CEC Working Paper

Desktop Research on E-waste Recycling and Health Effects

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Introduction

After the industrial and agricultural revolution, the world is currently witnessing the information technology (IT) revolution. Many of the improvements in productivity and efficiency can be attributed to the IT revolution. Electronic products have become part and parcel of everyday life. It has improved people's lives in many ways. Nonetheless, the problem with technology is that by its very nature it has to be new, or at least appear so. As a result, our televisions, mobile phones and computers seem ever too frequently out of date. Because of economic growth and technological advancement, it's often cheaper and convenient to buy a new electronic product than to upgrade an old one. So, we end up replacing them, and the old machines get chucked away. The stuff that gets chucked away is known as e-waste. ***Electronic waste, e-waste, or waste electrical and electronic equipment (WEEE) can be defined as waste material consisting of broken or unwanted electrical or electronic appliances.*** IT and telecom equipment, household appliances, consumer and lighting equipment, electrical and electronic tools, medical devices, and monitoring and control instruments are some sources of e-waste. The list of e-waste is very large and getting wider with the regular introduction of new electronic equipments.

At present, e-waste only represents 5 per cent of the world's municipal waste stream (accounting for 50 million tonnes of e-waste a year), but it is the fastest growing source of municipal waste on earth. In Europe, e-waste levels are growing at the rate of 3-5 per cent a year. In the developing world, e-waste levels are expected to triple in the next five years as consumers there spend their newly earned money on electronic gadgets. (By 2010, Greenpeace says there will be 178 million new computer users in China and 80 million new users in India alone.)

Evolution of Indian Electronics Industry

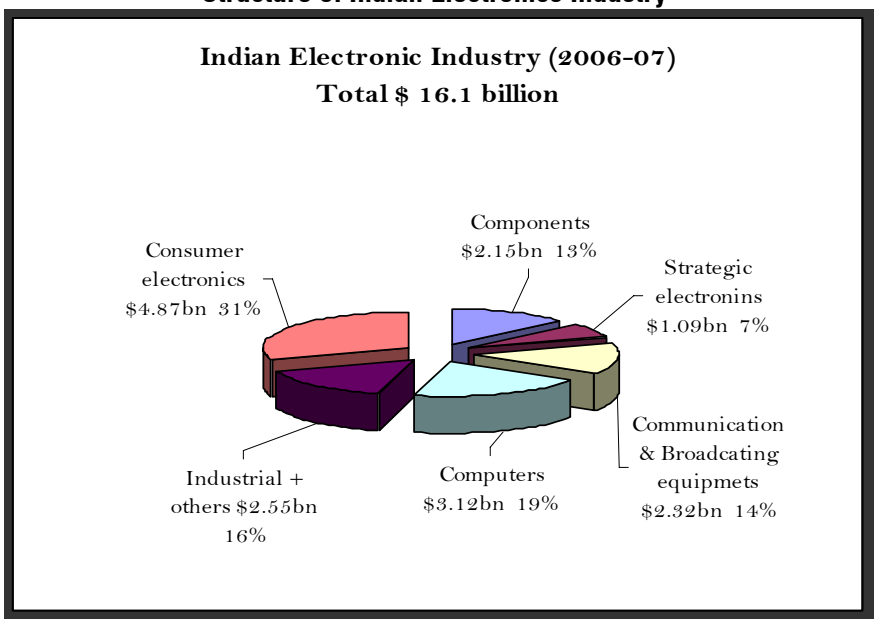
The electronics industry in India took off around the year 1965 with an orientation towards space and defence technologies. This was followed by developments in consumer electronics, mainly in transistor radios, black-and-white TVs, calculators and other audio products. In 1982, the government allowed thousands of colour TV sets to be imported into the country to coincide with the broadcast of Asian Games in New Delhi. The year 1985 saw the advent of computers and telephone exchanges, which were succeeded by digital exchanges in 1988. The period between 1984 and 1990 was the golden period for

electronics, during which the industry witnessed continuous and rapid growth. After the software boom in the mid-1990s, India's focus shifted to hardware. In 1997, the ITA agreement was signed at the WTO where India committed itself to total elimination of all customs duties on IT hardware by 2005, thereby helping companies like Moser Baer, Samtel Colour, and Celetronix to mark their presence globally.

Indian Electronics Industry: An Overview

The electronics industry in India constitutes just 0.7 per cent of the global electronics industry. It comprises consumer electronics, industrial electronics, computer hardware and software, communication and broadcasting equipment, and strategic electronics and electronic components. In recent years, the electronics industry has been growing at a vigorous pace. It is currently worth US$25 billion and is growing at a rate of about 30 per cent per annum. At this rate, it is projected to exceed US$70 billion by 2010 and US$158 billion by 2015[1]. The consumer electronics market is one of the largest segments in the electronics industry in India, with market size of Rs 18,390 crore ($4.5 billion) in 2007[2].

Structure of Indian Electronics Industry[3]



[1]http://elcina.com/industry_IndianMarket.asp
[2]India's Consumer Electronics Industry Scales New Heights, 03 Jul 2007
http://www.eetindia.co.in/ARTP_8800470743_1800007.htm
[3]http://www.elcina.com/industry_size.asp

Hazardous Constituents of E-waste

Electronic equipment is a complicated assembly of more than a thousand materials, many of which are highly toxic, such as chlorinated and brominated substances, toxic gases, toxic metals, photo-active and biologically active materials, acids, plastics and plastic additives. Certain materials are hazardous depending on their condition and density. For example, Basel Action Network (BAN) estimated that 500 million PCs contain 2.87 billion kilograms of plastics, 716.7 million kilograms of lead, and 286,700 kilograms of mercury.

E-waste either ends up in landfills or is burnt by scrap handlers. If waste is left untreated to lie around in landfills or dumps, they leach into the surrounding soil and water, as well as the atmosphere, thereby generating obvious adverse effects for human health and ecology. And, if burnt, it releases toxic chemical fumes like dioxins into the atmosphere.

Materials and Composition of E-waste in Different Products

Material Composition of a Refrigerator

Product substance	Weight (kg)	% of product weight
Steel	28.50	49.78
Copper	2.32	4.05
Aluminium	0.54	0.94
Polyurethane foam	6.36	11.11
Rubber	0.77	1.34
Other plastics	17.48	30.53
Paper	0.10	0.17
Glass	0.04	0.07
CFCs and oil	0.30	0.52
PCBs	0.16	0.28
Condenser	0.03	0.05
Loss during disassembly	0.65	1.14
Total	57.25	100.0

Source: Asia-Pacific Regional Scoping Workshop on Environmentally Sound Management of Electronic Wastes

Material Composition of a Television

Product substance	Weight (kg)	% of product weight
Steel	3.93	10.70
Copper	1.06	2.88
Aluminium	0.16	0.44
Phosphor bronze	0.09	0.24
Stainless steel	0.01	0.03
Ferrite	0.39	1.06
Other plastics	8.15	22.19
Paper	0.10	0.27
Lead glass	18.18	49.48
PCBs	1.95	5.31
Electron gun	0.06	0.16
Transformers	0.93	2.53
Loss during disassembly	1.73	4.71
Total	36.74	100.0

Source: Asia-Pacific Regional Scoping Workshop on Environmentally Sound Management of Electronic Wastes

Material Composition of a Computer
(Based on a typical desktop computer, weighing ~27 kg)

Name	Weight of material in computer (kg)	Content (% of total weight)
Plastics	6.3	22.9907
Lead	1.7	602988
Aluminium	3.9	14.1723
Germanium	<0.05	0.0016
Gallium	<0.05	0.0013
Iron	5.6	20.4712
Tin	0.3	1.0078
Copper	1.9	6.9287
Barium	<0.05	0.0315
Nickel	0.23	0.8503
Zinc	0.6	2.2046
Tantalum	<0.05	0.0157
Indium	<0.05	0.0016
Vanadium	<0.05	0.0002
Beryllium	<0.05	0.0157
Gold	<0.05	0.0016
Europium	<0.05	0.0002
Titanium	<0.05	0.0157
Ruthenium	<0.05	0.0016
Cobalt	<0.05	0.0157
Palladium	<0.05	0.0003
Manganese	<0.05	0.0315
Silver	<0.05	0.0189
Antinomy	<0.05	0.0094
Bismuth	<0.05	0.0063
Chromium	<0.05	0.0063
Cadmium	<0.05	0.0094
Selenium	0.0004	0.0016
Niobium	<0.05	0.0002
Yttrium	<0.05	0.0002
Mercury	<0.05	0.0022
Arsenic	<0.05	0.0013
Silica	6.8	24.8803

Source: Table presented in: Microelectronics and Computer Technology Corporation (MCC), 1996, Electronics Industry Environmental Roadmap. Austin, TX: MCC

Material Composition of a Mobile Phone (weight percent)
(Ref: BT Cellnet and Mobile Takeback sites, Sept. 2001)

Name	**Content (% of total weight)**
ABS-PC	29%
Ceramics	16%
Cu and compounds	15%
Silicon plastics	10%
Epoxy	9%
Other plastics	8%
Iron	3%
PPS	2%
Flame retardant	1%
Nickel and compounds	1%
Zinc and compounds	1%
Silver and compounds	1%
Al, Sn, Pb, Au, Pd, Mn, etc.	Less than 1%

Source: Envocare Ltd (2001): http://www.envocare.co.uk/mobile_phones.htm

Status of E-waste in India

A study conducted by MAIT[♣] and GTZ (German Technical Cooperation) in 2007 reveals that India generated 3.3 lakh tonnes of e-waste in 2007 (which is expected to rise to 4.7 lakh tonnes by 2011), and is saddled with an additional 50,000 tonnes of it through imports. While individual and households generate 18-20 per cent and the manufacturing industries around 10 per cent of the country's e-waste, the corporate and the public sector account for 70 per cent[4]. Ramapati Kumar, a campaigner for Greenpeace, estimates that government offices, alone, can store up to 5,000 to 10,000 tonnes of e-scrap, putting in perspective what offices using IT hardware can generate, with computers and other gadgets going rapidly obsolete. As revealed by Planning Commission in the 11th Five Year Plan, Mumbai ranked topmost with 11,017 tonnes in 2006, followed by Delhi with 9,730 tonnes, and Bengaluru, Chennai, Kolkata and Ahmedabad with 4,648, 4,132, 4,025 and 3,287 tonnes, respectively[5].

The status of e-waste is mainly driven by the use of electronic equipments. This section analyses the status of three major drivers of e-waste: use of computers, mobile phones and television sets.

Computers

According to MAIT's Industry Performance Review for fiscal 2007-08, the total PC sales (including desktop computers and notebooks) between April 2007 and March 2008 were 7.34 million (73.4 lakh) units, registering a growth of 16 per cent over the previous year. PC sales are projected to touch 8.5 million (85 lakh) units in fiscal 2008-09. Commenting on the findings of the study, MAIT Executive Director Mr Vinnie Mehta said: "Although the sales to the large enterprises were less than expected, the overall consumption in the PC market was led by telecom, banking and financial service sectors, education and BPO/IT-enabled services, and the e-governance initiatives of the union and the state governments."

[♣]Manufacturers' Association of Information Technology (MAIT) is the apex body representing India's IT hardware, training and R&D service sectors.

[4]What goes around must come back, too. *Business Standard*, June 05, 2008

[5]E-waste management options. *Education Times, The Times of India*, July 21, 2008

Total Computer Sales in India						
Product	**Total sales**			**Total revenue (in Rs crore)**		
	2006-07	2007-08	% Growth	2006-07	2007-08	% Growth
Desktop Computer	5,490,591	5,522,167	1	10,431	10,216	-2
Notebook	850,860	1,822,139	114	3,830	7,289	90
Server	90,189	122,178	35	1,533	2,016	32
Source: http://www.mait.com/admin/press_images/press08-07-08.htm						

Mobile Phones

India's phenomenal growth in the mobile subscriber base and penetration rate (or teledensity, as measured by number of phones per 100 inhabitants) has attracted global attention. India's mobile subscribers constitute about 6 per cent of global users, 11 per cent of developing countries, and 16 per cent of developing Asia's mobile subscribers[6].

Companies and their share in subscriber base have been illustrated in the table below:

Companies and their Market Share in Terms of Subscriber Base		
Company	Subscribers (in millions)	Market share (%)
Bharti Airtel	66.8	24.4
Reliance Communication	48.8	17.8
Vodafone Essar	47.5	17.3
BSNL	36.9	13.5
Idea (including Spice)	30.0	11.0
Total mobile connections	273.0	
Source: Has Idea's Time Come? Business Standard*, July 8, 2008*		

All inhabited areas (and, hence, the entire population) of India should be covered by mobile networks by the end of 2009, from 45-50 per cent coverage today. The number of total mobile subscribers is expected to increase from just over 100 million today to over 348 million by year-end of 2010, and India will become the number-two mobile subscriber market in the world by 2010, after China, which has already crossed 400 million subscribers[7].

The total revenue from cellular service in India is expected to exceed the $37 billion mark by 2012, with an annual growth rate of 18 per cent, according to the latest Gartner study. The total number of connection is expected to exceed 737 million, with an annual growth rate of 21 per cent. Gartner analyses that the cellular penetration will also exceed 60.7 per cent, as compared to only 19.8 per cent in 2007. The growth of the cellular service sector in India,

[6]UNCTAD's Information Economy Report 2007-08

[7]India Mobile Market: The Next Land Run for Mobile Vendors?
http://www.researchandmarkets.com/reports/349576/india_mobile_market_the_next_land_run_for.htm

according to Gartner's observation, is a result of the development of the rural market, the relatively low rates of handsets, and low tariff rates[8].

The massive growth of the Indian telecom industry has also led to an unprecedented acceleration in India's mobile handset sales. The handset market touched revenues of Rs 21,434 crore in the year 2006-07. Mobile handset sales, including new users and replacements, in India surged 26 per cent to touch 93 million units in 2007[9].

Mobile Stakes (Global Market Share and Sales in 2007)		
Company	Market share (%)	Handsets sold (in millions)
Nokia	38.8	437.1
Samsung	14.3	161.2
Motorola	14.1	159.0
Sony Ericsson	9.2	103.4
LG	7.2	80.5
Source: Motorola unit on Videocon radar. Business Standard*, April 2, 2008*		

Television Sets

The Indian television market is set to grow to 18.7 million units by 2011 – expanding at a compound annual growth rate (CAGR) of 9 per cent – from 12.1 million units in 2006. On the revenue side, overall television sales will reach $4 billion by 2011, rising at a CAGR of 9.6 per cent, up from $2.5 billion in 2006.

Unit Shipment and Revenue Forecast of the Indian Television Market, 2006-11		
Year	**Unit ('000)**	**Revenue ($)**
2006	12,141	2,513
2007	15,917	2,973
2008	17,290	3,324
2009	16,132	3,043
2010	17,805	3,540
2011	18,717	3,976
Source: iSuppli Corp. May 2007		

[8]Indian cellular market projected to exceed $37 bn, July 4, 2008 http://siliconindia.com/shownews/43377

[9]This bin ain't laden. *Business Line*, Feb. 4, 2008

Possible Health Hazards

Electronic devices are a complex mixture of materials and components, often several hundreds of different substances, many of which are toxic and create several environmental and occupational health problems upon disposal. These include heavy metals such as lead, mercury, chromium, cadmium and flame retardants like polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs). The health effects of these chemicals and their compounds are extremely evident. These have been linked to the growing incidence of several lethal or severely debilitating health conditions including cancer, neurological and respiratory disorders, and birth defects. Due to the health hazards involved, disposing and recycling e-waste has serious legal and environmental implications. When it is disposed in landfills or burnt (incinerated), it poses significant contamination/pollution problems. Landfills leach toxins into groundwater and burning emit toxic air pollutant including dioxins. Likewise, the recycling of computers has serious occupational and environmental implications, particularly when the recycling industry either cannot afford or may not intend to take the necessary precautions to protect the environment and worker's health. The impact of these chemicals may also affect the health of people living in close proximity to dumps or landfills of untreated waste.

Constituents of E-waste, Sources and Health Hazards

Content	Source	Health hazard
Lead	▪ Solder in printed circuit boards ▪ Glass panels and gaskets (frit) in computer monitors	▪ Damage to central and peripheral nervous system, blood systems, kidney and reproductive system
Cadmium	▪ SMD chip resistors, infra-red detectors and semiconductor chips	▪ Accumulates in kidney and liver ▪ Neural damage ▪ Teratogenic (causes congenital malformations)
Mercury	▪ Thermostats, sensors, relays and switches (e.g., on printed circuit boards and in measuring equipment), medical equipment, lamps, mobile phones, and batteries ▪ Flat panel displays ▪ Accumulation of methylated mercury in fishes	▪ Chronic damage to the brain and kidneys ▪ Developing foetus is highly susceptible through maternal exposure
Hexavalent chromium	▪ Chromium VI used as corrosion protection of untreated and galvanised steel plates ▪ Decorator or hardener for steel housing	▪ Asthmatic bronchitis ▪ DNA damage
Plastic including PVC	▪ Cabling and computer housing	Burning produces dioxins that causes: ▪ Reproductive and developmental problems; ▪ Immune system damage ▪ Interference with regulatory hormones
Brominated flame retardants (BFRs)	▪ Plastic housing of electronic equipments and in circuit boards	▪ Neurological and developmental reproductive problems ▪ Hypothyroidism ▪ Neurobehavioural changes

Barium	▪ Front panel of CRTs	Short-term exposure causes ▪ Muscle weakness ▪ Brain swelling ▪ Damage to heart, liver and spleen
Beryllium	▪ Computer motherboards	Exposure through inhalation of beryllium dust, fumes, or mist causes ▪ Chronic Beryllium disease; beryllicosis, a disease of lungs ▪ Poor wound healing and wart-like bumps on skin
Toners	▪ Computer printer cartridge containing black and colour toners	▪ Carbon black in black toners can cause respiratory problems ▪ International Agency for Research on Cancer (IARC) has classified carbon black as a class 2B carcinogen
Phosphor and additives	▪ Applies as a coat on the interior of the CRT faceplate	▪ Not well reported ▪ Contains heavy metals, e.g., zinc and vanadium, as additives ▪ If it touches the skin, seek medical attention immediately
Sources: ➢ *Exporting Harm: The high-tech trashing of Asia. Feb 25, 2002* ➢ *Brominated flame retardants in dust on computers: The case for safer chemicals and better computer design. Cleaner Production Action, June 2004* ➢ *Dark underbelly of digital age.* Hindustan Times*, June 9, 2008*		

Regulation of E-waste

Existing Legal Statutes Governing E-waste in India	
Rules and regulations	**Main content**
Hazardous Waste Management and Handling Rules (2000)	Lay down stringent curbs on imports and exports of hazardous wastes
Batteries (Management and Handling) Rules, 2001	Apply to every manufacturer, importer, re-conditioner, assembler, dealer, recycler, auctioneer, consumer and bulk consumer involved in manufacture, processing, sale, purchase and use of batteries or components thereof. These rules confer responsibilities on the manufacturer, importer, assembler and re-conditioner; they govern the registration of importers, the customs clearance of imports of new lead acid batteries, procedures for registration/renewal of registration of recyclers, and also the responsibilities of consumer or bulk consumer and responsibilities of auctioneers
Hazardous Waste (Management and Handling) Amended Rules, 2003	These define hazardous waste as "any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger, or is likely to cause danger, to health or environment, whether alone or when on contact with other wastes or substances." In Schedule 1, waste generated from the electronics industry is considered as hazardous waste. Schedule 3 lists waste of various kinds including electrical and electronic assemblies or scrap containing compounds such as accumulators and other batteries, mercury switches, glass from cathode ray tubes and other activated glass and PCB capacitors, or contaminated with constituents such as cadmium, mercury, lead, polychlorinated biphenyl, or from which these have been removed

DGFT (Exim Policy) 2002-07	The directorate general of foreign trade under the ministry of commerce governs the EXIM policy, and as per Para 2.17 of EXIM policy, 2002-07, it says: "All second-hand goods shall be restricted for imports and may be improved only in accordance with the provisions of this policy, ITC (HS), Handbook (Vol. 1), Public Notice or a licence/certificate/permission issued in this behalf"
Guidelines on e-waste[10]	The Central Pollution Control Board (CPCB) has formulated guidelines on management of e-waste which allow the producers of electronic and electrical equipment to levy an 'appropriate fee' on the product at the point of sale, to facilitate the operation of a 'take-back system' for collection and recycling of such equipment at the end of a product lifecycle. The guidelines have also called for manufacturers' direct involvement in establishing a 'take-back system' with an individual or collective responsibility. As of now, the new guidelines are 'voluntary' and are a reference document for management, handling and disposal of e-waste
Source: E-wastes in Asia and the Pacific. UNEP	

[10] Let Producers charge e-waste levy on buyers. Business Line. Apr10, 2008.

Recent Developments

The Planning Commission has allocated Rs 130 crore towards developing operational, legal, technological, monitoring and political frameworks for handling e-waste management. An agency called Electronic Waste Agency (EWA) has been constituted in Bengaluru to look after the management of e-waste. Several industry associations like Manufacturers' Association of Information Technology (MAIT), Electronic Industry Association of India (ELCINA), Telecom Equipment Manufacturers' Association (TEMA), Consumer Electronics and TV Manufacturers' Association (CETMA), and National Association of Software and Service Companies (NASSCOM), along with Karnataka Pollution Control Board, ministry of environment and forests, government of India, NGOs, international research institutes such as SECO and EMPA, citizens' representatives and recyclers, are active participants in the initiative. The EWA has undertaken several initiatives including drafting legislation on e-waste, providing training to unorganised recyclers, and conducting several awareness programmes on e-waste management.

Management of E-waste

The management of huge and growing quantities of electronic waste may emerge as one of the more important environmental problems in the near future. It is a sight that is increasingly only too common in urban India, and now even in the more prosperous rural areas of the country – visible as ramshackle piles of dismembered pieces of discarded electronic equipments such as computers, compact disc players, televisions and cell phones lying around in the odd corners of offices and homes, or else, simply dumped in the open in garbage heaps, and then being painstakingly searched through by rag pickers of all ages for anything that can be resold.

There are different ways in which e-waste can be dealt with, and none of them is really very satisfactory. These are described below:

Re-use

Obsolete devices from industrialised countries are finding their way to developing countries like India, where old computers and cell phones are often used for a few more years. For instance, out of nearly five million PCs in India, 1.38 million are either model 486s or below, and may be eight years old or more. Re-use is a good way to lengthen a product's life span. But in India, it means that a vast amount of equipment will soon be added to the waste

stream as upgradation beyond a point becomes uneconomical and incompatible with the software in demand. On the other hand, developed countries, dumping their old devices in developing countries, sometimes legally (as charity) or illegally, are liberating themselves from the waste disposal problem.

Recycling

Electronics 'recycling' is a misleading characterisation of many disparate practices, including de-manufacturing, dismantling, shredding, burning, or exporting. Although the amount of e-waste rises steadily, the industry has not yet developed very sophisticated or automated recycling procedures. Recycling needs to be done in particular ways that protect the workers concerned, who would otherwise be exposed to all the health hazards mentioned above. In most developing countries, this is a real problem because recycling is dominantly done in scrap yards by hand, without any protection for the unskilled workers involved in such activity.

Landfill Disposal

The disposal of e-waste in landfills is, again, very problematic. It has become common knowledge that all landfills leak. Even the best 'state of the art' ones are not completely sealed throughout their lifetimes, and a certain amount of chemical and metal leakage will occur. These leachates contaminate the groundwater and pose danger to the health of communities residing nearby. The situation is far worse for older or less stringently controlled dump sites. The vapourisation of metallic mercury and dimethylene mercury is also of concern. Uncontrolled fires may begin at such landfills, posing additional health and environmental risks.

Imports

India has to deal with e-waste that is far in excess of what is generated by production and consumption within the country, as we are net importers of e-waste that is mockingly dumped on us by the developed world. The European Union has implemented a ban on the export of e-waste, but it has generally been found to be ineffective as the illegal trade in e-waste continues to flourish. According to Greenpeace, inspections of 18 European seaports in 2005 found that 47 per cent of the waste destined for export, including e-waste, was illegal. In the United Kingdom alone, at least 23,000 tonnes of undeclared or 'grey' market electronic waste was illegally shipped in 2003 to China, India and countries in Africa. India is one of the important destinations for this global hazardous trash because of availability of cheap labour, along with the lack of strict compliance with rules and regulations. Greenpeace has found that in 2005, as many as 25,000 workers were employed at scrap yards in Delhi alone, where 20,000 tonnes of e-waste were being handled in a year, with around a quarter of this coming from computers. Other e-waste scrap yards have been found in Meerut, Ferozabad, Chennai, Bengaluru and Mumbai, but there are surely many more spread across the country which have not been identified.

Exports

Export to developing countries is a dangerous but cost-effective, and sometimes illegal, waste management option chosen by some companies in industrialised countries. Sometimes, illegal export is phrased as or hidden under the umbrella of charity ('computers for the poor'), or qualified as recycling. This originates in the fact that environmental and occupational regulations are lax or not well-enforced in some developing countries, and

labour costs are much lower than in industrialised countries. A recent report by Toxics Link (2004) found that 70 per cent of electronic waste collected at recycling units in New Delhi, India, was actually exported or dumped by developed countries.

In the backdrop of the resurgent growth of the Indian economy and the greater reliance on electronic hardware for household, industrial and office automation, a commitment to eco-responsibility is seen as a sine qua non for the society, the economy, and the environment.

There is unanimity that electronic waste containing substances like lead, cadmium, mercury, and polyvinyl chloride (PVC) has immense potential to cause harm to human health and environment if not disposed properly, since the extant prescriptions for its disposal and safeguard are inadequate. Thus, there is an imperative need for early formulation of a holistic e-waste legislation that will eventually lead to an enabling policy. The policy must appropriately reflect the concerns of various stakeholders besides views of practitioners in the field, both in the organised and unorganised sectors.

The literature on health effects on the recycling workers is scarce in India, since not many studies have been done on collecting data on these unorganised workers. However, the sheer volume of e-waste and the projected huge employment in recycling of e-waste in India clearly demands basic research needs on the health effects on recycling workers.