American Journal of Environmental Engineering 2018, 8(1): 4-10
DOI: 10.5923/j.ajee.20180801.02

Electronic Waste Management Approaches, Saudi Arabia

Bader A. Hakami

Faculty of Earth Sciences, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract Electronic waste is growing at a fast pace with emerging problems of pollution across the world. The increasing presence of toxic substances damages the environment and affects the health of human beings in case of unmanaged disposal protocols. This study demonstrates the overview of toxic substances in electronic waste, potential impacts of waste on the environment and its impacts on human health. Additionally, it presents possible electronic waste management strategies. There are different tools to deal with e-waste, such as material flow analysis, extended producer responsibility, life cycle assessment and multi-criteria analysis for managing e-waste. The major keys to success for electronic waste is to utilize eco-design devices, collection of e-waste in proper manner and recycle the material safely. It also includes, disposal of waste with suitable technique, raising awareness of negative impact of electronic waste and forbidding the transfer of electronic devices. The study indicates that there is not any single tool for management of e-waste but complementary strategies can solve the issues in best possible manner. Furthermore, the efficient policies of extended producer responsibility are quite feasible for solving the problems of electronic waste up to maximum potential.

Keywords Electronic Waste, Waste Management, Saudi Arabia

1. Introduction

Electronic wastes have been identified as one of the fastest growing waste streams in the world. In addition, Arab countries generate yearly more than 40 million tons of electronic wastes (Fig. 1). Volumes of this type of hazardous wastes is rising continuously, about three times faster than any other form of municipal waste. Moreover, e-waste can be considered as an overland mine for specific metals. During the last two decades, Arab countries were characterized as having a high generation rate of e-wastes, consequently, theses wastes became a priority among many countries in the Arab World (e.g. Saudi Arabia, Egypt, Qatar, Jordan, Tunisia, Kuwait, Morocco and Algeria). Saudi Arabia has initiated strategic plans for the assessment and management of the electronic waste problem, nevertheless these plans need to be continuously updated as e-wastes are ever so changing in composition and levels of toxicity. The proper electronic wastes management (collection, sorting, storage, collection, and disposal) requires unceasingly updated and accurate information (e.g. rate of waste generation, quantities, composition and sources). These types of information were not available for the principle cities of Saudi Arabia (e.g. Jeddah) during the preparation of this research.

One of the rapidly growing problems of pollution relates to electronic waste management worldwide. Current practice suggests that most countries around the world dispose of e-waste in landfills despite adverse impacts on the environment. Furthermore, new designs, and smart technologies are coming up in consistent manner and becoming more so ever complicated in technology. This causes the obsolescence of various electronic items contained in each device in way that makes the separation process more difficult compared to previous older technologies. These newer electronic items have a shorter life span due to new consumer designs, compatibility issues and electronic advancements. For example, computers had an average life span of 4 years in 1992 however, today they have, on average, a life span of about 2 years and this is decreasing as time goes by and companies try to find new ways to reduce prices as they compete to sell more. Moreover, the disposal of older computers is increasing in great volumes as new more sophisticated ones are being produced every year. The globally increasing e-waste is impacting our environment negatively along with associated risks to human, flora and fauna health in a significant manner [1]. Major problems of electronic waste arise from its imports from first world countries to other third world countries (Fig. 1). Which, in most cases, can be described as not being ecologically friendly, have no or very limited legislation and safeguard, no or very little enforcement of safe waste disposal processes. The social, environmental and human health problems are increasing in many countries. This study provides an insight into e-waste issues, risks it possesses to the environmental and human health from land disposals. It also offers a glance into established ways for the

* Corresponding author:
bhakami@kau.edu.sa (Bader A. Hakami)
Published online at http://journal.sapub.org/ajee

recycling and management of this ever so growing waste stream [2]. The article also gives guidance as to possible policy actions to control the e-waste problem and to limit the disposal of it in municipal dumpsites and in landfills.

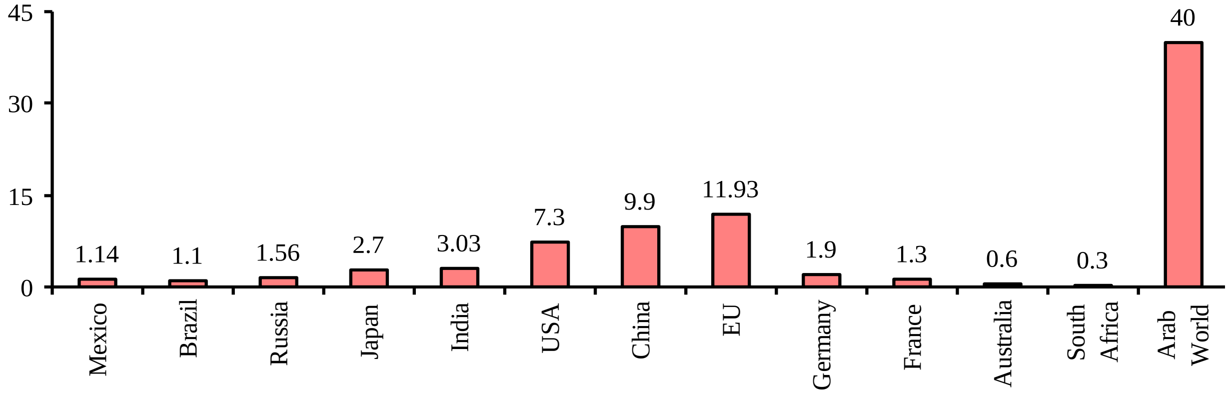

Figure 1. E-waste generation rate (million tone/year) [3]

2. Human Toxicity and Electronic Waste

E-wastes include huge quantities of toxic materials and heavy metals that cause significant damage to the environment such as; lead, cadmium, cathode ray tubes and mercury…etc. (Fig. 2). Lead can be found in computer batteries, monitors and panels, it may directly influence the nervous system, blood circulation, kidneys and the immune system. Cadmium is found in cathode ray tubes which has direct effects on the kidneys and liver. Mercury is largely found in mobiles, sensors and medical electronics, and is very poisonous to both humans and the environment. There is large number of toxic hazardous substances to humans in electronic waste that can even have adverse effects on human health through the recycling process of this waste. The waste contains a variety of materials and some of them have so many toxic substances which can contaminate the environment and impact every living aspect of it. The disposal methods of electronic waste include incineration and landfill. The landfill process can transfer many toxic substances to soil, surface and groundwater, while the combustion process emits tens of different toxic gases into atmosphere [4]. Another option is recycling of e-waste which also produces toxic substances into environment and affects health of human beings, flora and fauna. The major associated toxic substances with e-wastes also include cobalt, manganese, lanthanum, cadmium, copper, chromium, lead, iron, nickel, molybdenum and many other inorganic and organic pollutants [5]. The main impacts of e-wastes on human health include food chain issues such as contamination of soil and water resources. The recycling processes result in entrance of byproducts into the food chain. Secondly, it directly impacts recycling areas by direct exposure to toxic substances included within them. The toxicity of e-wastes to human health could be very severe and could cause acute and chronic conditions. It should also be pointed out that exposure to heavy metals for humans is a considerable health risk, especially to workers and local inhabitants.

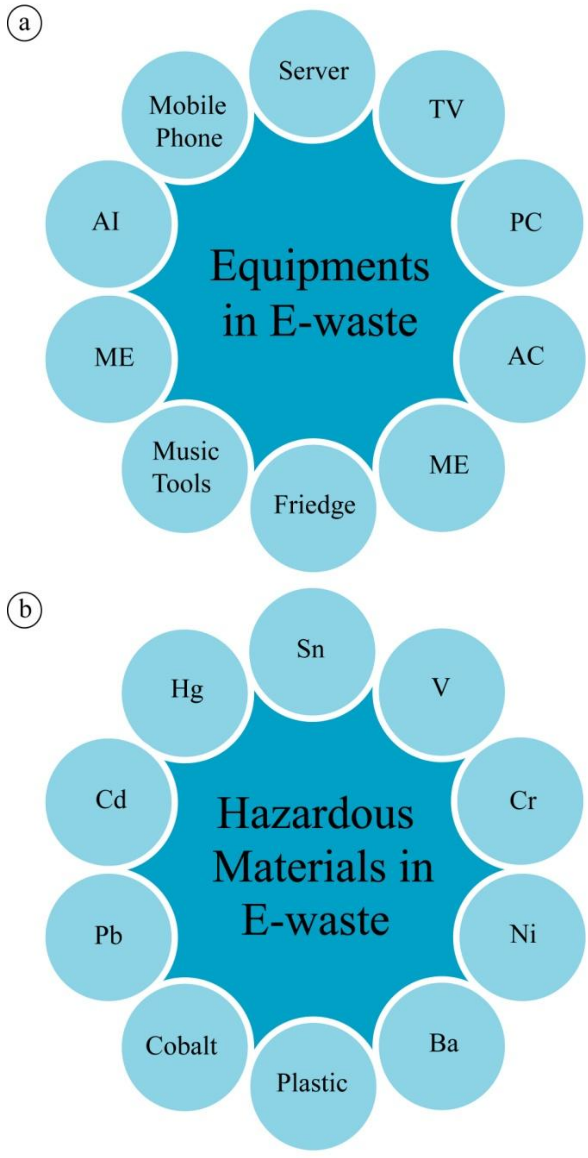

Figure 2. Different types of e-waste equipment and hazardous materials included in them (a and b respectively)

3. Environmental Impacts of E-Waste

Electronic equipment contain different substances including toxic heavy metals and organic substances which can pose serious environmental pollution problems upon irresponsible disposal. There are various environmental impacts of electronic waste at the time of treatment processes. The toxic substances present in e-waste have been well recognized in the past 20 years. Ineffective legislation across the world has resulted in unsuccessful management of this type of waste. Its amounts are rapidly increasing and ineffective legislation has led to incorrect management strategies in most countries worldwide [6]. This, today, is leading to significant impacts on the environment and, inefficient management of e-waste by landfill disposals and recycling, have posed major risks to the environment.

4. Electronic Waste Treatment Options

There are several different treatment options currently available for the management of electronic waste. These are characterized below.

4.1. Recycling Methods

The recycling and disposal of some electronic wastes is a challenge to developed countries. However, developing countries are more affected especially when cheap, low-quality electronics with lesser specifications are exported to them. This affects the economies and environments of developing countries because of their inability to dispose of the wastes or recycle them. For example, Saudi Arabia produces three million tons of electronic wastes annually. Electronic wastes are considered an environmental problem because of the effects they cause if not properly recycled or disposed of. Recycling activities are mostly manual and are labor intensive. Composting is also gaining increased interest in Saudi Arabia due to the high organic content of municipal solid waste (around 40%) in e-wastes. Efforts are also underway to deploy waste-to-energy technologies in the Kingdom. All activities related to e-waste management are coordinated and financed by the government.

There are large quantities of electronic wastes that are being moved from different areas across the world to mostly, third world countries for recycling and are being processed using manual methods in residential area's backyards in many cities. These practices usually result in considerable soil, air and water contamination. They also cause heavy metal poisoning incidents to local people and workers during these recycling practices. Some of the largest e-waste recycling sites are Gauteng in South Africa, Taizhou in China, New Delhi in India, Karachi in Pakistan, Accra Ghana where pollution levels are increasing from recycling processes [1]. It should also be indicated that there is significant pollution by heavy metals in soil, air, dust, fresh water and sediments around the electronic wastes recycling sites. These sites share the existences of heavy metals such as, Hg, Pb, Ni, Cd, Cr and As. In addition, organic pollutants are emitted from flame retardants which are formed during recycling practices of e-wastes. The production, weathering and recycling processes of e-waste generate huge amounts of impurities and can affect entire ecosystems which can get contaminated by various toxic substances.

4.2. Landfill Disposal

Developed countries are working towards achieving zero e-waste being sent to landfills. Numbers and areas are increasing for these sites for many countries worldwide. Although, modern landfills are constructed with safe isolation of electronic pollutants from the environment. The presence of old landfills which contain large quantities of e-wastes continue to cause contamination to soil and groundwater. These pollutants have large potential to migrate with groundwater and soils within landfill sites, especially where soils are highly porous and permeable [6]. Toxic organic pollutant materials in landfills decompose and percolate through soil as landfill leachate. The leachate is also highly toxic, especially if in high concentrations, consisting of suspended and dissolved organic substances, heavy metals and inorganic compounds. The concentrations of these toxic substances in leachate depend on characteristics of waste in various stages of decomposition within the landfill. The most important procedure for assessment of potential toxic substances of leachate from e-waste disposal is known as, Toxicity Characteristic Leaching Procedure [7]. It evaluates the simulation of landfill leaching in context to the eventuality of worst cases. There are many electronic devices which are subject to this procedure as it helps in determining chemical and physical properties of solid waste which outline the toxicity characteristics of hazardous waste. Toxicity of electronic devices are considered according to how many hazardous substances these devices contain. This includes heavy metals and higher than regulated concentrations of various perilous materials. For instance, the acceptable concentrations of some heavy metals in electronic devices include 100 mg/l of Ba, 5 mg/l of As, 5 mg/l of Pb, 5 mg/l of Cr, 5 mg/l of Ag, 1 mg/l of Se and 0.2 mg/l of Hg. The leachability of various components need to be evaluated comprising of e-waste [7]. For example, cathode ray tubes in television and computers are highly toxic substances which can affect the ecosystem in a significant manner. In addition, there is usually a significant probability of Pb leachability in printed circuit boards of computers which are found in many landfills. Major toxic electronic waste substances are generated from twelve appliances i.e. laptops, monitors, color TV, printers, cellular phones, video recorders, mice, key boards, smoke detectors, remote controls and flat panel television displays. All these need to be examined for heavy metal concentrations. It is indicated that concentrations of Pb in these electronic items normally exceeds 5 mg/l. Electronic items like expansion cards, motherboards, power supply units, disk drives also have high concentration of As, Hg, Cd, Cr, Ba, Se and Ag. Moreover, printed wire boards have high concentration of Pb which has major impacts on simulated landfills [9].

4.3. Incineration of E-Wastes

Incineration of e-wastes is the process of burning these wastes under high temperatures which normally exceed 1000℃. The concentration of toxic metals in leachate from electronic waste is usually higher than normal waste in landfills. This is also attributed to the requirement for incineration of these wastes before disposal in landfills in some countries. Furthermore, the incineration process is likely to destroy the organic components of e-waste and reduce their concentrations. Nonetheless, air pollution is an important factor that should not be ignored when incinerating e-waste, especially if the process is not carried out properly i.e. in designated and controlled incineration facilities.

5. Strategies to Manage E-Wastes

There are various tools for the management of electronic waste, such as life cycle assessment, material flow analysis, extended producer responsibility and multi-criteria analysis. E-waste can be managed by taking further steps with the application of the following strategies when managing electronic waste and electrical equipment to reduce the disposal of e-waste and improve the quality of the environment [10]. E-waste components can also be separated for recycling and recovery of precious and rare metals. The most efficient management strategies are summarized below.

5.1. Life Cycle Assessment

Life cycle assessment is a very efficient tool for managing e-waste and minimizing the problems of e-waste to maximum possible extent. Life cycles of electronic devices are evaluated with respect to technical development of product, eco-design and their impacts on environment. It is also necessary to consider different technical designs of electronic devices to effectively determine possible economic and environmental impacts. An environmental friendly design is always recommended for the production of all electronic devices. Life Cycle assessment is a powerful tool that can be used for the identification of potential impacts on the environment. This is done in order to develop eco-friendly products, such as desktop, computers, printers, washing machines, air conditioning systems and heating devices, electronic toys etc. [9]. LCA also defines the possible impacts on different environmental components such as the ozone layer, carcinogens, climate change, acidification, eco-toxicity, land use and eutrophication in order to improve product design and performance while mitigating possible impacts on the environment. The process of LCA is, therefore utilized for the efficient management of e-waste. LCA has also been applied for the estimation of impacts of e-waste on all aspects of the environment. It can be used to evaluate the potentials of recycling in terms of environmental and economic scores. Moreover, disposal methods including landfill, incineration, and/or secondhand markets and recycling process should all undergo LCA to determine how environmentally efficient they actually are. Recycling has negative environment impacts and landfill disposal results in high carbon emissions along with environmental load. LCA acts as a decision making tool for electronic waste management and evaluates different aspects, perceived risks and impacts on the physical environment. The life cycle of electronic items, their optimized cost and values are assessed for better decision making of waste disposal processes [12]. It is indicated that recycling is a better strategy when compared to landfilling or incineration for the management of e-waste. However, recycling may not be a suitable option every time as the process of recycling also has negative impacts on environment. Thus, a detailed LCA needs to be put in place before making any final decisions with regards to treatment options.

5.2. Material Flow Analysis

There are large quantities of electronic wastes in many developed and developing countries which are exported for recycling and reuse purpose. Material flow analysis is a technique utilized to determine material routes flowing to areas of disposal and recycling sites in the considered time and space. It links the sources of materials, their pathways, intermediate and destinations. This analysis helps in taking better decisions for environmental waste management. It considers the flow of e-waste and evaluates it in terms of economic, environmental and social terms. For example, a significant amount of electronic waste is generated due to increasing second hand electronic materials and devices [9]. E-waste can also be generated by improper recycling methods. There are many different methods available to estimate e-waste quantities from market supply and sales of electronic items and their disposal in fixed time periods. Surveys can also be utilized for estimating electronic waste quantities. It is also indicated that the quantity of e-waste has increased by 70 percent from 2005 to 2010 for obsolete electronic devices, based on material flow analysis. The material flow analysis is utilized for evaluating the economic values for analysis of Cu and Au flows from recycling of electronic devices [6]. It is indicated that there is high amount of Au and Cu in the metals which results in profit for recyclers. It is clear that the economic evaluation and MFA coupling can be very useful for areas with limited data.

5.3. Multi Criteria Analysis

MCA is another tool for decision-making and considers most appropriate solutions by solving complex problems. There are complex problems with several criteria’s and different quantitative and qualitative aspects. Multi Criteria Analysis is mostly applied in environmental problems including electronic waste issues and provides suitable strategies for e-waste management. For example, this decision making tool can be utilized for determining the trade-off between economic benefits and environment benefits. MCA is a six step method which includes characterization of scenarios, defined model of products, development of model for evaluation, formulation of objective problems, Pareto set of solutions, development of strategy graphics according to Pareto set solutions that can minimize the economic cost and impacts of environment [12]. This technique is also used to examine the alternative systems for management of electronic waste in better manner. After investigation, the method provides various alternative systems for managing the waste according to their efficiency and performance. One of the most suitable options for e-waste management is the disassembling and forwarding of partial materials that can be recycled in local markets. The remaining materials can be disposed of in landfill sites. Though, this technique is not used widely for electronic waste management, instead, its mostly used for solid and hazardous waste management. MCA can be utilized for gaining the social response to e-waste management and can be useful as a supporting tool with other tools of e-waste management.

5.4. Extended Producer Responsibility

This technique of e-waste management is basically an environmental law that obliges the manufacturers to be responsible for the safely disposal or treatment for the products they manufacture after end usage. The policy is based on the principles of pay-offs by polluter [11]. This approach of extended producer responsibility should be applied to the electronic waste management at the national level. The programs of EPR are conducted by their leaders and focuses on prevention of pollution. Currently, most of the countries do not have an active EPR system. Different municipalities have also considered that the e-waste disposal is the responsibility of manufacturers for collection cost, recycling, recovery and ultimately, electronic waste disposal processes [5]. Various approaches have also been developed to manage the problems of e-waste by taking back the electronic devices. Most of the countries are following practices of backyard e-waste recycling processes and not EPR programs. The policies of EPR have some major barriers i.e. huge grey markets of electronic devices and illegal imports of electronic waste. But these barriers can be managed through strategic implementation of programs in different countries. The whole life cycle of electronic devices need to be evaluated from product designing to waste for developing suitable waste management strategies. Other strategies include reduction of specific hazardous substances in the production process of electronic devices, and prohibition of importing second hand electronic devices for purposes of charity. The consistent flow of taking back electronic waste can help in managing the e-waste and help reduce possible negative environmental impact in significant manner. The proposed flow of take back system is demonstrated in below figure (Fig. 3).

The flow of take back system indicates that recyclable materials can either be recycled at manufacturer developed recycling plants or in other common recycling plants. Manufacturers should take responsibility of waste generated by their production of electronic devices. This process has extended capability to resolve many problematic issues concerning e-waste management. EPR intends to integrate different strategies for better management of this waste stream. The six major objectives of EPR are, to manage the e-waste generated by consumers post usage, the establishment of sustainable systems of e-waste management, the reduction of hazardous wastes starting from the production process of electronic devices. In addition, EPR emphasizes on the promotion of environmental friendly products, the enhancement of competitiveness between countries in terms of international trade and have an efficient and integrated system of e-waste management [14]. The execution of EPR is quite a costly process because of policy tools arrangement and rigidness of governmental funding processes.

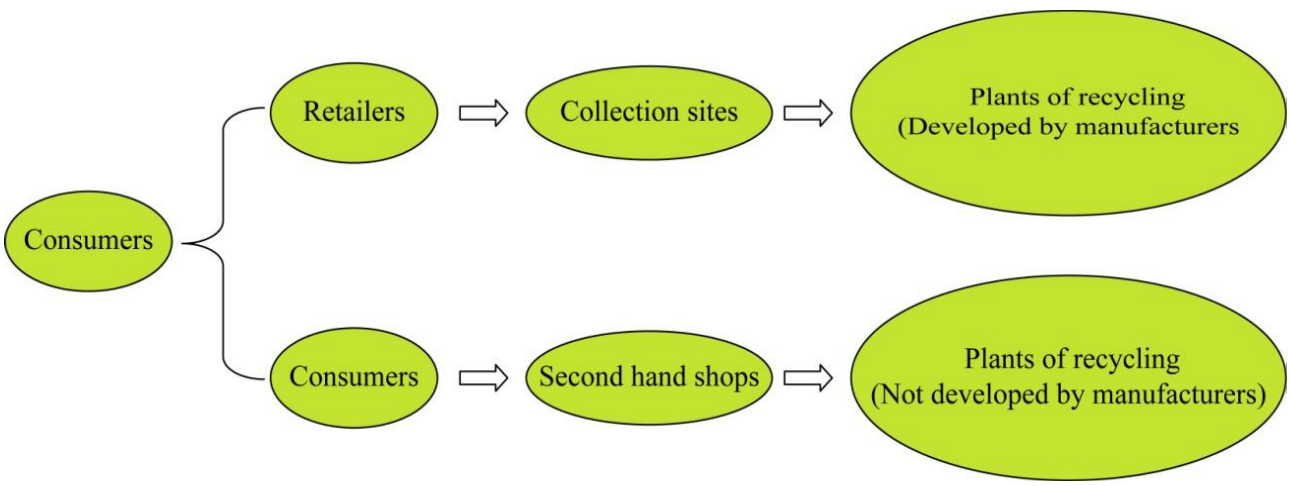

Figure 3. Flow chart of recyclable materials take-back system

6. Features of Specific Tools for Management of E-Waste

A major key player in the success of e-waste management is the development of eco-friendly production methods of electronic devices. Moreover, proper collection, recovery and recycling of waste by safe means are also very important. The disposal of e-waste has to be carried out with suitable safe eco-friendly techniques. At the same time, promoting awareness for possible impacts of e-waste on the environment and human health. These approaches need to be implemented in a consistent manner to gain positive results. The study has focused on some tools of e-waste management i.e. LCA, MCA, MFA and EPR. Every tool has different features, advantages and disadvantages when applied to manage electronic waste. LCA determines material consumption effects, which have major impacts on eco-friendly designing of products. It allocates both economic and possible impacts on the environment and its various components. LCA is one of the most popular tools for e-waste management in many countries. MFA investigates the e-waste flow and accordingly, estimates the generation of e-waste and its utilization for the decision making process. MFA is mostly used in areas that accommodate large recycling facilities. MCA is another useful tool that helps in the decision making process, though it is not much suitable for e-waste management. EPR is completely focused on the policies related to responsibility of waste generators i.e. manufacturers and producers. EPR concentrates on responsibility of manufacturers and producers to take back the waste and manage its treatment processes. EPR technique is currently used in some developed countries such as United States, United Kingdom, and Canada etc. [13]. However, it is quite difficult to get end users cooperation to aid in the implementation of this approach to manage e-wastes. It is indicated that LCA, MCA and MFA are mainly related to the decision-making process regarding e-waste, and EPR is focused on management of e-waste at national scale in terms of national policies. EPR can be most appropriate option to minimize e-waste generation in different areas.

7. Conclusions

To sum up, this study has aimed to shed light on the worldwide e-waste issue. The problems of e-waste have been initiated in developed countries only, but now, it has extended in many countries across the world. The e-waste volumes are increasing at a very fast pace because of rapidly changing technologies and the development of innovative technologies in consistent manner causing rapid obsolescence and causing the generation of huge quantities of electronic wastes. There are various hazardous materials in e-waste which can cause significant impacts on the environment and also, impacts human health. The study also pointed out that there are various toxic chemicals and heavy metals that are present in electronic wastes, these pollutants contaminate the environment in significant manner. These contaminants also cause the spreading of hazardous substances in the ecosystem. The option of landfill disposal is considered for the management of waste but it can contaminate groundwater as well, ultimately affecting the whole environment. E-waste problems can be mitigated by proper examination of nature, volume of e-waste and the examination of potential impacts on the environment and human health is also necessary for better management of e-waste. The tools for e-waste management include LCA, MCA, MFA and EPR. It can be considered that implementation of any single tool will not resolve the issue but requires a combination approach. In addition, the implementation of EPR is a good option as a national scheme for solving the growing issues of e-waste. The interaction of several tools can drive success for management of e-waste. The benefits of these policies and processes can only be reaped if end users can accept and adhere to them in sustainable manner.

REFERENCES

[1] Czuczwa, H. (2004). Environmental fate of combustion-generated polychlorinated dioxins and furans. Environmental Science & Technology.

[2] Belboom, R. D. (2011). Electrical waste management effects on environment using life cycle assessment methodology: the fridge case study. Hungary: Symposium Sustainable Lifestyles.

[3] Sepúlveda, A. et al. (2010). A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India ‖ , in Environmental Impact Assessment Review, Vol. 30, No. 1, pp. 28–41.

[4] Musson, J. T. (2010). Characterization of lead leachability from cathode ray tubes using the toxicity characteristic leaching procedure. Environmental Science & Technology.

[5] Andersson, A. (2005). Significance of intermediate production processes in life cycle assessment of electronic products assessed using a generic compact model. Journal of Cleaner Production, 1269-1279.

[6] Hicks, D. E. (2005). The recycling and disposal of electrical and electronic waste in China-legislative and market responses. Environmental Impact Assessment Review.

[7] Shinkuma, N. (2009). The flow of e-waste material in the Asian region and a reconsideration of international trade policies on e-waste. Environmental Impact Assessment Review.

[8] Zhang, F. (2007). Mechanical separation-oriented characterization of electronic scrap. Conservation and Recycling.

[9] Brigden, L. S. (2008). Recycling of Electronic Wastes in China and India: Workplace and Environmental

Contamination. Amsterdam: Greenpeace Research Laboratories, Department of Biological Sciences University of Exeter.

[10] Deng, Z. (2007). Distribution of PBDEs in air particles from an electronic waste recycling site compared with Guangzhou and Hong Kong. Environment International.

[11] Hatami, T. M. (2013). A fuzzy group Electre method for safety and health assessment in hazardous waste recycling facilities. Safety Science.

[12] Wang, J. L. (2005). Determination of polybrominated diphenyl ethers in soil and sediment from an electronic waste recycling facility. Chemosphere.

[13] Steubing, B. S. (2010). Assessing computer waste generation in Chile using material flow analysis. Waste Management.

[14] Mayers, F. C. (2005). Extended producer responsibility for waste electronics: an example of printer recycling in the United Kingdom. Journal of Industrial Ecology, 169-189.