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E-Waste Management in India – An Overview

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Abstract: The existing practices of e-waste management in India suffer from quite a few disadvantages like appropriate inventory, unhealthy conditions of informal recycling, inadequate legislation, poor awareness and reluctance on part of the corporate to address the critical issues involved. As such, these lead to toxic materials entering the waste stream with no special precautions to avoid the known adverse effects on the environment and human health and recoverable bye-products are wasted when economically valuable materials are dumped or unhealthy conditions are developed during the informal recycling. This paper attempts to provide a brief insight into this concept of e-waste, its generation in India and the environmental and health concerns attached to it. Further, it highlights the e-waste recycling economy in the existing informal and the nascent formal sector and the immediate need for a more defined legislation and strategies to tackle this problem.

Keywords: *E-waste, Management of E-waste, recycling of E-waste, E-waste management strategies, sustainability*

1. Introduction

The electronics industry is the world's largest and fastest growing manufacturing industry [1]. In the last few years, it has played a significant part in socio - economic and technological growth of societies. The Basel convention defines wastes as substances or objects which are disposed of or are intended to be disposed of by the provisions of national laws. There are so many types of wastes and e-waste is one of its types. Electronic waste or e-waste for short is a generic term embracing various forms of electric and electronic equipment that have ceased to be of any value to their owners. The approach of consumer targeted growth policy combined with rapid product obsolescence and technological advances have generated a new environmental challenge; the threat of "Waste Electrical or Electronic Equipment (WEEE)" or "e-waste" that consists of obsoletes electronic devices. Table 1 presents the different definitions of e-waste as per different conventions. E-waste is one of the fastest growing waste streams in the world. In developing countries, WEEE accounts for 1% of total solid waste and is expected to grow to 2% by 2010 [2].

Two major problems are associated with generation of WEEE including the large volume generated and safe environmental disposal of e-waste. Studies conducted have shown that about 3.3 hundred thousand tons of e-waste is generated annually in India and the total generation of e-waste was almost about 4.8 tons by 2011 as predicted [3]. TRAI reports suggested about 113.26 million new cellular customers in 2008, with an average 9.5 million customers added every month. Cellular market grew from 168.11 million in 2003–2004 to 261.97 million in 2007–2008 [4]. In 2006, microwave ovens and air conditioners registered a growth of about 25%. Refrigerator sales amounted to 4.2 million in 2006–2007 and its production went up by 17% as compared to the preceding year. Washing machines, which have always seen poor growth, have seen reasonable growth in 2006. The sale of color televisions (CTVs) is increased 3 times by 2007 [5]. Of the total amount of e-waste that is generated only about 19,000 tons of the e-waste is recycled, 95 % in the informal sector. E-waste contains valuable constituents such as precious and strategic metals like silver, gold and copper and hence is economically viable to recycle. The processes includes disassembly of the e-waste and the extraction of valuable materials which poses environmental and health hazards, if such recycling activities are carried out by the informal sector in an unregulated manner [6]. This is an interesting paradox as it combines an emerging problem with a business opportunity of increasing significance, given the volumes of e-waste being generated and the content of both toxic and valuable materials in them. The fraction including iron, copper, aluminum, gold and other metals in e-waste is over 60%, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70% [7]. Since the recovery and extraction procedures in the informal sector are highly unregulated, use of crude and highly hazardous techniques is used for processing and extraction of recoverable bye-products from the e-waste. The role of informal sector in collection, segregation and dismantling plays a beneficial role both environmentally and socially. The environmental benefits stem from higher levels of efficiency in secondary processing if the primary processing is done manually, which is the standard practice in the informal sector. The social benefits are

due to retaining and creating jobs in the sector in the process of ensuring environmentally sound recycling of e-waste. This implies that the role of the informal sector is essential even when an economy graduates from an unregulated to a regulated system [8]. Solid waste management, which is already a huge problem in India, has become more complicated due to e-waste. Further, e-waste from developed countries find an easy way into developing countries in the name of free trade [9] is further complicating the problems associated with waste management. The paper discusses the emergence of e-waste in India, existing legislations and provides sound management strategies for dealing with huge volumes of generation of e-waste in India.

Table 1: *Definition of E-waste as per different conventions*

Ref	Definition
EU WEEE Directive (EU, 2002a)	"Electrical or electronic equipment which is waste including all components, sub-assemblies & 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 Convention Action Network (Puckett & Smith, 2002)	"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 (2004)	"An electrically powered appliance that no longer satisfies the current owner for its original purpose."
StEP (2005)	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."

2. Objective

The major objective of the paper is to present an introduction to e-waste, discuss its global context, the environmental and health hazards, its generation in India and the legislations laid out by the Government of India to combat this issue. It reviews the existing legislation regarding e-waste in India and its drawbacks so that remedial measures can be undertaken for better management of e-waste in India. The paper also looks at the economical aspect of e-waste including the existing informal sector in India and the nascent formal sector developing in India. Some proposed strategies have been discussed for better management of e-wastes in Indian context.

3. Categorization of E-waste

Characterization of e-waste is complex as e-waste as it contains lots of substances classified as hazardous and nonhazardous substances. As per EU Directive (EU 2002), WEEE consists of 10 categories of e-waste. Table 2 shows the different categories of WEEE out of which 95% of the total WEEE is consists of items between numbers 1 and 4 shown in Table 2 [10].

Table 2*: Different Categories of WEEE*

Sr. No	Category	Label	% Contribution
1	Large household appliances	Large HH	42.1
2	Small household	Small HH	4.7
3	Consumer equipment	ICT	33.9
4	Lighting equipment	CE	13.7
5	Electrical and electronic	Lighting	1.4
6	Toys, and leisure and sports equipment	E&E tools	1.4
7	Medical devices (with the exception of all implemented and infected products)	Toys	0.2
8	Monitoring and control instruments	Medical equipment	1.9
9	Automatic dispensers	M&C	0.1
10	Automatic dispensers	Dispensers	0.7

4. E-waste in Global Context

E-waste is the fastest growing municipal waste across the world, and more than 50 MT of e-waste is generated globally every year. The developed western economies accounted for only 2 % of the total solid waste generated in developed countries by 2010. Developing countries with increasing consumer base and an anticipated rise in the sales of electronic products in these countries due to their heavy prospective demand would experience rapid economic and industrial growth along with the huge quantity of e-waste generation that will be of serious concern [11]. Recent studies carried out by UN reports that e-waste from old computers would jump by 400 % in China and by 500 % in India on 2007 levels by 2020. Further, e-waste from discarded mobile phones would be about seven times higher in China and, 18 times higher in India than 2007 levels by 2020 [11]. Such predictions highlight the urgent need to address the problem of e-waste in developing countries like India where the collection and management of e-waste and the recycling process is yet to be properly regulated. According to the UNEP, China, India, Brazil, Mexico and others would face rising environmental damage and health problems if e-waste recycling were left to the informal sector. The EU (30%) and the U.S (28%)

accounts for maximum e-waste generation during this current decade [12]. As per the Inventory Assessment Manual [13], it is estimated that the total e-waste generated in the EU is about 14-15 kg per capita or about 5MT to 7MT per annum whereas India and China, contributes less than 1kg [11]. In Europe, e-waste accounts for 6 million tons of solid waste per annum. The e-waste generation in the EU is expected to grow at a rate of 3 per cent to 5 per cent per year.

A major reason for the rapid generation of e-waste and the resulting growth of the recycling market can be found in the high rate of obsolescence in the electronics market. Most electronic goods, especially in the West, have very short life span. Such goods are routinely replaced at least every two years, and then either simply discarded or exported to developing countries where there is still a demand for second-hand merchandise [14].

5. E-waste in Indian Context

The complexity of e-waste flows within India and inadequate record keeping by industry participants make the estimation of the generation of e-waste within India difficult [15]. Although no definite official data are available projections based on independent studies conducted by the NGOs or government agencies are often reported. For example, according to the Comptroller and Auditor- General's (CAG) report, over 7.2 MT of industrial hazardous waste, 4 lakh tons of electronic waste, 1.5 MT of plastic waste, 1.7 MT of medical waste, 48 MT of municipal waste are generated in the country annually [16]. It was reported that about 3, 30,000 tons of E-waste was generated in 2007 [17]. Figure 1 illustrates the growing trend in demand of e-wastes in India from 2007 to 2025 as reported by [17]. The Central Pollution Control Board (CPCB) estimated India's e-waste at 0.573 MT per day back in 2005. Interestingly, reports from a study limited to examination of computers, mobile phones and televisions reckoned that about 382,979 tons of e-waste was generated in 2007, of which 50,000 tons (13%) were illegally imported [18]. Of the e-waste imported into India, it is estimated that approximately 80% is imported from the US, while the remaining 20% is predominantly imported from the EU [18]. However, since of lot of these goods are imported via third markets [15], the reliability of such statistics is questionable. According to survey of Confederation of Indian Industries, the total waste generated by obsolete or broken down electronic and electrical equipment in India has been estimated to be 1,46,000 tons per year [19].

A study released by the Electronics Industry Association of India (ELCINA, 2009) had estimated the total e-waste generation in India at a whopping 4.34 lakh tons by end 2009 [20]. The CPCB estimated that total e-waste generation will exceed 0.8 MT mark by 2012 [21]. About ten states contribute 70 % of the total e-waste generated in the country, whereas about 65 cities generate more than 60 % of the total e-waste in India. The state-wise breakup of the generation of WEEE in India was reported in a detailed study carried out in 2005 [22]. Figure 2 shows the region wise generation of e-waste in India. Amongst the 10 largest e-waste generating States, Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Figure 3 shows the percentage of generation of e-wastes in these states. Among the top ten cities generating e-waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat and Nagpur [23]. Figure 4 shows the percentage of generation of e-wastes in such cities. The main sources of electronic waste in India are the government, public and private (industrial) sectors, which account for almost 70 % of total waste generation. The contribution of individual households is relatively small at about 15 %; the rest being contributed by manufacturers. An Indian market Research Bureau (IMRB) survey of 'E-waste generation at Source' conducted in 2009 found that out of the total e-waste volume in India, televisions and desktops including servers comprised 68 per cent and 27 per cent respectively. Imports and mobile phones comprised of 2 per cent and 1 per cent respectively.

Although the per-capita waste production in India is still relatively small, the total absolute volume of wastes generated will be huge. At present, the growth rate of the mobile phones (80%) is very high compared to that of PC (20%) and TV (18%). The public awareness on e-wastes and the willingness of the public to pay for e-waste management as assessed during the study based on an organized questionnaire revealed that about 50% of the public are aware of environmental and health impacts of the electronic items. The willingness of public to pay for e-waste management ranges from 3.57% to 5.92% of the product cost for PC, 3.94 % to 5.95 % for TV and 3.4 % to 5 % for the mobile phones. The total e-waste generated for 2009 was predicted to be 0.4 kg per capita for a population of 1.12 billion in 2007 [24] Because of the important role of the refurbishment and resale market in India, only19000 tons were ultimately recycled [25]. As large household appliances constituted approximately 20% of the e-waste stream in India in 2007 [15], the inclusion of these appliances increases this figure by approximately 25%. The informal sector recycles 90-95% of the e-waste recycled in India [25].

Additionally considerable quantities of e-waste are reported to be imported [26]. Figure 5 shows the different methods of import of WEEE in Asian countries [13]. Since no confirmed figures available on how substantial are these trans boundary e-waste streams, as most of such trade in e-waste is camouflaged and conducted under the pretext of

obtaining 'reusable' equipment or 'donations' from developed nations. The government trade data does not distinguish between imports of new and old computers and peripheral parts and so it is difficult to track what share of imports are used electronic goods [1].

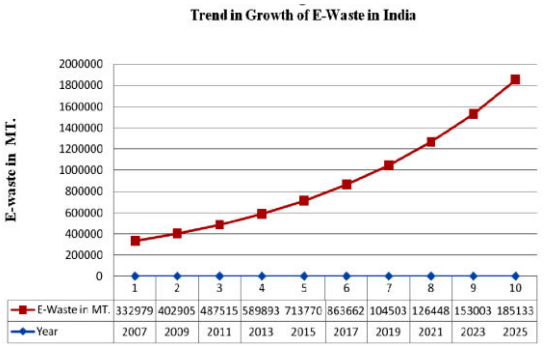


Figure 1: *Increase in trend of E-Waste in India*

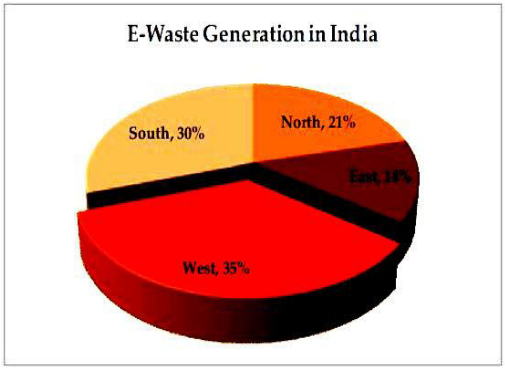


Figure 2*: Region wise generation of E-waste in India*

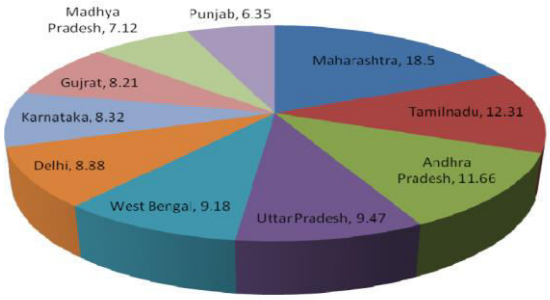


Figure 3*: Generation of E-Waste in Top 10 states in India*

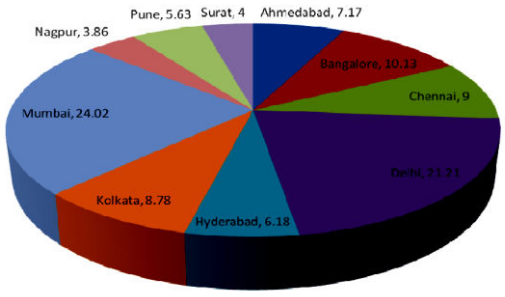


Figure 4: *Generation of E-Waste in cities in Top 10 states in India*

Figure 5*: WEEE export in Asian Countries*

6. Environmental and Health Effects of E-waste

Environmental effects of hazardous waste arise due to primary, secondary and tertiary emissions of hazardous waste. Primary emissions include hazardous waste present in e-waste including heavy metals like lead, arsenic, mercury and PCB whereas secondary emissions are generally due to incomplete treatment of e-waste which leads to generation of dioxins and furans. Tertiary emissions occur due to harmful chemicals used for recycling of hazardous waste [27]. Often electronic goods can be classified into three main categories, white goods that consist of household appliances, brown goods including televisions, and cameras and grey goods include computers, printers and scanners. Literature review suggests that grey goods are more hazardous than white and brown goods [28-29].

EEEs are made of multitude of components, some containing toxic substances that have an adverse impact on human health and the environment if not handled properly. Often, these hazards arise due to the improper recycling and disposal processes used.

Some of the major associated health impacts include affecting reproductive systems of humans both male and female, damaging lymphocytes and affecting growth retardation. Toxic chemicals present in e-waste can damage central nervous system and vital organs including liver and kidney. Continuous handling of such materials without use of protective gear can cause skin cancer, anemia, and carcinogenic tumors and may cause hormonal problems. Other problems include hypertension and psychological problems [30].

Studies conducted by Greenpeace International (Greenpeace, 2005b) studied environmental contamination from the storage of e-waste CRTs, prior to recycling from Kantinagar and Brijgang areas in New Delhi, India. The study revealed excessive high levels of toxic metals including Ni (0.4%), Pb (1.5%), Zn (2.1%), Ba (0.3%), and Cd (310mg/kg) from dust and soil samples taken from these storage sites and the values have been shown in Table 3. Lead concentrations in the soil samples were 1580 mg/kg,

which was in excess of 50 times the background soil concentration of lead with typical values varying upto 30 mg/kg.

Hence, there exists sufficient evidence of health effects of e-waste which are often very critical in nature. Both scientific and non-scientific literature show growing incidence of several lethal or debilitating health conditions, which includes cancer, neurological, respiratory disorders, and birth defects. This impact is found to be worse in developing countries like India where people engaged in recycling e-waste are mostly in the unorganized sector, living in close proximity to dumps or landfills of untreated e-waste and often working without any protection or safeguards. Many workers engaged in these recycling operations are the urban poor and unaware of the hazards associated with them. For example, such recycling activities can lead to contamination of local drinking water sources causing severe health impacts [31].

Table 3: Sample Analysis of E-waste showing speciation of different heavy metals

Metals	Powder in CRT* (mg/kg)	Soil** (mg/kg)	Dust (mg/kg)	Dust/soil (mg/kg)
Ag	52	<2	10	155
Ba	3850	277	2610	193
Cd	16800	54.5	310	16.4
Cr	11	20	86	21
Cu	74	61	439	82
Pb	494	1580	14600	1370
Ni	121	47	3900	157
Zn	273000	964	21100	506
Yt	<1	171	10500	67

7. E-waste economy in the unorganized sector

India is the second largest e-waste generator in Asia. Recycling activities of e-waste are carried out majorly by the informal sector [3]. The informal sector recycles 90-95% of the e-waste recycled in India [25]. The unorganized sector mainly consists of the urban slums of the metros and mini-metros, where the unskilled employees using the most primitive methods to reduce cost carry out recycling operations. A study by the Basel Action Network (BAN) in partnership with the Toxic Link revealed that e-waste informal recycling techniques were similar for India and China.

The unorganized sector consists of an assortment of small and informal businesses not governed by any stringent health and environmental regulations. Workers face dangerous working conditions as they may be without protection like gloves or masks. Released gases, acid solutions, toxic smoke and contaminated ashes are some of the most dangerous threats for the workers and for the local environment. Many workers function from homes to reprocess waste, further exposing themselves, their families and the environment to dangerous toxins. The workers in unorganized sector are also vulnerable to workplace hazards including physical injuries, respiratory problems, asthma, skin diseases and long-term incurable diseases like cancer [6]

The informal sector generally recycles precious components for metal recovery and the non-recoverable portions are disposed off in landfills. The efficiency of precious metal recovery is around 28-30% whereas the gold extraction efficiency is around 99.99% by the smelting companies in developed countries [6]. The e-waste trade chain in India comprises of aggregators who purchase scrap from households and businesses, followed by segregators who dismantle the components manually and sell off to recyclers who process the waste further for extraction of precious metals. Most of the workers are usually illiterate, and belong to rural parts f the country. Children of age as low as five to eight years are also employed [6]. Many workers work from homes to reprocess waste, thereby exposing themselves and their families and the surrounding environment to dangerous toxins. For example, to extract metals from circuit boards, gas torches are used to heat a board just enough to melt the solder, which separates the metal parts from the boards [31]. Metals are also extracted by soaking the circuit boards in open acid bath followed by manual scrapping to extract copper and precious materials next to open drains. In this sector, the dismantlers extract metals on their own or work with a big trader, earning about INR 100 per day. Two motherboards usually weighing one kilogram cost INR 230. A profit of 10 per cent is made after selling the metals [31]. Figure 6 shows the details of recycling of e-wastes in the informal sectors.

***Figure 6**: E-waste recycling in unorganized sectors*

8. E-waste economy in the organized sector

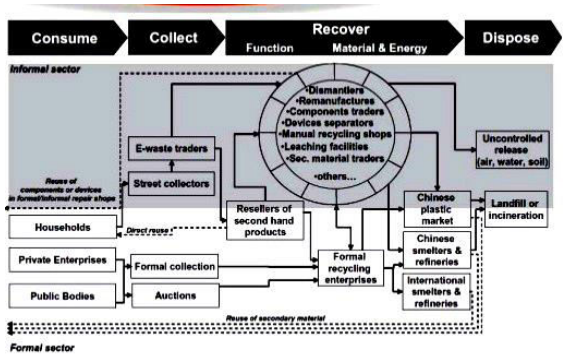
Organized recycling of e-waste in India commenced from the year 2009 and account for only 10 % of the total recycle process. One of the major problems experienced by the organized sector is the lack of proper collection and disposal mechanisms and appropriate technologies and the stiff competition from the large informal sector. Due to lack of proper collection systems, households and institutions at times end up storing obsolete products in their warehouses or storerooms. Further, they are often refurbished and resold thereby only a small percentage is recycled. This is observed from the functioning capacity of 10,000 sq. ft. formal e-waste dismantling unit in Noida (Uttar Pradesh) belonging to the TIC Group India Pvt. Ltd, which can process up to 500

tons of e-waste annually but has processed only 200 tons till date after its launch in 2008. Similarly, the Attero recycling unit in Roorkee (Uttarakhand) can process 36,000 tons of waste in a year but is functioning at a capacity of 600 tons. The organized sector is further hampered due to lack of refineries for precious metals recovery. Therefore, according to the e-waste recyclers' association formed by organized recyclers in July 2009, the only way to sustain formal business in the current scenario is the license to import [31].

Opinions however differ on the issue of license to import as the only way to sustain formal business in the current scenario. Many are of the view that the aim of e-waste management should be safeguarding environment rather than sustaining businesses. Further, allowing imports would mean many non-recyclable hazardous materials dumped in our landfills from other countries that should not be allowed and is ethically wrong.

Unlike the informal recyclers, the formal recyclers do not use any chemicals or incinerations and use environmentally sound processes. Clients of the formal recyclers include multinational companies, who do not want their products to enter the grey market and compete with their new products. Unlike the organized sector, the informal dealers refurbish and sell a computer, even if it can be classified as e-waste, with some parts of it in working condition [31]. Selling any part of a computer that is functional would fetch more money than selling it as metal parts [31]. About 10 per cent of the e-waste generated every year is recycled and the remaining is refurbished. Figure 7 shows the E-waste recycling components in the organized sector.

Figure 7: *E-waste recycling in organized sectors*



8. Integration of unorganized and organized sector in India

The process of integrating the informal sector with the formal sector poses significant challenge. In practice, majority of recyclers in the informal sector dismantle and sell the components to local recycling units whereas others are involved in recovering bye-products. Similarly, e-waste recycling units in India permitted by the government are involved in dismantling of the used equipment. The plastics, steel, aluminum, glass etc. are recycled in India while the printed circuit boards are shredded and exported to other countries like Europe, Singapore, Australia, and even China for precious metal recovery [6].

The path to formalization of the informal sector units would require a number of steps. This would involve in identification of clusters in the informal sector. This process should also raise the awareness level in the workers in informal sector regarding the harmful effects of e-waste and how to avoid them thereby also educating these workers on environmental friendly processes. They should also be educated on concepts of recycling and reuse including financial benefits associated with them. Providing hands-on training, and demonstration of process efficiency will be an important step in converting them from unorganized to organized sector [6]. Most importantly, the integration would need trust, improved relations and strong bond between the two sectors for the effort to work. Further, the economical dynamics of the informal sector would change due to introduction of certain processes, which were not considered before. The government should provide financial aid, easy access to credit and provision of financial incentives such as subsidies and introduction of insurance schemes to ensure no loss of income for workers switching from the unorganized sector to organized sector. The organized sector could also support this integration process by building the capacity of informal sector associations as well as jointly developing the norms for trade of material between the two sectors [6].

9. E-Waste Legislation in India

The environmentally sound management of e-waste is a significant challenge for India. The challenge relates not only to imported e-waste, but also to the increasing amounts of domestically produced e-waste. Till date, no legislation dealing exclusively with e-waste exists. The following section examines the current regulatory framework for e-waste in India, examining existing legislation, voluntary e-waste guidelines released by the central government, and the new draft rules dedicated to e-waste management. Although no e-waste laws currently exist, two regulations – the Hazardous Waste (Management and Handling) (HWM) Rules and the Batteries (Management and Handling) Rules – are applicable to some extent [34]. The HWM Rules require receiving, treating, transporting or storing hazardous waste to first obtain permission from the relevant State Pollution Control Board (SPCB) by both a company and individual. Furthermore, the HWM Rules also stipulates banning of imported hazardous waste for disposal or dumping. The central government can revoke this by issuing an import authorization document for hazardous waste that is to be processed or reused. Amendment to the HWM Rules in 2000 expanded the scope of the Rules to include provisions on e-waste for the first time. However, these

provisions only applied to import and export activities [32].

The new Hazardous Wastes Management, Handling and Tran's boundary Movement Rules of 2008 replaced the old HWM rules that contain additional provisions on e-waste handling within India. These provisions require every person planning to recycle or reprocess e-waste to obtain prior authorization from the relevant SPCB. However, the SPCB registration process has been criticized for granting the same authorization to collectors, dismantlers and recyclers without assessing their capability to treat the e-waste in an environmentally sound manner [15]. The responsibility has been divided between the states and the central government. While central government authorizes individuals importing e-waste for processing or reuse, and the SPCBs authorize collectors, dismantlers and recyclers.

The Batteries (Management and Handling) Rules exclusively cover lead acid batteries and hence have a very limited impact on e-waste. The Batteries (Management and Handling) Rules were, however, the first regulation to implement aspects of EPR in India. Under the regulation, manufacturers, importers and assemblers are responsible for organizing a collective take-back system for batteries [15].

The allocation of responsibility under existing legislation also causes problems. Responsibility for monitoring some activities falls to the states, while the federal government is responsible for others. This combination of factors has resulted in the dominance of the informal recycling sector as environmentally sound recyclers have difficulty sourcing enough e-waste to operate at capacity [15]. Many stakeholders have thus argued, "the absence of legislation is one of the biggest stumbling blocks in implementing an e-waste management system" [17].

The draft e-waste (Management and Handling) Rules 2010 is the most recent attempt to regulate e-waste in India. The draft rules are yet to be ratified and involve no significant changes. The draft's scope includes all the stakeholders involved in e-waste handling, with a focus on producers, dealers, refurbishers, collection centers, consumers, dismantlers and recyclers. The regulation is based entirely on the EPR and IPR principles. If enacted, it would be the first piece of Indian regulation to integrate these principles comprehensively [15]. The final outcome of this draft rules are still awaited

Highlights of the draft E-Waste (Management and Handling) Rules 2010:

The draft rules state that e-waste producers have to ensure that their waste products cause no harm and that their products have been produced in line with the Reduction in the use of Hazardous Substances (ROHS) in the manufacture of electrical and electronic equipment requirements [15]. They will also have to ensure that all their products have a unique serial number or individual identification code and take responsibility for all previously generated waste branded with their name. Addition- ally, producers are responsible for implementing and financing an effective take- back system only involving authorized stakeholders [33].

E-waste dealers, refurbishers, dismantlers, recyclers and collection centers are all required to register with the relevant State Pollution Control Board (SPCB) or Pollution Control Committee (PCC). They are also required to comply with detailed provisions on how to handle the e-waste to ensure that they do not create any health hazards or harm the environment [31]. Dealers of electrical equipment are responsible for collecting e-waste by providing a collection box. They are also required to submit information about the e-waste collected to the SPCB or PCC [33].

The draft rules specify that all electrical and electronic equipment be provided with a unique serial number or individual identification code for product tracking in the e-waste management system. They shall also finance and organize a system to meet the costs involved in the environmentally sound management of e-waste generated from the 'end-of life' of its own products and 'historical waste' available on the date from which the rules come into force. The producers will also have to provide contact details of dealers and authorized collection centers to consumers so as to facilitate return of e-waste [31]. Although the draft rules require consumers to dispose of e-waste by taking it to authorized dealers and collection centers, large consumers are still allowed to auction their waste. However, they may only auction it to authorize collection centers, dismantlers, recyclers or to the collection services offered by the producers [33].

The draft rules assign all responsibility for ensuring enforcement to the respective SPCB or Pollution Control Committee (PCC). Every institution registered by the authorities has to provide the SPCB or PCC with annual reports. If a registered and authorized institution fails to comply with the regulations, the SPCB or PCC may revoke its authorization [33]. However, the draft does not specify any further concrete measures to ensure proper monitoring, implementation and enforcement. This could lead to future implementation and enforcement problems, particularly given the previous reluctance of producers to take responsibility for their waste, the failure to enforce EPR in the Batteries Rules, and the complex logistics and high potential costs involved in tracking and collecting e-waste seen in other countries.

Importantly, the draft rules also address imports. An initial draft of the rules stipulated that imports would not be allowed for recycling or disposal. WEEE imported for refurbishment or repair would be allowed, "subject to the same being exported" [17]. However, the latest draft simply states that: "Every

producer(s), dealer(s), collection center(s), refurbisher(s), dismantler(s), recycler(s), auctioneer(s) consumer(s) or bulk consumer(s) shall not import used electrical and electronic equipment in India for use" [33]. This total import ban will be very difficult for India to enforce. As all shipments are illegal, many would be falsely declared; any future distinction that export-import codes make between old and new computers would also be redundant. Although current enforcement is not working, the current draft rules do not specify how such an import ban should be enforced.

Drawbacks of the draft E-Waste (Management and Handling) Rules 2010:

The regulation seeks to formalize the informal sector by organizing, registering and monitoring their activities rather than aiming to shut them down. However, the major drawback of the proposed law is it does not entail measures for rehabilitating those personals who are involved in the unorganized sector [31]. The draft rules intend to shift recycling and metal-extraction activities to the formal sector. Ideally, the informal sector would become part of the EPR solution [6]. However, beyond requiring registration, the draft does not specify how it will ensure that informal recyclers reduce their operations to dismantling and collection activities. Furthermore, the underlying incentives that result in the informal sector being able to outbid the formal sector remain unaddressed. While formalization may be an appropriate goal, the draft rules are ill equipped to achieve it [31].

A further obstacle to the new draft rules' implementation is a lack of awareness of the hazards of improper e-waste disposal. Most manufacturers currently ship their products without any information about how to handle them at their end-of-life. Consequently, consumers are unaware of proper disposal methods. The Indian Central Government has not made any attempts to educate the general public about the issue thus far; the only education campaigns were small ones run by NGOs [15]. Informal collectors, traders and dealers of e-waste are often either unaware of the problems or do not see the necessity of acting upon them. Without seeing a reason to adopt environmentally sound recycling processes, informal recyclers will be reluctant to integrate into the formal sector [31].

Another drawback of the draft legislation is it does not describe the business plan for collection of e-waste from consumers. The legislations enacted by the Government cover generation, storage, transportation and disposal of hazardous waste but do not propose a streamlined collection mechanism [31]. Further, though the new rules takes into account the consideration of import of e-waste it does not recognize the magnitude of trans-boundary movement of e-waste under different categories, for example, under the pretext of metal scraps and secondhand electrical appliances are imported in the country which become unaccounted [31].

The Ministry of Micro Small and Medium Industries (MSME) has imposed many responsibilities on the producers (MSMEs) in regard to collection, disposal and recycling of e-waste [31]. One of the major recommendations of MSME is that environmentally sound recycling units should only be constructed by the industry. Since it involves heavy investment because of the technology involved and considering the low scale of operation and locational aspects (of producers and users), it may not be economically viable and physically feasible for each and every producer (MSME) to establish an e-waste recycling unit either individually or collectively, nor will it be feasible for them to set up collection centers individually or collectively [31]. Another major drawback in the new draft rules is landfill is the only option for disposal of e-waste [31].

Summary of the draft E-Waste (Management and Handling) Rules 2010:

In sum, the proposed draft rules are a comprehensive piece of regulation that at least refers to all-important e-waste issues. Although commendable, the draft rules are likely to encounter many of the difficulties experienced in the EU and US; the draft does little to address monitoring and enforcement mechanisms, the role of informal recyclers in India or how the import ban will be enforced [31]. The damage caused by informal e-waste recycling activities in India is immense. Future increases in metal prices are unlikely to erode the advantages that have ensured the informal sector's dominance, and the problems related to informal recycling will only increase as domestic production of WEEE grows. As a result, including the informal sector is key to achieving a successful transformation of the current e-waste handling and recycling processes. Unfortunately, the draft rules do not address this problem adequately [15]. The formalization of collectors and dismantlers may be effective, but as long as informal recyclers are able to pay more for e-waste, an incentive exists for market participants to shirk compliance and illegally sell toxic material to informal recyclers. The regulation's effectiveness at reducing the role of informal recyclers will thus depend on the ability of the respective bodies to present a credible threat of enforcement [15].

The draft rules contain several mistakes including dividing the enforcement policy between states and center which are likely to be magnified in India, a country where capacity for enforcement is already strained. Devolving enforcement to a state level may result in 'leakage' from states actively enforcing the regulation to states taking a less stringent approach. Further, the process of keeping records of organized sector participants and compliance with the regulation's requirements would be expensive in

addition to the administrative costs to formal recyclers already struggling to compete [15]. By concentrating e-waste sources, the auctions provide Indian regulators with the ability to target their enforcement to some extent. The most positive aspect of the draft rules is the inclusion of ROHS provisions [15]. Addressing the toxicity of e-waste recycling by preventing pollutants from becoming part of the e-waste stream is likely to be enforceable and represents a further convergence of India's legislation with that of the EU. However, given the role of the refurbishment market in India, it may take considerable time for the benefits of this provision to become evident in recycling facilities [15]

10. E-Waste management Strategies in India

The e-waste management strategies in India should address issues from production and trade to final disposal, including technology transfers for the recycling of electronic waste. This should include proper training, legislations and guidelines for all involved. Considering the severity of the problem, it is absolutely necessary that certain management options be adopted to handle the bulk e-wastes. Following are some of the management options suggested for the government, industries and the consumers to manage and handle e-waste effectively and in an environment friendly manner [35]. Figure 8 shows a possible e-waste management strategy in India [1].

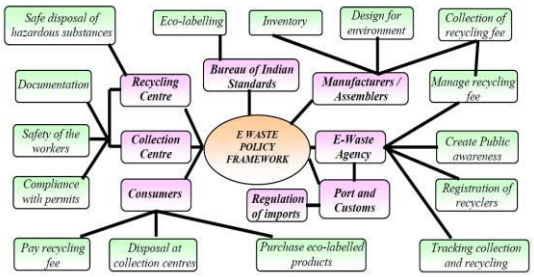


***Figure 8**: Flow sheet for Waste Management System in India*

Responsibilities of the Government

Governments should set up regulatory agencies vested with the responsibility of coordinating and consolidating the regulatory functions of the various government authorities regarding hazardous substances.

Governments should be responsible for providing an adequate system of laws, controls and administrative procedures for hazardous waste management [36]. Existing laws concerning e-waste disposal needs to be completely overhauled. A revamped legislation with policies on e-waste regulation, management and proper disposal of hazardous wastes should be formulated. Further, the law should empower the agency to control, supervise and regulate the relevant activities of government departments. The law should cater to information on the materials from manufacturers, processors and importers and to maintain an inventory of these materials [35]. The information should include toxicity and potential harmful effects. Further, identity of potentially harmful substances and require the industry to test them for adverse health and environmental effects [35]. Risk management policies should be clearly formulated for manufacture, processing, distribution, use and disposal of electronic wastes. Beneficial reuse of "e-waste" and business activities that use e-waste should be encouraged. Educational programs should be conducted for both manufacturers and consumers on harmful effects of e-waste and to promote recycling among citizens and businesses. The proposed draft e-waste (Management and Handling) Rules 2010 incorporates to a certain extent all these proposals

The proposed draft e-waste (Management and Handling) Rules 2010 should provide incentives for conducting research into the development and standard of hazardous waste management, environmental monitoring and the regulation of hazardous waste-disposal along with testing and authenticating the use of environmental friendly products for manufacture of electronic goods. Strict regulations against dumping e-waste in the country by other nations. If the laws are flouted, stringent penalties must be imposed. In particular, custodial sentences should be preferred to paltry fines, which would deter foreign nations from dumping their quota of e-waste in India. The proposed draft e-waste (Management and Handling) Rules 2010 incorporates to a certain extent all these proposals

The proposed draft e-waste (Management and Handling) Rules 2010 should enforce strict regulations and heavy fines levied on those industries that do not conform to the policies of the government. Further, the government should take strict action against those manufacturers that do not practice waste prevention and recovery in the production facilities. Uncontrolled dumping is an unsatisfactory method for disposal of hazardous waste and should be phased out [35].

Governments should encourage and support endeavor of NGOs and other organizations to involve actively in solving the nation's e-waste problems. Governments should explore opportunities to partner with manufacturers and retailers to provide recycling services [35].

Responsibility and Role of industries

Manufacturers should take responsibility to provide management options if the products sold by them include hazardous materials. Personals involved and handling such e-wastes should be properly qualified and trained at all levels including managerial and operational levels. Companies can adopt their own policies while handling e-wastes. Companies should adopt waste minimization techniques, which will make a significant reduction in the quantity of e-waste

generated and thereby reducing the impact on the environment. In reality, a "reverse production" system should be conceptualized to recover and reuse every material contained within e- wastes metals such as lead, copper, aluminum and gold, and various plastics, glass and wire for which proper infrastructure may be required. This leads to "closed loop" system with manufacturing and recovery system in place leading to recovery of precious metals thereby reducing the harmful effects of toxic chemicals on the environment. Manufacturers, distributors and retailers should undertake the responsibility of recycling/disposal of their own products [35].

Further, manufacturers of electronic products using hazardous materials must provide education to the general public regarding the potential threat to public health and the environment posed by their products. Proper labeling should be done on such products to identify their potential environmental hazards.

Responsibilities of the Citizen

Waste prevention is perhaps more preferred to any other waste management option including recycling. Donating electronics for reuse extends the lives of valuable products and keeps them out of the waste management system for long periods of time. However such products should be in proper working conditions to ensure such products are not disposed with household wastes. The products should be segregated on site and sold or donated to various organizations [35].

Sustainable product design

The following factors should be considered to reduce use of hazardous substances and incorporate innovative sustainable design concepts [35]:

Rethink the product design: New ideas should be conceptualized to design products with fewer amounts of hazardous materials. For example, new computer designs are flatter, lighter and more integrated and also use very less amount of materials.

Use of renewable materials and energy: Bio-based plastics are plastics made with plant-based chemicals or plant-produced polymers rather than from petrochemicals. Bio-based toners, glues and inks are used more frequently. Solar computers also exist but they are currently very expensive.

Use of non-renewable materials that are safer: Manufacturers and designers should ensure the product is manufactured for re-use, repair and/or upgradeability since many of the present day materials used are non-renewable in nature.

Figure 9 shows the flow sheet for sustainable electronic waste management and recycles process [37].

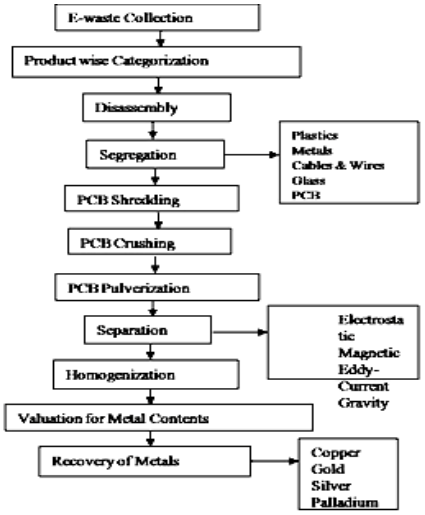


***Figure 9**: Sustainable Methods for Recovery of By-products from e-waste*

Extended producer responsibility

Extended producer responsibility (EPR) is an environmental policy approach in which a manufacturer of the product is responsible for post-consumer stage of the product's life cycle, including its final disposal. In practice, all the stakeholders along the product chain are responsible for lifecycle environmental impacts of the product. The greater the ability of the stakeholder to influence the environmental impacts of the product system, the greater the share of responsibility for addressing those impacts should be. The different stakeholders involve consumers, the suppliers, and the product manufacturers. Consumers can affect the environmental impacts of products by choosing environmentally friendly products, proper maintenance and the environmentally conscious operation of products, and by proper recycling and disposal methods. Suppliers play a significant role by providing manufacturers with environmentally friendly materials and components. Manufacturers can reduce the life-cycle environmental impacts of the products by using appropriate product design, recyclable material choices, environmental friendly manufacturing processes, product delivery, and product system support [38].

The goals of the manufacturer involve reducing toxicity and use of energy, streamlining product weight and materials, identifying and incentivizing the concept of recycling and reuse. Manufacturers can improve design components by reducing or totally substituting the use of hazardous substances such as lead, mercury, cadmium, hexavalent chromium and certain brominated flame retardants; techniques to identify and reuse components and materials, including plastics and measures to promote the use of recycled plastics in new products.

Manufacturers should give incentives to their customers for product return through a "buy back

approach" whereby old electronic goods are collected and a discount could be given on new products purchased by the consumer. All vendors of electronic devices should provide this option for their products at the end of life of those products. The old electronic product should then be sent back to be carefully dismantled for its parts to be either recycled or re-used, either in a separate recycling division at the manufacturing unit or in a common facility permitted by the government. Existing companies in India that are involved in buy back policy are Apple, Microsoft, Panasonic, PCS, Philips, Sharp, Sony, Sony Ericsson and Toshiba and observe take back policy at their production plant. Samsung supposedly has only a single take back service and only one collection point for the whole of India while some other branded companies do not have taken back service. HCL and WIPRO have some of the best take back policies in India. Other brands that do relatively well are Nokia, Acer, Motorola and LGE [30].

Consumer driven solutions

Properly educated customers aware of the consequences of e-waste are likely to not only participate in appropriate initiatives but also spread the word about the dangers of e-waste while promoting alternatives solutions to their disposal. An example of a consumer driven solution is concept of free cycle. Free cycle is a US based initiative that works via the use of internet-based technologies. Members use features of Yahoo groups such as blogs, e-mails and distribution lists to post details of unwanted items, and other members can act in response to the offers. Another similar example is the use of Craigslist wherein one posts unwanted electronic goods and is brought by another personal. The company suggests that a conservative estimate of one pound per item exchanged through the group, thereby saving 40 tons per day from landfills [35]. Another aspect to the consumer driven approach is 'responsible purchasing'. This stems from the notion that if consumers are aware of the environmental impact of their purchases; they will be inclined to choose between manufactures for the most environmentally friendly products [35].

Innovative EEE designs

In the future engineers and designers of EEE will have to consider e-waste when developing new products, creating mechanical and electrical design interfaces will become more challenging considering regulations from the EU legislation on WEEE and Restriction on Hazardous Materials (ROHS) directives. The fundamental engineering challenge will need to addresses three important themes [39] The systematically design new electronic products with a high degree of certainty that they will function properly; new product designs must be compliant with new EU directives involving environmental protection and recycling; and all designs must meet stringent US and international electromagnetic compliance requirements.

Recycling

Discarded machines often contain reusable parts that could be salvaged and combined with other similarly discarded equipment's to create a working unit. Institutional infrastructures including e-waste collection, transportation, treatment, storage, recovery and disposal need to be established at national and/or regional levels for the environmentally sound management of e-wastes. These facilities should have regulatory permits from concerned authorities and if required should be provided with appropriate incentives for its smooth operation. Establishment of e-waste collection, exchange and recycling centers should be encouraged in partnership with governments, NGOs and manufacturers [35].

Environmentally sound recycling of e-waste involves sophisticated technology and processes, which are highly costly to implement and also require skilled personal for its operation [35]. Proper recycling of complex materials requires the expertise to recognize or determine the presence of hazardous or potentially hazardous constituents as well as recoverable products and thereby direct the recycling process systems in an appropriate manner. Appropriate air pollution control devices for the fugitive and point source emissions are required for operation and should be installed [35]. Guidelines are to be developed for environmentally sound recycling of e-wastes.

Public awareness campaign

Public awareness of the e-waste problem is a beginning and the public has to be willing to support the companies and manufacturers that properly dispose of e-waste even if the cost of their products is slightly higher. Consumers hold the power but need to be educated with the facts of harmful effects of e-waste. Recycling initiative is often started by an individual and with a little effort and the average individual could learn where to recycle their electronic products [35].

The future of e-waste management depends not only on the effectiveness of local government and its policies nor only the manufacturers nor operator of recycling services, but also on the attitude and willingness of citizens for recycling of e-waste and on the key role of manufactures and bulk consumers to shape and develop community participation. Often, lack of civic sense and awareness among city residents are major hurdles involved in keeping e- waste out of municipal waste stream. Collaborative campaigns are required to sensitize the users and consumers should pay for recycling of electronic goods.

The general public needs to be educated about the harmful impacts of e-waste and hence Awareness raising programs and activities on issues related to the environmentally sound management (ESM) practices

for disposal of e-wastes should be conducted. Technical guidelines for the ESM of e-wastes should be developed as soon as possible [35].

Design for the environment (DfE)

An important concept that has the potential to tackle the e-waste predicament is the Design for Environment (DfE) concept [40]. The Design for the Environment (DfE) Program is a global initiative that is overseen by either government or nonprofit organizations within a country. DfE organizations typically work in partnership with a variety of stakeholders to reduce risk to people and the environment by preventing pollution. The remit of a DfE program can be broad covering chemical risk reduction, energy efficiency to facilitate positive and sustainable changes chemical assessment tools and expertise to inform companies of substitutions to safer chemistries. Design for Environment (DfE) and better management of restricted substances may be implemented through measures such as specific product recycling obligations for industry, financial responsibility for actions and schemes, greater attention to the role of new product design material and/or substance bans including stringent restrictions on certain substances and greater scrutiny of cross-border movements of Electrical and Electronic Products and e-waste

Further, public awareness should be increased by labeling products as 'environmental hazard'. Mandatory labeling of all computer monitors, television sets and other household/industrial electronic devices may be implemented for declaration of hazardous material contents with a view to identifying environmental hazards and ensuring proper material management and E- waste disposal.

The key questions about the effectiveness of such methods would include the categories of items covered under e-waste, responsibility of manufacturer, incentives for voluntary commitments, pricing and responsibilities for disposal systems and effective by product recovery to make the disposal system environmentally friendly [35].

A complete national level inventory must be initiated. A separate e-waste regulatory body must be developed must be developed. This could be a Working Group comprising of Regulatory Agencies, NGOs, Industry Associations, experts etc. with adequate experience to keep pace with the temporal and spatial changes in structure and content of E-waste. This Working Group can be the feedback providing mechanism to the Government that will periodically review the existing rules, plans and strategies and legislation for e-waste management [35].

The efforts to improve the situation through regulations, though an important step; are usually only modestly effective because of the lack of enforcement. While there has been some progress made in this direction with the support of agencies such as GTZ, enforcement of regulations is often weak due to lack of resources and underdeveloped legal systems. Penalties for non-compliance and targets for collection or recycling are often used to ensure compliance [35].

11. Strategies for educating consumers on e-waste:

It is imperative to educate the worldwide population on the harmful effects of e-waste. An integrated approach needs to be developed and coordinated by the world governments for education purpose rather than following the traditional straight-line approach. Different levels of education should be provided to different stages of population and also keeping in mind the diverse population group. The straight line approach provides the educational step in sequential manner and is often not flexible enough to address diverse population groups (youth, family and mature life) hence it becomes difficult for the different stake holders to identify the information imparted to them. This method would increase the complexity and it would be almost impossible to get the message through [35]. Figure 10 shows the e-waste educational strategy [35].

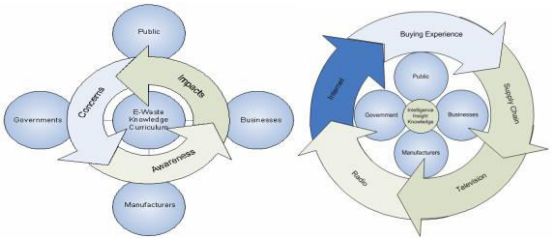


***Figure 10**: E-waste educational strategy in India via different mediums*

Further, consumers are to be informed of their role in the system through a labeling requirement for items. Consumers should be educated to buy only necessary products that utilize some of the emerging technologies (i.e. lead-free, halogen-free, recycled plastics and from manufacturers or retailers that will 'recycle' their product) to be identified through eco-labeling.

E-waste education strategy 1

The first stage of the educational strategy involves educating the consumer during the time of purchase. An informed consumer at the time of purchase broadens direct coverage for providing information and offers suitable alternative to educate consumers with critical insight and information. Further, such educational strategies should be extended to those companies involved in mass purchase of electronics so as to educate them on different options and various processes to reduce the impacts of e-waste.

E-waste educational strategy 2

This stage of the process draws support from the businesses and manufacturers that create and sell the electronic products to the industry. It will be their

responsibility of these businesses to enforce the process of education and deliver valued solutions to all audiences and consumers. Implementation of such additional processes results in additional costs to the product which can be offset by implementing a disposal or educational retainer surcharge. This will increase buyer's educational insight on the product since they are paying a surcharge on the products they are purchasing and hence may think twice before inappropriately disposing the item

E-waste educational strategy 3

The third stage involves use of existing media channels (e.g., radio, television, newspaper) to deliver high level awareness and create awareness on the effects of e-waste. Finance could be an issue for such advertising details particularly on such a mass scale however; the strategy will look to the media companies to fulfill their corporate social responsibility. This strategy will also utilize current non-profit organizations and forums to continue their efforts and support the educating actions.

E-waste educational strategy 4

This stage utilizes the internet and social media network for educating the audiences on the impacts of e-waste. Since the internet has a global reach worldwide, it is one of the truly possible strategies that can be utilized to convey the harmful effects of e-waste reaching out to huge population worldwide.

E-waste educational strategy 5

The final stage involves high level cooperation between different governments of the world. A memorandum of agreement should be signed between governments and those countries signatory to such memorandum will have the responsibilities to educate and oversee processes related to e-waste. This strategy will most likely be the component necessary for eliminating the roadblocks under strategy 4.

E-waste curriculum development strategies

E-waste is considered to be a critical risk to environment and has been portrayed as one of the key issues that need to be considered under banner of sustainable development. Providing education through sustainable development activities has gained significant ground since the launch of the United Nations Decade of Education for Sustainable Development in 2005. In this context, UNESCO has developed toolkits and learning resources that incorporate the standards, values, and practices of sustainable development into all parts of instruction and learning. It is expected that these educational programs and learning resources will educate and encourage the general population to seek sustainable products for betterment of future generations [41].

E-waste education introduction courses

General modules on environment could be introduced at the high school level or in undergraduate levels and discussions can be done through case studies, research projects or group discussion to illustrate the challenges of e-waste in society. These modules can be developed depending upon the age of the general public. Awareness of e-waste can be build up in the society via media, journalistic articles, social sciences and general education courses.

12. Sustainable engineering: using whole system design concept

Whole System Approach (WSA) is a procedure, which involve links between sub-frameworks and frameworks and which employs one solution for multifaceted problems. Developing and teaching the concept of WSA to engineers and designers is crucial for developing cost effective measures to reduce environmental health impacts of e-waste. Designers and planners need to know how to actualize WSA ideas to guarantee feasible plans. Considering the 'end of life' procedure of an item at the outline stage will have colossal profits to ecological manageable quality [35].

13. Green IT: reducing waste in the IT environment

Green IT is a multi-faceted approach to securing and maintaining sustainable operation in an IT business capacity. Sustainable IT is gaining acceptance in numerous workplaces in India. A review of both the government and corporate organizations revealed that 80% of IT operatives accept utilizing sustainable IT business solutions in their business and 49% refer to positive reputation as one of the major achievements. About, 51% of IT chiefs refer to cost as a major disadvantage for implementing sustainable IT innovations while 25% refer to multifaceted difficulties execution and maintenance and 21% refer to potential interruptions to current IT structure [42]. An alternate thought is the idea of product service systems: and is known as sustainable or eco-efficient services. This idea urges clients to lease both hardware and software components whereas the vendor maintains the ownership and upkeep responsibility of the product.

14. Issues and Challenges

The most critical issue for e-waste administration in India is the installation of assembly pipelines that bring the waste from the generator to the recycler. As of now, the greater part of the material that reaches the recyclers is reused in a way that disregards the ecological, wellbeing and safety standards. Installation of recycling infrastructure conforming to proper environmental regulations would be insufficient since they face stiff competition from informal waste handlers. As such, proper and evaluative models need to be developed between the organized and the unorganized sector. Such models would require agreeable policies that characterizes and defines the roles of the different stakeholders. As such, this

system would provide initial steps to create a level playing field for those involved in e-waste administration.

Further, development of workable models is needed which are suitable for the Indian conditions and which are backed by the government policies. Since waste administration has clear societal benefits, government legislations should provide facilitation, mediation and incentives for proper working of these models. In the Indian setting, due to the presence of highly unorganized sector, the role of the administration is greatly increased and should involve concerted efforts to educate the masses for increasing the acceptability of the new practices.

There is an essential need of assimilating both organized and unorganized sectors to create a practical recycling model for e-waste recycling. In particular, unorganized sector needs to conform to organized sector for better economical and environment friendly solutions for e-waste administration in India. The different stakeholders included in this assimilation procedure would work under National Environment Policy (NEP) to ensure that the unorganized sector conform to environmental friendly e-waste management techniques to reduce problems related to environmental health and safety

15. Conclusions

Management of solid waste is a huge task and has become more complex due to introduction of e-waste in Indian solid waste disposal system. The paper discusses the need for detailed assessment of the current and future scenario of e-waste generation and its disposal including the need for a proper management system including quantification, characteristics and existing disposal practices. The paper also discusses both informal and formal sectors of recycling prevalent in India and explains the integration amongst these two methods for recovery of precious metals, plastic, glass and other materials which reduces the magnitude of e-waste as they have a potential to conserve the energy and keep the environment free of toxic material that would otherwise have been released. The paper discusses some of the sustainable e-waste strategies including the different roles played by the different stakeholders including the manufactures, consumers, regulators, municipal authorities, state governments, and policy makers which can severely reduce the impacts of e-waste. This includes a discussion on an "e-waste policy" and existing national legislative guidelines proposed by the GOI along with its drawbacks. Other methods of controlling of e-waste have been discussed including responsibility of product manufacturers in production of products that could be reused, repaired and upgraded. The paper also addresses different suggestive remedial measures for controlling e-waste including innovative approaches to addressing the e-waste educational challenges such as incorporating whole system design concepts into engineering and implementing green IT concepts to reduce waste and infrastructure costs. General methods of raising awareness of harmful effects of e-waste could be done using social media, journalistic articles and general education.

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