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Review Article

HAZARDS, REGULATORY RESPONSES AND ANALYTICAL TOOLS FOR ELECTRONIC WASTE MANAGEMENT

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ABSTRACT

As a result of industrialization and ever increasing demand of electronic products in daily life E-waste is generated at a much faster rate. E-waste is growing in India at the rate of 10%.The condition in India is much worse because about 80 percent of the e-waste generated in the US is exported to India, China and Pakistan under the name of charity. Current data indicate that the total domestic e-waste generation including imports is around 382979 MT, however waste available for recycling and actually recycled are 144143 MT and 19000 MT, respectively in which recycling by non-formal and formal sector are 95% and 5%, respectively. The paper discusses various treatment technologies used for treating E-waste along with recovery & reuse options. It also provides information regarding legislative measures that have been taken to deal with E-waste globally and in India.

Keywords: *Industrialization, E-Waste, Recycling, Non-Formal and Formal Sector*

INTRODUCTION

E-waste are going to become a great challenge for environmentalists and technologists as the rate of growth is much higher than the rate it is disposed, reused or recycled. There is an urgent need for improvement in E-waste management plan. There are new practices being adopted globally that will lead to the sustainable management of e-waste such as: design for environment, innovative product design, extended producer responsibility, standards and labeling, and recycling and remanufacturing. To tackle the future environmental problems that will eventually occur from improper management of e-waste, many developed countries and organizations have drafted legislation to address the reuse and recycling material recovered from EEE to reduce the amount of toxic materials disposed in landfills. Recycling of e-waste is important, because it allows the recovery of valuable material and reduces the amount of waste requiring disposal Gupta (2009). Recycling of e-wastes is carried out by the formal and non-formal sectors for the recovery of valuables and disposing of wastes. In India, participation for recycling of e-wastes by non-formal sector is about 95% and that of formal sector is 5%**.** Various government organization and research centers are trying to achieve an integrated process for the recovery and separation of metals from the e-wastes including pretreatment process like cutting, shredding, grinding, air classification followed by leaching and solvent extraction process. The processes have also been proposed for the recovery of precious metals such as gold. Researchers and industrialists are integrating together to parleys small scale e-waste recycling industries into large scale industries.

E-Waste Management

The story of current Indian e-waste management is different from the worldwide practices. In India, rag pickers pay some amount to the customer from whom they are collecting the waste and on the other hand, recycling fee is charged from customers to manage waste effectively in developed countries Kumar *et al.*, (2011). E-waste is mostly handled by unskilled workers and they do not take proper safety measures. Moreover, proper place is not used for e-waste handling. The operations to treat e-waste are carried out within the cities and slums. At some places, operations are carried out without proper ventilation and lighting facilities. Recycling and disposal is not properly done due to lack of appropriate technology Wath

et al., (2010). Also, very few companies are there which have implemented 'take back' system voluntarily. Hence, there is an urgent need of implementation of proper e-waste management system in India Kumar *et al.*, (2011).

E-waste Policy and Regulation

The Policy shall address all issues ranging from production and trade to final disposal, including technology transfers for the recycling of electronic waste. Clear regulatory instruments, adequate to control both legal and illegal exports and imports of e-wastes and ensuring their environmentally sound management should be in place. There is also a need to address the loop holes in the prevailing legal frame work to ensure that e – wastes from developed countries are not reaching the country for disposal. The Port and the Custom authorities need to monitor these aspects. The regulations should prohibit the disposal of e-wastes in municipal landfills and encourage owners and generators of e-wastes to properly recycle the wastes. Manufactures of products must be made financially, physically and legally responsible for their products.

Extended Producer Responsibility

The OECD defines EPR as an environmental policy approach in which a producer's responsibility for a product is extended to the post consumer stage of the product's life cycle, including its final disposal OECD (2001). Keeping in line with the Polluter-pays Principle, an EPR policy is characterised by the shifting of responsibility away from the municipalities to include the costs of treatment and disposal into the price of the product, reflecting the environmental impacts of the product. The goals of the product designer could include reducing toxicity, reducing energy use, streamlining product weight and materials, identifying opportunities for easier reuse, and more. Manufacturers have to improve the design by: (i) the substitution of hazardous substances such as lead, mercury, cadmium, hexavalent chromium and certain brominated flame retardants;(ii) measures to facilitate identification and re-use of components and materials, particularly plastics; and (iii) measures to promote the use of recycled plastics in new products OECD (2001).

E-Waste Recycling

Environmentally sound recycling of e-waste requires sophisticated technology and processes, which are not only very expensive, but also need specific skills and training for the operation. Proper recycling of complex materials requires the expertise to recognize or determine the presence of hazardous or potentially hazardous constituents as well as desirable constituents (i.e. those with recoverable value), and then be able to apply the company's capabilities and process systems to properly recycle both of these streams. Appropriate air pollution control devices for the fugitive and point source emissions are required. Guidelines are to be developed for environmentally sound recycling of E Wastes. Private Sector are coming forward to invest in the e-waste projects once they are sure of the returns Joseph (2007).

New Initiatives

Households, companies, and governmental organizations can encourage electronics manufacturers to design greener electronics by purchasing computers and other electronic goods with environmentally preferable attributes and by requesting takeback options at the time of purchase. The Organization for Economic Cooperation and Development (OECD), which has issued guidelines for the environmentally sound management of used and scrapped PCs, described the used computer as a new business with "somewhat informal origins. E-waste: problems, possibilities

The Central Pollution Control Board of India has just constituted a national-level working group with representatives from regulatory agencies, state pollution control boards, ministry of Information Technology, industry associations, and experts in ewaste, which has the task of developing guidelines for e-waste recycling and formulating. Japan has mandated producer take-back of electrical appliances; this is now being extended to computers and other electronics. Also in 1998, Taiwan started a take-back system for computers, televisions, and large home appliances that requires retailers to accept used electronics, regardless of where they were sold.

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Treatment Techniques for E-Waste

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 Pramila *et al.,* (2012).

Landfilling

It is one of the most widely used methods for disposal of e-waste. In landfilling, 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.

Incineration

It is a controlled and complete combustion process, in which the waste material is burned in specially designed incinerators at a high temperature (900-10000C). 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 substances 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. One study (Funcke and Hemminghaus,) did observe the formation of PBDDs/Fs and PXDDs/Fs as a result of combustion of BFR-containing e-waste Pramila *et al.,* (2012).

Bioremediation Approaches for E-Waste

Bioremediation is a general concept that includes all those processes and actions that take place in order to biotransform an environment, already altered by contaminants, to its original status. 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 lowgradeores are biologically treated to obtain metal values, which are not accessible by conventional treatments. Over the years, many methods have been tested, used, approved or rejected. The most common, ineffective and inexpensive way to deal with polluted areas is to ignore deliberately their existence. Biotreatment is well accepted by industry as it goes along with the current popularity of maintaining nature's harmony. Bioremediation has become a widely accepted option for the cleanup of contaminated soils and aquifers although it does not have a fully credible reputation within the regulatory community Pramila *et al.,* (2012). 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, landfarming, composting, intrinsic bioremediation and slurry bioreactor are included Pramila *et al.,* (2012).

Recycling, Reuse and Recovery Options

The composition of e-waste consists of diverse items like ferrous and non ferrous metals, glass, plastic, electronic components and other items and it is also revealed that e-waste consists of hazardous elements. Therefore, the major approach to treat e-waste is to reduce the concentration of these hazardous chemicals and elements through recycle and recovery. The recycle and recovery includes the following unit operations.

Collection of E-Wastes:

In India, the collection and recycling of e-wastes is largely linked among the manufacturers, distributors, consumers, collectors, traders and recyclers as shown in Figure 1. The unorganized sectors are largely

involved in the collecting, trading and recycling works. Unlike developed countries, waste pickers pay price to consumers for their discarded products and there is no concept of Advance Recycling Fee (ARF) which are paid by the consumers to the retailers, retailers to manufacturers and manufacturers to the recyclers Khetriwal *et al.*, (2005).

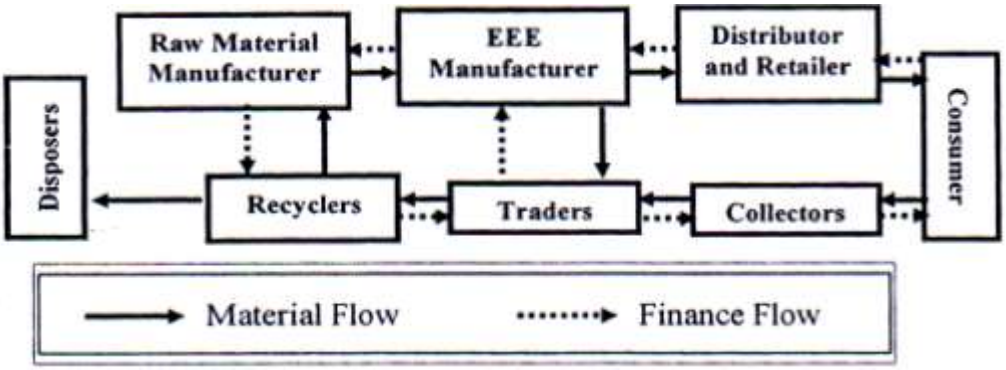

Figure 1: **Flow of E-wastes collection of recycling in India Khetriwal *et al.*, (2005)**

Segregation

Collected e-waste from diversified sources is segregated in various categories such as components, modules, metals, glass and plastics depending on the saleability for highest economic returns Chatterjee and Kumar (2009).

*Dismantling***:**

Dismantling is 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 Pramila *et al.*, (2012).

*Refurbishment and Reuse***:**

Refurbishment and reuse of e-waste has potential for those used electrical and electronic equipments which can be easily refurbished to put to its original use. The *Kawaries* and the scrape dealers sell all the dismantled and segregated parts of metal, glass and plastics to metal/glass smelters and plastic re-processor who specialize in converting these scrap of coppers, aluminium, iron, glass and plastics.

Recycling of E-Wastes:

Figure 2: Schematic flow diagram for the recycling of w-wastes in Indian Industry Jha *et al.*, (2011)

The recycling of e-wastes in India is mainly practiced in unorganized sectors while some industries are also recycling these materials in their plants. In order to develop suitable recycling methods, R & D institutions are also developing processes to recover the valuables to conserve the resources without affecting the environment. The collaborative research in association with foreign research institutions is also being made Jha *et al.,* (2011). Figure 2 depicts typical flow process for recycling of e-scraps in Indian recycling plant.

Regulatory Responses to the Electronic Waste Phenomenon

Global Aspects

Various initiatives are being undertaken to address the challenges that e-waste brings. In the EU, there are several pieces of legislation that restrict substances in electrical equipment. The two most important are RoHS Directive 2002/95/EC of 27 January 2003 on the restriction of the use of certain hazardous substances restricts six substances in eight categories of electrical equipment and Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the registration, authorisation and restriction of chemicals (REACH).

The Basel Convention

The *Basel Convention* is the universal normative framework on the transboundary movement of wastes. This treaty attempts to regulate waste movements by imposing restrictions to reduce transnational movement of wastes and to provide incentives for effective waste management. The treaty prescribes that each country must become self-sufficient in managing its own wastes and wastes are to be disposed of as close as possible to the locus of origination Khetriwal *et al.,* (2005), Waugh (2004).

The Bamako Convention

The Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa ('the Bamako Convention'), 1991, was adopted by the member-states of the defunct Organisation of Africa Unity (OAU), now African Union (AU), as a protest against the persisting dumping of hazardous and nuclear wastes in the territorial borders of African countries which the Basel Convention was perceived not to have effectively addressed Main (2002). By reason of its history, therefore, the Bamako Convention included in its definition of 'hazardous waste' hazardous substances 'banned, cancelled or refused in the country of manufacture.'

The Waigani Convention

Another notable regional treaty on the theme of this essay is the *Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region* ('the Waigani Convention'). This treaty opened for signature in Waigani, Papua New Guinea, in 1995, and entered into force in 2001. Apart from committing states parties not to import or export radioactive waste, to cooperate in preventing illegal import of such waste, to reaffirm existing commitments not to dump radioactive wastes at sea, and to 'give active consideration to the implementation of the IAEA Code of Practice on the International Transboundary Movement of Radioactive Wastes' and to 'participating in the development of a Convention on the Safe Management of Nuclear Waste', the treaty made no effort to introduce any landmark regulatory framework against menace of hazardous waste Michael, Hamel-Green,

Indian Aspects:

The environmentally sound management of e-waste is a significant challenge for India. The challenge relates not only to imported e-waste, but also to the increasing amounts of domestically produced WEEE. Despite this situation, as of September 2010, neither the central government nor the state governments had legislation in effect solely dedicated to e-waste. The following section examines the current regulatory framework for e-waste in India, examining existing legislation, voluntary e-waste guidelines released by the central government, and the new e-waste rules dedicated to e-waste management Skinner *et al.,* (2010).

The Hazardous Wastes (Management and Handling) Amendment Rules, 2008

The new Hazardous Wastes Management, Handling and Transboundary Movement Rules of 2008 replaced the old HWM rules and now contain additional provisions on e-waste handling within India.

These provisions require every person planning to recycle or reprocess e-waste to obtain prior authorization from the relevant SPCB. However, the SPCB registration process has been criticised for granting the same authorization to collectors, dismantlers and recyclers without assessing their capability to treat the e-waste in an environmentally sound manner Gupta (2009).

Guidelines for Environmentally Sound Management of E-waste, 2008

This guideline was a Government of India initiative and was approved by Ministry of Environment and Forest and Central Pollution Control Board. They are not the first one, however. Largely as a result of pressure from stakeholders following the publication of the Toxics Link study on ewaste in 2002, the Central Pollution Control Board (CPCB) released guidelines on e-waste management in 2008. It classified the E-waste according to its various components and compositions and mainly emphasises on the management and treatment practices of E-waste Borthakur and Singh (2012).

The E-waste (Management and Handling) Rules, 2011

This is the very recent initiative and the only attempt in India meant solely for addressing the issues related to E-waste. It was made available by the MoEF on 14 May 2010 and was opened for comments until the end of July and has come into practice from 1st May, 2012. According to this regulation, 'electrical and electronic equipment' means equipment which is dependent on electric currents or electro-magnetic fields to be fully functional and 'e-waste' means waste electrical and electronic equipment, whole or in part or rejects from their manufacturing and repair process, which are intended to be discarded. These rules are meant to be applied to every producer, consumer or bulk consumer involved in manufacturing, sale purchase and processing of electrical and electronic equipment, collection centers, dismantlers and recyclers of E-waste. Responsibilities of producers, collection centers, consumers, dismantlers, recyclers etc. are defined and incorporated in these rules Borthakur and Singh (2012). These rules also address imports. It states "Every [sic!] producer(s), dealer(s), collection centre(s), refurbisher(s), dismantler(s), recycler(s), auctioneer(s) consumer(s) or bulk consumer(s) shall not import used electrical and electronic equipment in India for use" Ministry of Environment and Forestry (2010).

CONCLUSIONS

Disposal of E-wastes is a particular problem faced in many regions across the globe. The story of current Indian e-waste management is different from the worldwide practices. In India, about 95% of recycling process is carried out in non formal units using primitive and hazardous methods. Inefficient recycling processes result in substantial losses of material value. Putting the onus of re-cycling of electronic wastes (E-waste) on the producers, the Ministry of Environment and Forest (MOEF) has for the first time notified E-waste management rules. The e-waste (management and handling) Rules, 2011 is the most recent attempt to regulate e-waste in India. These rules would recognize the producers' liability for recycling and reducing e-waste in the country. It also addresses imports and completely restricted import of any used electrical and electronic equipment in India for use. Such ambitious and comprehensive regulation goes a step beyond the US effort and represents an important first step taken by India in dealing with the complex problems that E-waste poses.

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