Electronic Waste Management in India: A Stakeholder's Perspective

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Abstract

E-waste or waste electrical and electronic equipment (WEEE) illustrate discarded appliances that utilize electricity for their functioning. Today, the Indian market is engrossed with massive volumes of electrical and electronic goods and gadgets, having tremendously high domestic demand. Consequently, the amount of E-waste being generated in the country is flourishing at an alarming rate, although the management practices and policy initiatives of the same are still in an elementary stage. The current methods of storage, processing, recycling and disposal of E-waste in India have immense potential to harm human health and the environment. Furthermore, the policy level initiatives related to E-waste in India are reasonably recent and inadequate to address the issue. The paper tries to evaluate the current status of E-waste management practices in India. The domination of informal sector in the E-waste recycling business with all its socio-economic, health and environmental implications are dealt with in detail and the dawdling progress of formal recycling units in the country is assessed upon. The paper tries to identify the range of diverse stakeholders in the E-waste management system in India. These stakeholders are significant right from the production of Electrical and Electronic Equipment (EEE) to the final disposal of E-waste. The paper concludes that identifying the range of stakeholders in the E-waste management system and constructing a sustainable E-waste management system involving these stakeholders are the needs of the hour.

E-waste management

In India, E-waste is becoming an important waste stream in terms of both quantity and toxicity (Wath et al., 2010). Managing the ever increasing volume of E-waste is a major concern for most of the countries today. The first major problem associated with E-waste management is its ever increasing quantum, and second is its scientific and environment friendly disposal, which is very crucial (Wath et al., 2010). In India, domestic E-waste is significant in addition to illegal imports (Sepúlveda et al., 2010). It is argued that due to low market penetration rate in the past, the stock of EEE already put on the market has not been as large as that in OECD countries and the market of most products is far from saturated (Ongondo, Williams and Cherrett, 2011). Due to these developments, countries like India face a fast increasing load of WEEE originating both inland and through illegal imports (Streicher-Porte et al., 2005).

According to the MoEF (2008), the electronics industry has emerged as the fastest growing segment of Indian industry both in terms of production and exports. The report further states that the share of software services in electronics and IT sector has gone up from 38.7 per cent in 1998-99 to 61.8 percent in 2003-04. A review of the industry statistics show that in 1990-91, hardware accounted for nearly 50% of total IT revenues while software's share was 22%. The scenario changed by 1994-95, with hardware share falling to 38% and software's share rising to 41%. This shift in the IT industry began with liberalization and the subsequent opening up of Indian markets (MoEF, 2008). With the development of IT industries emerged the problems related to E-waste. Although, today, IT industries contribute the most significant share to the E-waste stream, consumer electronics also mark a major portion of it.

Moreover, most of the businesses, banking sector, academic institutes etc rely heavily on EEE and thus, add end-of-life electronic gadgets to the existing waste stream.

However, estimates of E-waste in India are unavailable, or at most hazy (Sinha, 2004). Skinner (2010) argued that of the estimated 382,979 tonnes of E-waste generated in India, 144,143 tonnes entered the waste stream in the year 2007. According to Streicher-Porte et al. (2005), although the per capita waste production in populous countries like China and India is still relatively small, these countries are already huge producers of E-waste or WEEE. Considering the growth rate, several studies stated that the volume of E-waste will reach nearly 0.7 million MT by 2015 and 2 million MT by 2025.

Managing the increasing quantum of E-waste effectively and efficiently— both in terms of cost and environmental impact—is a complex task (Sinha-Khetriwal, Kraeuchi and Schwaninger, 2005). While some countries have organized systems for the collection, segregation, recycling, disposal and monitoring (as for example, Switzerland), other countries (mostly developing countries like India and China) are still to find a solution that ensures minimizing the negative environmental and human health impacts of E-waste treatment and recycling.

Current practices in E-waste management in India

India, today, is burdened with the enormous volume of E-waste, generated domestically or imported illegally. Over the last few decades, India, along with other Asian and African countries, has become a major destination for E-waste exports from OECD countries. In addition, Indians have been generating rapidly increasing amounts of E-waste domestically (Skinner, 2010). It is estimated that 75% of electronic items are stored due to uncertainty of how to manage it (Ramachandra and Varghese, 2004). A pervasive view of E-waste as a commodity causes a reluctance to dispose of E-waste immediately (Sinha, 2008). The electronic junks lie unattended in houses, offices, warehouses etc. and normally mixed with household wastes, which are finally disposed off at landfills (Sinha, 2008). Hence in order to get rid of the electronic junks, implementation of proper management practices is of utmost significance.

Moreover, India lacks a comprehensive regulation dealing with E-waste management (Skinner, 2010). Consequently, much of the domestic and imported WEEE end up in illegal dismantling and recycling facilities where workers use processes hazardous to both their health and the environment. Besides pollutions, backyard recycling also scores badly from the resource conservation and social point of views (Manomaivibool, 2009).

Most E-waste is not recycled, because E-waste items tend to go out with household waste and receive no special treatment (Ladou and Lovegrove, 2008). Most E-waste is currently landfilled (Robinson, 2009). For emerging economies the material flows related to E-waste offer a business opportunity (Streicher-Porte et al., 2005). An entire new economic sector revolves around trading, repairing and regaining materials from redundant electronic devices (Streicher-Porte et al., 2005). The backlog demand of EEE in developing countries as well as the lack of national regulation and lax enforcement of existing laws promotes the growth of a semi-formal or informal economy. It provides a living for the urban and rural poor, but causes severe risks for humans and the local environment. For some of the densely populated regions poorly controlled WEEE recycling with extremely risky techniques is a grim reality. Most of the participants in this sector are not aware of the risks, do not know of better practices or simply have no access to investment capital to finance profitable improvements.

In India, E-waste is recycled in Delhi, several states around Delhi, Chennai, Bangalore, Pune, and Kolkata, with Delhi acting as the center of E-waste recycling in the country (Shinkuma and Managi, 2010). In the Mandoli Industrial Area in Delhi, residents engage in illegal recycling of PCBs using acid bath processes to recover copper and gold (Shinkuma and Managi, 2010).

E-waste Recycling Practices in India

Recycling is a very lucrative business in India and dominated with informal actors (Manomaivibool, 2009). The "E-waste" recycling sector in many parts of Asia remains largely unregulated (Greenpeace, 2005) and India is no exception to it. This is due to values in some types of used products, mainly metal-based products and those with PWBs, and low labour costs (Manomaivibool, 2009). Moreover, the sector is poorly studied with regard to its impacts on the environment and on the health of recycling workers and surrounding communities. In the context of India, the E-waste recycling sector could be divided into Non-formal or Informal and Formal sectors.

Informal or Non-Formal Sector

The uncontrolled recycling of E-waste by the so called informal sector is the main concern in Non-OECD countries like India, China, etc (Wath, et al., 2010). In most of the cases, the entire E-waste treatment is being carried out in an unregulated environment in the informal sector, where there is no control on emissions (MoEF, 2008). The dominance of the informal sector can be explained by the toxic, yet efficient methods used in recycling (Skinner, 2010). Because of the important role of the refurbishment and resale market in India, only certain amount of E-waste were ultimately recycled (Skinner, 2010).

Based on the existing evidences informal recycling is the most pressing environmental issue associated with the E-waste (Williams et al., 2008). According to Chatterjee (2012), ninety-five percentage of the E-waste in India is being recycled in non-formal sector and five percentage of the E-waste volume are handled in formal unit. The authorized E-waste recycling facilities in India capture only 3% of total E-waste generated; the rest makes its way to informal recycling yards in major cities like Delhi, Mumbai and Bangalore (Greenpeace, 2008). This is because businesses sell their discarded IT and other equipment to informal recyclers for quick money without realizing the hazardous implications it causes to health and environment. Currently, in India, there are over 2000 units engaged in non-formal sector for E-waste recycling (Chatterjee, 2012). Such Non-formal units of E-waste recyclers are distributed almost all over India especially in states like in Delhi, Karnataka, Maharashtra, Gujarat, West Bengal etc.

There are well-established networks of waste collectors/dealers, dismantlers, and recyclers in India, most of which belong to the informal sector. Each such unit operates in a small scale, as for example in the form of door-to-door waste collectors/dealers, known locally as "kawariwalas" (Manomaivibool, 2009). Non-formal units generally follow the steps such as collection of the E-waste from the rag pickers, disassembly of the products for their useable parts, components, modules, which are having resell value. The rest of the material is chemically treated to recover precious metals causing leaching of hazardous substances to the air, soil, and water. Such recycling method has low efficiency and recovery is carried out only for valuable metals like gold, silver, aluminium, copper, etc and other materials such as tantalum, cadmium, zinc, palladium etc. could not be recovered.

The activities presently operating in the informal sector need to be upgraded to provide a support system for the integrated facility. This would enable to bring the non-formal sector in the main stream of the activity and facilitate to ensure environmental compliances (MoEF, 2008).

Stakeholders Involved in Informal or Non-Formal Sector

Stakeholders in the Non-formal sector in India involve IT industries, government offices, public and private sector establishments, educational institutes, business and corporate houses etc along with kawaries (ragpickers), scrap dealers, whole sellers, recyclers, dismantlers. Among these different stakeholders, IT industries, government offices, public and private sector establishments, educational institutes, business and corporate houses etc are chiefly responsible for the production or generation of the E-waste. They generate the E-waste and subsequently pass it to the kawaries (ragpickers), scrap dealers, whole sellers, recyclers, dismantlers etc for management purpose. Kawaries (ragpickers), scrap dealers, whole sellers, recyclers, dismantlers etc deal mainly with the management of the E-waste generated. The stakeholders responsible for managing E-waste in the non-formal sector primarily carry out major operations like collection, segregation, dissembling and dismantling. Kawaries and small scrap dealers are mainly responsible for door-to-door collection activities. They usually collect the E-waste from consumer with suitable compensatory price. Kawaries are one of the most efficient collectors of E-waste and also reduce the load of civil agencies responsible for waste collection (Chatterjee and Kumar, 2009). E-waste is collected in bulk quantity by large scrap dealers from IT industries, government offices, public and private sector agencies, school, universities and other business and corporate houses etc.

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). Such segregation operation is done either by the kawaries and scrap dealers or by whole sellers and recyclers. Similarly, dismantling and disassembling methods are also carried out by the same stakeholders along with dismantlers who particularly focus on the process of dismantling. 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. Non-formal units have lack of knowledge of the processes of smelting/ reprocessing and, therefore, prefer to sell such scrap. Thus, they play an important role in proper recycling a large quantum (~ > 95% by weight) of E-waste in reuse chain without harming environment (Chatterjee and Kumar, 2009).

Impacts of the informal recycling activities of E-waste in India

Social and Economic Impacts

Today the EEEs have become parts and parcel of everyday life, not only in the urban areas, but also of some of the remotest areas of the world. People, especially the ones working in the urban areas, cannot imagine their lives without some of the EEEs like computers, televisions, mobile phones etc. Moreover these equipments play crucial role in the social and economical development of any community and country. As for example, nobody, today, could imagine of running and developing modern businesses, effectively and efficiently, without the help of EEEs. An entire sector like IT industries has grown with the input and support of information and telecommunication equipments. In today's world, name any sector and EEEs are very much a part of the same. In the field of education, from

kindergarten till university education, the use of EEEs, especially in the form of computers, is observed. Banking sector, these days, depends heavily on internet and mobile banking. Customers in the sector are encouraged to shift to internet and mobile banking which is mostly convenient and less time consuming. Willingly or unwillingly, people, now-a-days, have to depend on EEEs to certain extent.

But due to the social and economic disparity in the developing countries like India compared with their counter parts in developed countries many people lacks the use of the new EEE (Wath et al., 2010). The considerable price difference between the new and used EEE makes the consumer to go for the purchase of the second hand EEE in developing countries like India. The demand for second hand EEEs in India is quite high. Unscrupulous organisations in rich countries use donations of obsolete electronic equipment as a loop-hole in the Basel Convention to export both functioning and non-functioning electronic equipment to countries such as India (Ladou and Lovegrove, 2008). Owing to the high demand for second hand EEEs and low initial investment required for starting a collection, dismantling, sorting, or a recovery facility (Sinha, 2004), the E-waste recycling business has become very attractive for small entrepreneurs. For E-waste recycling facility owners in India, rather than creating environmental or social awareness, the financial profit is the main incentive in India (Wath et al., 2010). This is the reason that many urban poors are involved in the E-waste recycling business. These people have least knowledge on the harmful effects of improper E-waste recycling on their health and environment. The involvement of women and children in the recycling activities further exaggerate the problem related to E-waste management.

However, the E-waste recycling units in India have great potential for generating employment. In the country, recovering reusable machines, components and materials from discarded WEEE act as a source of income for poor people (Wath et al., 2010). As collection, dismantling, sorting-segregation and recovery of E-waste are mostly done manually, in India this business provides significant employment opportunities (Baud et al., 2001) in several cities, especially to the urban and illiterate poors. It has been estimated that in Delhi alone, the number of unskilled workers involved in recycling and recovering operations, are at least 10,000 people (EMPA, 2004). Thus, the E-waste recycling sector opens the job opportunities and source of income, which also needs to be understood and addressed while framing the E-waste management system for India (Wath et al., 2010).

Occupational Health and Environmental Impacts

In the context of India, the E-waste recycling businesses pose serious threats to the worker's health and the environment. Various studies have shown that not only the health of the workers carrying out the recycling business is affected, but also the people residing in the vicinity of the E-waste recycling sites are adversely affected. A major problem in India is that as most of the people involved in the recycling business are illiterate and poor, they are totally unaware of the threats to their health and the environment as a whole from E-waste recycling operations. Such recycling areas are potential sites for uncontrolled air, water and soil pollution. However, such pollutions are neither quantified nor monitored. Wath et al. (2010) concludes that the whole E-waste management system in India is labour intensive and most of the recycling and recovery operations are carried out using outdated technologies and processes, which may lead to release of uncontrolled emission of pollutants.

Tsydenova and Bengtsson (2011) carried out a detail study on the chemical hazards associated with E-waste treatment. The study reveals that the unregulated recycling activities generate workplace and environmental contamination by a wide range of

chemicals. The authors point out that the rudimentary recycling techniques coupled with the amounts of E-waste processed have already resulted in adverse environmental and human health impacts in countries like China and India. As for example, in these countries metals from the E-waste are dissolved in strong acid solutions and subsequently recovered from the solutions. Similarly, plastic is manually removed from E-waste and mechanically shredded. Moreover, open burning of unwanted scrap and wastes is also a common practice everywhere in these countries. Such practices are carried out without any health and safety measures for the workers. Moreover, the workers and local residents are exposed to the chemicals through inhalation, dust ingestion, dermal exposure, and dietary intake.

Formal Sector

Most of the E-waste in India is channelized to non-formal sector, whereas, the formal sector is facing problem of not having sufficient input materials. Manomaivibool (2009) stated that there are only two Authorised Treatment Facility (ATF) related to E-waste present in the country, each of them having a full capacity of around five tonnes per day. These facilities are authorised to recycle E-waste or WEEE in the country. According to MoEF (2008), there are only two E-waste dismantling facilities in formal sector in India. These facilities are M/s. Trishiraya Recycling facilities, Chennai and M/s E-Parisara, Bangalore.

Domination of informal recycling units is evident in the E-waste recycling scenario of the country. Formalisation is perceived here as an exchange transaction between the government and enterprises (Manomaivibool, 2009). Currently, the two ATFs occupy a niche market in the processing of WEEE either from the established producers who run service centres and/or take-back schemes in India, or from the companies – institutional users of EEE – who have an environmental management system (EMS) or environmental policies on the disposal of WEEE (Manomaivibool, 2009). Apart from these two market opportunities, ATFs are unable to compete with the informal recycling and treatment facilities of E-waste prevalent in the country. The list of the formal dismantlers/recyclers authorised by CPCB are incorporated in the appendix of the dissertation.

Stakeholders Involved in the Formal Sector

The stakeholders in the formal sector differ from that of informal sector. They mostly include producers of EEE who run service centres and/or take-back schemes in India (example, Hewlett-Packard and Nokia), and the companies – institutional users of EEE – who have an environmental management system (EMS) or environmental policies on the disposal of WEEE (example, IT giants like Tata Technology Limited and Tech Mahindra). As the processes followed in formal sector are mainly limited to the segregation and dismantling of E-waste parts, the recycling and final disposal is primarily dominated by the informal sector. E-waste dismantling facilities in formal sector in India such as M/s. Trishiraya Recycling facilities, Chennai and M/s E-Parisara, Bangalore are key stakeholders in the formal sector.

Reuse and recycling techniques of E-waste in India

Electronic equipment that is no longer of use to the original purchaser may be reused, effectively extending its lifespan. Reuse is ultimately the source of some E-waste in many poor countries that accept donations of equipment considered obsolete in rich countries. Old yet functional electronic equipment is often shipped to developing countries by well-meaning donors in the West (Robinson, 2009). India has very lucrative second-hand markets for reusable products. Repair, recondition and component reuse, and refurbishing shops are

common features in the country (Manomaivibool, 2009). E-waste or WEEE can be recovered through disassembly, component reuse, bulk recycling, and energy recovery (especially from waste plastics) (Nnorom and Osibanjo, 2008). The recovery of WEEE for reuse or recycling conserves resources and feedstocks that supply steel, glass, plastics and precious metals and avoids air and water pollution, as well as greenhouse gas emissions associated with material production and manufacturing (Nnorom and Osibanjo, 2008). However, Wang et al. (2012) argued that the informal recovery of valuable materials like precious metals has low yields and thus leads to the loss of resources, resulting in an increased demand for mining and extraction capacity. Therefore, establishing environmentally sound treatment systems in developing countries is essential to reduce the impacts from rapidly increasing quantities of E-waste. Moreover, unlike some of the developed countries like Switzerland, where consumers pay a recycling fee, in India it is the waste collectors who pay consumers a positive price for their obsolete appliances. The small collectors in turn sell their collections to traders who aggregate and sort different kinds of waste and then sell it to recyclers, who recover the metals (Sinha-Khetriwal, Kraeuchi and Schwaninger, 2005).

The E-waste recycling industry is a very young industry (Agarwal et al, 2005). However, a rapid growth of the E-waste recycling industry has been observed in the last few years. As stated by Sinha (2004), there was already a strong scrap metal industry in existent in India, which, for many years, had reclaimed a wide variety of ferrous and non-ferrous metals, including steel, aluminium, copper etc from scrap, mainly from industries. With the advent of the electronic age, and as electrical and electronic appliances started becoming obsolete, the already established scrap metal industry absorbed this new waste stream to recover metals, which are then used as a feedstock to steel mills and non-ferrous smelters and refiners (Sinha-Khetriwal, Kraeuchi and Schwaninger, 2005). In the due course of time, there was an evolution of the scrap industry as it accepted used and scrap materials from many sources, one of which was the electronics sector (Sinha, 2004). As the volume of E-waste grew, there was a certain degree of specialisation, with some waste processors focussing only on E-waste. Given the low level of initial investment required to start a collection, dismantling, sorting business or recovery business, it has attracted many small entrepreneurs to join the industry (Sinha, 2004).

Wong et al. (2007) stated that the techniques used in recycling of E-waste are often primitive, without the appropriate facilities to safeguard environmental and human health. The authors listed down some of the techniques used for E-waste recycling as

- Stripping of metals in open-pit acid baths to recover gold and other metals,
- Removing electronic components from printed circuit boards by heating over a grill using honeycombed coal blocks (coal mixed with river sediment which is contaminated) as fuel,
- Chipping and melting plastics without proper ventilation,
- Burning cables for recovering metals, and also burning unwanted materials in open air,
- Disposing unsalvageable materials in the fields and riverbanks,
- Toner sweeping,
- Dismantling electronic equipment, and
- Selling computer monitor yokes to copper recovery operations.

Complementing Wong et al. (2007), Ha et al. (2009) stated that the recycling techniques used by most of the backyard recyclers of E-waste in developing countries are often unskillful and there are only very few appropriate facilities that consider environmental problems and human health implications during their operations. Primitive tools and methods of E-waste recycling often involve the open burning of plastic waste, exposure to toxic solders, acid baths to recover saleable materials and components from WEEE with little or no safeguards to human health and the environment which results in polluting the land, air and water due to river dumping of acids and widespread general dumping (Manomaivibool, 2009). The whole E-waste treatment is dominated by backyard/informal recyclers using intensive manual dismantling of equipment. This is usually followed by primitive processes for material recovery like acid-leaching of printed wiring boards (PWBs) or burning of cables and residues without basic working protection regarding health and safety (Wang et al., 2012). The recycling techniques used in relation to E-waste poses serious threats to the human health and the environment by releasing several toxic and persistent pollutants. For example, the recovery of copper wires through the burning of polyvinyl chloride (PVC) and PBDE protected cables can release toxic chlorinated and brominated dioxins (PCDD/PBDD) and furans (PCDF/PBDF), and the open burning of computer casings and circuit boards stripped of metal parts can produce toxic fumes and ashes containing polycyclic aromatic hydrocarbons (PAHs) (Wong et al., 2007). Likewise Ha et al. (2007) noted that during the processes of informal recycling, toxic chemicals such as Cd, Pb, Hg, polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs), polybrominated diphenyl ethers (PBDEs) and polycyclic aromatic hydrocarbons (PAHs) may be released into the environment. Therefore, direct and/or indirect exposures of human to these chemicals and their toxic effects are of great concern.

Nnorom and Osibanjo (2008) argued that the crude 'backyard' recycling processes for E-waste, currently taking place in China, India, and in some other countries in the Asia-Pacific axis, are usually carried out with no or very little personal protection equipment or pollution control measures. In open burning of materials, fly ash particulates laden with heavy metals and other toxic materials are usually emitted and results in inhalation of these toxic materials, contamination of food, soil and surface water after deposition. These crude material recovery processes have resulted in environmental pollution while exposing millions of people to toxins (Nnorom and Osibanjo, 2008). Moreover, sampling of heavy metals and toxic organics sediments in E-waste recycling sites such as Guiyu (China) and Bangalore (India) showed that heavy contamination from backyard recycling brings severe damage to the local environment and leads to human health risks (Wang et al., 2012). Sinha-Khetriwal, Kraeuchi and Schwaninger (2005) concludes that the biggest drawback of the current Indian system of E-waste recycling is the uncontrolled emission of hazardous toxics that are going into the air, water and soil. The health hazards from fumes, ashes and harmful chemicals affect not only the workers who come into contact with the E-waste, but also the environment.

Environmentally sound E-waste management system

Wath et al. (2010) argued that unlike developing countries like Switzerland, the India's E-waste management system is not formally developed. Moreover it is very ill defined and unorganised. The author further listed down some of the major requirements and considerations for developing sound E-waste management system. These include:

- Special logistic requirements for collecting the E-waste from the source of its generation or origin and transporting to the site of final disposal and/or treatment/recycling/recovery/reuse.

- E-waste contains many hazardous substances which are extremely dangerous to human health and environment, and therefore disposal requires special treatment to minimize impacts in environment.
- E-waste is a rich source of metals such as gold, silver and copper, which can be recovered and recycled/reused into the production cycle.

MoEF (2008) listed down environmentally sound treatment technology for E-waste and stated that the environmentally sound E-waste treatment technologies are used at three levels as described below:

- 1st level treatment
- 2nd level treatment
- 3rd level treatment

All the three levels of E-waste treatment are based on material flow. The material flows from the 1st level to the 3rd level treatment. Each level treatment consists of unit operations, where E-waste is treated and output of 1st level treatment serves as input to 2nd level treatment. After the third level treatment, the residues are disposed off either in Transfer, Storage and/or Disposal Facility (TSDF) or incinerated. The efficiency of operations at first and second level determines the quantity of residues going to TSDF or incineration. Simplified version of Environmentally Sound Treatment of E-waste is presented in Figure 1.

As stated by MoEF (2008) following are the significance of each level.
At the 1st level of treatment the input include E-waste items like TV, refrigerator and Personal Computers (PC) and the unit operations at first level of E-waste treatment are:

- Decontamination : Removal of all liquids and Gases
- Dismantling -manual/mechanized breaking
- Segregation

All the three unit operations are dry processes, which do not require usage of water.

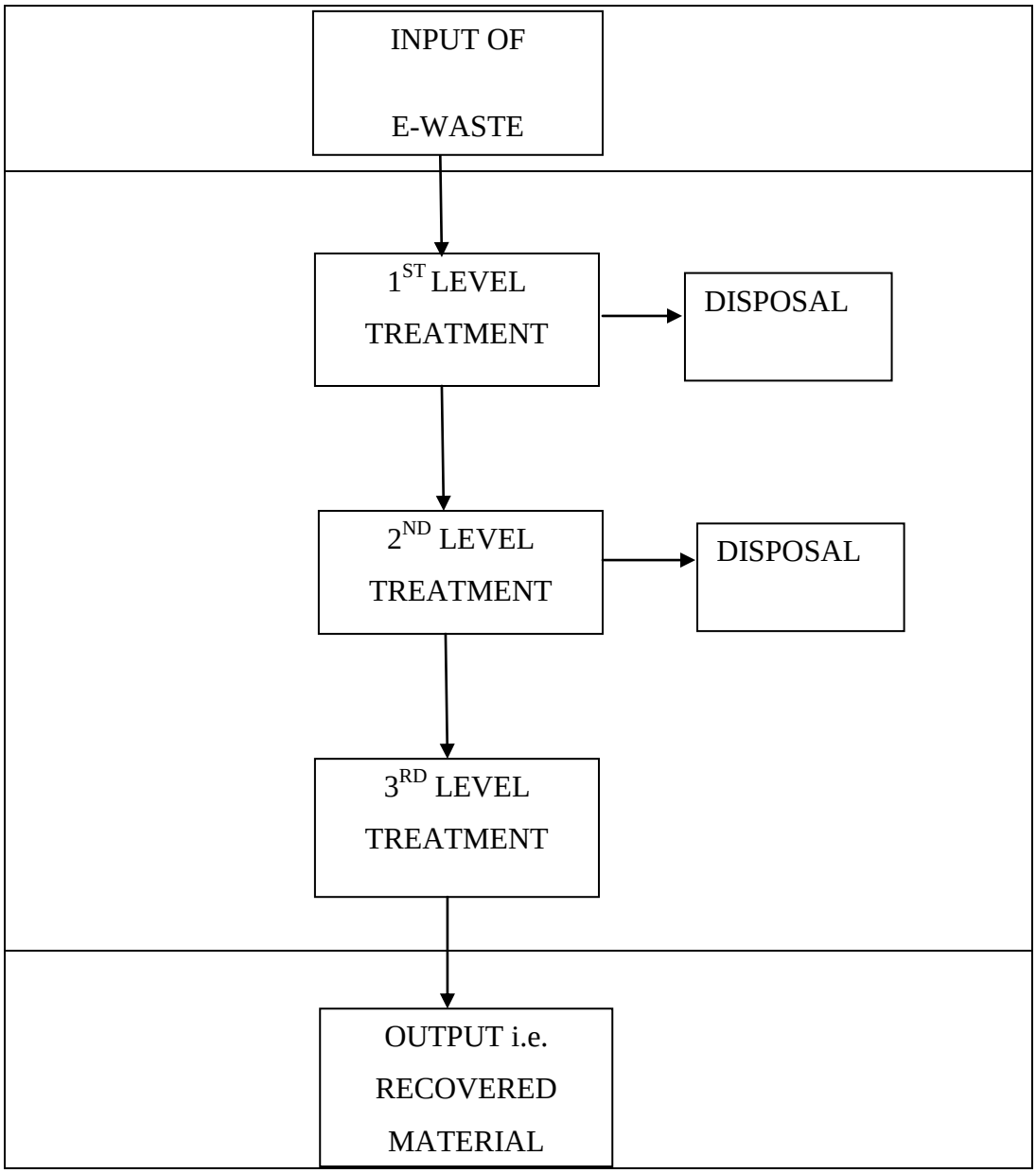
At the 2nd level of treatment, inputs are in the form of decontaminated E-waste consisting segregated non hazardous E-waste like plastic, CRT, circuit board and cables.

Unit Operations in this stage include: Hammering, Shredding, and Special treatment Processes comprising of:

- CRT treatment consisting of separation of funnels and screen glass.
- Electromagnetic separation
- Eddy current separation
- Density separation using water

The two major unit operations in this phase are hammering and shredding, the major objective of which is the size reduction.

Figure 1: Steps to Environmentally Sound Treatment of E-waste



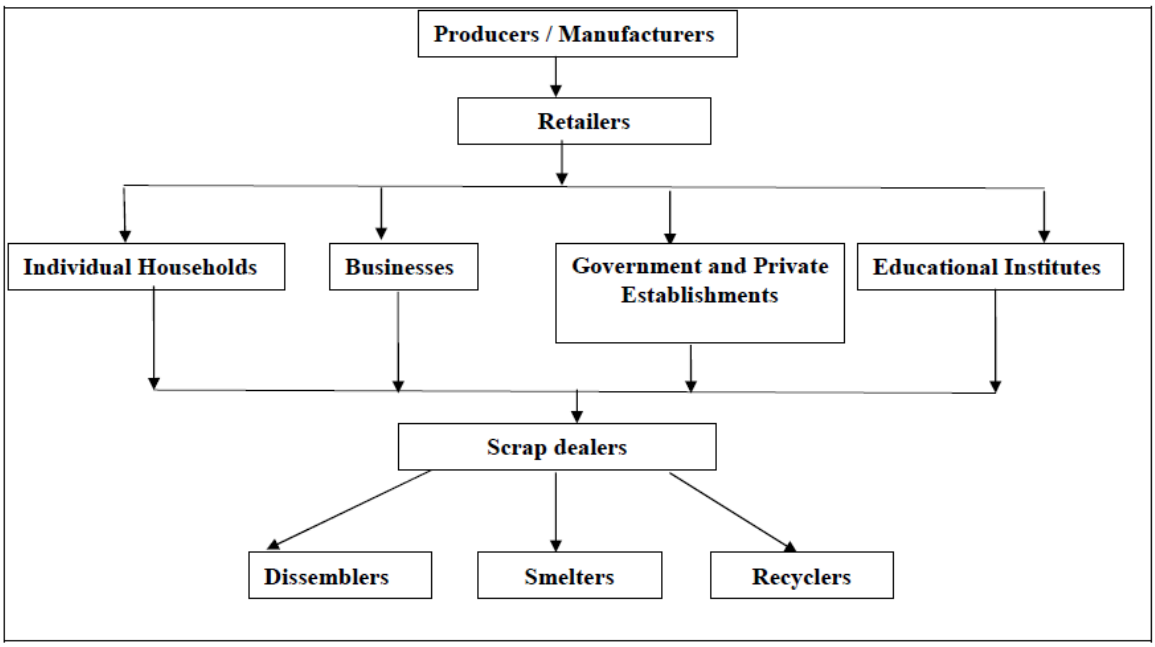
Source: MoEF, 2008

The 3rd level E-waste treatment is carried out mainly to recover ferrous, nonferrous metals, plastics and other items of economic value. The major recovery operations are focused on ferrous and non ferrous metal recovery, which is either geographically carried out at different places or at one place in an integrated facility. Here inputs are in the form of sorted plastic, CRT, ferrous metal scrap, non-ferrous metal scrap etc. The unit operations include recycling, incineration/energy recovery, iron recycling etc.

An overview of the different stakeholders in the E-waste management system in India

The E-waste management system in India consists of a number of diverse stakeholders. These stakeholders (see Figure 2) are significant right from the production of EEE to the final disposal of WEEE or E-waste.

Figure 2: Different stakeholders involved in the E-waste flow



Source: Borthakur A., 2012

The stakeholders in India are divided into following four batches for the purpose of the study:

The First Batch of Stakeholders,

The Second Batch of Stakeholders,

The Third Batch of Stakeholders,

Others

The First Batch of Stakeholders

The first bunch of the stakeholders mainly involves the EEE generators. This level marks the actual entry of the new electrical and electronic equipments, raw materials, components, assemblies and sub-assemblies in India either in the form of production/manufacturing, by the producers and manufacturers who are located in India, or in the form of its import from the foreign countries by the importers (Wath et al., 2010). As stakeholders such as assemblers, distributors, retailers, raw material suppliers are not the real user of these EEE items and raw materials, they are considered as the stakeholders only of the EEE generation, rather than of the WEEE generations (Wath et al., 2010).

- **Manufacturers/ Importers**

The volume of EEE released in the market is growing day by day. However, in India, the manufacturers responsible for introducing the EEE in the market hardly bear any responsibility of their products once they become obsolete. Same is the case with EEE importers.

Some of the manufacturers claim that they practice Extended Producer Responsibilities or carry out Take-Back services. A study carried out by Greenpeace in the year 2008 reveals that global giants such as Apple, Microsoft, Panasonic, PCS Technology, Philips, Sharp, Sony, Sony Ericsson and Toshiba have no take-back services in India. It is noteworthy that these are the companies with extremely high market share of EEE in the country. Some of them have take-back schemes in countries like the USA, but they don't operate such services in India. The global brands with no take-back programme in India, despite some tall claims on producer responsibility, undoubtedly falter on their commitment in India and treat their Indian customers as second-grade clients. These companies indirectly foster the growth of the informal recycling by failing to provide easy and free take-back service to ensure responsible recycling (Greenpeace, 2008).

While some manufacturers, like Hewlett-Packard (HP), are starting to offer collection programmes, these are limited for the large corporate clients who generate reasonable volume (Sinha, 2004). Companies providing take-back services in India include Acer, Dell, HCL, Hewlett-Packard (HP), Lenovo, LG Electronics, Motorola, Nokia, WIPRO, Samsung and Zenith (Greenpeace, 2008). According to Sinha (2004), the cartridge take back by HP is motivated by commercial reasons, than from an environmental point of view, because the company would like to discourage the proliferation of cartridge reuse which is substantially cheaper than its own original supplies. Since global manufacturers often have production facilities in India, they themselves are also the substantial contributors to the E-waste stream. Most of the times, they dispose their waste, either through a tendering process or via the informal recycling sector. One encouraging fact is that despite the absence of any legal binding requirements, Indian brands like HCL and WIPRO are offering voluntary take-back and recycling service to their customers. This is a positive development from the side of EEE manufacturers.

- **Assemblers**

Assemblers are the people responsible for assembling different parts of EEE. They are involved in the EEE generation phase. The role of the assemblers are most significant in the case of personal computers where they purchase the local made or branded components, assemblies and sub-assemblies from the raw materials manufactures and suppliers, assembled it and directly sells it to the consumers . In many public-private sector offices, educational institutes, households etc in India, such assembled PCs are in function. It is because of the fact that usually the price of such products is much cheaper compared with the branded PCs. As Indian EEE market is cost sensitive, such assemblers provide the Indian customers an opportunity to own a first-hand EEE with less cost.

- **Retailers**

The retailing industry in India is still in its infancy, and is dominated by individual proprietary shops in contrast to the large formal retail chains in developed countries (Sinha, 2004). The retailers currently only play an infrequent and arbitrary role in the collection of E-waste,

which is limited only to a few products with high resale values (Sinha, 2004). This is mainly in the form of exchange offers, and the buy back or take-back value, left to the judgement of the retailer. In the case of EEE, exchange offers attract the customers to a great extent. Today, in India, especially during the festive seasons, such offers attract attention in major Indian cities. People exchange their old goods with new ones. As for example, there is a gradual shift from CRT to LCD screen televisions in India. The exchange programmes offer an opportunity to the consumers of EEE to enjoy such shift in comparatively less expenses. The problems associated with the take-back programme in India are discussed in the previous section. Acer, HCL, WIPRO, LG Electronics, Motorola and Nokia are the only brands having relatively fully operating take-back services in the country (Greenpeace, 2008).

- **Raw material producers**

India has a large mining sector and industrial smelters for various metals who buy scrap from traders and recyclers of E-waste (Sinha, 2004). The recycler/dismantler dismantles the E-waste and the readily reusable/recyclable materials like plastic, glass, cable-wires, components, etc. are resale back to raw material supplier for reuse (Sinha, 2004). However, the involvement of raw material producers in a large way on influencing the collection and sorting of the E-waste is still insignificant in the country. Only a small fraction of E-waste material such as iron goes to steel mills.

The Second Batch of Stakeholders

The second batch of the stakeholders includes E-waste or WEEE generators in the form of consumers of E-waste. The domestic as well as official consumers are the real users of EEE, who purchases the generated new EEE from the stakeholders of first batch, in order to serve their present need. Often in case of the personal computers, TVs, etc. the consumers discard their old items for the sake of latest version, features and options to meet their present need (Wath et al., 2010). In India, the EEE may find more than one user, as the first user may resale or give the used EEE to their relative or friend for further use in case of domestic consumer. Practices may also be found of donating the used EEE by the official consumers to the economically week social institutes like charitable schools, hostels, orphanage, hospitals, village societies, etc (Wath et al., 2010).

- **Consumers**

The consumers of EEE are diverse and wide spread. As stated earlier, the use of EEE is distributed to the remotest parts of the world. In the urban scenario, there is hardly any sector devoid of EEE. Some of the major consumers or users of EEE include IT industries, public and private sector establishments, educational institutes, households, business and corporate offices etc.

However, in the present scenario in India, while purchasing EEE, consumers do not pay for end-of-life appliances. Moreover, once the EEE becomes WEEE, consumers in India, be it institutional, commercial or individual users, do not pay for the recycling of their old appliances. Unlike some of the developed countries, it is the waste collector who pays a reasonable price to the consumers for their obsolete EEE. It has been observed that in the country, the consumers are still reluctant to pay a positive price for the recycling of E-waste. In the case of large corporate houses, E-waste is often auctioned. Unaware of the methods of disposal of E-waste, many households and other institutes dispose their E-waste with

other household wastes. Many of the E-waste lies unattended in several establishments for ages because of lack of knowledge about their proper management.

On the other hand, consumers could play an important role in keeping the EEE out of the waste stream for a longer period of time, by preferring to repair or hand-down the appliance to various relatives, friends or employees, than dispose it outright. In a positive note such practices are very much evident in India. A pervasive view of E-waste as a commodity causes a reluctance to dispose of E-waste immediately (Sinha, 2008) and hence it finds second or even third hand users in the country. It has been observed that the average life of consumer durables in India is much longer than in developed countries.

It has been observed that most of the households do not directly sell obsolete E-waste into the scrap market. The preferred practice is to get it exchanged from retailers while purchasing a EEE, or pass it on to relatives or friends (UNEP, 2007). The "Take-Back" policies are also in practice in India, although it is in a very nascent stage in the country. In the case of Exchange or Take-Back Policies, it is the retailer's responsibility to dispose off the end-of-life EEES in an appropriate way. However, the people in the country are still to shift to Eco-friendly products, as most of the times such products are expensive than the normal ones. The energy-stared products are good example of the same. Although more stars reflect more environmental compliance, yet at the same time such products are highly expensive.

The Third Batch of Stakeholders

This group of stakeholders are those responsible for collection, segregation, dismantling, treatment and disposal of E-waste. The stakeholders involved in this batch are mostly unorganised.

- **Kawaries and Scrap Dealers**

In the E-waste management practices in India, kawariwalas and small and large scrap dealers play significant role. The collectors and recyclers are the heart of the E-waste management in India. The collectors collect the E-waste from the consumers and pass them to the recyclers. The collectors and recyclers, and a host of intermediaries, work together on the basis of informal business contracts (Sinha, 2004). In the country, collection of the E-waste is mostly done by the unorganized sector of scrap dealers/traders, called as "Kawariwala" in local language, who purchases E-waste along with the other recyclable waste or scrap like old news papers, books, cardboards, plastics, ferrous-tin material items, glass bottles, etc., from the consumer at a specific cost, and sell it through small traders to the wholesaler/bigger trader who segregates and sort out different types of waste material components, and ultimately sells it to the recycler/dismantler and disposers for reprocessing (Wath et al., 2010). Thus in India, E-waste is one of the fractions of the total recyclable waste or scrap, which are been purchased by the Kawariwala from various consumers like individual houses, offices, institutions, government, commercial and industrial establishments, etc (Wath et al., 2010). In many government and private establishments these scrap or reusable/ recyclable items are auctioned through advertisements in the news papers.

- **Recyclers**

Sinha (2004) states that in the context of India, it is not known how many people are involved or how widespread the network of collectors and recyclers is as data collection on this sector is particularly difficult in the absence of a controlling or monitoring mechanism.

However, many studies reveal that the number of people working in the recycling of E-waste is pretty high. EMPA (2004) reveals that in Delhi alone, there are around 10,000 workers working in the recycling sector. Chatterjee (2012) estimated that more than 2000 unorganised recyclers along with 270 medium and big scrap dealers are involved in the recycling business in India. Today, nearly 20,000 to 25,000 numbers of unskilled workforces are involved in unorganised sector alone in Delhi (Chatterjee, 2012). The recycling practices operating in India are extremely meagre and pose serious threats to the human health and the environment.

- **Disposers**

The main disposal options of E-waste available in India are landfilling and incineration (MoEF, 2008). Non-recyclable materials go to the landfill or incineration sites. The landfills in most of the Indian cities are not well equipped to handle hazardous waste like E-waste. Hence such waste has the potential for air, water and soil pollution. The leaching of toxins into the soil and ground water in the poorly lined landfill is a major cause of concern in the most of the municipal landfill sites. According to the MoEF (2008), at present it is not possible to quantify environmental impacts from E-waste in landfills for the following reasons:

- Landfills contain mixtures of various waste streams;
- Emission of pollutants from landfills can be delayed for many years;
- According to climatic conditions and technologies applied in landfills (e.g. leachate collection and treatment, impermeable bottom layers, gas collection), data on the concentration of substances in leachate and landfill gas from municipal waste landfill sites differ.

Incineration has advantage over landfilling in reduction of waste volume and the utilization of the energy content of combustible materials. However, it may lead to significant air and soil pollution as the majority of the waste is incinerated in the open or accumulated in illegal dumps. Therefore, the disposers of E-waste must be aware of all aspects related to the incineration and landfilling of E-waste for secure and safe disposal.

Other Stakeholders

- **Government**

The Government of India has considered E-waste in “The Hazardous Wastes (Management and Handling) Rules, 2003” and “the E-waste (Management and Handling) Rules, 2011”. However, the implementation of such rules is still at the nascent stage. The local governments of the major Indian cities who are responsible for the collection and disposal of the municipal solid waste, till date, are inefficient in the collection or disposal of E-waste in an eco-friendly manner. Proper governance is essential to ensure environmentally responsible collection, treatment and disposal of E-waste.

- **NGOs**

Some of the NGOs play active role in creating and demanding proper awareness on the issues related to E-waste. NGOs such as Greenpeace, Toxics Link, Saahas etc are vocal about unacceptably of current E-waste management practices. Moreover, the illegal import of E-waste is a major focus area for these NGOs. These NGOs are responsible for carrying out studies related to all major aspects of E-waste and providing policy suggestions in the country. Through the work of these NGOs, the real E-waste scenario of the country is coming up.

Conclusions

It has been observed that the current management practices in India have the potential to adversely impact the health of the recycling workers and the environment as a whole. The recycling activities that are carried out offer utter danger. Techniques such as acid-bathing to extract the valuable and reusable components from the E-waste are usually carried out by the urban poor without any health and safety measures. Moreover, the involvement of women and children in such recycling activities further amplify the problem of E-waste recycling in the country. As most of the E-waste in India is channelized to non-formal sector, the formal sector is facing problem of not having sufficient input materials. Hence, the evolution of formal sector is still a leisurely process in the country. The key stakeholders identified along the management chain have their respective roles and responsibilities towards sustainable E-waste management in the country. The consumers of EEE are found to be highly perplexed on the future of their obsolete EEE. Most of the consumers are unaware of the improper disposal of E-waste and continue to discard their end-of-life appliances with regular household waste. However, the policy level initiatives related to E-waste in India are reasonably recent and inadequate to address the issue. For instance, the IT revolution started in India way back in early 1990s, whereas a proper policy related to E-waste was being introduced almost after 20 years, in 2011, in the form of the “E-waste (management and handling) Rules, 2011”. It is high time to consider different policy level initiatives in the form of legislations and other market-based policy initiatives such as Extended Producer Responsibility, Take Back Policies, Advanced Disposal Fee, Advanced Recycling Fee, Tax Credit, Deposit-Refund System, Pay-As-You-Throw etc. in order to address the issues related to E-waste in India.

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