Chapter 17
Aspects of E-waste Management in India

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Abstract Increased urbanization and globalization have led to marked increase in use of consumer products with the use of electronics being the most prevalent. Wherein in one aspect it has led to global connectivity and social inclusivity, adversely it has led to generation of e-waste in massive proportions. In principle, e-waste comprises of precious heavy metals which are highly toxic in nature and thereby have severe human and environmental effects if disposed of unscientifically. The chapter deals with the different aspects of e-waste generation in India, its potential environmental health and environmental impacts, and associated legislative measures and discusses sustainable methods for effective disposal of generated e-waste including the commercial viability of such waste.

Keywords E-waste management · Environmental effects · E-waste management handling rules

17.1 Introduction

Increased urbanization and globalization have led to rapid urban development leading to rise of use of electronic goods and appliances in our daily lives. These electronic goods and appliances enhance our living standards but have a definitive shelf life. The problem arises when it comes to the disposal of such electronics after the completion of shelf lives of such electronics. This is primarily because such electronics comprise of precious and toxic metals which have severe human health and environmental effects if they are not disposed of carefully. The increased generation of such electronic wastes (e-waste) is a rising concern, particularly in the context of presence of both toxic and precious metals (Babu et al. 2007). The production of e-waste is expected to rise continually with an expected production of

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about 72 million tons in 2017 (Garlapati 2016) with China and the United States being the major producers (Nisa 2014). Recent reports (Bhutta et al. 2011) suggest that annual generation of electronic waste worldwide varies from 20 to 50 million tons having the potential to cause significant human health and environmental damage. In the context of developing countries, earlier reports suggest that such electronic waste would comprise 1% of the total municipal solid waste generated and will rise to 2% by 2010 (Chaturvedi et al. 2007) with the total generation between the periods 2007 to 2011 being estimated at 2.5 metric tons (Dwivedy and Mittal 2010) (Fig. 17.1). Recent studies conducted by Associated Chambers of Commerce of India (ASSOCHAM) reveal that the growth rate of e-waste in India is about 25% with an expected generation quantity of 15 metric tons by 2015 (Nisa 2014). From the existing statistics, it is quite evident that the usage of such products will continue to increase, and the fact that electronic industry is one of the fastest-expanding industries in present context leads to more manufacture and generation of electronic waste (Garlapati 2016). Figure 17.1 shows the increasing trend of generation of e-waste in India.

The major drawback associated with the safe disposal and recycling of such electronic wastes is its harmful human health and environmental impacts. For example, older televisions and computer monitors have toxic metals like lead, cadmium, and mercury as their major constituents, while other electronic circuitry have nickel, beryllium, and zinc as primary constituents (European Union 2012). Hence, it is imperative to have an effective waste management system for such e-wastes which pose significant challenges to both government and common public as it comprises both precious and toxic elements. In this context, special e-waste handling rules have been formulated for safe handling practices of such wastes.

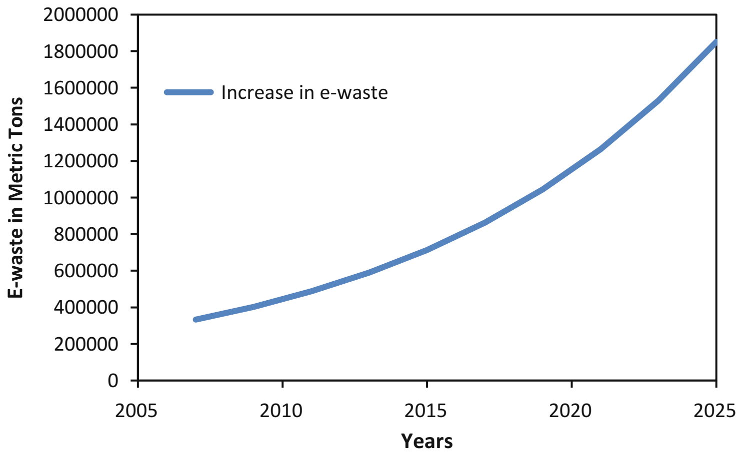

Fig. 17.1 Increasing trend of generation of e-waste in India

17.2 Definition and Classification of E-waste

E-waste or waste electrical and electronic equipment (WEEE) is a terminology that is used to define all electronic and electrical products achieving the end of shelf life. It also incorporates discarded appliances or electronic goods that are rejected during the manufacturing, refurbishing, and the repair process (Ganguly 2016). In practice, e-waste includes a broad denomination with both personal and household electronic equipments varying from television, mobiles, refrigerator, microwave, juicer grinder, mixer, and personal computer all falling within its purview (Puckett et al. 2002). Since the term e-waste encompasses a broad category, certain definitive bodies and researchers have given the definition of e-waste, the most important of which are highlighted in Table 17.1.

As per the definition of electronic waste by EU WEEE directives 2002/96/EC and 2012/19/EU, there exist ten different classifications of e-waste which have been summarized in Table 17.2 along with their respective percentages.

The constituents of e-waste is widely varied as they not only include metals (both ferrous and non-ferrous) but also ceramics, plastics, and different other combinations (APME 2004). The specifications of the electronics depend on the different constituents present in the manufactured product being categorized as both hazardous and non-hazardous waste. Classification of the metal components is primarily done on the basis of presence of ferrous and non-ferrous metals, whereas other components include plastics, ceramics, glass woods, and other inert and non-reactive materials (Garlapati 2016). In the category of non-ferrous metals, metals like aluminium, copper, silver, platinum, etc. are considered precious metals and often considered for recovery. Presence of other metals like mercury, lead, arsenic, cadmium, selenium, and chromium classifies the e-waste as hazardous in nature (Garlapati 2016).

Table 17.1 Definition of E-waste as per different conventions

EU WEEE Directive (EU 2002)	'Electrical or electronic equipment which is waste including all components, sub-assemblies and consumables, which are part of the product at the time of discarding.' Directive 75/442/EEC, Article 1 (a) defines 'waste' as 'any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force'
Basel Action Network	'E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air-conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users'
OECD (2001)	'Any appliance using an electric power supply that has reached its end of life'
Sinha (2008)	'An electrically powered appliance that no longer satisfies the current owner for its original purpose'
Gregory (2009)	E-waste refers to 'the reverse supply chain which collects products no longer desired by a given consumer and refurbishes for other consumers recycles or otherwise processes wastes'

Table 17.2 Definition of e-waste as per different conventions

Sr. no.	Waste category	Label	Contribution (%)
1.	Major household gadgets	Large HH	42.1
2.	Minor household gadgets	Small HH	4.7
3.	IT and telecommunication gadgets	ICT	33.9
4.	User gadgets	CE	13.7
5.	Illumination gadgets	Lighting	1.4
6.	Electrical and electronics appliances	E&E tools	1.4
7.	Toys, leisure, and sports gadgets	Toys	0.2
8.	Medical device	Medical equipment	1.9
9.	Monitoring and control instruments	M&C	0.1
10.	Automatic dispensers	Dispensers	0.7

17.3 E-waste Generation in Global and Indian Context

Recent studies mention that the proportion of e-waste generated from developing countries will double within the next decade. Further by 2030, it is expected that developed and developing countries will have obsolete computer wastes of 200–300 and 400–700 million, respectively (Duan et al. 2015). The rapid increase in generation of e-waste can be attributed to the discontinuance of the electronic goods. Primarily in developed countries, the lifespan of such electric products is only 2 years after which therein they are discarded or are then exported to developing countries as there is a demand for such used electronic goods (Ganguly 2016). In the context of production of such voluminous quantities of e-waste, it is imperative to have proper regulations for handling of such wastes. As per United Nations Environmental Program (UNEP), developing countries like China, India, Mexico, and Brazil would encounter the maxim of the environmental and health effects of such wastes.

The problem is more compounded for developing countries wherein there exist almost no governmental records on the production of e-waste in the country. Available data from studies conducted by Non-Governmental organizations (NGO) and other sources are reported. An earlier study conducted by the Comptroller and Auditor General (CAG) of India suggested the presence of 1.5 MT of plastic waste, 7.5 MT of industrial wastes, 1.7 MT of medical waste, and about 4 lakh tones of electronic waste being generated in the country (Agarwal 2010).

Another primary concern is the import of used electronics goods from developed countries to developing countries for usage and dumping which is of serious concern. There exists no official figures for import of such wastes, and they are often passed into developing nations on basis of false pretences like goodwill, reusable category, and charity purposes (Garlapati 2016). Such increased burden of e-waste severely affects the local population and the surrounding environment.

17.4 Health and Environmental Effects of E-waste

The hazardous components of the e-waste generated have the propensity to cause severe environmental damage. Primary emissions involve release of PCB and heavy metals (selenium, cadmium, chromium, etc.), whereas dioxins and furans are generated from secondary sources. Secondary emissions arise from untreated or improper treatment of the e-waste, whereas tertiary treatment involves emissions from those hazardous chemicals involved in treatment of e-waste (Gupta 2014). In simpler terms, electronic appliances can be classified into white category (household electronics), brown category (televisions, camera), and grey category (PC and other associated subsidiaries), and earlier studies have reported that the grey category is more hazardous than the other two categories (Sheng and Etsell 2007; Jomova et al. 2011). The practice of unscientific and lay methods in handling leads to hazardous emissions from such wastes.

Human health effects associated with exposure to emissions from such e-wastes lead to adverse functioning of reproductive system, thyroid, nervous system, lung functioning, and stunted growth (Grant et al. 2013). Workers associated with handling of e-waste without protective equipments can develop further ailments like skin cancer, tumours, anaemia, and related diseases (Janagam and Jeymani 2011). In this context, it is important to mention that exposure to e-waste is highly detrimental to human health. In particular, the effects are more profound for developing countries like India wherein there is a lack of proper implementation of handling of such e-wastes. The worst affected population groups are those living nearby the landfill dumpsites and the personnel involved in the handling of these wastes (Ganguly 2016).

17.5 Existing Practices of Handling of E-waste

Handling of e-waste is highly complex and requires special expertise primarily due to its constituents which are toxic in nature to both the environment and the human health. Generated e-wastes from LCDs, CRTs, capacitors, electrical circuitry, copier, and cartridges are highly toxic due to presence of heavy metals like mercury, selenium, lead, and chromium. Further, incineration (secondary emission source) of circuitry boards, plastic casings, and PVC materials leads to generation of dioxins and furans.

In developing countries, most of the e-wastes are generally disposed of in open landfills. For example, land filling of such burnt wastes can lead to severe groundwater pollution if hydrographical and soil conditions are favourable in nature. Cadmium (from mobile phones) alone has the potential for polluting 600 m^3 of water and has the potential for long-lasting effects (Garlapati 2016). Further, land filling of sites with e-waste can produce highly toxic nature of leachate which can severely contaminate the groundwater (Rana et al. 2018). Additionally, acid treatment of dissolving computer chips can cause acidification of soil and the groundwater (Milovantseva and Saphores 2013).

Similarly, incineration of such wastes leads to air pollution. For example, flammable components of electrical equipment when burnt (incinerated in dump sites) releases brominated flame retardants causing extensive damage to human health and surrounding environment. Hence, continual methods of open dumping and incineration have the potential to cause severe and long-lasting health and environmental impacts (Osibanjo and Nnorom 2007; Chen et al. 2011; Milovantseva and Saphores 2013; Rana et al. 2018).

17.6 Strategies for Management of E-waste

17.6.1 Responsibility and Role of Industries Including Sustainable Design Philosophy

It is given that management of e-waste is imperative for electronic goods and other appliances stored in warehouses which account for almost 75–80% (Garlapati 2016). It is imperative that if the generation of e-waste is controlled at the manufacturing phase, it will be highly beneficial. This can be achieved by reducing the volume of hazardous waste in the manufacturing process and also reducing the stock quantity of such process will reduce the generation of e-waste. Further the implementation of reuse and recycle policy could significantly reduce associated disposal costs and raw material procurement and also boost resale of such electronics. In principle, both on- and off-site recovery of wastes can be carried out along with the possibility of exploring inter-industry exchange (Garlapati 2016). These may involve inventory management, post-production, modification, and salvaging of such wastes (Freeman 1997).

The concept of managing inter-industry exchange of such wastes can be easily maintained by an updated inventory management system. A proper inventory system will regulate the use of such hazardous materials in the industry and will also help in alleviating the generation of excess wastes. This is primarily achieved by reducing the use of hazardous and surplus raw materials, verification of material purchase, and evaluation and regulation of control procedures (Garlapati 2016). In general, the first step involves using a detailed methodology for identifying the process and than followed by material procurement. Alternatively, a procedure of ordering required volume of materials may be implemented followed by detailed inventorisation to reduce purchase of any surplus hazardous material (Gaidajis et al. 2010).

Further to the above, reduction in e-waste generation can be controlled by using accomplished and natural materials in the manufacturing process and by altering the production process thereby conceptualizing new product design. This can be achieved by material alteration and amendment in manufacturing process, better working measures, and more endurable end products. For example, plant and bio-based plastics and plant-based polymers may be used in the design system instead of those made from petrochemicals. Similarly, natural (bio-based) inks and toners glue could be used more periodically. Proper implementation of abovementioned schemes can help in optimizing the system in utilization of such hazardous materials. Finally, the personnel involved in such activities should be provided training and made aware of process of optimizations, safety guidelines, etc. in handling of such wastes as they play a significant role in this aspect (Gaidajis et al. 2010).

Similarly, the use of natural and non-hazardous materials for production of electronic goods can significantly reduce the generation of e-waste, thereby reducing disposal costs in the future (Gaidajis et al. 2010). This can be successfully carried out by source segregation and waste concentration methods. The former involves the separation of metal components and application of treatment methods for recovery of such precious metals and is one of the most economical options. Treatment techniques generally involve reverse osmosis, bioleaching, ultrafiltration, and other pressure-based filtration techniques (Dasgupta et al. 2017). This is also termed as 'reverse production' (Ganguly 2016). Possible recovery of such metals leads to a closed-loop system minimizing the potential health and environmental impacts (Dasgupta et al. 2017). Labelling on packaging should be done to make aware of potential environmental hazards by the industries.

17.6.2 Extended Producer Responsibility (EPR) and Producer Responsibility Organization (PRO)

The EPR is the newer concept wherein the control of e-waste generation focuses primarily on the system instead of the production facilities, i.e., the manufacturer takes the responsibility for post-consumer stage of the product's life cycle, including its final disposal. In this aspect, the manufacturer bears the full responsibility of the manufacture, performance, and the care needed after the shelf life of the equipment. This in turn induces the industry in promoting and using sustainable product design and technology thereby preventing pollution. The main aim of EPR is promoting sustainable development via environmentally friendly product development and recovery.

EPR has been successfully implemented in developing countries but is still in its infancy in developing countries. For example, Germany was the first country to implement EPR policies in spirit followed by other European countries in facilitating legislative policies for implementation of EPR. In the United States, it is the state's prerogative for implementing EPR wherein the state directives dictate policies like disposal fees and refund system and compulsory take-back of old electronics. Similar policies are also implemented in Japan, but the regulations allow charging the consumers for the benefit.

17.6.3 Responsibility of Citizens

Another important aspect in controlling e-waste generation is proper management of such electronic products used by the consumers. In this context, consumers should be advised to use the electronic products till the end of its shelf life with proper servicing schedules to increase their life spans. Further old and unwanted electronic products should be given away for refurbishing and reusable purposes. Further, the consumers should be made aware of environmentally friendly products including their maintenance, recycling, and disposal methods.

17.6.4 Responsibility of Government

It is the government's prerogative in setting up regulatory bodies for integrating policy decisions of different authorities for management of hazardous wastes. In principle, the government should lay down regulations, laws, administration, and penalties for management of such wastes. The regulations should entrust the agency in monitoring the activities of the government. It should provide information on raw materials procured and used by the different manufacturers and supervisory authority on checking the roster of the industry (Skinner et al. 2011).

Further, relevant information on the toxicity of the materials and the results of their testing for adverse health and environmental effects should be made available to the regulatory authority. Policies related to risk management should be clearly mentioned for the manufacture, processing, distribution, use, and disposal of electronic wastes. The government should promote the concept of reuse of e-waste and discuss potential business avenues for the same. Similarly, they should impart education to the consumers on the environmental and health effects of such wastes and suggest precautionary measures for such cases (Skinner et al. 2011). Finally, the government should use the endeavours of NGOs in managing such voluminous quantities of waste and can explore partnerships with them for promoting reuse and recycling of the wastes.

17.7 E-waste Legislation in India

In the context of management of health effects of such wastes, the government has highlighted the latest E-waste Management and Handling Rules, 2011. It was approved in May 2011 and came into effect in May 2012. A year's time was given to the industries to make them aware of the rules and policies so as to help them abide and consider the products they manufacture. Some of the important excerpts from the rule are as follows: (Garlapati 2016)

- As per Schedule-I, regulations will be applicable to producer, purchaser, collection centres, and recycling of the wastes. The CPCB and SPCB will be the main regulatory authorities.
- The Battery Management and Handling Act passed in 2001 will encompass all industries producing lead batteries, whereas the Enterprises Development Act will be responsible for handling all micro- and small-scale industries. Similarly, the Atomic Energy Act of 1962 will cover all radioactive wastes.
- Schedule-I will be applicable to all manufacturing equipment's and raw products involved in the generation of the electronics and the electrical appliances and will be functional part of the product till the shelf life of the goods.
- The regulations also impose stringent measures on the hazardous materials used in the production and enables reduced use of such materials in electronic goods and appliances. This suggests that the manufacturers have to abide by the specified ranges of heavy metals used for the manufacture of such goods.
- The MOEF/CPCB has the final authority in deciding the use of any hazardous waste material which does not conform to Schedule-I components after comparison.
- The manufacturing unit is beyond the scope of Schedule-I components; the wastes generated from such manufacturing processes have to be transferred to a recycling facility and ensured that complete recycling takes place.

In the context of management of health effects of such wastes, the government has highlighted the 'E-waste Management and Handling Rules, 2011' which was approved in May 2011. The potential drawbacks of the legislation have been discussed in detail elsewhere (Ganguly 2016). However, to summarize, one of the major potential flaws of these regulations is subdivision of enforcement policy between state and the centre. This could possibly induce 'spillover' from those states which diligently implement the regulations to other states which might be slightly lax in imposition. This would also involve additional administrative costs to the states in keeping detailed roster about the details of formal recycling units within their jurisdiction (Skinner et al. 2011). The regulations also discuss about bringing the informal sector within the purview of the governmental monitoring but do not discuss in detail how the process will be implemented and the fate of the workers associated with the informal sector. Further, the regulations also fail to describe how awareness about the hazards of e-waste would be distributed to the consumers. This is particularly important as manufacturers do not describe the potential pitfalls of electronic wastes on the packaging as a result of which consumers are unaware about safe disposal of these products after their life span.

17.8 Recycling of E-waste

Recycling of hazardous wastes is one of the most economical methods for preventing environmental problems associated with them and is even commercially viable. However, setting up of recycling of such wastes involves detailed logistical planning and requirement as it involves collection, transportation, segregation, treatment, recovery, and disposal of such wastes. In principle, such logistical functioning should be supervised by the pertaining regulatory authority and incentives should be provided for improving the functioning of the entire system. As mentioned earlier, the NGOs at national and state levels may be involved for smooth functioning of such systems (Garlapati 2016).

Further, skilled personnel should be involved to ensure environmentally friendly practices of recycling as they help in separating out toxic materials and recover materials from the complex electronic system. Recycling facilities should have control equipment for capturing air emissions released from the toxic pollutants during the recovery process. Proper control equipment and safety measures should be provided to the personnel involved during the recovery process. In this context, methods like bioleaching which involves use of microbes for recovery of precious metals are more favourable as it prevents exposure to personnel and is an environmentally friendly method.

This is particularly important in Indian context as majority of the recycling operations are carried out by the unorganized (informal) sector. This sector is responsible for about 90–95% of all recycling activities in India with an efficiency of about 30% in recovery of precious metals. The sector mainly comprises of unskilled labourers who reside from city slum areas and use pristine methods to carry out such recycling methods, exposing them to such harmful toxics like acidic solutions, fumes, burnt residual ashes, and other agents and in turn causing asthma and respiratory, reproductive, and physical injuries. Long-term exposure may also lead to cancer. Since the informal sector falls outside the purview of the government, they are not guided by governmental healthcare policies and hence suffer from such repeated exposures.

In contrast, the organized sector (under governmental regulations) accounts for only 10–15% of the recycling process carried out in the country. The problems experienced by the formal sector of recycling are the competition faced from the informal sector in the collection and disposal of e-waste leading to financial losses. Further, many of the collected e-waste are transferred for refurbishing or resold with only a small proportion accounting for the recycling process. The treatment process used by the formal recycling sector is an environmentally friendly process without the use of toxic chemicals or open incinerations. Primarily, the clients of such formal recycling units are surrounding industries and even MNCs.

17.9 Economic Potential from E-waste

E-waste is a potential income-generating source for industries and also has the potential for creating a new job market in India. This is primarily because a large proportion of e-waste consists of precious material in sufficient quantity to be harnessed for potential economic viability. Further, there exists scope for reusing some materials from older e-wastes to newly built electronic equipments like circuit boards, capacitors plastics, and other components. Further, thermo-chemical treatment is a viable option for treating plastic waste generated from e-waste as it is an environmentally friendly process (Garlapati 2016). This treatment process can lead to production of synthetic fuel from plastics which can be used to power diesel generators (Kantarelis et al. 2011). The plastic waste generated from the e-waste can also be used as a raw feed for production of hydrogen using two-stage pyrolysis-gasification systems (Acomb et al. 2013). Other possible recovery from e-waste includes use of LCD computer screens as electrodes for electricity generation from Microbial Fuel Cell (MFC) (Gangadharan et al. 2015). Such business initiatives can possibly reduce dumping of e-waste.

17.10 Conclusions

E-waste is one of the fastest-growing wastes in both developed and developing countries due to rapid obsolescence of present-day modern electronics. The chapter discusses about the existing condition of e-waste generation both globally and in the Indian context and the need for quantification of overall wastes generated. Discussion on health effects of exposure to such hazardous wastes has also been presented in the chapter. The chapter further discusses some of the E-waste management strategies in India including the specific roles of the government, manufacturers, and the consumers in reducing generation and impacts of e-waste. This includes important tools like EPR, implementation of legislations, and establishment of recycling facilities to ensure safe disposal of such wastes in an environmentally friendly manner. The chapter also discusses in detail the importance of recycling such e-wastes including the roles of both the formal and informal sectors involved in the process. The chapter also discusses the existing legislation of handling such e-wastes in India and some of the potential drawbacks associated with the existing legislation. A discussion on potential business initiatives from the generated e-wastes has been presented.

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