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Electronics waste management: Indian practices and guidelines

Amitava Bandyopadhyay

Department of Chemical Engineering. University of Calcutta, 92, A.P.C.Road. Kolkata 700 009. India.

Abstract
Electronic waste or e-waste or waste electrical and electronic equipment (WEEE) is a popular, informal name for discarded electrical and electronic equipment (EEE) with all of their peripherals at their end-of-life. WEEE constitutes 8% of municipal waste and is one of the fastest growing waste streams. The fraction of precious and other metals in e-waste is over 60%, while pollutants comprise a meager 2.70%. Given the volume of WEEE generated containing toxic materials, it emerges as a risk to the society. Considering the high toxicity of these pollutants especially when burned or recycled in uncontrolled environments, the Basel Convention has identified e-waste as hazardous, and developed a framework for controls on transboundary movement of such waste. In contrast, WEEE can offer a tremendous business opportunity if it would treat in proper manner. The management of the WEEE has thus become a global challenge in today's world. Several nations across the globe have implemented or are about to implement WEEE regulations based on the principle of Extended Producer Responsibility (EPR). Both existing and proposed solutions are implemented with various degrees of centralization. Practical implementations however, can give rise to absurd organizational outcomes. In the light of these findings, the present paper deals with the Indian initiatives on the WEEE management keeping pace with the international scenario. Initially, this paper aims to draw an overview on the basics of WEEE. Next, the international legislative practices followed by Indian initiatives intended to help manage these growing quantities of this waste stream are discussed.

Keywords: E-Waste, WEEE directive, Extended producer responsibility, Inidan initiatives on e-waste, Basel convention.

1. Introduction

Rapid technology change, low initial cost and even planned obsolescence have resulted in the fastest growth of the EE products and simultaneoously resulted in the rapid development of e-waste around the globe due to enhanced rate of discarding these products after their end-of-life (EOL). E-waste is both valuable as source for secondary raw material, and toxic if treated and discarded improperly. Technical solutions are available but in most cases as in transition economies a legal framework, a collection system, logistics and other associated services are not orchrested in the manner it is needed to implement a technical solution [1]. E-waste is thus becoming a prime concern in to-day's society largely due to the toxicity of some of the substances. The toxicity is due in part to lead, mercury, cadmium and a host of other substances. A typical computer monitor may contain more than 6% lead by weight. E-waste may contain as high as thirty-six distinct chemicals. According to an estimate of European Commission, the

total amount of waste in Europe is expected to increase by about 45% between 1995 and 2020. This forecast has led to the development of European waste strategy based on three categories - waste prevention, recycling and reuse and environmentally sound disposal [2]. A flurry of research has been undertaken in the recent past on the sustainability of practices like "recycling and reuse" covering various types of packaging waste [3–5]. All these studies reported so far were based on single component waste stream, for instance, aluminium packaging or PET bottles. It is a matter of great uncertainty now as to whether similar conclusions can also be drawn for more complex waste stream like e-waste or not. The complexity in composition of each item in the e-waste stream makes it difficult for recycling. This is further augmented with the sparse user-friendly viable recycling methods. For example, poly brominated flame retardants (PBFRs) are widely used in plastics meant for the electrical and electronic equipment (EEE). Due to presence of halogens in PBFRs these plastics are difficult to recycle. The growth of this waste stream can be generally attributed to the paradigm shift from an industrial society to an information technology based society with ever increasing use of information and communication technology (ICT) based devices in particular. According to Cui [6], the production of electrical and electronic equipment (EEE) is one of the fastest growing areas. Hence, the amount of WEEE is also increasing very fast - in Europe, at an expected rate of at least 3% to 5% per year and is putting enormous pressure on all institutions involved in the end-of-life (EOL) management of electronic devices. The quantum of WEEE generated constitutes one of the fastest growing waste fractions, accounting for 8% of all municipal waste [7]. These facts have led to vigorous action among legislative bodies across the globe.

Due to poor environmental standards and working conditions in developing countries of transition economy, e-waste is being exported to these countries for processing in violation of the Basel Convention. As a couter measure several countries like Switzerland, Sweden, Belgium, Holland, USA, Norway, Canada, Japan, Australia have formulated their own regulations for e-waste management [8–10] while 25 Member States of the European Union (EU) follow EU Waste Electrical and Electronics Equipment (WEEE) Directive (Hieronymi, 2004). The principle of all these regulatory approaches is the Extended Producer Responsibility (EPR) manifested with a command and control for its enforcement. Extended Producer Responsibility (EPR) is a relatively new and market-oriented regulatory instrument. The Organization for Economic Cooperation and Development defines it as "an environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle" [11]. Application of EPR for the original equipment manufacturers (OEMs) of EEE is certainly appropriate. However, the feasibility analysis has to be carried out prior to finalization of the policy by the regulatory authorities. It is prudent to carry out an economic analysis since the policy under question ought to have considerable cost impacts of the different institutional system designs. Detailed economic analysis includes actual actions and activities in e-waste recycling practices. Such concerns were missing in the case of the WEEE directive in the European Union [12].

In India, there is no legislation for the management of e-waste at present excepting inclusion of a few items of WEEE under the Hazardous Wastes (Management and Handling) Amendment Rules, 2008 [13]. An attempt has therefore, been made in this article to give an overview of the basics of the e-waste, highlights of the EU, WEEE Directives and finally the Indian initiatives. While discussing legislative issues it would be prudent to discuss the Swiss regulation as a priori as Switzerland is the first country in the world to enforce the e-waste regulation.

2. What is electronic waste or e-waste or waste electrical and electronic equipment (WEEE)?

E-waste is a popular, informal name for discarded and EOL EEE comprising Information and Communication Technology Equipment, Home Electrical Appliances, Audio & Video Products and all of their peripherals. The standard definition of electronic waste or e-waste does not seem to be available in the existing literature. However, according to UNEP [14] "*e-waste is a generic term encompassing various forms of electrical and electronic equipment (EEE) that are old, end-of-life electronic appliances and have ceased to be of any value to their owners"*. This is by far the reasonably best definition of e-waste as of now. A practical definition of e-waste is "any electrically powered appliance that fails to satisfy the current owner for its originally intended purpose".

3. WEEE categories

WEEE consists of the ten categories (Table 1) per the definitions in the EU Directive 2002/96/EC [2]. Of the ten categories listed in Table 1, Categories 1 to 4 account more than 95% of the WEEE generated.

Table 1. WEEE Categories [2]

Sl	Category	Label
1	Large household appliances	Large HH
2	Small household appliances	Small HH
3	IT and telecommunications equipment	ICT
4	Consumer equipment	CE
5	Lighting equipment	Lighting
6	Electrical & electronic tools (with the exception of large-scale stationary industrial tools)	E & E tools
7	Toys, leisure and sports equipment	Toys
8	Medical devices (with the exception of all implanted and infected products)	Medical equipment
9	Monitoring and control instruments	M & C
10	Automatic dispensers	Dispensers

4. WEEE composition

WEEE is a complex mixture of Ag, Au, Pd and Pt as precious metals; Cu, Al, Ni, Sn, Zn, Fe as base metals; Hg, Be, Pb, Cd, Cr(VI), As, Sb, Bi as metals of concern; halogens and combustibles [plastics/flame retardants] [15] many of which are toxic. It is, however, extremely difficult to present a generalized material composition for the entire e-waste stream since EEE is composed of various materials with wide range of physico-chemical characteristics. In general, six categories of materials are, therefore, reported in most of the studies to complete the inventory, such as ferrous metals, non-ferrous metals, glass, plastics, pollutants and others. "Pollutants" find a position in these categories to transpire the polluting behaviour of the WEEE matrix in reality. When WEEE is disposed off or recycled in an uncontrolled manner, the level of "pollutants" become significantly higher. Besides toxic materials, e-waste also contains considerable quantities of valuables in the form of precious metals. Recycling of such wastes, thus assumes significant importance from the commercial standpoint.

Iron and steel constitute the major fraction in the WEEE materials to the tune of 47.9% as against the plastics as second largest component constituting to about 20.6% [16]. The non-ferrous component contributes to 12.7% of which Cu weighs 7%. A similar breakup indicating the material composition is found in the e-waste recycled by Swiss Association for Information, Communication and Organization Technology (SWICO) / Swiss Foundation for Waste Management (S.EN.S) recycling system in Switzerland [17] wherein total metals account for 60.20% and plastics to the tune of 15.21%. The plastic content in WEEE can be understood from the generic plastic resins those were sold in electrical and electronic sector in the US in significant quantities in 1995 [18]. Approximately seventeen such plastic resins sold were: Acrylic mostly Polymethyl Methacrylate (PMMA), Acrylonitrile Butadiene Styrene (ABS), Epoxy (EP), Phenol Formaldehyde (PF), Polyacetal (POM), Poly Amide (PA), Poly-Carbonate (PC), Poly-Carbonate (PC) / Acrylonitrile Butadiene Styrene (ABS) Blend, Polyethylene (PE), Polyethylene Terephthalate (PET), Polybutylene Terephthalate (PBT), Unsaturated Polyester (UP), Polyphenylene Ether (PPE) / High-Impact Polystyrene (HIPS) Blend, Polypropylene (PP), Polystyrene (PS) (including HIPS), Polyurethane (PU) and Polyvinyl Chloride (PVC).

The six most commonly used resins in EEE were PS (29 %), ABS (14 %), PP (12 %), PU (9 %), PC (8 %), and PF (5 %) and were found widely varying in their quantities within product categories.

5. Indian scenario of e-waste

The electronic industries have emerged as the fasted growing segment of Indian industries in terms of production, internal consumption, and export. In the IT action plan, the government has targeted to increase the present level of penetration, from 5 per 500 people to 1 for 50 people, by 2008. This envisages applying IT in every walk of the economic and social life of the country. When compared to the USA, the Indian configuration of 5 PCs per 500 people does not represent any sign of massive rise in PCs' obsolescence rate. Though invisible and slow, however, this annual growth rate of 1.65 million PCs

has begun to work in increasing obsolescence rate of IT product. Besides this, of the nearly 5 million PCs in India, 1.38 million are either 486s or below. Although given that the figure of 1.38 million is quite low in comparison with the US estimate of 20 million obsolete computers, it represents a growing trend, particularly in the context of a rising annual growth of 1.65 million new PCs. It was estimated [19] that over 2 million old PCs ready for disposal India. An estimated 30,000 computers become obsolete every year from the IT industry in Bangalore alone and was attributed to an extremely high obsolence rate of 30% per annum. The global annual generation of WEEE is given in Table 2. It can be seen from the table that India is ranked 4th amongst the selected countries.

Table 2. E-waste generation in selected nations

Country	Rank	Generation TPA	Categories of Appliances counted in e-waste	Year	Reference
Switzerlan	7	66,042	Office & Telecommunications Equipment,	2003	[20]
Germany	2	1,100,000	Consumer Entertainment Electronics, Large	2005	[21]
UK	3	915,000	and Small Domestic Appliances, Refrigerators, Fractions	1998	[22]
USA	1	2,124,400	Video Products, Audio Products, Computers and Telecommunications Equipment	2000	[23]
Taiwan	9	14,036	Computers, Home electrical appliances (TVs, Washing Machines, Air conditioners, Refrigerators)	2003	[24]
Thailand	8	60,000	Refrigerator, Air Conditioners, Televisions, Washing Machines, Computers	2003	[25]
Denmark	5	118,000	Electronic and Electrical Appliances including Refrigerators	1997	[26]
Canada	6	67,000	Computer Equipment (computers, printers etc) & Consumer Electronics (TVs)	2005	[27]
India	4	146,180	Electronic and Electrical Appliances	2003	[28]

The annual WEEE generation in India has been estimated to be 146,180 t based on selected EEE tracers' items [29]. The state wise breakup of generation of WEEE in India is shown in Table 3.

Table 3. WEEE Generation in top ten states in India

Sl. #	STATES	WEEE (MT)
1	Maharashtra	20270.59
2	Tamil Nadu	13486.24
3	Andhra Pradesh	12780.33
4	Uttar Pradesh	10381.11
5	West Bengal	10059.36
6	Delhi	9729.15
7	Karnataka	9118.74
8	Gujarat	8994.33
9	Madhya Pradesh	7800.62
10	Punjab	6958.46

In India the electronics industry has emerged as the fastest growing segment of Indian industry both in terms of production and exports. Within this segment, the IT industry is prime mover with an annual growth rate of 42.4% between 1995 and 2000 [17]. By the end of 2000, India had an installed base of 5 million personal computers (PCs). As per IT industry's estimates, about 1.65 million PC units were sold for the fiscal year 2001-2002. The Indian IT industry has a prominent global presence today largely due to the software sector. Promotion of the software industry and protection of the hardware industry from external competition has resulted in this skewed growth. More recently however, policy changes have led to a tremendous influx of leading multinational companies into India to set up manufacturing facilities, R&D Centres and offshore software development facilities. The domestic market is getting revitalized

due to buoyant economic growth and changing consumption patterns. This growth has significant economic and social impacts. The increase of electronic products' consumption rates and higher obsolescence rate leads to higher generation of electronic waste (e-waste). The increasing obsolescence rates of electronic products added to the huge import of junk electronics from abroad create complex scenario for solid waste management in India.

The estimated e-waste in Delhi from PCs is 6803 tonnes with 7 years obsolescence rate and 4082 tonnes with 5 years obsolescence rate assuming all the obsolete PCs go for dismantling [17]. This estimate is based on installed base of PCs in Delhi region and findings of the field survey, which indicated that 2 trucks per day of e-waste come to Delhi every day from outside for dismantling. However, tracer analysis indicates 7 years obsolescence rate of computer, which confirms that approximately 941 computers are dismantled in Delhi every day. Therefore, the PCs, which are being dismantled in 2003-04, were sold into market around 1996, the beginning of Internet era in India. PCs dismantled may reach 700000 to 800000 per annum by 2010 considering 7 years obsolescence rate.

6. WEEE legislation and activity in Switzerland

Switzerland is the first country in the world to introduce legislation on e-waste management in 1998 in the form of an Ordinance entitled "The Return, the Taking Back and the Disposal of Electrical and Electronic Appliances" (ORDEA) [30]. Two separate WEEE recycling systems operate in Switzerland [31]: the Swiss Association for Information, Communication and Organization Technology (SWICO) Recycling Guarantee created in 1993 and the Swiss Foundation for Waste Management (S.EN.S) system established in 1990. SWICO is an association of manufacturers and importers of office electronics and IT equipment in Switzerland and S.EN.S is a non-profit organization that operates recuperation solutions on behalf of manufacturers, importers and retailers. They have established a regulation that outlines the prerequisites for the recycling companies to be commissioned for either of the systems to process the electronic scrap taken back by the respective system. Both the systems have complete take-back and recycling programmes financed by an Advanced Recycling Fee (ARF) charged on all new appliances. The ARF is charged to the customers for collecting, transporting and recycling of the disposed appliances. The Swiss system is based on EPR—both legally and operationally. Manufacturers and importers are physically and financially responsible for environmentally sound disposal of EOL products. Export of e-waste is prohibitive to non-OECD countries since Switzerland is a signatory to the Basel Convention Ban Amendment. Appliances for disposal are permitted for export as specified under Section 3 of Article 9 of the ORDEA [30] and having prior consent of the importing country. On this account, an exporter must ensure environmentally tolerable disposal of e-waste. Illegal import and export of e-waste to and from Switzerland are prevented by strict surveillance. Also multiple levels of independent controls enable checking of free riding and pilferage as well as ensure recycling quality and environmental standards.

SWICO manages "brown goods" such as office electronics, IT equipment, mobile telephones, equipment used in the graphics industry, telephones and telephone switchboard systems, consumer electronics and dental equipment. While S.EN.S handles "white goods" namely, refrigerators, washing machines, ovens, electrical tools, building, gardening and hobby appliances, electrical and electronic toys, as well as lighting equipment. The Technical Control Body of the Swiss Federal Laboratories for Materials Testing and Research, EMPA, has a bridging function between the two systems since it is a member of both organizations. One of the main responsibilities of EMPA is to collect data annually and collation thereof in respect of material inflow to and outflow of all licensed recycling companies induced by the electronic scrap taken back in the two systems. In 2003 there were 500 official collection points of SWICO and S.EN.S around Switzerland in addition to the thousands of retail locations which have to take back old equipment free of charge, irrespective of the brand or year of manufacture, thereby making it easier for consumers to dispose of their e-waste at appropriate locations [32]. SWICO and S.EN.S together paid almost 8% of the total ARF received in 2003, to the collection points. In all, the collection and logistics expense was representing almost 22.5% of the ARF received. By having common collection points, the Producer Responsibility Organizations (PROs) are better able to manage logistics, benefit from economies of scale and provide a consumer friendly, all-inclusive solution instead of a prohibitively expensive brand specific one. The two systems are well established in Switzerland. In 2004 they enabled the participating recycling companies to process about 75,000 t of WEEE—which corresponds to about 11 kg recycled WEEE per inhabitant. This figure significantly exceeds the goal of 4 kg recycled WEEE per inhabitant defined in the European WEEE directive [2]. Even though the 68,000 t of e-waste

collected in Switzerland in 2003 represented only 2.6% of the waste stream, it corresponds to a little over 9 kg per capita - substantially more than the 4 kg per capita target set by the EU in the WEEE Directive [33].

7. EU WEEE directive and RoHS directive

The European Union was established under that name in 1992 by the Treaty on European Union (the Maastricht Treaty). However, many aspects of the Union existed before that date through a series of predecessor relationships, dating back to 1951. The European Union has enacted two Directives on e-waste regulation, the first on the product recycling after being discarded at the EOL (i.e., Waste Electrical and Electronic Equipment, WEEE) [2, 34] and the second limiting the use of certain substances (Restriction on the use of Hazardous Substances, RoHS) [35].

7.1 WEEE Directive Rationale

In the EU, electro-scrap is the fastest growing waste stream, growing at 3-5% per year, which is three times faster than average waste source. Each EU citizen currently produces around 17-20 kg of e-waste per year. Some 90% of this waste is still land filled, incinerated, or recovered without any pre-treatment. This allows the substances it contains to make their way into soil, water and air where they pose a risk to human health. Based on the premise of producer responsibility and that improved product design can better facilitate recycling and disposal of products at EOL, the principal objectives [36] of the WEEE Directive are to:

- Reduce WEEE disposal to landfill;
- Provide a free producer take-back scheme for EOL equipment from August 13, 2005;
- Improve product design that prevents generation of WEEE and enhances its recoverability, reusability and/or recyclability;
- Establish collection facilities for WEEE; and
- Provide finance by the producers for the recovery and treatment of WEEE, including provisions for placing financial guarantees on new products placed on the market.

The WEEE Directive is very broad in scope, covering virtually all electrical and electronic equipment used by consumers or intended for professional including products sold in the EU from abroad and products sold electronically [36]. There are ten categories of products covered as discussed earlier. The EU does impose the requirements of its Directives directly on its Member States rather than on companies or consumers. Member States are responsible to implement policies to ensure compliance with EU Directives. The EU can impose penalties on Member States that fail to comply. The legal basis of the WEEE Directive is environmental protection, meaning that the EU sets a minimum standard and Member States can choose to implement more restrictive policies. For example, a country may set higher recycling targets than those contained in the Directive and/or require that they be achieved by an earlier date. To encourage designs that facilitate repair, reuse, disassembly, and recycling, the WEEE Directive establishes the principle of EPR for dealing with this waste stream. Producers are financially responsible for taking back their own products at EOL and managing them in accordance with the Directive. Producers may form an individual or a collective system to fulfill their obligations. They may not use design features that prevent products from being reused unless such features provide overriding safety or environmental benefits.

A primary goal of the Directive is "to minimize the disposal of WEEE as unsorted municipal waste and to achieve a high level of separate collection of WEEE." Member States were to ensure by August 13, 2005, that there were systems financed by producers, to separately collect WEEE from end users. WEEE must be separately collected from private households at an average rate of at least 4 kg (8.8 lbs) per person per year by December 31, 2006. The EU will set a new target by December 31, 2008. Producers on an individual or collective basis may organize management systems. The Directive sets separate targets for reuse/recycling and recovery (which includes waste-to-energy recovery), based on amounts collected by weight. Producers must give priority to reuse, and targets must be achieved by December 31, 2006 although extensions have been offered to several Member States. Member States must ensure that records are kept on the amounts of materials entering and leaving treatment, recycling, and recovery facilities. The best available treatment, recycling, and recovery techniques must be used. Member States must also ensure that treatment facilities obtain all relevant permits from the appropriate authorities. Any exports of WEEE for treatment must comply with EU and OECD regulations on the export of waste.

Exported equipment will not count toward recovery and reuse/recycling targets unless the exporter can prove that the waste treatment methods used meet the requirements of the Directive. The Directive also specifies many substances and components that must be removed from all separately collected WEEE.
Producers are responsible for the costs of picking up WEEE from collection facilities and for refurbishing waste products for reuse or for recycling and recovery. For "Historical Products" those put on the market before August 13, 2005, the costs of waste management are to be shared by all producers in existence at the time those costs are incurred. These producers may impose a separate "visible fee" (one that is explicitly designated, perhaps on the price tag) to cover these costs for eight years (ten years for large household appliances). End users other than households may be made partly or totally responsible for financing the management of historical products. For "New Products" those put on the market after August 13, 2005, producers have "individual responsibility." That is, they must pay the cost of managing their own products. They can do this through programs set up by individual companies or through participation in collective schemes. No visible fees are permitted to fund the management of waste from new electrical and electronic products. When producers put a new product on the market, they must provide a financial "guarantee" that waste management of the product will be paid for. Producers can make good on this guarantee by participating in a PRO, paying recycling insurance, or setting up a special bank account for this purpose.
Member States must establish a register of producers and collect annual information on the amounts of EEE that are put on the market, collected, reused, recycled, and recovered. They must transmit this information to the EU Commission every two years. The EU has established a standard format for this reporting. The first set of information will cover the years 2005 and 2006. Member States must establish inspection and monitoring systems and impose effective penalties for lack of compliance. The imposition of penalties for non-compliance ranges from fines (up to €1.2 million in Spain, and €50,000 in Germany) to imprisonment (in eight countries, including the Netherlands and Ireland) as well as revocation of trade licenses (Czech Republic, Poland, Spain), recalling products (Germany, Ireland) or prohibition of sales (Ireland, Finland, Poland) [37]. The recovery and recycling targets to be met by EU Member States (excluding those who have received derogation) are outlined in Table - 4.

Table 4. Recovery and reuse/recycling targets to be met by EU member states [2]
(excluding those who have received derogation)

Product Category [Annex IA]	Recovery Target, wt.	Recycling Target, wt.	Target Date
Large Household Appliances	80%	75%	
Small Household Appliances	70%	50%	
IT and Telecommunications Equipment	75%	65%	
Consumer Equipment	75%	65%	31.12.2006
Lighting Equipment	70%	50%	
Electrical and Electronic Tools	70%	50%	
Toys, Leisure, Sports Equipment	70%	50%	
Medical Devices	NA	NA	31.12.2008
Monitoring and Control Instruments	70%	50%	31.12.2006
Automatic Dispensers	80%	75%	

By end 2006: All EU countries should ensure that 4kg of waste is to be collected per person each year (2008 for some of the newest Member States)

8. Directive on the use of certain hazardous substances (RoHS)

This Directive [35] covers the same scope as the Directive on WEEE (except for medical devices and monitoring and control instruments). It also applies to electric light bulbs and luminaires in households. From 1 July 2006, lead, mercury, cadmium, chromium (VI), polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) in EEE must be replaced by other substances. However, as it is not always possible to completely abandon these substances, the Commission provides for a tolerance level of 0.1% by weight in homogenous materials for lead, mercury, chromium (VI), polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), and a tolerance level of 0.01% by weight in homogenous materials for cadmium. In addition, certain uses specified in the Annex to the Directive are tolerated.

9. Drawbacks of the WEEE directives

The freedom of each member state to interpret conceptual rules set under a policy framework like the WEEE directive might look attractive. Experience with different implementation approaches also creates the opportunity to learn from best practice in different countries. However, the Directive suffers from few drawbacks [12]:

a. Verbose definition of system design rules that necessitates a relative boost of the manpower to ensure legislation and creates substantial cost burdens to the equipment manufacturers.
b. Fail to create a design feedback loop to the manufacturer.
c. Missing is the consideration for eco-efficiency in recycling.
d. Entail inefficient organizational structures that are far from being simple and clear.
e. Missing is the decentralized decision-making.

The hazardous components present in the WEEE and the provision under Annex II of the directive on comparison indicated that the removal of hazardous substances from WEEE-stream might not necessarily lead to the removal of all hazardous substances present in the waste stream. Clearly, this fact demonstrates that, a treated WEEE-stream in conformity to EU WEEE Directive may still be hazardous. This is a serious drawback of the Directive and it requires further refinement.

10. WEEE management in India – an informal sector

Recycling of e-waste is a market-driven and growing industry in India. The waste collectors 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. The EMPA field study in New Delhi [20] indicated that the entire recycling activity was based on a network existing among collectors, traders and recyclers, each adding value, and creating jobs, at every point in the chain. The initial investment required starting a collection, dismantling, sorting or recovery is low which makes the business very attractive for small entrepreneurs. However, this business has significant employment potential under Indian conditions. Collection, dismantling, sorting and segregation and even metal recovery are done manually in India. Therefore, the informal e-waste recycling sector employs many unskilled or semi-skilled workers. EMPA pilot study [20] estimated that the recycling and recovery operations in Delhi alone involve at least 10,000 people in a situation where there are no national figures available as yet. Of course, the national figure would be much higher. In Bangalore there are more than 500 operating recyclers of discarded computers and electronic components [38]. They sell second-hand parts either to computer assemblers in the grey market or to buyers directly. Most of them then burn the waste; mainly plastics and printed circuit boards, in illegal dump yards near residential colonies. Some of the wastes including lead are dumped along with the municipal waste and then burnt in the open air. There are more than 100 illegal dumping sites working in Bangalore. On the other hand, the import situation of the WEEE in India is very alarming at present. The wastes are collected by recyclers abroad and are sold to waste traders from India. Wastes are then landed in ports like Mumbai, Chennai, Cochin, Kandla etc. The traders got these wastes cleared from customs paying fines. Finally, the wastes are distributed throughout the country for recycling in the informal sector like in Delhi, Mumbai and Chennai. Computer wastes imported through Chennai port during the period July 2002 to January 2004 was about 1321.12 MT. Computer wastes imported as mixed computer scrap through Chennai port between January 2003 and Januray 2004 was about 13,328 MT [19]. The recyclers, most of whom work with their bare hands, also extract precious metals such as gold and silver using very primitive chemical processes deploying children and women indiscriminately. The workers profile in the informal sector is given in Table 5.

Table 5. Workers profile

Workers	Numbers	25,000
E-waste processed	TPA	10,000-20,000
Work duration	Hours/day	8 to 10
Daily Wages (Rs)	Women	50
	Men	100
Working place	Assemblers	Shops go down
	Dismantlers	Residence basement
	Recyclers	Closed door units
Safety measures		Minimal

However, e-waste handlers are at a much higher risk of uncontrolled emission of hazardous toxics from the perspective of Occupational Hazard in India. 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 associated with the recycling operations. This could be perhaps due to (i) the low level of awareness among workers regarding the hazards of the chemicals, (ii) adopting primitive process in which they are exposed to, (iv) the minimum protection and safety measures they are obliged to take, and (v) the lack of formal guidelines as well as a lax enforcement of existing environmental laws.

11. Indian initiatives

The growing hazards of e-waste in India as discussed above were noticed by the government, industry, users and NGOs and felt it necessary that the treatment of WEEE for recovery shall follow environmentally sound technologies. In view of the above scenario, "Indian initiatives" have beginning to develop. A collaborative programme entitled "Indo-Swiss-German e-Waste Initiative" has been formed [39]. The marshaled objective and scope of the initiative include (i) Management of e-waste in an environmentally sound manner so as to reduce the risks to the society as also to abate the pollution of the environment owing to unsafe e-waste handling; (ii) Development of skills to all concerned through knowledge transfer by means of seminars, workshops, campaign etc. and (iii) Initially the existing informal recyclers to be selected as the target group for evolving methodologies to create an integrated formal category. This programme has been conceived with various supports as: **(a) National Support** for WEEE Strategy & Coordination Work Group; **(b) Local & Regional support,** for instance, from Delhi, Bangalore and Mumbai; **(c) Industry Initiatives** from MAIT, e-Parisaraa Pvt. Ltd. Trichyraya and others; **(d) International Support** primarily from Germany and Switzerland as also from UNEP (for Environment & e-Waste in India) and from EU (for the Creation of Optimum Knowledge Bank for Efficient E-Waste Management in India).

A National WEEE Task Force headed by Chairman CPCB was thus formed in July 2004, comprising representatives from other governmental agencies, NGOs, Industry Associations, experts in the field and producers from both formal and informal sectors. The mandate of national task force is to identify, plan and implement all issues related to e-waste in India to fulfill the ambition of the initiatives [40].

12. Indian WEEE policy framework

The Government of India has reiterated its commitment to Waste Minimization and Control of Hazardous Wastes, both nationally and internationally. The Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Disposal was signed by India on 15th March 1990 ratified and acceded to in 1992. A ratification of this convention obliges India to address the problem of transboundary movement and disposal of "hazardous wastes" through international cooperation. India cannot export "hazardous wastes" per the Basel Convention, listed in Annex VIII of the Convention from the countries that have ratified the ban agreement. The Hazardous Wastes (Management and Handling) Amendment Rules, 2008 [13] control the import of hazardous waste from any part of the world into India. However, import of such wastes may be allowed for processing or reuse as raw material. There are no specific Rules pertaining to the management of e-waste as of now excepting speciation of some waste electrical and electronic items in the aforementioned Rules of India. However, draft guidelines pertaining to the environmentally sound management of e-waste were proposed in India [41]. Some of the suggestions that are elicited in the aforesaid draft guidelines are described herein:

- Current Indian guidelines as well as practices for hazardous waste management in India may be adequate for establishing and operating "Integrated E-Waste Management Facility" (IEWMF). This will reduce interventions in the existing regulatory institutional mechanism related to pollution prevention, abatement and control.
- In order to ensure availability of e-waste to IEWMF, collection and transportation in tandem shall be developed. An organization comprising industries or industry association both at national and at local level may be empowered for collection and transportation of e-waste similar to that operates outside India. However, the operator of the e-waste treatment facility will integrate these steps till such an organization is being set up.
- Secured Land Filling (SCF) and Incineration solely for e-waste residues shall be permitted within the national regulatory framework as is being practiced for the hazardous wastes.
- Burning of plastic containing flame-retardants can be permitted in common hazardous waste incineration facilities. But monitoring and control of plastic burning at these facilities is a big

environmental health and safety issue. Therefore, such plastic is recommended to be land filled in nearby TSDF.

- CFCs shall be handled as per the Montreal Protocol.
- Capacitors containing PCB's can be incinerated in common hazardous waste incineration facilities.
- CRT breaking and glass recycling are being practiced in organized sector in India. These facilities fall under the purview of existing environmental regulations in force. Lead generated from this stage of operation can be either recycled or disposed off in nearby TSDF.
- Existing Lead recycling facilities from batteries and mercury recovery facilities (distillation process) fall under the provisions of environmental regulations in force. These can be temporarily stored at e-waste dismantling facility and later disposed in TSDF in case of very low recovery.
- The complete recycling of e-waste including the Metal Recovery should be encouraged for setting-up of IEWMF.
- Used Oil needs to be disposed out in conformity to the HWR.
- It is recommended that the equipment used in dismantling facility to be covered under category of pollution control equipment so that the treatment facility can charge 100% depreciation in the first year. This will improve financial viability of the e-waste facility.
- Government at State level may encourage in the allocation of land through various incentive schemes.
- Applicability of EPR can be reviewed under Indian Context.

13. Conclusion

Electronic waste, or e-waste, or WEEE has been emerging as a risk to the society as also a business opportunity of increasing significance, considering the volumes of e-waste being generated and the content of both toxic and valuable materials in them. The valuables in e-waste are over 60%, while pollutants comprise a meager 2.70%. WEEE constitutes 8% (ca.) of municipal waste. The Basel Convention has identified e-waste as hazardous considering the high toxicity of pollutants especially when burned or recycled in uncontrolled environments, and developed a framework for controls on transboundary movement of such waste. The Basel Ban, an amendment to the Basel Convention that has not yet come into force, would go one step further by prohibiting the export of e-waste from developed to industrializing nations. Several countries across the globe have implemented or are about to implement specific electronics recycling regulations based on the principle of Extended Producer Responsibility (EPR). The international legislative practices (legislation of Switzerland, the EU WEEE Directive, RoHS and the weaknesses of EU, WEEE Directive) followed by Indian initiatives intended to help manage these growing quantities of e-waste are discussed. A National WEEE Task Force headed by Chairman CPCB was formed in India in July 2004 comprising representatives from other governmental agencies, NGOs, Industry Associations, experts in the field and producers from both formal and informal sectors for exploring WEEE Management practices in India. Though no specific Rules pertaining to the management of e-waste in India are prescribed, draft guidelines however, pertaining to the environmentally sound management of e-waste was proposed.

References

[1] Puckett, J. Smith.T., Exporting harm: the high-tech trashing of Asia. The Basel Action Network. Seattle. 2002. Silicon Valley Toxics Coalition. San Jose.

[2] EU, Pages 24-39 in Directive 2002/96/EC of the European parliament and of the council of 27 January 2003 on waste electrical and electronic equipment (WEEE). Official Journal OJ L 37 of 13.02.2003; Accessed in Jun 2006: http://europa.eu.int/eur-lex/en/.

[3] Detzel, A., Giegrich, J., Krüger, M., Möhler, S. Ostermayer, A., Ökobilanz für PET-Einwegsysteme unter Berücksichtigung der Sekundärprodukte [Life cycle assessment study of PET one-way bottles respecting secondary products]. IFEU GmbH, on behalf of PETCORE. 2004. Brussels, Heidelberg: IFEU GmbH.

[4] Grether, T., Gilgen, P.W. Dinkel, F., Nachhaltigkeit von aluminium-verpackungen [Sustainability of aluminium packagings]. Arbeitsgemeinschaft S.E.E.ch- on behalf of IGORA-Genossenschaft. 2003. Zurich, St. Gallen.

[5] Prognos, Nachhaltigkeitsbewertung und Perspektiven des Dualen Systems in Deutschland [Sustainability assessment and perspectives of "Duales System" in Germany]. Prognos AG- on behalf of Duales System Deutschland AG. Cologne. 2002. Germany: Prognos Ltd.

[6] Cui, J., Mechanical Recycling of Consumer Electronic Scrap. Ph.D. Dissertation. Department of Chemical Engineering and Geosciences, Division of Mineral Processing. 2005. Luleå University of Technology. SE-971 87, Luleå, Sweden.
[7] The Economist, 29.01.2005. p. 56. 2005. London.
[8] Hieronymi, K., Implementing the WEEE directive, Proc. Int. Symposium on Electronics and the Environment, May 7-9, 2001. Denver, US.
[9] Ueno, K., Current Status of Home Appliances Recycling in Japan, ECP - Newsletter no. 18, 2003. JEMAI, Japan.
[10] Ronningen, B., Competitors together in PRO (Producers Responsibility Organization) – A case study of the PRO-system in Norway, Proc. Int. Symposium on Electronics and the Environment, May 16-19, 2005. New Orleans, US.
[11] OECD, Organization for Economic Cooperation and Development (OECD), Extended Producer Responsibility: A Guidance Manual for Governments. 2001. Paris.
[12] Bohr, P. Policy tools for electronics recycling characteristics of a specific certificate market design. ISEE. 1-6. 2006. Accessed on Aug 2006: http://web.mit.edu/ebm/Bohr_ISEE_2006.pdf.
[13] MoEF, Hazardous Wastes (Management and Handling) Amendments Rules, 2008. Ministry of Environment and Forests, Government of India. 2008. Available from: http://envfor.nic.in.
[14] UNEP United Nations Environment Programme. E-waste Management. Accessed on December 2007: http://www.unep.fr/pc/pc/waste/e_waste_fag.htm.
[15] Hagelüken,C., Art, S. Recycling of e-scrap in a global environment – chances and challenges: Umicore Precious Metals Refining. Indo-European Training Workshop. Bangalore & New Dehli. May 4/5 & 8/9, 2006.
[16] ETC/RWM. European Topic Centre on Resource and Waste Management (Topic Centre of the European Environment Agency) part of the European Environment Information and Observation Network (EIONET); Accessed on Jan 2007: http://waste.eionet.eu.int/waste/6.
[17] EMPA. The e-waste guide; Accessed on Aug 2006: http://www.ewaste.ch/.
[18] APC. An Industry Full of Potential Ten Facts to Know about Plastics from Consumer Electronics - 2003 Update: American Plastics Council.
[19] Sinha, S., E-Waste-An Indian Perspective. Workshop on efficient e-waste management. 8–9 May 2006. Venue Hotel Intercontinental Eros. Nehru Place, New Delhi. India.
[20] EMPA, E-waste pilot study Delhi: knowledge partnerships with developing and transition countries. St. Gallen. Accessed on Jun 2006: http://www.ewaste.ch/.
[21] ZVEI. Deutscher Zentralverband Elektrotechnik-und Elektroindustrie, i.e. German Electrical and Electronic Manufacturers' Association. 2005.
[22] ICER. UK Status Report on Waste from Electrical and Electronic Equipment Industry Council for Electronic Equipment Recycling (ICER). 2000.
[23] USEPA. Municipal Solid Waste in the United States: 2000. Facts and Figures. Office of Solid Waste and Emergency Response. Pages 150-160 in EPA530-R-02-001. 2002.
[24] RRFMC. Resource Recycling Fund Management Committee (RRFMC), Environment Protection Administration, Taiwan, ROC. 2003. Accessed on Jan 2007: http://cemnt.epa.gov.tw/eng/.
[25] Multimedia. Government moves to stem tide of 'e-waste'; 2003. Accessed on Jan 2007: http://www.nationmultimedia.com/page.
[26] Waste 21. Waste management plan 1998-2004, Denmark. 2004. Accessed on Jan 2007: http://www.mst.dk/udgiv/publications/ 2003/87-7972-740-9/html/.
[27] Fact Sheet. Proposed End-of-Life Information Technology Equipment and Consumer Electronics (e-waste) Recycling Program, Saskatchewan Environment, Environmental Protection Branch. 2005. Canada.
[28] Ramlogan, R., Persadie, N. E-waste: Why legislate? in SWMCOL's E-Waste Symposium held at the Crowne Plaza Hotel, Port of Spain, Trinidad, WI. 17- 18 August 2005. Accessed on Dec 2006: http://www.swmcol.co.tt/documents/ eWASTE2005.htm.
[29] Jain, A. E-Waste Management in India (Current Status & Needs): Creation of Optimum Knowledge Bank for Efficient e-Waste Management in India, Workshop on efficient e-waste management. 8–9 May 2006. Venue Hotel Intercontinental Eros. Nehru Place, New Delhi. India.
[30] SAEFL, Ordinance on the return, take-back and disposal of electrical and electronic equipment. Adopted on 14 January 1998, Entry into force 1 July 1998, http://www.umwelt-schweiz.ch/imperia /md/content /abfall/.

[31] Eugster, M., Knowledge partnerships with developing transition countries in e-waste recycling: presented at the International Conference on Electronic Waste and Producers' Environmental Responsibilities in China/Bejing, 21st – 22nd April, 2004. Accessed in Jul 2006: http://www.e-waste.ch .
[32] Sinha, D., Kraeuchi, P. Schwaninger, M., A comparison of electronic waste recycling in Switzerland and in India. Environ. Impact Assess. Review 2005, 25, 492-504.
[33] EU, Waste electrical and electronic equipment; Accessed in Jun 2006: http://europa.eu.int/comm/environment/waste /weee_index.htm.
[34] EU, Pages 106-107 in Directive 2003/108/EC of the European Parliament and of the Council of 8 December 2003 amending Directive 2002/96/EC on waste electrical and electronic equipment (WEEE). Official Journal OJ L 345 of 31.12.2003; Accessed in Jun 2006: http://europa.eu.int/eur-lex/en/.
[35] EU, Pages 19-23 in Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS). Official Journal OJ L 37 of 13.02.2003; Accessed in Jun 2006: http://europa.eu.int/eur-lex/en/.
[36] Savage, M., Implementation of Waste Electric and Electronic Equipment Directive in EU 25. Institute of Prospective Technological Studies (IPTS), 2006. European Commission, Joint Research Centre, Spain.
[37] EurActiv, EU plans revision of intricate e-waste laws; 20.07.2006. Accessed on Aug 2006: http ://www.euractiv.com/en /environment/eu-plans-revision-intricate-waste-laws/article-156784.
[38] Shankar, J., Bangalore chokes under tons of e-waste. Accessed on Aug 2006: http://sify.com/news/fullstory.php? id=13601252.
[39] Widmer, R., Indo-Swiss-German e-Waste Initiative: Development of the Initiative Objectives and Activities Clean e-Waste Channel Organisational Set-up. 2006.
[40] WEEE Initiatives, WEEE Initiatives in India. Accessed in Aug 2006: http://www.e-waste.in/weee_initiatives.
[41] CPCB, Draft Guidelines for Environmentally Sound Management of e-waste. Central Pollution Control Board (CPCB). Ministry of Environment and Forests (MoEF), Government of India. New Delhi. India. Accessed in November 2007: http://www.cpcb.nic.in/Electronic%20Waste/E-Waste-draft-3.html.

Amitava Bandyopadhyay:
- ✓ B.Tech. Chemical Technology. University of Calcutta, India. 1988, First Class First.
- ✓ M.Tech. Chemical Engineering. Indian Institute of Technology, Kharagpur, India. 1990.
- ✓ Ph.D. Chemical Engineering. Indian Institute of Technology, Kharagpur, India. 1996.

Major fields of study: Air Quality Modeling, Air Pollution Control, CO_2 Capture, Wet Scrubber Modeling, Advances Waste Water Treatment, Gas-Liquid Mass Transfer Operations, Waste Management especially Electronics Waste and Hazardous Wastes. Risk and Consequence Analyses.

He has published 29 articles in peered reviewed International Journals. At national level he has so far published 30 articles. Before joining as a Faculty Member in the Department of Chemical Engineering at the University of Calcutta he has served Indian Regulatory Agency for a period of more than 10 years in a very senior position dealing with implementation of various Environmental Rules and Regulations. Legion of technical reports prepared by him on the premise of Indian regulatory regimes on the abatement of industrial of pollution have been used with great success in the country, for instance, the National Environmental Standards on its revision on Indian Petroleum Oil Refinery includes the effluent discharge parameters after careful consideration of his action taken report on an Indian Petroleum Oil Refinery. He was a state representative for the Development of Emission Standards for Indian Petrochemical Industries under the World Bank funded Project. He has visited Japan and the USA and visited a large number of industries.

Dr. Bandyopadhyay has received several laurels for his excellent research works. He has organized several Symposia, Workshops etc as also chaired a number of technical sessions of national/international events on Environmental Sciences & Engineering. He is carrying out many projects related to environmental pollution control. Dr. Bandyopadhyay is involved as a key person in the CO_2 Capture Projects from Coal Fired Thermal Power Plants in the State of West Bengal. He is a Member of the Editorial Board of Journal of Water Resource & Protection of Scientific Research Publication, Member of the Editorial Advisory Board of International Journal of Energy and Environment, and a Member of the Editorial Advisory Board of International Journal of Environmental Science & Technology of Iranian Society of Environmentalists. Dr. Bandyopadhyay is a Life Member of several professional bodies like, The Institution of Engineers (India); Indian Institution of Chemical Engineers; Institution of Public Health Engineers, India; Oil Technologists Association of India: Coal Ash Institute of India; Air Pollution Control Association of India; Indian Water Works Association; Indian Association for Environmental Management; Indian Science Congress Association.

E-mail address: amitava.bandy@gmail.com, Tel: +91-33-2350 8386, Extn. 515.

