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E-WASTE, AND ITS FUTURE CHALLENGES IN INDIA

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ABSTRACT

India is a developing country and is having world's second largest population after china. The present growth rate of 4.7 percent of GDP and achieved growth of 8 percent during eleventh five year plan from 2007 to 2012. As per this growth rate needs and lifestyle of Indian people changes continuously. Due to a huge revolution in technology there is advancement in every sector. The electronic and communication market is also booming in India. Electronic waste or E-waste is relatively a novel addition to the ever-growing hazardous waste stream. The manufacturing of electrical and electronic equipment (EEE) is one of the emerging global activities. The main factors identified to be responsible for the increased consumption and productions of electrical and electronic equipment are rapid economic growth, coupled with urbanization and industrialization. Developing countries are facing enormous challenges related to the generation and management of E-waste which are either internally generated or imported illegally; The Indian Information Technology (IT) sector is one of the major contributors to the global economy. At the same time, it is responsible for the generation of the bulk of E-waste or Waste Electrical and Electronic Equipment (WEEE) in India. Although the global E-waste problem has been able to attract attention across the world, not much emphasis has been given to the E-waste engendered in developing countries. Developing countries like India, today, is burdened with the colossal problem of E-waste which is either locally generated or internationally imported, causing serious menace to human health and environment. The hazardous components in electrical and electronic equipment are a major concern during the waste management phase. In the context of India, recycling of Waste Electrical and Electronic Equipment is not undertaken to an adequate degree. However, the existing management practices related to E-waste in India are reasonably poor and have the potential to risk both human health and the environment. Moreover, the policy level initiatives are not being implemented in an appropriate way. The austere problem of E-waste along with its policy level implications is looked upon in the paper. During the course of the study it has been found that there is an urgent need to address the issues related to E-waste in India in order to avoid its detrimental future consequences on environment as well as health of human population. The purpose of the review was to improve understanding of electronic waste (e-waste) and the effect on health and the environment on a global scale. The review involved examining data and policies of governmental,

national, and global organizations in dealing with electronic waste and recycling efforts from 1980 to 2012. Methods of recycling were examined as well as the hazardous composition of electronic components and the result on the environment.

Keywords: E-waste, hazardous waste, risk, management, Human health

INTRODUCTION

Over the past few decades, enormous quantities of industrial pollutants have been released into the environment. Solid waste management, which is already a massive task in India, is becoming more complicated by the invasion of e-waste, particularly computer waste. Electronic-waste (e-waste) represents electronic products including computers, printers, photocopy machines, television sets, mobile phones, and toys, which are made of sophisticated blends of plastics, metals, and other materials. Indian electronics and IT industry has grown very fast and it not only resulted in more consumption of raw materials but also in problems due to waste generated and E-waste is one of them [1]. E-waste stands for electronic waste, which is a branch of Waste Electrical and Electronic Equipment (WEEE). According to European Union (EU 2002), e-waste is, "Electrical or electronic equipment, which is waste, including all components, subassemblies and consumables, which are part of the product at the time of discarding." [2]. There are different electronic equipments which are responsible for e-waste generation but this paper mainly focuses on the e-waste generation due to computers and mobile phones. The objectives of this study are: firstly, to know about different sources of e-waste and Indian e-waste market followed by reasons for e-waste generation; secondly, to compare Indian e-waste management scenario with developed countries and lastly, to discuss various issues related to sustainability and best practices that may be adopted for sustainable management of e-waste. The paper concludes with some suggestions and future plan of Indian Government regarding management of E-waste.

E-waste Global scenario

As far as global e-waste management is concerned, Switzerland is the first country to implement the organized e-waste management system in the world. Extended Producer Responsibility(EPR) and Advance Recycling Fee (ARF) are the backbone of e-waste management system in Switzerland and other developed countries Advanced countries like USA, UK, France &Germany generate 1.5 to 3 million tons of eWaste annually and are among the largest generators of eWaste. But these countries also have standardized e-waste management processes in place. Proper eWaste management, from

efficient sourcing and collection right up to extraction and disposal of material, has ensured that this huge pile of junk turns into a lucrative business opportunity. Due to very stringent environmental standards, the cost of collection, preprocessing, recycling and disposal are pretty high. So for every organized recycler in the first world countries, there are quite a few who pose as recyclers and are mere brokers who ship these obsolete items to developing countries like India and China in the pretext of donation or second-hand goods. With very ambiguous laws related to environmental protection, India , China and a few African countries have become dumping sites to the first world countries. There are many countries that have already started the „take back" system for electronic products and they also have dedicated laws on e-waste management. In USA, National Electronics Action Plan has been initiated by US Environment Protection Agency to address the various issue related to electronic waste. Two very important frameworks for protecting environment from e-waste have been put forward by European Union i.e., WEEE Directives and Restriction of use of Certain Hazardous Substances (RoHS), which are also implemented by other countries. According to E directives (2003), it is mandatory for all 27 countries of European Union to recycle their e-waste. Basel Convention is also nice step taken by UNEP to control the international trading of hazardous waste and India is also signatory to this [3, 4, 5]

E-waste Indian Scenario

The story of current Indian e-waste management is different from the worldwide. Practices waste is a serious Issue because of the Informal recycling activities. Therefore, quantification of e-waste in India is very difficult and, there is no mechanism and policy to check the flow of e-waste I the system. In case of PCs, 22% of the e-waste is generated by households and it is the business sector which accounts for the 78% the e-waste, because 83% of household customers are first time buyers. So business sector is mainly responsible for the waste generation. In addition to this, about 1050 tonnes per year of computer waste comes from retailers' and manufacturers. This is important to note that in spite of global agreements, e-waste from developed nations is imported to developing nations like India[5]. Sixty-five cities in India generate more than 60% of the total e-waste generated in India. Ten states generate 70% of the total e-waste generated in India. Among top ten cities generating ewaste, Mumbai ranks first followed by Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat and Nagpur. There are two small e-waste dismantling facilities are functioning in Chennai and Bangalore. There is no large scale organized e-waste recycling facility in India and the entire recycling exists in

unorganized sector [6]. In India, probably the e waste is given to the rag pickers who pay some amount to the customer from whom they are collecting the waste. Most of the activities, like collection, transportation, segregation, dismantling, recycling, disposal, etc., are carried out by informal sector. The rag pickers (also known as kabadiwala) collect all kind of waste like papers, books, newspapers, plastic, cardboard, polythene, metals, etc. including e-waste, and earn their livelihood by selling it to middlemen or scrap dealers. This is a very good source of income not only for rag pickers but also for middlemen and scrap dealers. E-waste is mostly handled by unskilled workers and they do not take proper safety measures. Recycling and disposal is not properly done due to lack of appropriate technology. Also, very few companies are there which have implemented take back" system voluntarily. There is no clear data on the quantity generated and disposed of each year and the resulting extent of environmental risk. According to the literature review it's revealed that about 50% of the public are aware of environmental and health impacts of the electronic items. Hence, there is an urgent need of implementation of proper e-waste management system in India [7].

It is an emerging problem because of the volumes of e-waste being generated and the content of both toxic and valuable materials in them. The fraction including iron, copper, aluminium, gold and other metals in e-waste is over 60%, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70%. Electronic devices form a complex mixture of materials and components, often containing several hundreds of different substances, many of which are toxic and create serious pollution upon disposal. These include heavy metals such as mercury, lead, cadmium, chromium and flame retardants such as polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs). Disposal of the e-wastes is an emerging global environmental issue, as these wastes have become one of the fastest growing waste types in the world. The recent investigations of workers involved in manufacturing the chips, he drives and circuit boards are reporting health problems. Even the workers who handle even e-waste as a scrap has health problems. The cycling and disposal of computer waste in these countries becomes a serious problem since their treatment methods remain rudimentary. Such activities pose grave environmental and health hazards; for example, the deterioration of local drinking water which can result in serious illnesses.

Different categories of E-waste

E-waste means electrical waste and electronic equipment, whole or in part included in, but not confined to equipment, scraps or rejects from their manufacturing process. E-waste is divided into different categories according to Environment Protection Act, 1986.

E-Waste: Types and Composition

Electrical and electronic equipment can contain a large number of hazardous substances, including heavy metals (e.g.,mercury, cadmium, lead, etc.), flame retardants (e.g., pentabromophenol, polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol A (TBBPA), etc.) and other substances (figure presence of these substances, e-waste is generally considered as hazardous waste, which, if improperly managed, may pose significant human and environmental health risks. components' of ewaste can be divided on the basis of their quantity; large, small and trace amounts. large quantities include epoxy resins (polyvinyl chlorides), thermosetting plastics silicon, beryllium, carbon, iron certain common components/parts of electrical and electronic appliances that contain the majority of the hazardous substance.

Americium: one of the radioactive sources, known to be carcinogenic.

Mercury: Mainly found in fluorescent tubes applications), tilt switches (mechanical doorbells, and flat screen monitors. It causes health effects such as; sensory impairment, dermatitis, memory loss, and muscle weakness. Environmental effects in animals include death, reduced fertility, slower growth and development.

Sulphur: Found in lead-acid batteries. Health effects include liver damage, kidney damage, heart damage, and eye and throat irritation. When released in to the environment, it can create sulphuric acid.

BFRs (Brominated flame retardants**):** Used as flame retardants in plastics in most electronics includes PBBs, OctaBDE, PentaBDE. Health effects include impaired development of the nervous system, thyroid p problems. Environmental effects: similar effects as in animals as humans. PBBs were banned from 1973-1977 on. PCBs were banned during the 1980's.

Cadmium: Found in light-sensitive resistors, corrosion alloys for marine and aviation environments and cadmium batteries. When not properly recycled it can leach into the soil, harming microorganisms and disrupting the soil ecosystem. Exposure is caused by proximity to hazardous waste sites and

factories and workers in the metal refining industry. The inhalation of cadmium can cause severe damage to the lungs and is also known to cause kidney damage.

Lead: Found in CRT monitor glass, lead-acid batteries formulations of PVC. A typical 15-inch cathode ray tube may contain 1.5 pounds of lead but other CRTs have been estimated as having up to 8 pounds of lead.

Beryllium oxide: Commonly used as filler in some thermal interface materials such as thermal grease used on CPUs and power transistors, magnetrons, X-ray transparent ceramic windows, heat transfer fins in vacuum tubes and gas lasers.

Impact on Human Health and Environment

Electronic waste can come in many forms including computers, photocopiers, printers, faxes, monitors, batteries and mobile phones. E-waste contains significant quantities of toxic metals and chemicals. Electronic wastes can cause widespread environmental damage due to the use of toxic materials in the manufacture of electronic goods Hazardous materials such as lead, mercury and hexavalent chromium in one form or the other are present in such wastes primarily consisting of Cathode ray tubes (CRTs), Printed board assemblies, Capacitors, Mercury switches and relays, Batteries, Liquid crystal displays (LCDs), Cartridges from photocopying machines, Selenium drums (photocopier) and Electrolytes. Although it is hardly known, e-waste contains toxic substances such as Lead and Cadmium in circuit boards; lead oxide and Cadmium in monitor Cathode Ray Tubes (CRTs); Mercury in switches and flat screen monitors; Cadmium in computer batteries; polychlorinated biphenyls (PCBs) in older capacitors and transformers; and brominated flame retardants on printed circuit boards, plastic casings, cables and polyvinyl chloride (PVC) cable insulation that releases highly toxic dioxins and furans when burned to retrieve Copper from the wires. All electronic equipments contain printed circuit boards which are hazardous because of their content of lead (in solder), brominated flame retardants (typically 5-10 % by weight) and antimony oxide, which is also present as a flame retardant (typically 1- 2% by weight).

Nickel (Ni) which is present in E-waste causes skin damage, asthma, lung damage and carcinogen. It enters in environment through air. Antimony (Sb) causes skin irritation, hair loss, lung and heart damages and fertility problems. This element is better absorbed in soil containing steel, magnesium or aluminium. Poly brominated diphenyl ethers(PBDE) causes

anaemia damages skin,liver,stomach and thyroid, contamiante water and contaminate chain of production of some food. Tetra bromo bis A(TBBPA) has some mutations and carcinogen effects. It causes damages to endocrine system. Poly brominatedbiphenyls (PBB) passes along with food chain damages kidneys liver and thyroid. Chliroflorocarbon (CFC) destroys ozone layer. Polyvinyl chloride (PVC) damages animal kidney and soluble in water and Arsenic is carcinogenic causes skin and lung cancer. Barium causes gastrointestinal disorder and muscle weakness, changes heart beat rate, paralysis and accumulate in aquatic system. Beryllium inhalation causes pneumonia, respiratory inflammation and lung cancer. Cadmium and Mercury are carcinogenic and causes lung damage. Therefore, a treatment technology needs to be developed for cleanup of ewaste from the environment.

Treatment Techniques for E-Waste Management

Hazardous substances generated by E-waste are very harmful for environment as well as for humans. Therefore, an effective removal technique needs to be developed for clean-up of environment. Following techniques are currently used for decontamination of environment from e-waste:

Electronic Equipment

Land filling: It is one of the most widely used methods for disposal of e-waste. In land filling, trenches are made on the flat surfaces. Soil is excavated from the trenches and waste material is buried in it, which is covered by a thick layer of soil. Modern techniques like secure landfill are provided with some facilities like, impervious liner made up of plastic or clay, leachate collection basin that collects and transfer the leachate to wastewater treatment plant. The degradation processes in landfills are very complicated and run over a wide time span.

Recycling: Recycling involves dismantling i.e. removal of different parts of e-waste containing dangerous substances like, PCB, Hg, separation of plastic, removal of CRT, segregation of ferrous and non-ferrous metals and printed circuit boards. Monitors and CRT, keyboards, laptops, modems, telephone boards, hard drives, floppy drives, Compact disks, mobiles, fax machines, printers, CPUs, memory chips, connecting wires and cables can be recycled.

Incineration: It is a controlled and complete combustion process, in which the waste material is burned in specially designed incinerators at a high temperature (900-1000C). Advantage of incineration of e-waste is the reduction of waste volume and the utilization of the energy content of combustible materials. Some plants remove iron from the slag for recycling. By incineration some environmentally hazardous organic are converted into less hazardous compounds. Disadvantage of incineration are the emission to air of substances escaping flue gas cleaning and the large amount of residues from gas cleaning and combustion. E-waste incineration plants contribute significantly to the annual emissions of cadmium and mercury.

Bioremediation Approaches for E-Waste

Bioremediation is a general concept that includes all those processes and actions that take place in order to bio transform an environment, already altered by contaminants, to its original status. Although the processes that can be used in order to achieve the desirable results vary, they still have the same principles; the use of microorganisms or their enzymes, that are either indigenous and are stimulated by the addition of nutrients or optimization of conditions, or are seeded into the soil. Biological techniques can increase the removal efficiency whereas thermal or physico-chemical methods alone are less successful, as shown in copper and gold mining where low grade ores are biologically treated to obtain metal values, which are not accessible by conventional treatments.

There are numerous examples of employing bioremediation against various pollutants. Nowadays, there are four main biological techniques for treating soil and groundwater: (a) stimulation of the activity of indigenous microorganisms by the addition of nutrients, regulation of redox conditions, optimizing pH conditions, etc; (b) inoculation of the site by microorganisms with specific biotransforming abilities; (c) application of immobsilized enzymes; and (d) use of plants (phytoremediation) to remove and/or transform pollutants. In the specific methods used for bioremediating contaminated soil and water, land farming, composting, intrinsic bioremediation and slurry bioreactor are included.

Bendal et al., (2000) done research study in which microbiological processes were applied to mobilize metals from electronic waste materials. Bacteria-*Thiobacillus, thiooxidans, T. Ferrooxidans* and fungi-*Aspergillus niger, Penicillium simplicissimum* were grown in the presence of electronic scrap. The formation of inorganic and organic acids caused the mobilization of metals. Initial experiments showed that microbial growth was inhibited

when the concentration of scrap in the medium exceeded 10 g Ly1. *Thiobacilli* were able to leach more than 90% of the available Cu, Zn, Ni, and Al. Pb precipitated as PbSO while Sn precipitated probably as SnO. For a more efficient metal mobilization, a two-step leaching process is proposed where biomass growth is separated from metal leaching.

Phytoremedation in E-waste management

Phytoremediation might be a cost effective choice complementary to engineering based approaches. Phytoremediation is making use of vegetation for in situ treatment of soil, sediment, and water, which has been utilized successfully in sites contaminated by PCBs and other organic pollutants reaching 1.5 million tons. In one study Xiezhi, (2008) reported PCB removal, soil enzyme activities, and microbial community structures during the phytoremediation by alfalfa in field soils. Bollog et al., (2005) have reported enhanced phytoremediation potential of polychlorinated biphenyl contaminated soil from e-waste recycling area in the presence of randomly methylated-ßcyclodextrins. The study aimed to compare the phytoremediation potential of four plant species (rice, alfalfa, ryegrass and tall fescue) for PCBs contaminated soil from Taizhou city, one of the largest e-waste recycling centers in China.

E-waste legislation in India

In India, a lot of discussion and concern has now started regarding the e-waste management. A report of parliamentary standing committee on science and technology on the functioning of central pollution control board (CPCB) states that e-waste is going to be a big threat in future due to modern life style and increase in the living standards of people and rise of economic growth. The solid waste management process is defined in the Indian constitution under twelfth schedule and in municipal solid wastes (management & handling) rules, 2000 enacted by central government. These rule provide some guidelines for the management of the e-waste and can be used as a model in the e-waste recycling and disposal scheme such as house to house collection of waste, proper collection of waste from slums and squatters, hotels restaurants, office complexes and commercial areas, organizing awareness programmes for segregation of wastes; adopting suitable waste processing technologies; and restricting land filling of non-biodegradable inert waste. But there is no proper rule or regulation mainly for e-waste treatment. Some of the rules and regulation which are made related to e-waste are as follows.[10]

A. The Hazardous Waste (management and handling) Rules, 2003

This rule categorized e-waste or its constituents under „hazardous‟ and „non hazardous‟ waste. As per the rules, "hazardous waste" is defined as any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances.[11]

B. The Hazardous waste (Management. Handling and Tran boundary Movement) Rules, 2008

These rules provide the registration process of hazardous waste recycler. According to these rules, every person desirous of recycling or reprocessing hazardous waste including electronic and electrical waste is required to register with the central pollution control board (CPCB). The e-waste handler is required to register with the CPCB. The authorized recycler or re-processer or re-user should have environmentally sound facilities for recovery of metal and plastic and the waste should be sent to them. Under these rule the ministry of environment and forest is the nodal ministry to deal with the transboundary movement of the hazardous wastes and to grant permission for transit of the hazardous wastes through any part of India.[12] Part A of Schedule III (Basal No. 1180) consists of list of e-waste applicable for import with prior informed consent. Part B of schedule III (Basal No. 1110) deals with list of e-waste applicable for import and export not requiring prior informed consent [13].

C. Guideline for Environmentally sound managementof e-waste, 2008

The guideline are given by the government of India and approved by ministry of environment and forest and central pollution control board. The objective of these guideline is to provide guidance for identification of various sources of e-waste and the approach and methodology for handling and disposal of e-waste in an environment friendly manner. These Guidelines include details such as e-waste composition and recycle potential of items of economic value, identification of possible hazardous contents in e-waste, the recycle, re-use and recovery options, treatment and disposal options and the environmentally sound e-waste treatment technologies. The guideline also covers the concept of Extended Producer Responsibility [14]. After the approval of company‟s bill 2012 in the Rajya Sabha, it has become compulsory for the corporations to spend 2% of the net profits on Corporate Social Responsibility (CSR) activities. This will promote the equitable and sustainable growth in the country [15].

D. The e-waste (Management and Handling) Rules, 2011

The primary objective of these rules is to channelize the e-waste generated in the country to make the recycling of the e-waste in environmentally sound manner. The concept of extended producer responsibility is introduced in these rules by placing the main responsibility of e-waste management on the producer of the electrical and electronic equipment. These rules had notified in May 2011 and get implemented from 01 May 2012. These rules are applicable to every producer, consumer involved in the manufacture, sales purchase, and processing of electrical and electronic equipment or components, collection centers, dismantlers and recyclers of e-waste comes under this law.[16] The is law is also applicable on the people involved in purchase and processing of electrical and electronic equipment or components. According to the newspaper (Business Standard, Dec 25, 2013) a study "e-waste management in India- Role of state agencies" done by Toxics Link reveal that most of the Indian states have failed to implement e-waste rules in the country which came into being in 2011[17]. The study also reveals that lack of efforts and action is made by most state pollution control board and committees. This shows that e-waste (management and handling) rules, 2011 are not properly implemented in the country. [18]

Conclusions

The present article summarizes that e-waste contains a number Hazardous substances. Heavy metals and halogenated compounds are of particular concern. Improper handling and management of e-waste during recycling and other end-of-life treatment options may develop potentially significant risks to both human health and the environment. Current simple recycling carried out in many developing countries is causing risks that could to a large extent, be avoided through the use of improved treatment methods. Bio hydrometallurgical techniques allow metal cycling by processes similar to natural biogeochemical cycles. Using biological techniques, the recovery efficiency can be increased whereas thermal or physico-chemical methods alone are less successful, as shown in copper and gold mining where low-grade ores are biologically treated to obtain metal values, which are not accessible by conventional treatments. Bioremediation methods can improve scenario of current treatment practices available for e-waste. Besides, management practices for e-waste there is a need of doing more research in the area of bioremediation so that these techniques can be used for the treatment of E-waste.

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