Current state of e-waste management in India

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Current state of E-Waste Management in India

Abstract

Electronic Waste, or E-Waste in common parlance, is increasingly becoming a cause of concern in developing countries like India, due to environmental and human health hazards associated with it. Ironically, constituents of e-waste can be valuable, at the same time being toxic. The practices involved in managing and treating the electronic waste in India have limitations that need to be identified and resolved. The waste management can be properly executed if there are proper collection and disposing methods adopted. This can be possible only if there is proper awareness related to the ill-effects of e-waste among common people. This paper highlights the status of e-waste in India and the various techniques used for recycling and their limitations. The indicators assessing e-waste can be utilized as basic parameters for analysis in any nation. The valuable constituents present in e-waste can be used in creating business opportunities if properly treated and recycled.

Keywords

e-waste, management, recycling, business opportunities

1. Introduction

Electronic waste (also referred to as e-waste) or the waste from electrical and electronic equipment (WEEE) (Kahhat et.al, 2008), mainly consists of equipment used in data processing, communication, entertainment and businesses (Liu, Tanaka and Matsui, 2006). E-waste is the electronic components after their usage and it is growing rapidly due to the increasing use of electronic products globally (Dwivedy and Mittal, 2010). The usage of electronic components is increasing due to decreased prices, growing usage of internet advancements in Information and Communications Technology (Nnorom and Osibanjo, 2008), (Osibanjo and Nnorom, 2007). More than half of the globally generated e-waste is exported for recycling mainly in the Asian countries like China and India due to the cheap labor (Ha et.al, 2009).

E-waste in India is not only increasing in amount but also in its toxicity, reason being the rapid growth in productivity and consumption in the electronics' sector (Dwivedy and Mittal, 2010). About 50,000 tons of e-waste is imported to India each year (Manomaivibool, 2009). The electronic and electrical components manufacturing industries are the largest growing sectors in India (Sepulveda et. al, 2010) producing 40,000 tons of e-waste itself every year (Sthiannopkao and Wong, 2013). The prediction says that India would generate approximately 52 million tons of e-waste by 2020 which constitutes about 40% of total e-waste generated all over the world (Vaidya, 2016). Electronic waste contains hazardous substances such as Cathode Ray Tube consisting of lead oxide, Lead, Mercury, Tin and other harmful metals which, if landfilled, can induce toxicity in groundwater and soil. E-waste is greatly hazardous for human as well as the environment if a proper management system is not followed for its treatment (Mundada, Kumar and Shekdar, 2004). Therefore, the 3R Principle needs to be implemented. The Rs in the 3R Principle stand for Reduce, Reuse and Recycle (Terazono et. al, 2006).

This paper also describes the management system and recycling methods for handling E-waste in India and the challenges faced in the task, elaborating on the points on what exactly is e-waste, its generation, effects on environment and human health, the current adopted management system, recycling processes and challenges that the management system faces, etc. The indicators for analyzing e-waste management system is also reviewed that can be applied for any nation. Another important aspect, the business opportunities produced by e-waste in India, to create an employment generated platform is also discussed.

2. E-waste

Wastes from electronic and electrical components are categorized into ten groups as shown in the Table 1 given below:

Table 1: Categorization of E-waste

S. No.	Category of Waste	Appliances
1.	Large Household Equipment	Air conditioner, dishwasher, washing machine, refrigerator and microwave oven, etc.
2.	Small Household Equipment	Television, alarm clock, electric kettles, electric chimneys, etc.
3.	IT and Telecommunication Equipment	Modems, landline telephones, mobile phones, teleprinters and communication satellites.
4.	User Equipment	Radio receivers, digital cameras, personal computers, video recorders, MP3 player, CD and DVD players
5.	Illumination Equipment	Ballast lamp, LED and compact fluorescent lamps
6.	Electrical & Electronic Components	Generators, transistors, motors, transformers, wires, integrated circuits and batteries
7.	Toys, Leisure & Sports Equipment	Batteries in cars, trains and airplanes, etc.
8.	Medical Apparatus	Thermometer and biotechnological apparatus
9.	Monitoring & Controlling Apparatus	Relays, thermostat and microcontrollers
10.	Automatic dispenser	Automatic water dispenser, automatic soap dispenser and automatic spray dispenser, etc.

Source: Garlapati, (2016)

The different kinds of electronic or electrical devices and their projected lifespan that leads to generation of e-waste in future are shown in the Table 2 given below:

Table 2: Types of E-Waste and their Lifespan

S. No.	Electronic Equipment	Mass of the Device (in kg)	Estimated Lifespan (in years)
1.	Personal computer	25	3

2.	Fax machine	3	5
3.	High-fidelity systems	10	10
4.	Cell phone	0.1	2
5.	Electronic games	3	5
6.	Photocopier	60	8
7.	Radio	2	10
8.	Television	30	5
9.	Video recorder	5	5
10.	Air-conditioner	55	12
11.	Dish washer	50	10
12.	Electric cooker	60	10
13.	Food mixer	1	5
14.	Freezer	35	10
15.	Hair-dryer	1	10
16.	Iron	1	10
17.	Kettle	1	3
18.	Microwave	15	7
19.	Refrigerator	35	10
20.	Telephone	1	5
21.	Toaster	1	5
22.	Tumble dryer	35	10
23.	Vacuum cleaner	10	10

Source: Gaidajis, Angelakoglou & Aktsoglou, (2010)

3. Scenario of e-waste in India

Some of the major electronic devices that are responsible for increasing e-waste in India are television, laptops, mobile phones and desktops. The forecast of the e-waste generated from these devices are shown in the Table 3 given below:

Table 3: Generation of e-waste every year (in metric tons)

Devices	2014	2015	2016	2017	2018	2019	2020
Desktop PCs	59558	66429	67102	49648.5	41699	35947	32511
Laptops	12640	15248	20673	25280	32360	40367	50769
Mobile Phones	22919	23101	28827.5	33475	36172.5	38870	41925

Televisions	130200	145800	168000	184200	202770	221550	241500
Total e-Waste generated Every Year	225317	250578	284602.5	292613.5	313001.5	336734	366705

Source: Ahmed, Panwar & Sharma, (2014)

The states that contributes maximum of e-waste in India are Maharashtra, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. The amount of e-waste produced by these states is described in the Table 4 and the major cities which are largest producer of e-waste are depicted in the Table 5 given below:

Table 4: States Generating E-Waste

S. No.	State	Generated E-Waste (in tons)	Percentage
1.	Maharashtra	20270.59	18.49
2.	Tamil Nadu	13486.24	12.30
3.	Andhra Pradesh	12780.33	11.66
4.	Uttar Pradesh	10381.11	9.47
5.	West Bengal	10059.36	9.18
6.	Delhi	9729.15	8.87
7.	Karnataka	9118.74	8.32
8.	Gujarat	8994.33	8.20
9.	Madhya Pradesh	7800.62	7.11
10.	Punjab	6958.46	6.35

Source: Begum, (2013)

Table 5: Major E-Waste Producing Cities in India

S. No.	City	Generated E-Waste (in metric tons per year)
1.	Mumbai	1,20,000
2.	Delhi (NCR)	98,000
3.	Bangalore	92,000
4.	Chennai	67,000
5.	Kolkata	55,000
6.	Ahmedabad	36,000
7.	Hyderabad	32,000
8.	Pune	26,000

Source: Ghosal, (2016)

In India, 60% of the total generated e-waste is kept in warehouses and the remaining 40% is sent for recycling or recovering processes. A large amount of energy can be saved if the generated electronic waste is recycled properly. The recyclers collect the e-waste at a very low cost from the persons involved in gathering waste from the communities, and recycle metals such as copper, iron, aluminium and steel through primitive techniques. A large amount of pollutants are infused in the environment through these primitive techniques. The formal recyclers are registered by control pollution control board (CPCB) each year. Presently, 23 formal recyclers are registered who treat the generated e-waste in the country through formal techniques. These recyclers are given only a particular amount of e-waste to be treated (C. Vats & Singh, 2014). India ranks fifth in the world in generating e-waste (Dutta, 2017). The number of formal recyclers registered in the states of country is shown in the Table 6 given below:

Table 6: Enrolled recyclers with the amount of e-waste allotted to them

S. No.	States	No. of Registered Recyclers	Amount of E-Waste to be Recycled
1.	Andhra Pradesh	2	11,800 MTA
2.	Gujarat	1	12,000 MTA
3.	Karnataka	7	3,140.6 MTA and 120,000 numbers cartridges
4.	Maharashtra	3	8,060 MTA
5.	Haryana	1	1,200 MTA
6.	Rajasthan	1	450 MTA
7.	Tamil Nadu	6	38,927 MTA
8.	Uttar Pradesh	1	1,000 MTA
9.	Uttarakhand	1	12,000 MTA

Source: C. Vats & Singh, (2014)

4. Environment and Human Health related Issues from E-Waste

E-waste is severely harmful for environment and health as it contains toxic materials like lead and other metals. The Cathode Ray Tubes (CRT) present in Personal Computers and televisions have high concentration of lead that must be treated separately. The 5.015 million units of Personal Computers (PCs) and 21.1 million units of televisions (TVs) were sold in 2013 (Ahmed et al., 2014). The constituents of different kinds of CRT are shown in the Table 7 given below:

Table 7: Constituents of different types of CRT glass

S. No.	Item	Constituents	Basic Properties
1.	Panel	0-4% lead oxide Alkaline/alkaline earth aluminosilicate	Optical quality glass, x-ray attenuation, color and tint control
2.	Funnel	22-28% lead oxide Alkaline/alkaline earth aluminosilicate	High x-ray resistance, viscosity control
3.	Neck	30% lead oxide Alkaline/alkaline earth aluminosilicate	Thermal expansion match to funnel composition, x-ray absorption
4.	Stem	29% lead oxide alkaline aluminosilicate	Expansion match to metal wire feed throughs, x-ray absorption

5.	Gun mount	Potassium aluminosilicate sintering	Crystallization
6.	Frit	70-80% lead oxide zinc borate	Low temperature

Source: Nnorom and Osibanjo, (2008)

E-waste must be treated separately from other wastes. If it is treated along with the other household wastes such as food waste, bottles, cans and clothes, then it'll be harmful for environment as well as for human health (Ramchandra and Saira, 2004). It has a high level of hazardous effect on human and environment (Tsydenova and Bengtsson, 2011).

By considering the impacts of e-waste as given in the Table 8, the electronic products must be designed properly so as to prevent the environment from its hazardous effects (Bridgen, Labunska, Santillo and Allsopp, 2005). The various causes of generating e-waste in India and its negative impacts on the human health are summarized in the Table 8 given below:

Table 8: Sources of e-waste and its impact on human health

S. No.	Sources of E-Waste	Elements	Health Issues
1.	Solder in printed circuit boards, Glass panels and Gaskets in Computer Monitors	Lead	• Damage to Central Nervous System, blood and Kidneys.
2.	Chip Resistors and Semiconductors	Cadmium	• Accumulates in the Liver and Kidneys • Causes Neural damage • Teratogenic
3.	Relays and switches, Printed circuit boards	Mercury	• Respiratory and Skin Disorders due to bio-accumulation in fishes.
4.	Corrosion protection of untreated and galvanized steel plates, hardener for steel housings	Chromium	• DNA damage • Asthmatic Bronchitis
5.	Cabling and Computer housing	Plastics	• Burning produces dioxin which causes damage to immune system and interfere with regulatory hormones

6.	Plastic housing of electronic components and circuit boards	Brominated flame retardants	• Disrupts the Endocrine System functions
7.	Front panel of Cathode Ray Tubes	Barium	• Short term exposure causes damage to Heart, Liver and Spleen
8.	Motherboard	Beryllium	• Lung cancer • Skin diseases like warts • Inhalation of fumes and dust causes chronic beryllium disease.

Source: Kush and Arora, (2013)

The various harmful constituents of e-waste that leads to the degradation of the environment and are also responsible for various health hazards in human beings are depicted in the Figure 1 given below:

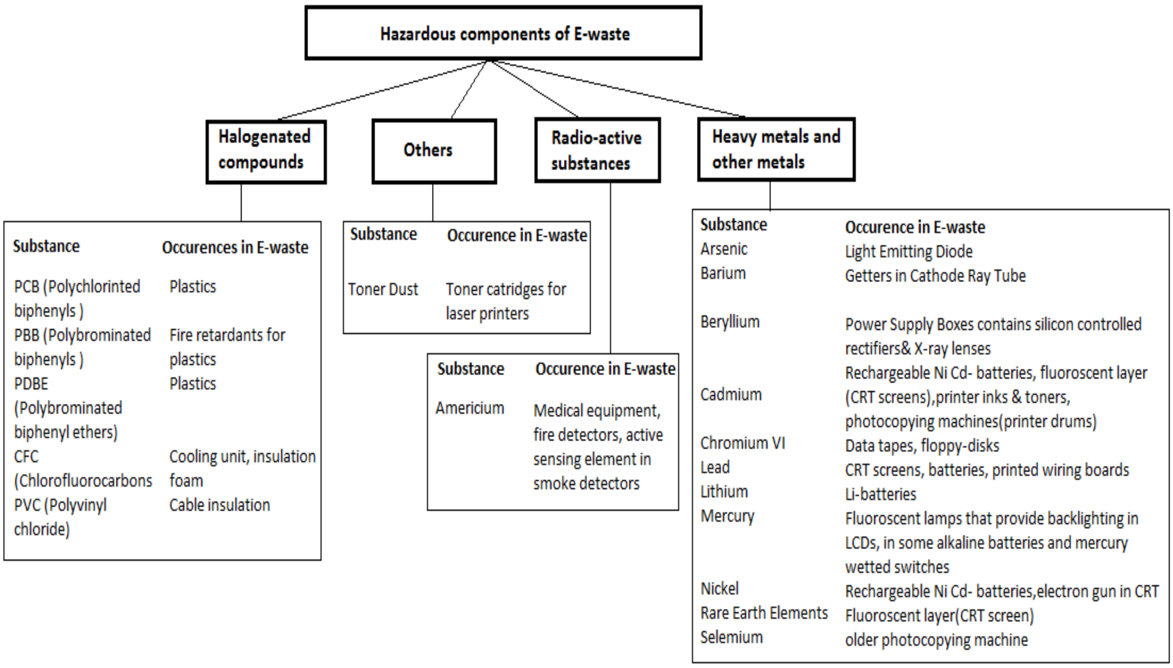

Figure 1: Harmful substances in E-waste

Source: Garlapati, (2016)

5. Management of E-Waste in India

E-waste is managed in industries by adopting four steps which are inventory management, production-process management, volume reduction and recovery and re-use. In the inventory management step, the components used in the manufacturing of electronic devices are controlled and thereby amount of waste produced can be decreased. The amount of e-waste can be decreased by following two ways – firstly, by *creating review* over purchasing of material and control processes and secondly, by *an inventory tracking method*. In the production-process management step, waste can be minimized by improving operating and maintenance processes, by changing materials used in manufacturing of product and by changing the existing procedure for developing the product. In the third step, that is the volume reduction, the techniques are applied to extract the harmful part of waste from non-harmful part and thereby the volume of the waste is minimized. Minimization of waste is achieved by segregating the waste at the source. Finally, in the recovery and reuse step, waste is recycled and the environment can be saved, as the recycling transfers the harmful substances into other products which are to be disposed (Sastry & Ramachandra Murthy, 2012). The quantity of e-waste can be minimized to a large extent through recycling and reusing the products. Recycling and reusing of the material helps in conserving the energy and also in making the environment free from toxic substances (Joseph, 2007). The various elements of E-Waste Management System are shown in the Figure 2 given below:

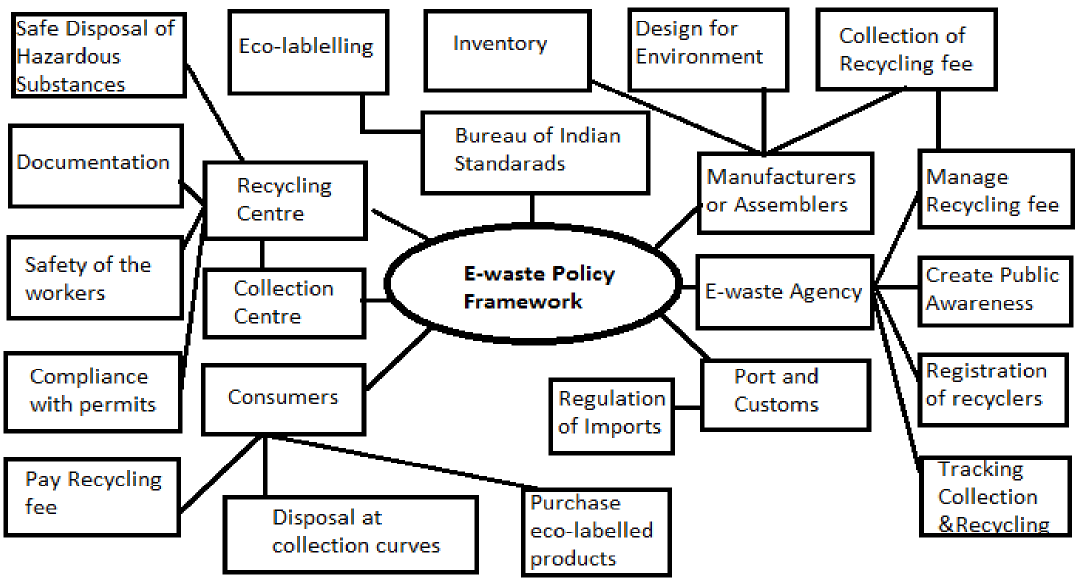

Figure 2: Components of E-Waste Management

Source: Joseph, (2007)

The various tools used for managing e-waste are Life Cycle Assessment (LCA), Material Flow Analysis (MFA), Multi Criteria Analysis (MCA) and Extended Producer Responsibility (EPR).

- ***Life Cycle Assessment (LCA)*** is a tool used for designing eco-friendly electronic equipment and for minimizing the problems created by e-waste. LCA is used for making decisions on managing computer-related waste in India.

- ***Material Flow Analysis (MFA)*** is a tool used to manage the flow of e-waste in environment and is used to analyze gold and copper flowing from recycling personal computer in India.

- ***Multi-Criteria Analysis (MCA)*** is a tool used to find a suitable location for setting up recycling plants for e-waste.

- ***Extended Producer Responsibility (EPR)*** is a policy for ensuring responsibility of electronic components to the manufacturers even after their end of life (Kiddee, Naida and Wong, 2013).

Various tools used in India for managing e-waste are shown in the Table 9 given below:

Table 9: Tools to manage e-waste and their applications

S. No.	Tool	Application	Aspects
1.	Life Cycle Assessment (LCA)	Decision makers for managing computer waste	Environment and economic
2.	Material Flow Analysis (MFA)	E-waste trade value chain	Life span and market supply
3.	Material Flow Analysis (MFA)	The flow of personal computers and pathways of recycling	Economic value

Source: Kiddee, Naida and Wong, (2013)

The present management system for handling and treating e-waste in India is shown in Figure 3, given below:

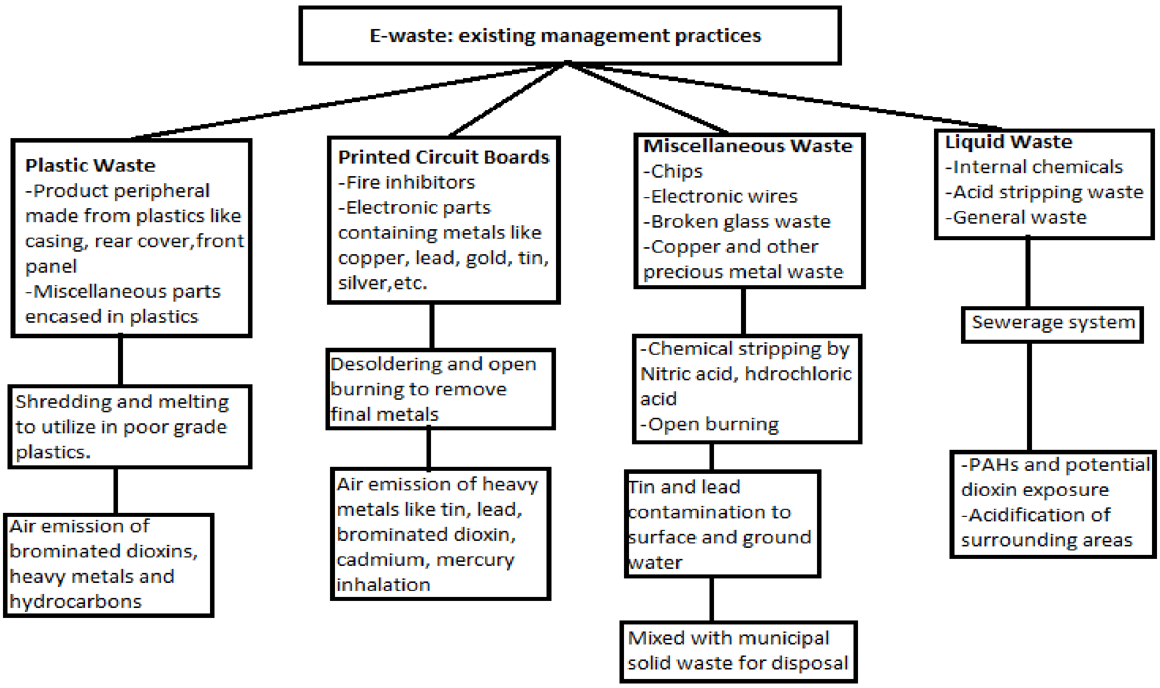

Figure 3: Existing management processes of e-waste in India

Source: Mundada, Kumar and Shekdar, (2004) The various initiatives taken by the Government of India for managing e-waste are given below:

- E-Parisaraa - This is the first scientific plant established for recycling e-waste to minimize the e-waste pollutants and also recover metals.

- Earth Sense Recycling Private Limited - This Company was established for managing bio-medical waste in 2000 and now it handles every kind of waste management, including e-waste.

- Trishyiraya Recycling India Pvt. Ltd. - This Company has been certified by Government of India and it recycles the e-waste.

- Plug-into E-cycling - Here, *e-cycling* refers to recycling and recovering. This helps to reduce emissions of greenhouse gases in the atmosphere.

- Installations of e-Bins in Bangalore City - E-bins are installed to create awareness among the dwellers regarding e-waste (Jhariya, Sahu & Raj, 2014).

The various factors responsible for creating problems in managing e-waste properly are generation of e-waste in large amount; not having a proper law for banning children involved in different processes of e-waste treatment; ill-effects of e-waste on human beings and environment; lack of awareness among people; e-waste coming from other countries for recycling in India; and large investment in recycling plants of e-waste (Kumar, 2016). E-Waste Management Practices in India face many challenges which must be analyzed as shown in Figure 4 given below:

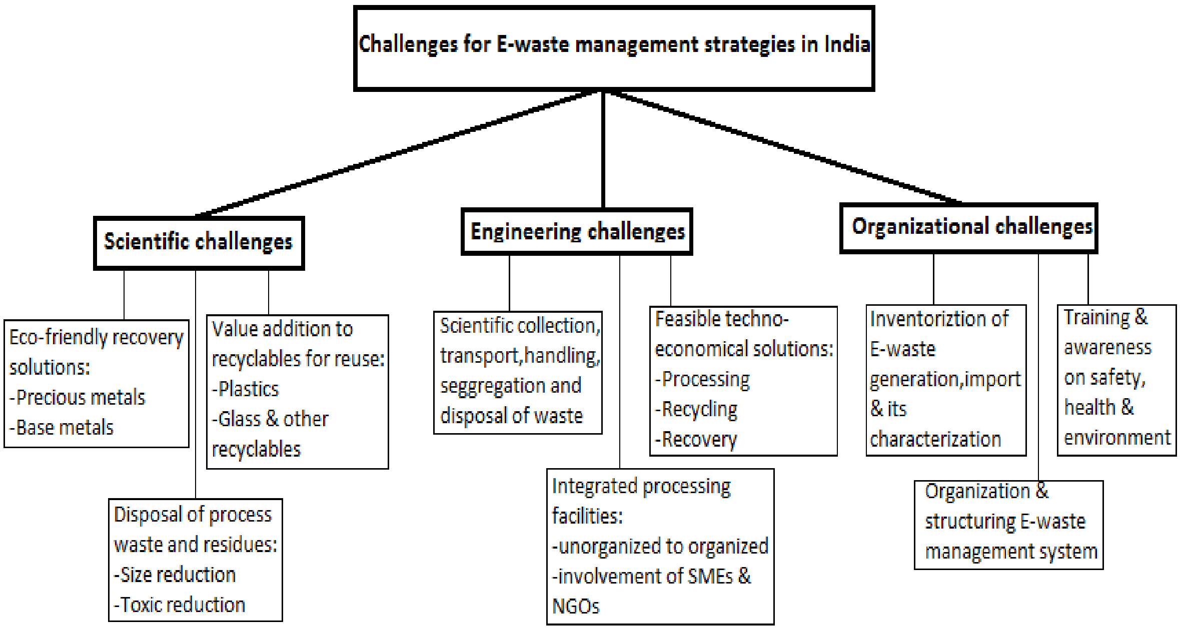

Figure 4: Challenges Faced by E-waste Management Strategies in India

Source: Wath, Dutt and Chakrabarti, (2010)

6. Recycling methods of e-waste in India

The recycling methods used to recycle the waste generated from printed circuit boards are pyrolysis method, hydrometallurgical method, mechanical recycling, air classification method, bio metallurgical method and magnetic separation method. In pyrolysis method, the printed circuit boards are placed at a very high temperature so that solder is melted and this process leaves a blackish material which yields metal-like copper by following leaching process. In the hydrometallurgical method, the metal constituents are dissolved in strong acids and the metals are recovered. In bio-metallurgical recycling, the metals are recovered by using bioleaching process. After recycling of waste PCB in which metals are recovered, non-metallic portion is left. This non-metallic portion is very light and can be used as filler materials (Gupta, Modi, Saini & Agarwal, 2014). The different levels in recycling of e-waste are primary level, secondary level and tertiary level. The procedures followed at each level and the output of each level is shown in the Table 10 given in the next page.

Table 10: Different Levels in the Recycling of E-Waste

S. No.	Level of Treatment	Processes	Output	Role of Technology	Main Technologies
1.	Primary	Decontamination, dismantling, disassembly and sorting	Waste is segregated into decontaminated waste, like plastic, printed circuit board, and harmful waste like batteries, mercury switches, etc.	low	Typically a manual process

2.	Secondary	Hammering, shredding, separation of waste streams and CRT treatment	The material output can be categorized into glass, plastic, contaminated plastic stream, ferrous metal stream and non-ferrous metal stream	Medium	Electromagnetic, eddy current, density separation, and variable vortex technology Splitting technology in CRT treatment like Ni-chrome wire cutting, thermal shock, laser cutting and diamond wire method
3.	Tertiary	Pulverization and advanced separation, leaching for metal recovery and energy recovery	Plastic, ferrous metal, precious group metals like gold and platinum and other metals like aluminum and lead and energy recovered from contaminated plastic stream	High	Plastic separation using skin floatation technology and electrostatic separation PGM recovery using smelting, electrochemical process and Haber's process

Source: Frost & Sullivan, (2013)

The recovery of materials from recycling of e-waste is shown in Figure 5 given below:

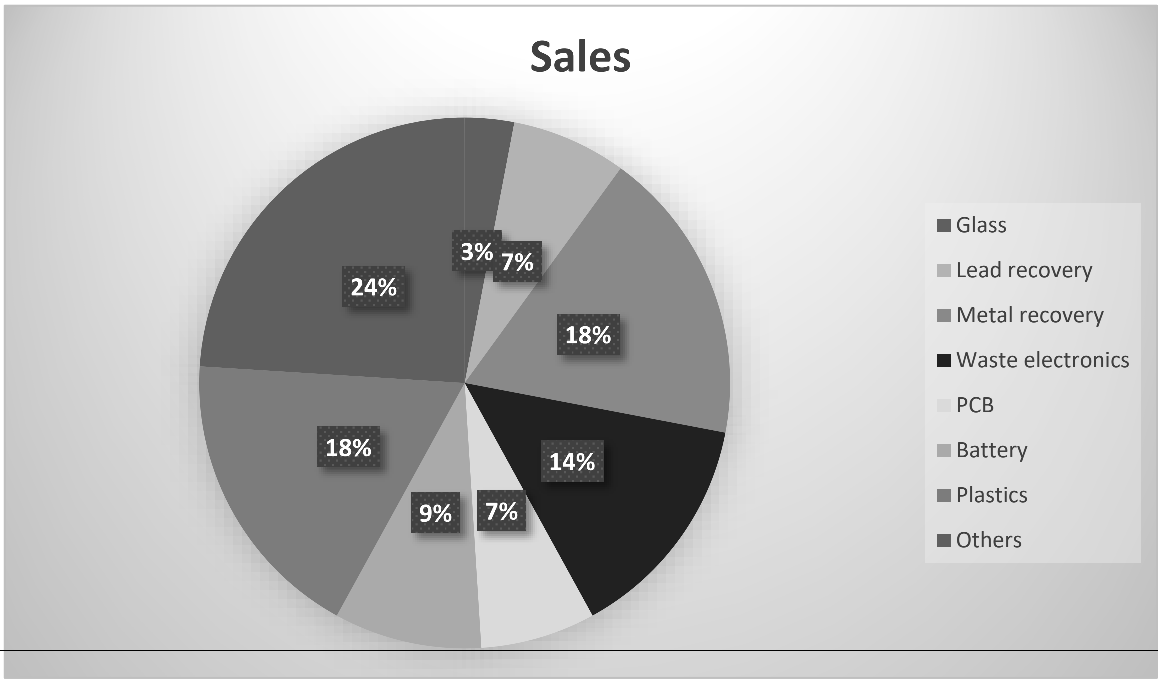

Figure 5: Recovered Materials from Recycling Processes

Source: Dey, (2014)

7. Indicator Model for E-Waste Management System

The indicator model used to assess the e-waste management system for a country is a three-pointer scale. The model is used to analyze the management of e-waste for a nation and there are three aspects involved in modeling the indicator which is summarized in the given below Table 11:

Table 11: Aspects of Indicator Model to Assess E-Waste Management System

S. No.	Aspects	Criterion	Indicator
1.	Structural Framework	Policies and Legislation	Ratification of Basel Convention Status of National Waste Legislation Status of National E-Waste Legislation
		Economy	Corruption Perception Index Capital Cost Secondary Raw Material Market
		Society and Culture	Civil and Political Liberties NGO Activities Recycling Culture Environmental Awareness in Society
		Science and Technology	Knowledge in E-Waste Recycling Technologies Research in Recycling Technologies
2.	Recycling System	Material flow	E-waste generation per capita Closed loop recycling management
		Technologies	Efficiency of material recovery Quality of recovered material
		Financial flow	Financial coverage Externalities coverage

3.	Impacts	Environment	Final disposal of e-waste in unsafe landfills Emissions of harmful materials
		Human health	Health and safety implementations at workplace Exposure of neighboring population to harmful substances
		Labor	Number of jobs generated Income distribution

Source: Widmer et. al, (2005)

8. Rules and Laws of E-Waste in India

Basel Convention, by the United Nations, came into effect on May 5, 1992 that proposed an agreement between nations for controlling and managing hazardous materials across their boundaries. According to Basel Convention, recycling of wastes is a way of disposing the substances (Babu, Parande an Basha, 2007). The laws for preventing the environment and human health from e-waste in India are shown in Table 12 given below:

Table 12: Laws to protect from e-waste hazards

S. No.	Laws	Content	Date
1.	Environment (Protection) Act, 1986 (Amendment 1991)	Empowers Central Government to take measures to protect and improve environment quality.	Effective from 1986
2.	Hazardous Waste Rules, 2008 (Amendments 2009)	Provides stipulations on management, disposal and transboundary movement of solid waste of hazardous nature.	Effective from 2008
3.	Batteries (Management and Handling) Rules, 2001	Responsibility for safe disposal and recycling of lead acid batteries	Effective from 2001
4.	National Environmental Tribunal Act, 1995	Provide for strict liability for damage arising out of accidents caused from handling of hazardous substances.	Effective from 1995

5.	The Air (Prevention and Control of Pollution) Act	Provide for prevention, control and abatement of air pollution in India	Effective from 1981

Source: Wath, Vaidya, Dutt & Chakrabarti, (2010)

E-waste (Management and Handling) Rules are there to manage and handle the e-waste at various steps while collecting or treating it. These rules were notified under Environment (Protection) Act in 2010 (Notification number: S.O. 1035) to reduce the e-waste impacts on environment. The salient characteristics in these rules are depicted in the given below Table 13

Table 13: E-Waste (Management and Handling) Rules

S. No.	Chapters	Titles	Problems Addressed
1.	Chapter 1: Preliminary	• Short Title and Commencements • Definitions • Applications	Includes the titles and commencements of the laws, applicable stakeholders and related definitions of the terminology.
2.	Chapter 2: Responsibilities	• Responsibilities of Producers • Responsibilities of Collection Centers • Responsibilities of Consumers • Responsibilities of Dismantler • Responsibilities of Recycler	Responsibilities of do's and don'ts of stakeholders are discussed.
3.	Chapter 3: Procedure for seeking Authorization for Handling E-Waste	• Procedure for Grant of Authorization • Power to Cancel an Authorization • Procedure for Grant of Registration	• Includes the procedure and formalities for potential e-wastes handlers to obtain authorization. • Procedure for grant of registration at State Pollution Control Board is included.

4.	Chapter 4: Procedure for Storing E-Waste	• Procedure for Storage of E-Waste	Maximum permissible storage period of e-waste with any costumer is 180 days.
5.	Chapter 5: Reduction in Use of Harmful Substances in Manufacturing of Electrical and Electronic Devices	• Reduction in use of harmful substances in manufacturing of electrical and electronic devices	Advises the manufacturers to reduce harmful substances in electronic and electrical devices. The maximum permissible limit of lead, mercury, calcium and other elements are included.
6.	Chapter 6: Miscellaneous	• Duties of Authorities • Annual Report • Transportation of E-Waste • Accident Reporting and Follow-Up • Collection, Storage, Transportation, Segregation, Recycling and Disposal of E-Waste shall be in accordance with the Procedures.	Includes the duties of authorities, & norms of collection, storage, transportation, and disposal of e-waste, duties of authorities, etc. as well as reporting of e-waste.

Source: Chatterjee, (2011)

9. Business Opportunities From E-Waste

The various sectors involved in generating e-waste are manufacturers, imports, information technology industries, educational institutes, individual households, traders and recyclers (Borthakur & Sinha, 2013). The route of e-waste in management system is shown in Figure 6 given below:

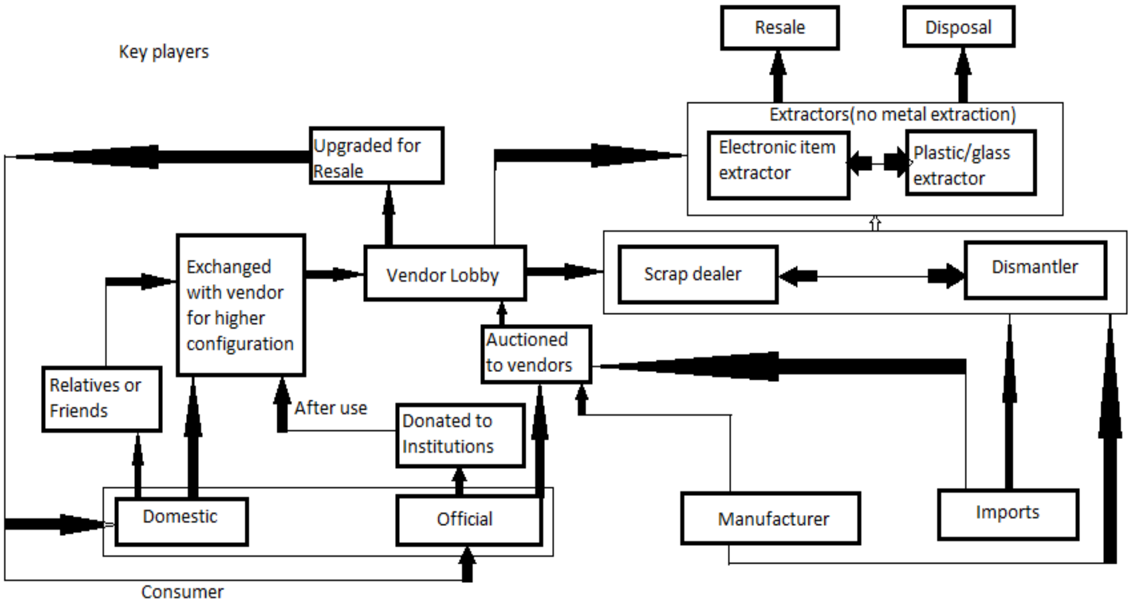

Figure 6: E-Waste Flow

Source: Wath, Vaidya, Dutt & Chakrabarti, (2010)

In spite of the hazardous nature and effects of e-waste, one advantage of it is that it contains valuable metals such as gold, silver and copper. These metals can be brought back by adopting proper recycling methods. This presence of valuable metals in e-waste has made its recycling a platform for business in developing countries like India. The recycling processes of e-waste have high potential for employment in India (Khetriwal, Kraeuchi and Schwaninger, 2005).

10. Conclusion

E-waste is increasing at a rapid rate in India due to many reasons like growth in the electronics sector in the country and globalization that has increased the import of electronic items in the country. The electronic waste is greatly harmful for the ecosystem that includes humans, animals and environment. The toxic substances present in e-waste can cause serious damage to human health and other living organisms in the ecosystem.

Even though management systems and strategies exist to handle the task of safe disposition of the e-waste, still there are various challenges faced by the system for their successful implementation. There are various recycling processes have been discussed in this paper, which are not only helpful in removing toxic substances from the waste but also helpful in recovering valuable metals which might ultimately create substantive business opportunities in a developing nation like India.

The initiatives taken by the government such as rules and laws on e-waste described in section 8 in the direction of reducing harmful substances from the environment are commendable and useful to reduce the threat on human health and other environmental and ecological hazards caused by the wastes such as e-waste.

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