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Review Research Paper

E-waste, A New Challenge to the Environmentalists

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ABSTRACT

Electronic waste or e-waste is one of the rapidly growing problems of the world. E-waste comprises of a multiple of components, some containing a toxic substance that can have an adverse impact on human health and the environment if not handled properly. Rapid economic growth in Asia and the increasing transboundary movement of secondary resources will increase that require both 3R endeavours (Reduce, Reuse and Recycle) in each country. In India e-waste management assumes a greater significance not only due to generation of its own e-waste but also because of the dumping of e-waste from developed countries. This paper highlights the concise overview of India's current e-waste scenario, namely magnitude of problem, environmental and health hazards, current disposal and recycling operation, existing legal framework, organization working on the issue and recommendation for action with regulatory bodies in India.

INTRODUCTION

Electronic waste popularly known as E-waste, broadly covers waste from all electronic and electrical appliances and comprises of items such as computers, mobile phones, digital music recorder/players, refrigerators, washing machines, televisions and many other households consumer items, which connect with power plug, batteries, and which have become obsolete due to advances in technology, changes in fashion, style and status nearing the end of their usual life. The increasing 'market penetration' in the developing countries, 'replacement market' in the developed countries and 'high obsolescence rate' make e-waste one of the fasted waste streams (Radha 2002, DIT 2003) of our nation's waste stream (Kumar 2010). This new kind of waste is posing a serious challenge in disposal and recycling to both developed and developing countries. Guiya in the Shantou region of China is a huge electronic waste processing area. It is often referred to as the e-waste capital of the world. In India, the e-waste market is mostly unorganized (Sinha-Khetriwal et al. 2005) and also some companies in India are neither registered nor authorized legally but operate and working informally (Mundada et al. 2004, CII 2006). India does not have any dedicated legislation for management of e-waste that cause it treated as municipal waste in most of the places (Devi et al. 2004). Currently, e- waste handling is regulated under "The Hazardous Materials (Management, Handling and Transboundary Movements) Rules, 2008". Under these rules, there are some companies in India, for the scientific and environmental friendly management and treatment of e-waste which are authorized by government agencies. But there is improper handling of e-waste in India due to involvement of unskilled workers and absence of adequate technologies due to unorganized sector in management of e-waste (Wath et al. 2010). Moreover, there is lack of social and environment concerned because companies are more emphasized and focused on the financial profits. Hence, there is strong need to adopt sustainability practices to tackle and stop the growing threat of e-waste (Kumar et al. 2011). India facing the IT revolution, the country is starting to choke under a heap of e-waste generated (Cairns 2005) from obsolete computers and discarded electronic components. Frequent advances in technology require replacement rather than repair of older electronic devices. The throwaway electronics have created an e-waste crisis that is out of control and which has made management of this waste an environmental and health concern. The e-waste contains several hazardous and toxic materials (Widmer et al. 2005) like lead, mercury, cadmium, PVC plastics and brominated flame retardants, which are known to cause severe defects in the human body (Ramachandra & Saira 2004). On an average when 1 tonne of e-waste is shredded and undergoes other separation steps during mechanical recycling, approximately 40 kg of dust like material is generated having precious metals, which are otherwise toxic if they exist in nature in such high concentration (Brandl et al. 2001). It clearly shows that a hidden treasure lies beneath this huge ever-growing mountain of e-waste. If metals are extracted properly from e-waste, this will create a new business opportunity of recycling. Till now, few companies have realized the potential of this booming business. Investments in this new sector will lead to a win-win situation for both the company as well as the country. Moreover, the land which is being wasted as

landfills or dumping sites for e-waste can be put to more productive use like agriculture, infrastructural development etc. Such substances when junked and disposed off in a haphazard manner, pollute the environment. To avoid these risks the Electronic Waste Recyclic Act was signed into law in 2004. SB 50 (Senate Bill) established and funded a programme for consumers returns, recycle and ensure safe and environmentally sound disposal of covered electronic device (CEDS).

CLASSIFICATION OF E-WASTE

E-waste encompasses ever growing range of obsolete electronic devices such as computers, servers, main frames, monitors, TVs and display devices, telecommunication devices such as cellular phones and pagers, calculators, audio and video devices, printers, scanners, copiers and fax machines besides refrigerators, air conditioners, washing machines, and microwave ovens. E-waste also covers recording devices such as DVDs, CDs, floppies, tapes, printing cartridges, military electronic waste, automobile catalytic converters, electronic components such as chips, processors, mother boards, printed circuit boards, industrial electronics such as sensors, alarms, sirens, security devices, and automobile electronic devices.

INDIAN SCENARIO

In India, it is estimated that the e-waste is 0.1-0.2% of the total municipal waste. The business sector is mainly responsible for the waste generation. The reason behind this is that the business sector accounts for the 78% e-waste, and 83% of household customers are first time buyers. In case of PC, 22% of the e-waste is generated by households. In addition to this, computer waste comprises about 1050 tonnes per year coming 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 (Pinto 2008, Williams et al. 2008, Mundada et al. 2004). In year 2005, estimated e-waste generation was 1, 46,180 tonnes/year, which has grown to 8,00,000 tonnes by 2012. The north, south and east regions generate less amount of e-waste comprising 21%, 30% and 14% in compression to west regions which generate highest amount of e-waste i.e., 35%, in India (Sinha-Khetriwal et al. 2005, Jain 2009, Wath et al. 2010). As far as sales of computers and mobile phones are concerned, sale of computers and laptops has been grown at 18% in 2009-10 as compared to 2008-09 (MAIT 2010). Whereas, mobile subscriber base is concerned, the total wireless subscribers (CDMA & GSM) have reached 391.76 million. There were only 261.07 million subscribers in 2007-08 but in 2008-09 additional 130.69 million subscribers were added with annual growth rate of 50.06% (TRAI 2009). India at present generate about 4,00,000 tonnes of e-waste annually of which only 19,000 tonnes is getting recycled according to the recent data by hardware manufacture association (MAIT 2011-2012). The first comprehensive study to estimate the annual generation of e-waste in India is being undertaken up by the National WEEE (Waste from Electronic and Electrical Equipment) taskforce and total WEEE generation in India is approximately 146000 tons per year. States like Maharashtra, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab comprise highest contribution to WEEE. The cities like Mumbai, Delhi, Bangalore, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat and Nagpur are contributing highest ranking of largest WEEE generators. There is an estimate that about 2 million tones of total obsolete computers are originating from government offices, business houses, industries and households. Manufactures and assemblers in a single calendar year, estimated to produce around 1200 tons of electronic scrap. It should be noted that obsolence rate of personal computers (PC) is one in every two years. The consumer finds it convenient to buy a new computer rather than upgrade the old one due to the changing configuration, technology and the attractive offers of the manufacturers (Ramesh & Joseph 2006). Due to the lack of governmental legislation on e-waste, standards for disposal, proper mechanism for handling these toxic hi-tech products, mostly end up in landfills or partly recycled in unhygienic conditions and partly thrown into waste streams. The individual households; the government, public and private sectors; computer retailers; manufacturers; foreign embassies; secondary markets of old PCs all these are contributing to wastage of computers. Of these, foreign countries, which are the biggest sources of PC scrap, that export huge computer waste in the form of reusable components. India as a developing country needs simpler, low cost technology keeping in view of maximum resource recovery in environmental friendly methodologies. E-Parisaraa, an eco-friendly recycling unit, deals with practical aspect of e-waste processing.

INTERVENTION ON E-WASTE

Toxic link has been engaged with the issue of e-waste since 2002-2003 and was the first one to raise the related concerns in India. Toxic link carried out a detailed study on trade and recycling of used and unserviceable PCs in Delhi in 2002-2003. This study also focused on the toxic contaminants in computer scrap, the recycling operations and its impact on human and environmental health. The report was titled "Scrapping the Hi-Tech Myth: Computer waste in India" and brought out very interesting data in public domain which

catalysed the interest of many citizens and professionals.

Since then, we have been actively campaigning on the issue of safe management of e-waste in India through various researches, reports, awareness and building exercise. Toxic links has been very actively involved in pushing the national government for separate rules on e-waste, which finally saw success with the issuance of E-waste Management and Handling Rules, 2011.

E-WASTE HAZARDS

Improper recycling and disposal of households appliances, IT and telecommunications equipment, lighting equipment, electrical and electronic tools, toys, sports equipment, medical devices, monitoring devices, etc. can result in dangerous health and environmental hazards from toxic chemicals and persistent pollutants (Mehra 2004, Sharma et al. 2012). E-waste makes a place and takes up space in the communities it invades and can be very harmful to humans and animals, mainly due to presence of toxic and carcinogenic substances if proceed improperly (Saoji 2012). These toxic substances can have an adverse impact on the surrounding environment as well as on human health, if not disposed or recycling in proper way. For example, cathode ray tubes have high content of carcinogens such as lead, barium, phosphor and other heavy metals. When disposed off carefully in a controlled environment, they do not pose any serious health or environmental risk. Otherwise, improper handling and recycling causes harmful side effects for the workers and release toxins into the soil, air and groundwater, which alters the ecological characteristics of the environment. On a broader scale, analysing the environment and societal impact of e-waste reveals a mosaic of benefits and costs (Alastair 2004). Another dangerous process is the recycling of components containing hazardous compounds such as halogenated chlorides and bromides used as flame-retardants in plastics, which form persistent dioxins and furans on combustion at low temperatures. Copper, which is present in printed circuit boards and cables, acts as a catalysts for dioxin formation when flame-retardants are incinerated. The PVC sheathing of wires is highly corrosive when burnt and also induces the formation of dioxin. A study on burning printed wiring boards in India showed alarming concentrations of dioxins in the surroundings of open burning places reaching 30 times the Swiss guidance level. Long-term exposure to these substances damages the nervous systems, kidney and bones, and the reproductive and endocrine systems, and some of them are carcinogenic and neurotoxin (Saoji 2012). The other most widely used methods of disposal is landfilling e-waste, but it is also prone to hazards, because of leachate that is leaching some heavy metals like mercury, cadmium and lead (Townsend et al. 2004). Older landfill sites and uncontrolled dumps pose a much greater danger of releasing hazardous emissions. For example, mercury leaches when certain electronic devices such as circuit breakers are destroyed. Lead has been found to leach from broken lead containing glass, such as the cone glass of cathode ray tubes from TVs and monitors. When brominated flame retarded plastics or plastics containing cadmium are landfilled, both PBDE and cadmium may leach into soil (Envocare 2001, Osako et al. 2004, Takigami et al. 2006) and groundwater. The cadmium from one mobile phone battery is enough to pollute 600m^3 of water (Trick 2002). In addition, landfills are also prone to uncontrolled fire which can release toxic fumes (Ramachandra & Saira 2004).

E-WASTE: A BURDEN ON HUMAN HEALTH AND OUR ECOSYSTEM ALIKE

A great deal of attention has been given to the profoundly damaging effect e-waste has on human health, however, electronics may also have more subtle and long term repercussions for our greater ecosystem (Kirsten 2013). The health hazards that people who dismantle or recycle e-waste or exposed to are devastating, and often render them incapable of working once they reach the age of 40. According to the centre for occupational and environmental health at Maulana Azad Medical College in New Delhi, recycler and dismantlers have recorded dangerously high level of lead, mercury and chromium in their bodies. The toxic chemicals significantly damage the respiratory, urinary and digestive system as well as degrade the immune system and have been linked to certain kind of cancer.

The dangerous metals and toxic chemicals that electronic waste contains do not organically break down and can, overtime, seep into the environment around landfills, contaminating local groundwater or get absorbed into the atmosphere, thus seriously endangering the health of nearby communities and animal populations. Research has shown that it is especially dangerous because of the process of bioaccumulation, referring to the uptake of a chemical in organisms overtime, and biomagnifications, when there is an increase in the concentration of a chemical in the food chain as a result of ingestion of other organism, in ecosystem surrounding landfills.

E-WASTE DISPOSAL

In modern day, our life and living standard, all are going to digitalized, which on one hand, is making our life much simpler but then it is creating a different kind of problem. So there is need for proper handling and disposal of e-waste with utmost sincerity. The need for e-waste disposal arises from the fact that, old and useless electronic items are not

biodegradable. In most of the developing countries, these e-waste materials are collected through scrap dealers. From them, they end up in the unorganized recycling places. Recycling and disposal is not properly done due to lack of appropriate technology (Mundada et al. 2004, Wath et al. 2010).

The most common practices adopted for disposal of e-waste are acid baths, land filling and open air burning. When electronic equipments are burned, they release abundant fumes which are dangerous for environment way beyond our imagination and estimation. Stewart & Lemieux (2003) suggested that incineration may be a viable option for electronics waste disposal, provided an appropriate particulate control device is used to control metal emission. A lot needs to be done to make disposal of e-waste a safe process.

MANAGEMENT ASPECTS

Basic principles: The principle of "Reduce, Reuse and Recycle" applies here. Reduce the generation of e-waste through smart procurement and good maintenance. Reuse still functioning electronic equipment by donating or selling it to someone who can still use it. Recycle those components that cannot be repaired.

Public education: Public education and outreach may well be the most important component. That is because no matter what infrastructure is available and developed, what the laws are, and what the option are, no one will be aware of it without public education.

Hazardous waste solutions:

- Waste Management: Minimize impact
- Waste Prevention: Minimize the volume
- Reduce waste and pollution
- Reuse as many things as possible
- Recycle and compost as much waste as possible
- Chemically or biologically treat or incinerate
- Bury what is left

International solutions:

- Ban hazardous waste exports
- Get the poisons out
- Exercise precaution-no new poisons
- Make the producer responsible
- Require producers to take back
- Design for longevity, upgrade, repair and reuse

There is a need of governmental support to establish recycling facilities to manage e-waste with stringent environmental regulation, that can give us a better model. At present, e-waste recycling is largely going on in Delhi, Meerut, Bangalore, Mumbai, Chennai and Firozabad. The procedure of metal extraction includes manual sorting, magnetic separation, reverse osmosis, electrolysis, condensation, electrolytic recovery, filtration and centrifugation (Ramachandra Saira 2004). These methods are less efficient and harmful to both the environment and human health. The biohydrometallurgical techniques provide us with a better solution, i.e. to apply a bacterial leaching process (bioleaching) for mobilization of metals from the fine-grained e-waste. Microorganisms like bacteria and fungi (*Bacillus* sp., *Saccharomyces cerevisiae* and *Yarrowia lipolytica*) have already been used to mobilize Pb, Cu and Sn from printed circuit boards (Haun et al. 1993). At electronic scrap concentration of 5-10 g/L in the medium, *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans* were able to leach more than 90% of the available Cu, Zn, Ni and Al. *Aspergillus niger* and *Penicillium simplicissimum* were able to mobilize Cu and Sn by 65% and Al, Ni, Pb, Zn by more than 95% at a scrap concentration of 100 g/L in the medium (Brandl et al. 2001). Leached and recovered metals might be recycled and reused as raw materials by metal manufacturing industries. This method has the potential to reduce waste disposal and raw material costs and also provide income from e-waste (Gupta et al. 2008). Using biological techniques, recovery efficiency can be increased, where physico-chemical and thermal methods alone are less successful. Extended producer responsibility (Hanisch 2000) to recycle e-waste will soon become a financial and material necessity, if we are to continue with our current standard of living.

SOME INITIATIVES REGARDING E-WASTE MANAGEMENT IN INDIA

E-Parisaraa: It is the first government-authorized ecofriendly recycling unit which makes full use of e-waste. The plant, which is India's first scientific e-waste recycling unit, aims to reduce pollution, landfill waste and recover valuable metals, plastics and glass from waste in an eco-friendly manner. What makes E-Parisaraa different is that unlike the backyard handling of e-waste, there is no melting involved in the sorting. Notably, it protects data from discarded PCs and guarantees customers' confidentiality (Saoji 2012).

Earth Sense Recycle Private Limited: Earth Sense Recycle Private Limited is the joint venture between the E-Parisaraa Private Limited and M/s. GJ Multiclave India Private Limited, which is a bio-medical waste handling and management company. This company came into existence in the year 2000 and they recycle all types of e-wastes including de-bound assets and other electrical and electronic equipment.

Trishyiraya Recycling India Pvt. Ltd (TPL): It is the Indian company that offers safe and reliable disposal of e-waste. The Govt. of India as well as the Pollution Control

Board has certified the company. It has constant surveillance mechanisms like CCTV monitors etc. TPL feels proud of its innovative technology that helps recycle e-waste. Adding feather to its cap is the 'Total Termination Process' that is completely pollution free. There is no contamination of water or air, and no noise pollution.

Plug-into E-cycling: It is a partnership of Environmental Protection Agency (EPA) and consumer electronics manufacturers, retailers, and service providers that offer more opportunities to donate or recycle - to "e-cycle" used electronics. E-cycling includes recycling and recovers valuable materials from old electronics which can be used to make new products. It also includes reducing greenhouse gas emission, reducing pollution, saving energy and resources by extracting fewer raw materials from the earth. Safe recycling of outdated electronic items promotes sound management of toxic chemicals such as lead and mercury (Saoji 2012).

Installation of e-bins in Bangalore city: To ensure safe disposal of e-waste generated at government offices is set to become a reality shortly. Saahas, a non-governmental organization (NGO) involved in this pioneering effort, plans to hold campaigns in government offices to create awareness about e-waste and the need to dispose it safely. Toll-free telephone number is provided to get e-waste picked up from home and recycled.

MAIT: The Manufacturer's Association for Information Technology has incubated an Electronics Recycler's Association (ERA) to organize electronic waste (e- waste) handling in an environment-friendly manner. ERA will initially comprise nine members, of whom six are e-waste processors and three are executive members (Saoji 2012).

LEGISLATION IN INDIA

In India, Ministry of Environment and Forests (MoEF) is responsible for proper management of hazardous waste. The e-waste management was first included in the List-A and List-B of Schedule-3 of "Hazardous Wastes (Management & Handling) Rules, 1989". Then the law was amended in 2000 and 2003 (Pinto 2008). Finally, after amendments in 2007 and 2008, e-waste has been included in "The Hazardous Materials (Management, Handling and Transboundary Movements) Rules, 2008" (CPCB 2008). Putting the onus of recycling 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 2011 would recognize the producers' liability for recycling and reducing e-waste in the country. The rules will come into effect from May 1, 2012 (Saoji 2012). The rules will come under the Environment Protection Act (EPA). "These rules will apply to every producer, consumers and bulk consumers involved in manufacture, sale, purchase and processing of electronic equipments or components". Under the new rules, producers will have to make consumers aware about the hazardous components present in the product. They will also have to give information booklets to prevent e-waste from being dropped in garbage bins. For sustainable management of e-waste, a country has to develop such a flexible and adaptive system that can handle the variability in quantity and quality of e- waste flow (Sinha-Khetriwal et al. 2005). Present legislation needs to be transformed to active policies which will pave way for a brighter pollution free future in the country.

The e-waste is going to become a great challenge for environmentalists and technologists as the rate of growth is much higher than the rate it is disposed off, reused or recycled. There is an urgent need for improvement in e-waste management covering technological improvement, operation plan, implementing a protective protocol for the workers working in e-waste disposal and educating public about this emerging issue posing a threat to the environment as well as public health. Minimum standards and improved awareness are needed for recycling of e-waste in India. Alternatives for recycling technologies and materials must be developed. Harmonization is needed among government's concerning environmental issues and trade in the world. The informal sectors that are deeply involved in materials cycling must evolve into more formal sectors, especially in developing countries. This is a big issue for all downstream businesses. Generation of e-wastes must be reduced. This could be accompanied by the promotion of appropriate reuse. Moreover, basic sustainability practices i.e., reduce, reuse and recycle, should not be ignored. Sustainability management should be started from the product manufacturing stage. The problem of electronic waste or e-waste requires urgent global action.

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