the households thought that existing EEE items lacked additional features, whereas 19.13% of households discarded their electronic items because of backdated capacity (Islam et al., 2016). The reason for discarding items was not because the items are obsolete but due to the desire to have items with updated features (Islam et al., 2016).

4.4 Knowledge and practices among different socio-economic groups on E-waste management and recycling

The results of the descriptive analysis in Table 4.16 showed that the public have a good knowledge about the overall E-waste management and recycling program. Majority of the respondents agreed that E-waste must not be disposed with the other general wastes as they contain toxic metals that can be harmful to the environment and human health. Furthermore, the public were aware that E-waste can be a valuable resource and therefore, more recycling and reusing should be practiced as they can reduce the rate of illegal dumping. The current results are consistent with that of Mahat et al. (2019), get contradict that of Okoye & Odoh (2014) which highlighted that the knowledge of E-waste was low among the public (Mahat et al., 2019; Okoye & Odoh, 2014).

Table 4.17 summarises the public practice on E-waste management and recycling. The results revealed that most of the respondents do not practice waste segregation and recycling in their daily lives. Throwing broken or obsolete electronic items together with MSW, storing them in the house, or selling to scrap dealers, were the common practices among the public. Very few respondents were involved in community recycling programs. This means that the practice on E-waste management and recycling among the public were not satisfactory. These outcomes partially agreed with the previous research of Mahat et al. (2019) where communities in Selangor, Malaysia were at the medium level of practicing sustainable E-waste disposal and recycling.

Table 4.16: Summary of public statements to evaluate the knowledge on E-waste management and recycling

Variable	Public statements	Mean	S.D.	Percentage (%)	Mean Interpretation
Knowledge	I know E-waste should be disposed separately.	4.39	0.572	53.5	Agree
	I know E-waste contains toxic metals.	4.38	0.655	46.9	Agree
	I know unplanned disposal of E-waste is a threat to the environment and community health.	4.38	0.626	51.8	Agree
	I know E-waste can be a resource if properly managed.	4.34	0.850	54.9	Agree
	I have knowledge about the E-waste recycling.	4.25	0.729	48.1	Agree
	I know where to recycle my E-wastes.	3.39	0.884	58.4	Disagree
	I know reuse and recycling can reduce the illegal dumping of E-wastes at landfills.	4.18	0.735	52.2	Agree
	I am aware about the government initiatives to encourage E-waste recycling among the public.	3.38	0.672	73.2	Disagree
	Average score	**4.09**	**0.42**	**54.87**	**Agree**

Table 4.17: Summary of public statements to evaluate the practice on E-waste management and recycling

Variable	Public statements	Mean	S.D	Percentage (%)	Mean Interpitation
Practice	I separate my waste according to their components.	2.42	0.578	62.2	Not Practiced
	I throw my old and broken electronic items together general wastes.	2.73*	0.677	48.2	Moderately Practiced
	I store my old electronic items at home rather than recycle it.	2.43*	0.579	61.3	Moderately Practiced
	I reuse and recycle my electronic products.	2.32	0.531	70.9	Not Practiced
	I use recycle bin at my premises to dispose my E-waste.	2.31	0.469	70.5	Not Practiced
	I send my E-waste to the nearest recycling center.	2.29	0.550	75.3	Not Practiced
	I sell my E-waste to scrap dealers for more money rather than the authorized contractor.	2.33*	0.627	70.7	Moderately Practiced
	I was involved in the waste recycling awareness program in my community.	2.3	0.48	70.5	Not Practiced
	Average score	**2.39**	**0.33**	**66.2**	**Not practiced**

***Reverse Coding**

4.4.1 Relationship between public knowledge and practice towards E-waste management and recycling

To determinate the relationship between public knowledge on E-waste management and recycling and their practice, Pearson correlation analysis was performed. There was a significantly positive and weak relation observed between the public knowledge and practice (r = 0.067, $p < 0.05$). Since positive correlation was observed, therefore, an increase in the public knowledge will also help to increase the practice of E-waste management and recycling. A simple linear regression analysis was performed as well to predict the contribution of the practice (dependent variable) based on knowledge (independent variable) $\beta = .067$, t (1198) = 23.514, $p < 0.001$. A significant regression equation was found [F (1,1198) = 5.416, $p < 0.05$), with an R^2 of 0.005. The publics' predicted practice was equal to 2.179 + 0.053 when knowledge was measured. Publics' practice increased in 0.053 for their knowledge on E-waste management and recycling.

Current findings are supported by those of Ramos & Pecajaus (2016), where waste management was moderately practiced by the people from institutions even without having sufficient knowledge about it (Ramos & Pecajaus, 2016). The results are also in line with those of Arora & Agarwal (2012) and Laor et al. (2017), where significant relationship between knowledge and practice was also observed. In summary, it can be mentioned that proper knowledge can influence E-waste recycling practices among the public.

4.4.2 Difference in knowledge among different socio-economic groups

To acquire more information about the public understanding of the E-waste management practices, One-way analysis of variance (ANOVA) was performed to determine any significant difference between the different socio-economic groups. The findings revealed that the data was normally distributed. Moreover, based on Levene's F test, homogeneity of variance assumption was met for knowledge variables among city groups (p = 0.88), age groups (p = 0.927), education groups (p = 0.78) and income level groups (p = 0.60) (Appendix E). Results of ANOVA revealed significance differences between city groups [F (2,1197) = 12.886, $p < 0.05$] and between age groups [F (5,1194) = 2.344, $p < 0.05$]. However, education groups [F (3,1196) = 2.23, $p > 0.05$] and income groups [F (5,1194) = 0.67, $p > 0.05$] showed insignificant variations (Table 4.18).

Table 4.18: One Way ANNOVA results on the significant difference in knowledge among different socio-economic groups

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Name of the city	Between Groups	4.459	2	2.230	12.886	0.000
	Within Groups	207.101	1197	0.173		
	Total	211.560	1199			
Age	Between Groups	2.048	5	0.41	2.334	0.040
	Within Groups	209.512	1194	0.175		
	Total	211.560	1199			
Education level	Between Groups	1.178	3	0.393	2.233	0.083
	Within Groups	210.381	1196	0.176		
	Total	211.560	1199			
Income level	Between Groups	0.598	5	0.12	0.677	0.641
	Within Groups	210.961	1194	0.177		
	Total	211.560	1199			

Using Bonferroni Post Hoc comparisons between knowledge and area groups, the results indicated that Putrajaya ($\bar{X}$=4.16, *SD*= 0.414) has higher scores of knowledge than Shah Alam ($\bar{X}$= 4.07, *SD*= 0.399) and Petaling Jaya ($\bar{X}$= 4.01, *SD*= 0.43). There was no significant difference in knowledge between Shah Alam ($\bar{X}$= 4.07, SD= 0.399) and Petaling Jaya ($\bar{X}$= 4.01, SD= 0.43) (Figure 4.24 & Appendix F).

According to a research by Mukherji et al. (2016) on waste management in Delhi, India, elderly people have higher knowledge on waste management than other age groups (Mukherji et al., 2016). Corroborated results were also reported by Ramos & Pecajas (2016). Current results are equally supported by earlier findings of Arora & Agarwal (2011) where a significant difference on knowledge of waste management was reported between undergraduate and postgraduate students. Laor (2017) also mentioned that demographic characteristics mainly age, education, and occupation have significant influence on MSW management as compared to other factors. Furthermore, respondents in the range of 20 - 40 age group (81%) and bachelor and higher education group (92.9%) were more knowledgeable about MSW management (Laor, 2017). Echegaray & Hansstein (2017) realized that knowledge on E-waste among community members varied based on income levels, where high-income individuals were more aware about E-waste than low-income individuals (Mahat et al., 2019).

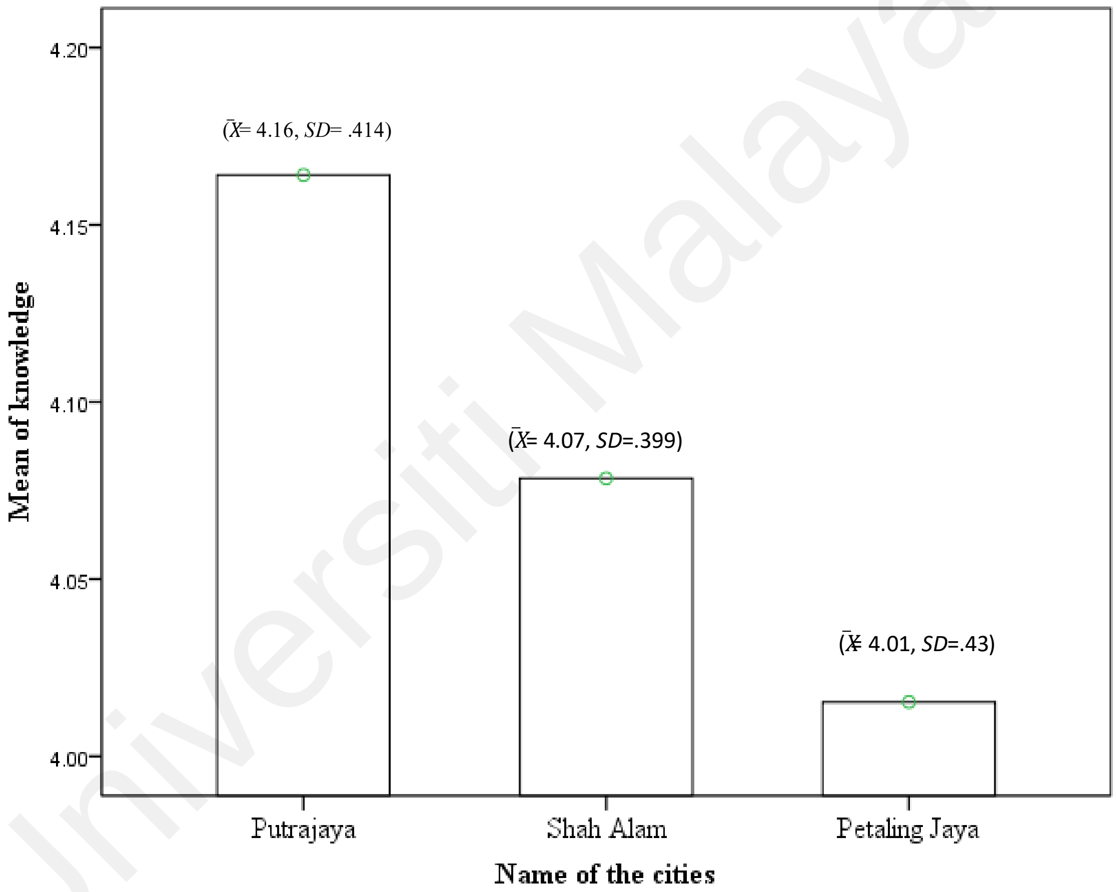

Figure 4.24: Means plot of Post Hoc test between knowledge and study area groups

4.4.3 Difference in practice among different socio-economic groups

With regards to the practice among different socio-economic groups, the assumption on the homogeneity of variances did not met between the three cities (p = 0.000), age groups (p = 0.000), and income level groups (p = 0.000). However, assumption was met for the education groups (p = 0.093) (Appendix E). *Welch's F* test was used to adjust the

F ratio for One Way ANOVA (Field, 2009). Based on ANOVA results, the average scores of public practices were significant in terms of city groups [Welch's F (2,770.49) = 119.79, $p < 0.05$], age groups [Welch's F (2, 388.52) = 7.66, $p < 0.05$], income level groups [Welch's F (2,419.35) = 8.22, $p < 0.05$] and education groups [F (3,1196) = 4.43, $p < 0.05$] (Table 4.19 & 4.20).

Table 4.19: One Way ANNOVA results on the significant difference in practice among different socio-economic groups (Robust Test)

	df_1	df_2	F	*Sig.*
Name of the city	2	770.489	119.793*	0.000
Age	5	388.518	7.66*	0.000
Income level	5	491.035	8.216*	0.000

*Asymptotically *F* distributed

Table 4.20: One Way ANNOVA results about the significant difference in practice based on education level

		Sum of Squares	*df*	Mean Square	*F*	*Sig.*
Education level	Between Groups	1.423	3	0.474	4.426	0.004
	Within Groups	128.176	1196	0.107		
	Total	129.598	1199			

Games-Howell Post Hoc test was performed on the three groups and the results showed that Putrajaya ($\bar{X}$ = 2.6, *SD*= 0.38) had higher scores of practice as compared to Shah Alam ($\bar{X}$= 2.31, *SD* = 0.27) and Petaling Jaya ($\bar{X}$= 2.27, *SD* = 0.23) (Figure 4.25 & Appendix G).

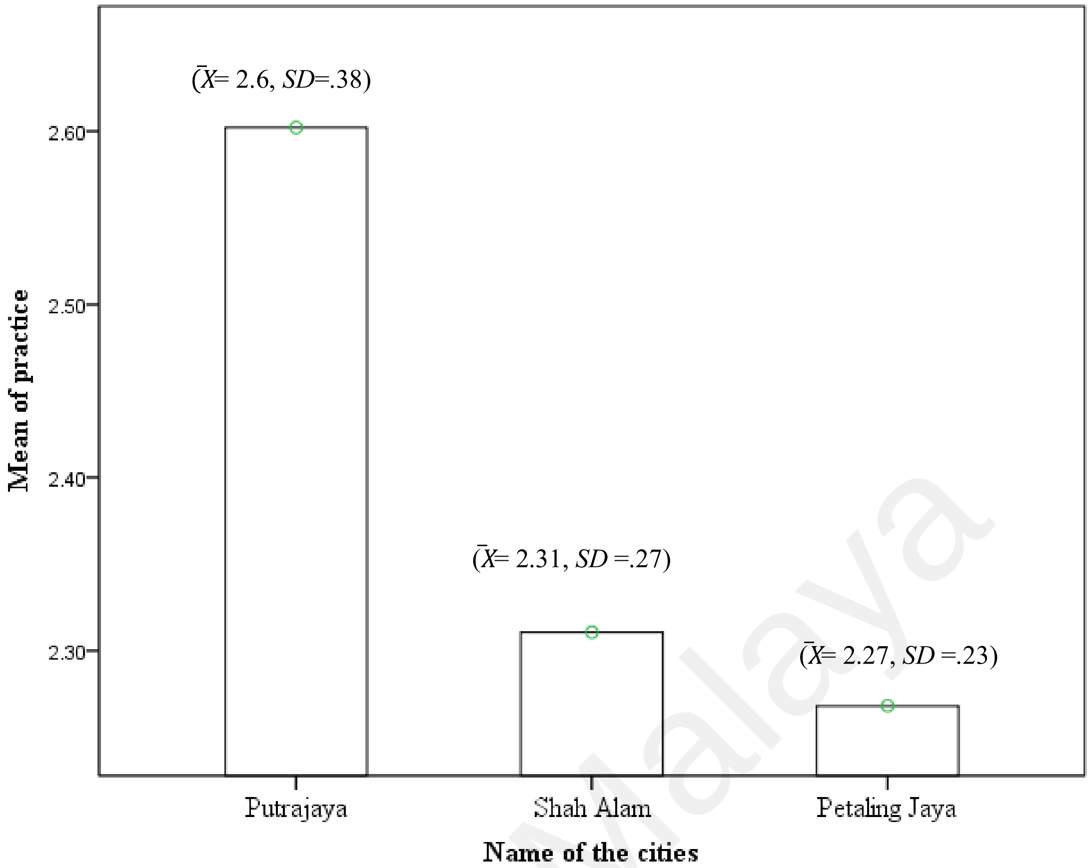

Figure 4.25: Means plot of Post Hoc test between practice and study areas

The means plot of Post Hoc test between practice and different age groups revealed that the average practice score for the age group was significant among 31 – 35 years old group ($\bar{X}$= 2.47, *SD* = 0.33) as compared to 21 - 25 years old group ($\bar{X}$= 2.33, *SD* = 0.28) and < 20 years old group ($\bar{X}$= 2.35, *SD* = 0.31). Additionally, 26 - 30 years old group ($\bar{X}$ = 2.42, *SD* = 0.35) had higher score than 21 - 25 years old group ($\bar{X}$= 2.33, *SD* = 0.28). On the other hand, the average score for 36 - 40 years age group ($\bar{X}$= 2.44, *SD* = 0.34) was higher than that of 26 - 30 years old group ($\bar{X}$ = 2.42, *SD* = 0.35) (Figure 4.26 & Appendix H).

Ramos & Pecajas (2016) revealed that respondents' profile (Socio-economic characteristics) does not affect solid waste management practice. However, Laor et al. (2017) reported that practice level of respondents was affected by demographic characteristics where respondents from the age group of 41 – 59 years practiced more recycling than the other age groups. In support of the present results, Akil et al. (2015) also reported that 45% of older age group of 55 years and above practiced more recycling than those between 35 to 44-year age groups (37.7%). This might be attributed to the fact that older age groups have more free time to practice recycling (Martine et al., 2016; Akil et al., 2015; Bruvoll et al., 2002). In addition, Alias et al. (2019) and Lee & Paik (2011) also revealed similar findings. Moreover, Choon et al. (2016) indicated that residents aged 40 and above were found to recycle more as compared to those between 30 and 31 - 40 years age group.

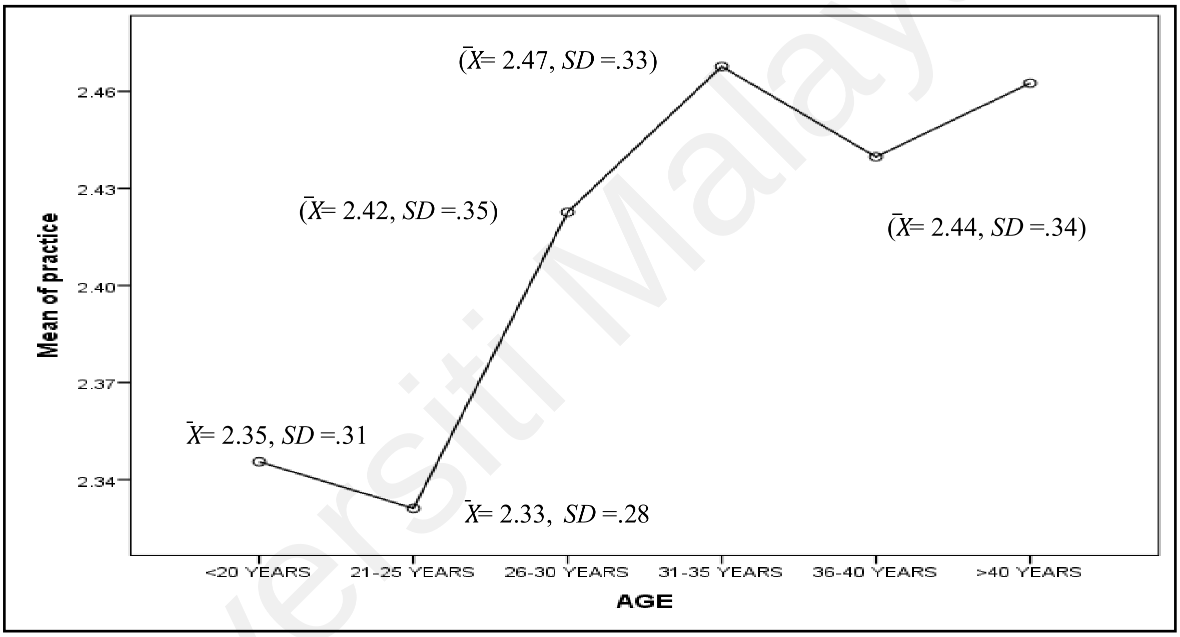

Figure 4.26: Means plot of Post Hoc test between practice and different age groups

In Figure 4.27 (Appendix I), higher practice was recorded among masters/post graduate/PhD group ($\bar{X}$= 2.45, *SD*= 0.37) as compared to school graduates/SPM/STPM group ($\bar{X}$= 2.35, *SD*= 0.30). However, the difference between other education-subgroups was not significant and therefore, the null hypothesis was accepted. Current outcomes are consistent with those of Arora & Agarwal (2011); Laor (2017) & Choon et al. (2016) where highly educated groups reportedly practiced waste management more than the other groups.

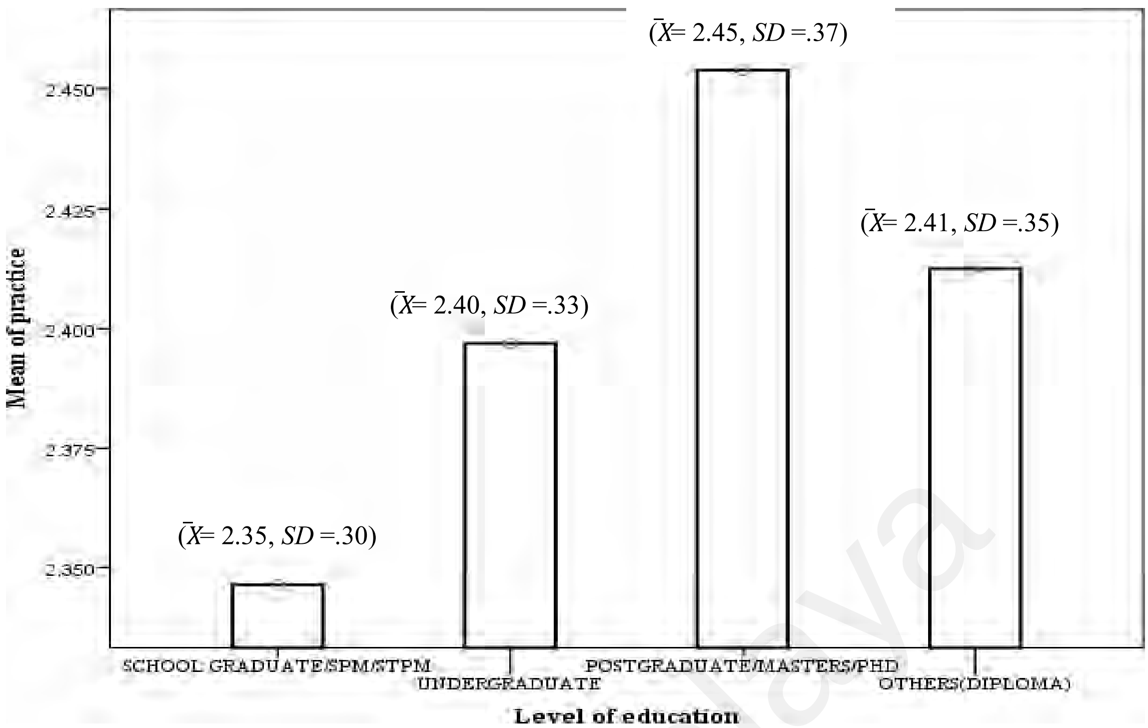

Figure 4.27: Means plot of Post Hoc test between practice and different education level

Among the income level groups, RM3001 - RM4000 income group had the highest average score ($\bar{X}$= 2.5, *SD* = 0.35) as compared to the other three groups, i.e. RM2001 - RM3000 income group ($\bar{X}$= 2.39, *SD* = 0.32), <RM1000 income group ($\bar{X}$= 2.36, *SD* = 0.3), and No income group ($\bar{X}$= 2.31, *SD* = 0.27). On the other hand, income group of > RM4000 has higher average value ($\bar{X}$ = 2.43, *SD* = 0.38) than the other income groups RM2001 - RM3000 ($\bar{X}$= 2.42, *SD* = 0.33), RM1000 – RM2000 ($\bar{X}$= 2.39, *SD* = 0.32) and No income group ($\bar{X}$ = 2.31, *SD* = 0.27). As such, the alternate hypothesis was accepted. Other subgroups however, remained insignificant and the null hypothesis was accepted (Figure 4.28 & Appendix J).

Murad & Siwar (2007) studied waste management in Kuala Lumpur, Malaysia and the results revealed statistically significant difference in recycling rate between income levels. In addition, people from MYR3001 - 6000 and > MYR6000 monthly income level groups reportedly practiced more recycling than other income level groups (Murad & Siwar, 2007). However, current findings contradict that of Wang et al. (2011) where income level had been shown to play insignificant role on E-waste recycling practice among the public in Beijing, China.

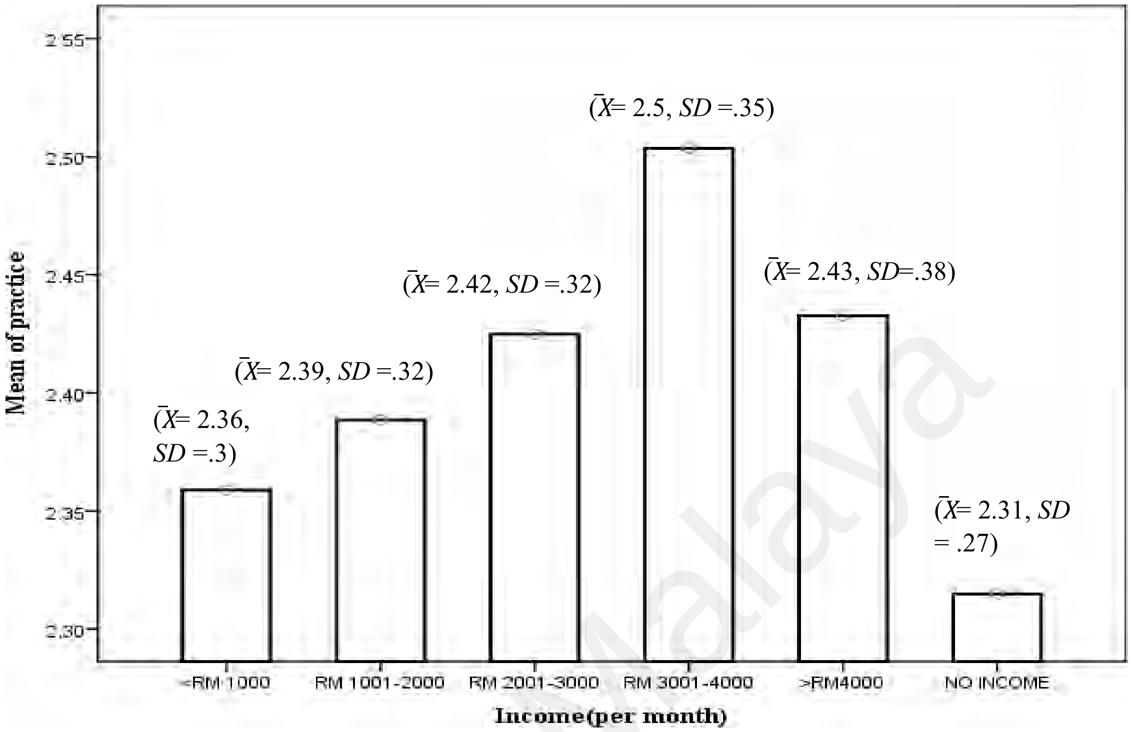

Figure 4.28: Means plot of Post Hoc test between practice and different income level

In summary, it was noted that significant relationship exists between knowledge and practice of the public in Putrajaya as compared to residents in Shah Alam and Petaling Jaya. People within the age groups of 31 - 35 years and 36 - 40 years, highly educated groups (master/post graduate/PhD) and higher-income groups (>RM4000 and RM3001 - RM4000) practiced E-waste management and recycling than the other socio-economic groups in the three study areas.

4.5 Public awareness and suggestions about current E-waste management program

4.5.1 Public awareness on E-waste management program

Publics generally received information about E-waste recycling program from various sources. 29% of the respondents received information from television, 27% from leaflets, 22% from newspapers, and 12% from radio announcement. Meanwhile, few (3%) used social networking sites (Figure 4.29).

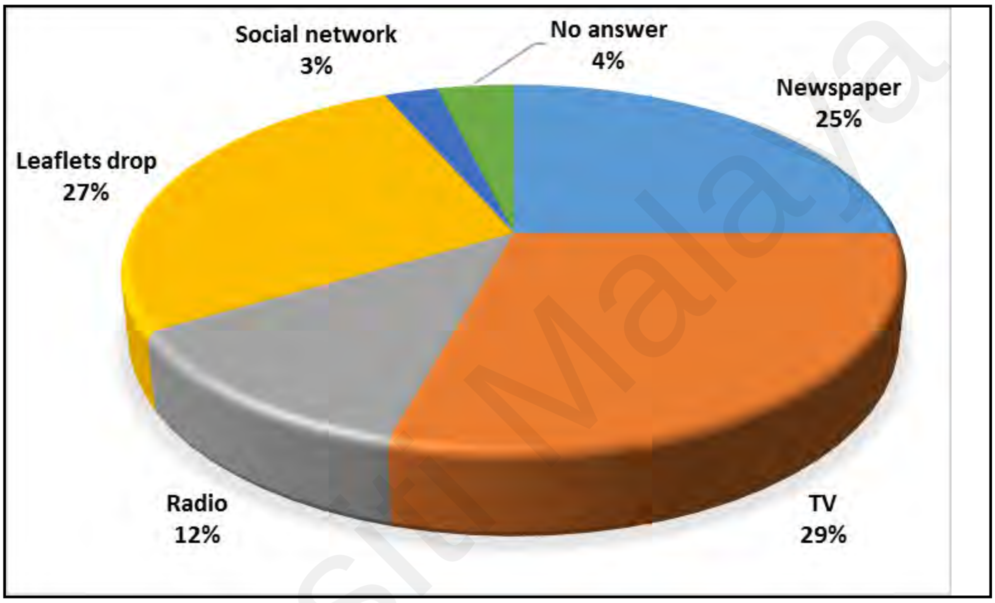

Figure 4.29: Preferred media that the public used to get information on E-waste recycling.

Many of the respondents were not well informed about the current E-waste management program conducted by the authorities. Only 9% from total respondents were very much informed about it, while 48% of them have no idea. Only 43% were informed about the current E-waste management program (Figure 4.30). In a similar instance, Tiep et al. (2015) showed that a significant number of Malaysian publics were not well informed about E-waste recycling program initiated by the government. In addition, current results are also supported by the recent findings of Yuan et al. (2019) where substantial number of the respondents were unaware of the rapid increase in E-waste. Equally, they were unaware of on E-waste recycling by the Malaysian government (Yuan et al., 2019). However, on the contrary, a research conducted by Yoke et al. (2019)

indicated that maximum number of respondents (82%) were aware of the government programs on recycling activities.

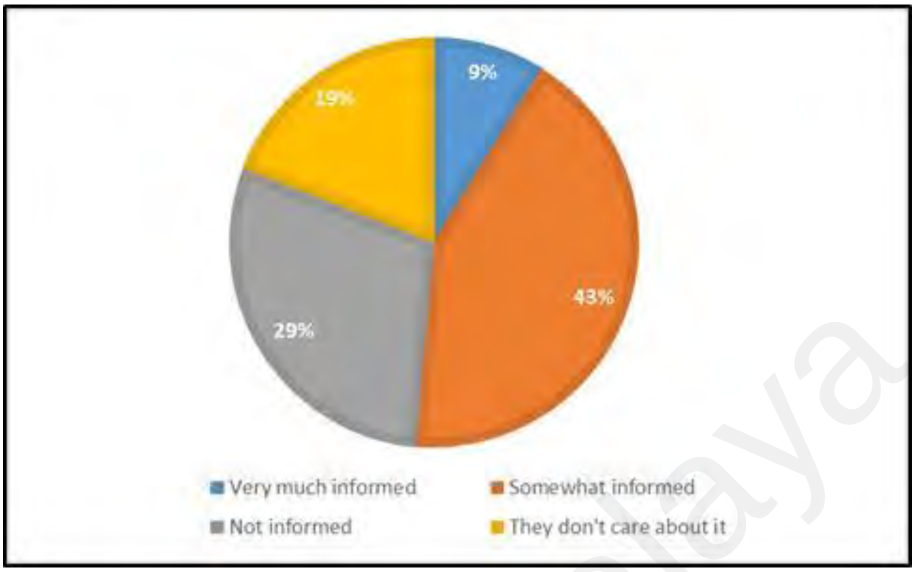

Figure 4.30: Level of awareness of public about the information on E-waste management program

With regards to overall satisfaction among public on E-waste management program, 76% of the respondents showed their dissatisfaction on the recent E-waste management program, meanwhile, only 24% were satisfied (Figure 4.31). In an open-ended question, the public pointed out some of the major reasons behind their dissatisfaction and the responses are:

I. Lack of space to collect E-waste.

II. Insufficient recycling bin.

III. Lack of publicity.

IV. Collect waste once a week.

V. No recycling facility in my area.

VI. No campaign.

VII. Lack of education.

VIII. Ignorance.

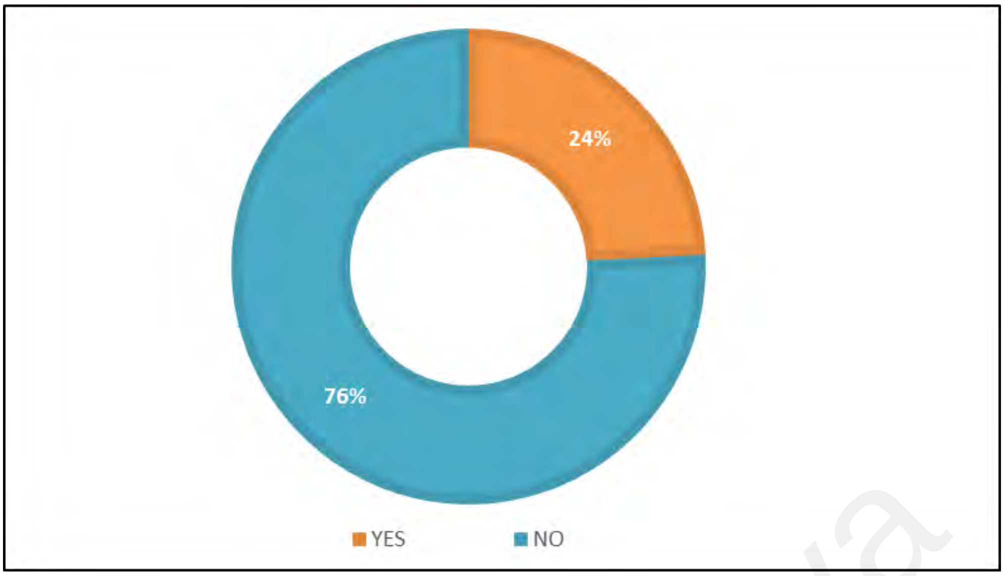

Figure 4.31: Public overall satisfaction on current E-waste management program

These findings are consistent with the study by Yuan et al. (2019). Yuan et al. (2019) further stressed that inadequate provision of facilities by the authorities and less cooperation were the major barriers to effective E-waste management.

4.5.2 Factors that can change public behavior toward recycling

Malaysian government is facing issues due to public attitude towards recycling activities (Yuan et al., 2019; Akhtar et al., 2014). According findings from this study, there are some major factors which would play a great role in changing the public attitude towards E-waste recycling. Some of the cited factors by the respondents include free charges for E-waste disposal, nearby recycling center, waste collection from home, primary knowledge about recycling, and awards/incentives for recycling (Figure 4.32).

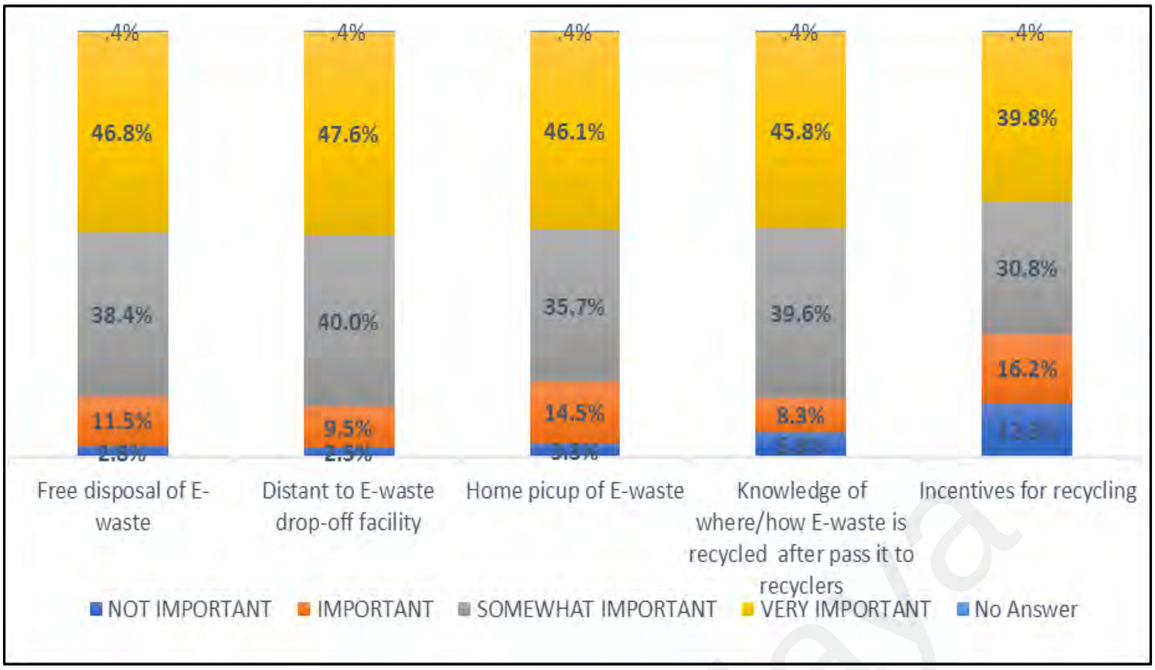

Figure 4.32: Factors that can change the current practice of E-waste recycling

Senawi et al. (2016) stated that distance plays an important role in fostering E-waste recycling behavior among communities. A more convenient distance will encourage community to recycle their E-waste (Senawi et al., 2016). Yee (2014) highlighted that the preferred distance of recycle bin for Malaysian students' community was between 100 to 500 meters. According to Senawi et al. (2016) and Amuteya et al. (2009), to increase recycling rate, any distance barriers or obstacles to recycling bins should be removed. The more convenience the recycling infrastructure, the higher the rate of participation in recycling activities (Senawi et al., 2016; Saphores et al., 2012). In an instance, Grazhdani (2014) highlighted that recycling rate increased at Prespa Park Village when the public were provided with drop-off facilities for waste recycling. This was consistent with the findings of Sidique (2010) which showed that recycling rate among the public of Minnesota increased by 1.28% upon increased of the drop-off centres (Sidique, 2010). According to the respondents, taking legal action for illegal dumping or improper disposal of E-waste could also help to raise the public participation in recycling. About 48% of the respondents were in favor of imposing fines, while only 2% agreed on imprisonment.

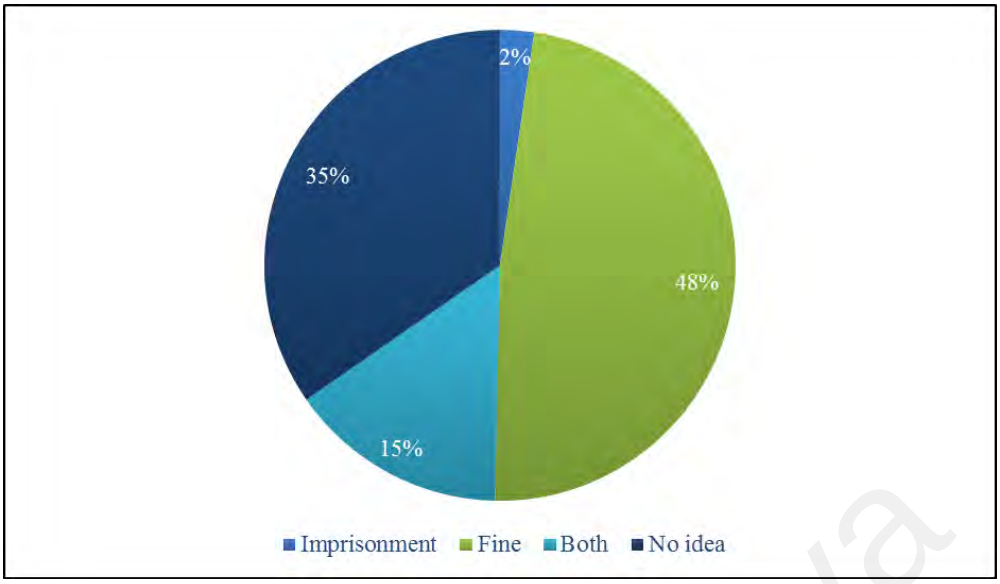

Figure 4.33: Preferred legal action for throwing /illegal dumping of E-waste

However, 15% agreed that using both actions can also change the public's behavior towards E-waste recycling (Figure 4.33). According to a study by Adela et al. (2015), the results revealed that residents failed to practice recycling due to lack of enforcement, while rewarding or punishment system can encourage recycling (Yuan et al., 2019; Adela et al., 2015).

4.5.3 Recommendations on the current E-waste management program

Education plays an important role in raising awareness, which is why education on E-waste management should be given a priority in the waste management policy agenda. In developed countries, people are more conscious about the environment, and many prefer to purchase environmentally friendly EEE products (Islam et al., 2016; Hang et al., 2006). According to Bashir et al. (2018), to create awareness among publics, environmental awareness with informal education is also needed along with the formal education. Bashir et al. (2018) further stressed that environmental education should not be narrowed or restricted to only educational institutions.

The proposed suggestions on how to reduce the generation of E-waste are presented in Figure 4.34. Based on the current findings, 35% of the respondents suggested that practicing re-use and recycling of the obsolete electronic items will help to reduce the rate of E-waste generation. 25% of the respondents recommended raising public awareness on recycling practice, while 22% were of the view of using high-quality products with long lifespan. Others (12%) suggested giving up the past habits, however, 4% recommended that wasting habit should be stopped.

According to Takahashi (2005), for a successful E-waste recycling, consumers' awareness is a must. Additionally, sufficient information on how to recycle, where to recycle, and the benefits of E-waste recycling should be provided to raise awareness among the public (Tanskanen, 2013). Nnorom & Osibanjo (2013) suggested that producers should provide information to the consumers about the recycling procedures for the product. Equally, the effects of improper disposal of the product should also be stated. The success of E-waste recycling program lies with public participation in the program.

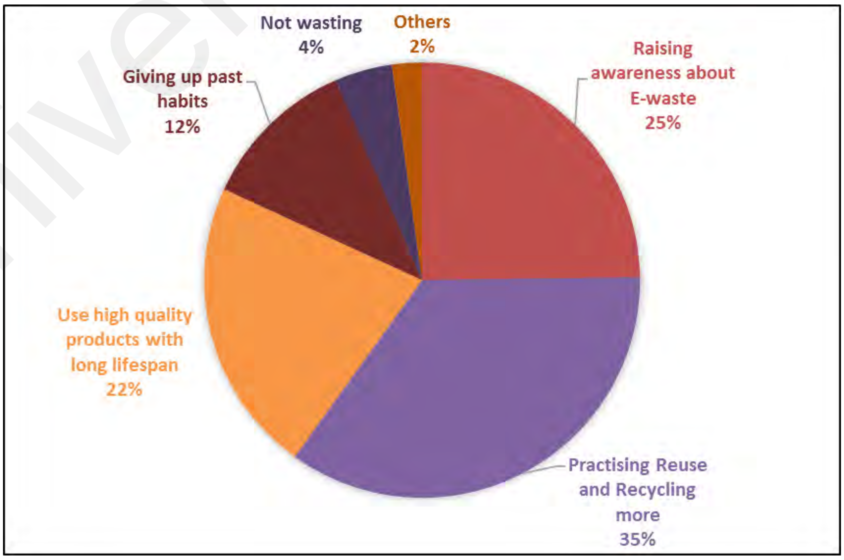

Figure 4.34: Preferred recommendations to reduce the E-waste generation

In case of public suggestions for achieving effective E-waste recycling program (Figure 4.35), 44% of the respondents agreed on the increase of public involvement in the program. About 29% suggested incentives/gifts, while 23% recommended proper training to families on how to practice recycling.

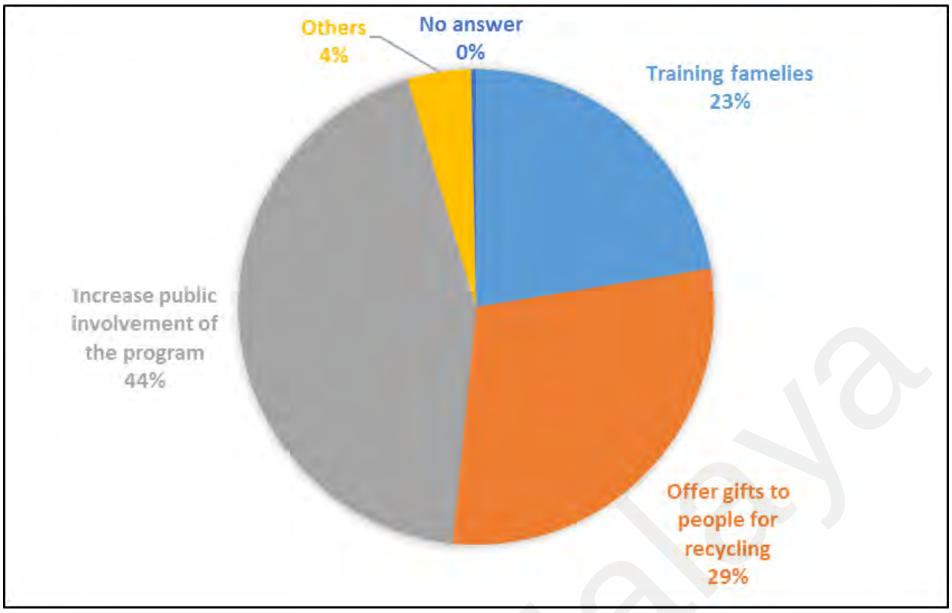

Figure 4.35: Public suggestions for effective E-waste recycling program

As for the preferred way to raise awareness about E-waste recycling, majority of the respondents (25.1%) suggested using popular social networking sites. 19.3% suggested organising education programs, 17% mentioned posting leaflets, and 15.5% recommended announcements in official websites. Others (12.2%) suggested exhibitions, while 10% highlighted open seminars (Figure 4.36). In support of the current results, an earlier study by Chibunna et al. (2012) also reprted that awareness on E-waste management was lacking among the staff and students of UKM. Chibunna et al. (2012) further stressed that, to raise the awareness, they need to provide more information through provision of formal and informal education, as well as, conducting seminars (Chibunna et al., 2012). Amuteya et al. (2009) stated that to change the current mind-set on E-waste recycling, and raising awareness, proper education and promotion from school, home, social media, and other communication systems can help to influence the public. Malik et al. (2015) also maintained that using internet will not only increase the public participation but improve knowledge and participation.

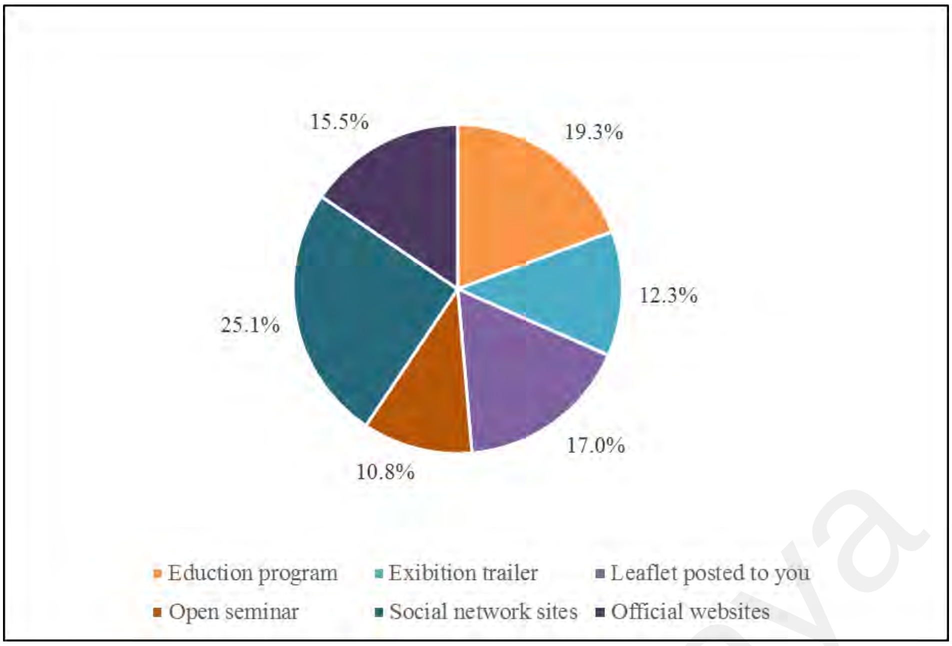

Figure 4.36: Preferred way to raise awareness about E-waste recycling

In respect to the preferred method for raising awareness among the public about E-waste management program, the respondents proposed that the most preferred method for communicating with the public is advertisement about E-waste recycling. Therefore, on that basis, 19% agreed on announcement through local radio, and 18% were of the view of sending information together with utility bills. On the other hand, publishing articles in local newspapers accounted for 18%. Others (12%) were of the view of passing information through community bulletin board, 7% preferred to get the information through the city council websites (Figure 4.37). Since local and federal governments play a significant role in the management of E-waste through creating public awareness (Dias et al., 2018). Bashir et al. (2018) suggested the role of mass media such as radio, television, and newspaper disseminate information to the public, creating knowledge, and encouraging good attitudes and behaviors. According to Alias et al. (2019), introduction of recycling concept in the community is very important as it can change the public attitude, behavior, and mindset through education. However, according to Teo (2016), the measure should not be just for creating awareness, encouragement, or improving the knowledge of recycling, however, effective management of waste should be learnt as a whole.

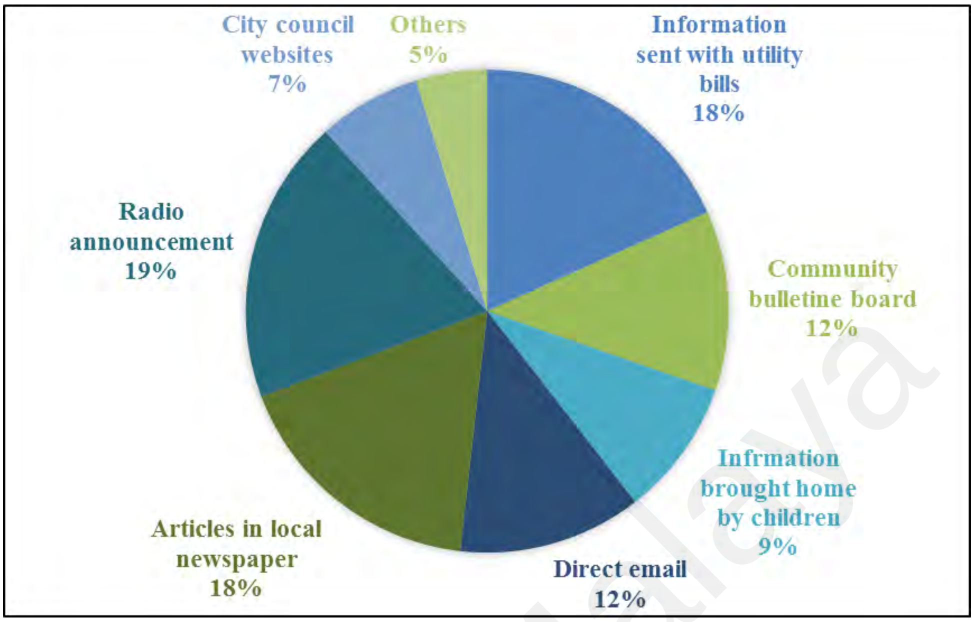

Figure 4.37: Preferred method to raise awareness about E-waste management program

Some of the public recommendations from the open-ended questions on the betterment of the current E-waste management and recycling program are:

I. More public need to involve.

II. Enforcement of local authority.

III. Need more publicity.

IV. Frequently arrange the awareness program.

V. Use social media more.

VI. More advertisement.

In order to deal with E-waste from households, Malaysian government should also enforce the regulations directly to the public. Equally, to improve the public awareness, regular campaigns should be organised to promote the importance of E-waste recycling. Additionally, researchers are recommended to adopt the "Upcycling' concept, which is the process of converting used products into valuable products that are of higher quality and benefit to the environment (Teo, 2016).

4.6 Recommendations

Based on the findings of the study, primary observations, and previous research findings, recommendations anchored on practical means to change the current situation in an effective manner are summarized below:

a. Strengthening of the policy and regulation on E-waste management

Continuous evaluation of the current E-waste management programs is necessary to determine their effectiveness on both short and long-term bases. By understanding the loopholes of a policy, improvements and new initiatives can be suggested and implemented. A close co-operation among all stakeholders, as well as comprehensive management and legal system are needed to deal with E-waste. Furthermore, both involvement and opinion of the Local Authority (LA) are essential as the LA works very closely with the community. In fact, each state should develop a Local Action Plan for E-waste collection, taking into consideration the local situation. The implementation of the new regulation is urgent, as it will be very hard to manage the household E-waste in Malaysia with all its limitations and challenges. Currently only six household electronic items have been chosen to be controlled and monitored under the new regulation. Other small electronic appliances which mostly end up in landfills or with the informal sectors should be added to this category as well. Inspired by other countries' successful stories on recycling, Malaysia also can adopt their concepts and implement them. The concept of the EPR policy can be redesigned according to the capacity of the authorities to execute it. If necessary, other favourable concepts like Pay-As-You-Throw (PAYT) and take-back programs should be included, keeping in mind different recyclable items and stakeholders/parties. Furthermore, authorities should enact regulations to penalize defaulters, that is, those who did not segregate and recycle E-waste. By the same token, those who practice recycling should be given incentives or rewards. The government should formulate sectoral regulations and in this case a regulation for household E-waste.

b. Setting up recycling centres nearer to residential areas

Based on the successful stories regarding recycling in this study, it is apparent that the location of recycling centres affects public behaviour and recycling practice. Under the DOE project, a recycling centre has been set up at a Putrajaya residential area. Due to the accessibility of the recycling service, public participation in recycling has been improved. In Shah Alam, a community service institution (mosque) is involved in providing recycling service to the residents. There are more than 200 families associated with this program who practice waste segregation and recycling. They send all recyclable items like papers, plastics, glasses, clothes, cooking oils, electronic items to the recycle centre, and some of the items were reused and recycled in a sustainable way. The collected recyclable items are sold to the recycling company, and the money obtained is used for the community's well-being.

Malaysian Communication and Multimedia Commission (MCMC) has also launched a "mobile E-waste collection box" at the community recycling centre at Taman Tun Dr. Ismail, Kuala Lumpur. Pertubuhan Amal Seri Sinar (PASS) has over 300 recycle bins located around the Klang valley which are accessible to residential areas. These success stories should provide a clear picture to the government and public authorities to act accordingly to obtain desirable results.

c. Involving educational institutions

There is great potential for collecting E-waste from both public and private institutes effectively. To raise awareness on E-waste management and recycling among the public, education is an important tool. Hence, it is essential that educational institutions should be involved in awareness raising. Environmental educational programs should be implemented for students from the primary level. Teaching children about the importance of recycling at an early stage means once they have learnt something, they are bound to share the knowledge with others. In addition, students can be kept motivated by educators in several ways: incorporating the importance of recycling in their daily lessons, providing lessons on how to recycle, holding recycling contests, organizing games and competitions on recycling or highlighting environmental issues of improper E-waste management, or encouraging the creation of prized bags of recycled items and so on. Similarly, at institutes of higher education, campaigns should be launched regularly to create awareness among students and staff. Besides, setting up E-waste collection bins at strategic points in campuses, holding seminars for information dispersal, and voluntary participation of students and staff in awareness programs will greatly help to enhance the campus recycling system.

d. Developing recycling partnership with local NGO's/private sectors

There are several private companies and local NGOs which are involved in collecting recyclable items from the community. The government should pass a legislation under which these companies can be enlisted, so that the activities they undertake will be in cooperation with the authorities.

e. Using social networking sites as platform to campaign and raise awareness

To bridge the gap between consumers' attitude and their actual practice towards E-waste recycling, it is essential to create greater awareness. Awareness can be raised by informing people about the adverse effects of improper waste management. The Government should use more social networking sites to engage public with awareness campaigns. Regular posting of photos, videos and news related to community participation in recycling programs, the celebration of recycling days and seminars would help to change the public's current attitude to an eco-friendly one. Individuals can make their pledges by sharing hashtags, for example, #nomorewaste; #mypledgeforrecycle on social media and this will enhance individual participation.

f. Celebrating national recycling day

The Ministry of Malaysian Housing and Local Government (MHLG) has proposed 11^{th} November as "National Recycling Day". It was launched in 2001 but currently it is celebrated on a very small scale. Government and Local Authorities (LA's) should organize different types of programs, educational and public awareness seminars/campaigns, competitions, and recycling fairs at regional levels where the participation of students from all institutions and the involvement of stakeholders will be compulsory.

g. Developing and upgrade a national E-waste database system and a mobile app

The government should develop and upgrade the national E-waste database system where the interface will be categorized according to generators, collectors, receivers, and recyclers of E-waste, from product usage to disposal. For data collection, a mobile app should be launched where the public can easily input their information and the collected data will be accessible for all students, researchers, government authorities, and all stakeholders.

h. Integrating waste management technology

The proper handling of E-waste cannot be achieved by itself as MSW management shares similar treatment and process. Hence, an integrated system should be considered because it can take advantage of the current infrastructure already set up by MSW management - from collection to final disposal. In this system, E-waste collection is a crucial stage where informal collection, manual separation and refining would be used to enhance the collection and recycle rates of E-waste. For a long-term approach, social, cultural and economic aspects, maintaining infrastructure, and educating technical support should also be included. The government may consider this approach to minimize E-waste generation. It should propose the integrated system to be implemented gradually by considering local priorities, as well as, continuously monitoring and evaluating the management system.

4.7 Limitation of the study

The major limitation of the study was the availability and accessibility of official data on household E-waste. Thus, the MFA was conducted based on primary data collected via questionnaire distribution. Though the residents of three cities participated in the survey very spontaneously, sometimes it was very difficult to get them to answer all the questions within a very short period. Moreover, the study areas are predominantly populated by Malays which is why the random sampling did not represent the presence of other ethnicities equally. The present study was conducted on a small scale as it was solely funded by the researcher (no research grant was funded by the university). Hence there is a need for further research on a larger scale and a sustainable E-waste management program to ensure a better environment for the future generations.

CHAPTER 5

CONCLUSION

The present study examined the issue of household E-waste management in three cities of Malaysia mainly Putrajaya, Shah Alam and Petaling Jaya. The overall findings of this study indicated that a total of 208,711kg per year of eight selected household EEE items was owned by the publics in the three cities of which 11.04% (23,034 kg per year) of obsolete electronic items will turned into E-waste. Public in Petaling Jaya and Shah Alam generated nearly the same amount of E-waste (3.80% and 3.79%), while Putrajaya produced 3.45%. Results indicated that mobile phones were the most commonly owned items (2.61 per household) among the public, while air conditioners were the highest based on weight (64,620 kg). However, on weight basis, washing machine is the highest kg per capita (5.13) of E-waste was generated as compared to other electronic items, while mobile phones were the lowest in weight (0.13kg per capita). On the other hand, 88.96% of stock of household EEE items recorded in the three cities (185,678 kg at 154.73 kg per capita). Air conditioners were the highest stock (28.38%) among the eight EEE items. Putrajaya recorded the lowest stock amount (144.41 kg per capita).

Majority of the public either stored their E-waste at home (33%) or sold to scrap dealers (33%) for more economic benefits, than selling them to authorised recyclers (16%). Putrajaya recorded the highest recycling proportion (18.53%) of the three cities due to the accessibility of recycling services and the initiatives taken by the local governments. The results revealed that the public have knowledge on E-waste management and recycling (55%). However, 64.2% do not practice recycling due to the unavailability of recycling facilities within their area. In terms of waste segregation, about 60% of the public do not practice waste segregation. However, public in Putrajaya (44.9%) practiced more waste segregation than those in Shah Alam and Petaling Jaya. On the other hand, the obsolete electronic items disposed commonly along with the MSW were batteries (22%), electronic toys (15%), CD's (13%) and computer accessories (12%).

A significantly positive relationship between public knowledge and practice of E-waste management was obtained. Upon comparison between the three cities, public in Putrajaya demonstrated greater knowledge and practice of E-waste management than those in Shah Alam and Petaling Jaya. The differences between socio-economic groups (age, education level and income level) and knowledge on E-waste management and recycling were found to be insignificant. However, the differences between socio-economic groups (age, education level and income level) and the public practice of E-waste management and recycling were significant between 31 - 35 and 36 - 40 age groups, postgraduate groups and those with income between RM3001 and higher.

Public were aware about the environmental consequences of improper handling and disposal of E-waste (55%) as well as its economic benefits (62.4%). However, 73.7% were not willing to pay for recycling of their E-waste. To raise awareness on E-waste recycling, most suggestion was to advertise campaign on social media (25.1%), radio (19%), while 18% supposed to see utility bills and local newspapers to disseminate the information. On issue of law enforcement, public (72%) agreed that law enforcement and provision of punishment can change people's behaviour towards E-waste management and recycling. On the other hand, in addition to law enforcement, frequent arrangement of the recycling program, available recycling facility around the residential areas, and offering incentives and gifts for recycling were the most frequent suggestions to enhance E-waste recycling within the communities.

In summary, it can be said that the overall situation of household E-waste management and recycling is still at its infancy though it's being practiced in some of areas. In comparison with three cities, Putrajaya showed the better result in practice of household E-waste management and recycling than Shah Alam and Petaling Jaya.

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