E-Waste Management in Unorganized and Organized Recycling Sectors:A State of Art

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ABSTRACT
Over the past decade, electronic advancements have revolutionized the human lifestyle. These advancements result in huge amount of discarded or obsolete electronic items which need proper management and recycling. E-waste constitutes both hazardous and non-hazardous materials and therefore needs to be treated by an organized E-waste recycling sector having advanced machinery and adequate safety standards. Unfortunately, the present E-waste management agencies have not been able to eliminate the interference of unorganized E-waste recycling sector. Therefore, majority of E-waste is handled by unskilled poor labor who is completely unaware of the subsequent occupational hazardous. Unorganized E-waste recycling has also become a potential threat for the environment as it involves exposure to toxic chemicals and careless disposal methods. The present paper high lights various hazards of unorganized E-waste recycling and simultaneously give an insight about the organized E-waste recycling sector. Further, a three tier set of recommendations for government agencies, industrial sector as well as for the consumers has been proposed in this paper.

Keywords: E-waste, Unorganized sector, Organized sector, Hazardous, Recycling

I INTRODUCTION

In the modern world of technological advancements, natural environment is being greatly deteriorated due to human interference in variety of ways. As soon as any electronic device gets upgraded, its older version gets obsolete. This use and throw attitude of consumers has worsened the situation. Massive increase in population has also directly influenced the rate of production and utilization of electronic devices through various utility sectors such as information and technology, music and entertainment, virtual gaming, telecommunication and others. Waste Electronic and Electrical Equipment (WEEE) may be broadly classified as appliances used in household (washing machines and refrigerators), information technology (IT) and consumer equipment (monitors, personal computers, laptops, TVs, DVD players, mobile phones, mp3 players) and leisure and sporting equipment. The components of various appliances like batteries, circuit boards, activated glass, CRTs, plastic casings, and lead capacitors also come under the category of electronic waste. Hence any electronic equipment which reaches towards its end of life and is not capable to fulfill its usage purpose anymore falls in the category of WEEE or commonly referred to as E-waste.

II HAZARDOUS CONSTITUENTS OF E-WASTE AND ITS CATEGORIZATION

It constitutes both hazardous and non-hazardous materials which require careful recycling practices in order to avoid or minimize the environmental pollution. Some hazardous metals found in electronic waste are lead, cadmium, chromium, mercury, copper, manganese, nickel, arsenic, zinc, iron, and aluminum. Apart from these metals, E-waste includes variety of persistent organic pollutants such as brominated flame retardants, polybrominated diphenyls, dibrominated diphenylethers, polychlorinated biphenyls, poly chlorinated or poly brominated dioxins and dibenzo furans dioxins, hexabromocyclododecanes, and perfluroalkyls. The valuable components include gold, silver, palladium, platinum and other precious metals. However, extraction of these metals involves tedious and risky procedures.

Due to presence of such large variety of materials, categorization of E-waste becomes complex. Categorization of E-waste is the foremost step in order to develop an efficient recycling mechanism. To sort this problem, EU (European Union, comprising of 17 developed nations) has listed ten different classifications as shown in figure 1. It can be clearly seen that the majority E-waste comes from large and small household devices, Information and technology, consumer electronic items and lightening furniture.

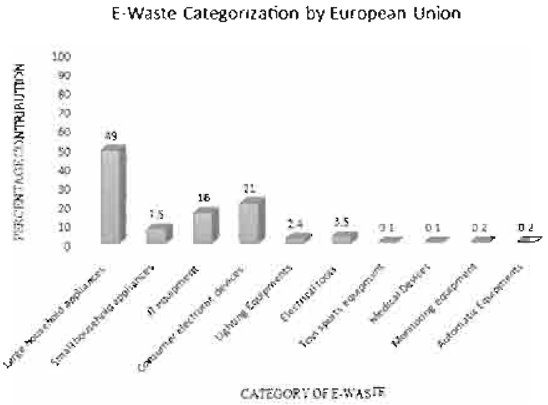

Fig.1: E-waste categorization as per EU directives

III E-WASTE GENERATION AND QUANTIFICATION

Sources for of E-waste generation in India can be broadly classified into domestic generation and foreign dumps. The domestic generation includes E-waste from all utility sectors established in various states of our country. About 70% of domestic E-waste generation is accounted for by public and private sectors where as the

individual municipal waste contributes only 15% of total domestic generation. Foreign dumps refer to the huge illegal imports of WEEE from developed nations to developing nations like India, China and other Asian countries. As per the reports of World Health Organization (WHO), about 75 to 80 percent of WEEE generated annually in developed countries is shipped to various Asian countries in the name of donations using the loopholes of present waste management guidelines. However certain problem solving initiatives such as Basel convention have come up with some useful actions in the form of Partnership for Action on Computing Equipment (PACE) that will surely limit the disguised illegal International trade of E-waste within different countries.

Global production of E-waste accounts about 72 Million tons (Mt) per year. Consumer usable items (such as Audio/video entertainments, laptops, tablet, mobiles etc) individually have produced 9.8 Mt of E-waste by year 2015. As per the reports of Central pollution Control Board (CPCB) in year 2005, per day of E-waste generation in India was 0.573 Mt. In year 2007, total E-waste generation was about 3.5 Mt. Besides, the total domestic E-waste generation is only about 8 million tons per year. At present production and consumption rate, it is expected that rate of E-waste generation will increase upto 33% by the year 2025. Figure 2 depicts the incremental E-waste generation trend in India since year 2007 to 2025. Expansion of consumer base, development in production technologies of electronic items and improvisations in marketing strategies will play a key role in increasing these quantities every year. Therefore, to avoid environmental as well as human health degradation, it is necessary to set up more a suitable E-waste management mechanism.

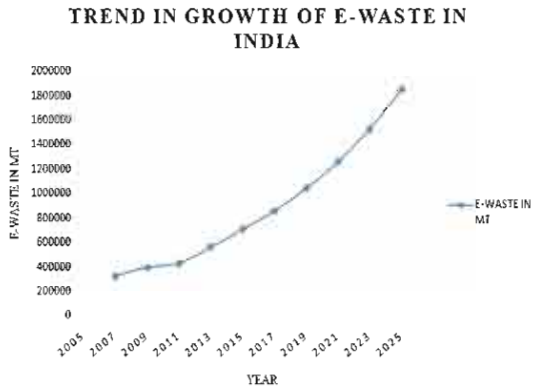

Fig.2: Incremental increase in generation E-waste

IV E-WASTE: END-OF-LIFE MANAGEMENT

E-waste management includes reuse, refurbishment of repairable items, segregation to obtain useful components, recycling and final disposal. The most appropriate management practice is always of reusing the functional as well as repairable items as it increases the utility life of these items. Recycling of discarded or obsolete electronic items involves separation of all types of precious and hazardous components in controlled conditions. It also reduces the overall quantity of waste to be disposed off finally and therefore helps in environmental conservation. The objective of E-waste management is to evolve an effective management system at both ends of production as well as consumer utilization. Effective recycling of E-waste is a two way beneficial process. Firstly, it reduces the amount of toxic solids and fumes released into the environment and secondly it generates a good business market for the people to set up E-waste recycling plants which further helps to generate employment. Also, E-waste recycling provides easier access to various precious metals in comparison to typical ore metal extraction process. Despite having numerous benefits of effective E-waste management, the present global E-waste recycling through organized sector accounts for only 13%. Lack of awareness and feudal legislations are the prime factors responsible for driving E-waste recycling to informal unorganized sectors.

(a) E-Waste Recycling in the Unorganized Sector

Unorganized E-waste recycling refers to an unauthorized recycling network which does not abide by any government agency. The recycling operations are performed by unskilled labor without using any precautionary measures. They get exposed to several gases, acids, toxic chemicals, contaminated ash and therefore suffer from various kinds of occupational hazards. Table 1 shows various sources of harmful constituents of E-waste and their corresponding impacts on health of workers. The working structure does not conform to any environmental and human health conservation regulations. Apart from the E-waste generated within the country, India accommodates a huge amount of E-waste imports every year. Unfortunately, due to lack of an effective E-waste management and legislations, almost 95% of E-waste is treated by the unorganized sector. The unorganized E-waste recycling is dominant in slums of various metropolitan cities like Delhi, Bombay and Pune. With due course of time, the roots of unorganized sector has penetrated deep into our community as it offers more profitable and easier services to consumers. Hence it has now established itself as a complex structure comprising of small scale businessmen and unemployed labor. The pollutants released during open-pit incineration contaminate the natural soil, water and air. Due to absence of any safety measures, workers usually face accidental injuries and burns. Long term exposure to Phthalates like Butylbenzyl phthalate causes problems related to reproduction.

In Delhi there a lot of people who have adopted manual dismantling of E-waste as full time family business. They work at home and hence expose their families as well as the surrounding environment to these hazardous materials. E-waste is collected by numerous isolated scrap dealers in all parts of the country. The collected material is sold to the scrap merchants with a suitable profit. The material then goes in the hands of illiterate and unskilled labor for manual dismantling to obtain

precious metals. E-waste recycling in unorganized sector is limited to metal extraction only. It involves careless use of gas torches and open acid baths in order to segregate metals from E-waste components. The efficiency of these processes is about 30% which is very less in comparison to the organized E-waste recycling methods. Hence, huge amount of left over waste including E-waste plastic and toxic materials are subjected to open incineration or landfills. These processes release various toxins such as polycyclic aromatic hydrocarbons (PAHs) and halogenated PAHs into the atmosphere. In certain places having nearby agriculture fields, the contaminants may also penetrate into soil and effect crop quality. Thus unorganized recycling of E-waste causes potential hazards to human health and environment.

Grant Kristen et al carried a potential review study to analyze the impact on health of workers involved in unorganized E-waste recycling and people living in surrounding contact area. They studied the relationship between E-waste recycling exposure and the corresponding health hazards. It was observed that the people who came in contact with E-waste treatment procedures were found to have disturbed thyroid function, abnormalities in cellular functioning and adverse effects on lungs. Children from 8-13 years, pregnant ladies and premature babies were also reported to be affected. People residing in nearby regions were reported to have permanent DNA abnormalities.

Table 1
Occupational hazardous of unorganized E-waste recycling

Constituent	Source	Impact
Lead (Pb)	Soldering of PCBs, glass panels and gasket of computer monitors, CRTs	• Skin diseases, Headaches, nausea, ulcers, • Damage to central nervous system • Effect on reproductive health
Cadmium (Cd)	Computer batteries (rechargeable), switches, CRTs, semiconductors	• Accumulation in liver and kidney • Neural impairment of infants
Mercury (Hg)	Printed circuit boards, Relay switches, lighting devices on flat screens	• Damage to central nervous system • Psychological effects (depression and tremors) • Inhalation and dermatological problems
Chromium (Cr)	Determent of rusting of galvanized steel plates, hardener for steel housing, floppy disks	• Multiple organ failure • Hindered neurodevelopment • Asthma and damage to DNA
Polyvinyl Chloride (PVC)	Cabling and computer housing	• Respiratory problems • Damaged immune system • Hormonal imbalance • Reproductive and developmental problems
Brominated Flame Retardants (BFR)	electronic equipment and circuit boards plastic casings	• Harm to reproductive and immune system • Endocrine disorders
Barium (Ba)	Front panels of CRTs	• Loss of muscle strength • Heart, liver and spleen damage and Silicosis
Beryllium (Be)	Motherboard	• Cancer causing • Fume assimilation leads to beryllicosis
Arsenic (As)	Light Emitting Diodes (gallium arsenide)	• Breathing problems • Cardiovascular, Renal and liver disease • Bladder cancer and Gastrointestinal aberration
Nickel (Ni)	Electron gun in CRTs, Nickel Cadmium batteries (rechargeable)	• Dermatological problems • Carcinogenic
Selenium (Se)	Old photo copying machines	• Gastrointestinal disturbances • Hair loss and Nail Sloughing • Irritability and lethargy
Lithium (Li)	Lithium batteries	• Gastrointestinal and nerve damage
Americium (Am)	Fire detectors, medical equipment	• Radiation induced damage
Zinc (Zn)	CRT screen interior	• Cytotoxicity and Ischemia
Chlorofluorocarbons (CFC)	Refrigerators, air conditioners, aerosols	• Danger to respiratory system • Ozone depletion which causes skin disorders
Polychlorinated Biphenyl (PCB)	Dielectric and coolant fluids in electronic appliances, PVC coatings of electrical cables	• Carcinogenic • Damage to immune system • Endocrine and reproductive disorders

(b) E-Waste Recycling in the Organized Sector

E-waste recycling in organized sector includes utilization of environmentally sound recycling techniques that protect nature from the hazardous end products of E-waste recycling. The mechanism is also helpful to the workers as it incorporates all kinds of safety equipment. The equipment and technology requirements for setting up an organized recycling plant with all safety and quality standards is quite expensive. Apart from the initial investment, employment of skilled persons and machinery running cost is also high. Therefore, installation of such E-waste management plants is difficult in developing countries. In India, only 10% of E-waste is treated by organized sector. Interference of unorganized sector in various stages of collection and recycling is another challenge for successful functioning of the organized sector. According to Central Pollution Control Board (CPCB) database, India has 178 authorized E-waste recycling units. There are only 27 high processing units having an annual E-waste handling capacity of 5000 metric tons or more. Karnataka has the maximum number of small E-waste recycling units (39), followed by Maharashtra (23) and Uttar Pradesh (9).

Organized sector provides effective E-waste treatment facilities. Effective E-waste recycling refers to a set of processes that is capable to handle hazardous waste product in an eco-friendly way. The procedures followed do not deteriorate human health and environment in any way. Effective E-waste recycling is a many-fold process: the first step after collection of E-waste is to categorize the huge heaps as per set standards. The next step includes dismantling or disassembly-mechanical pretreatment which involves segregation of useful as well as hazardous components in collection centers. Further, concentrating these separated components using various mechanical or metallurgical procedures. The third step is to refine the segregated components by extracting of large quantities of various expensive metals such as gold, silver, palladium, copper, iron, nickel, silicon, copper, aluminum, and steel. The final step is to ensure careful disposal of the residues as per industrial standards. Figure 3 depicts the organized E-waste recycling and disposal under controlled conditions.

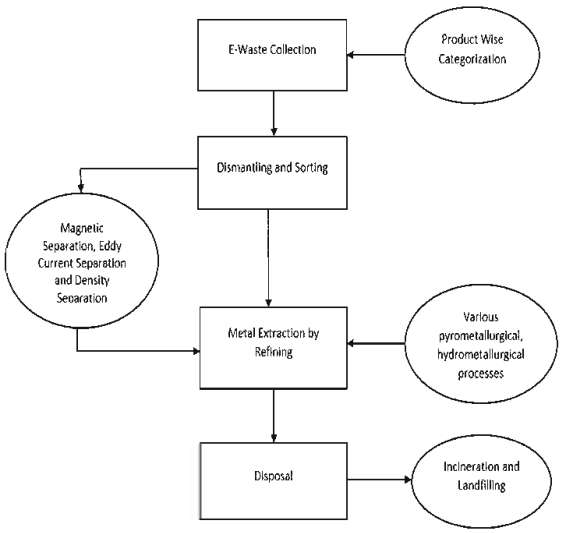

Fig. 3: Organized E-waste recycling and disposal

Some popular methods of E-waste refining are pyro-metallurgy, hydro-metallurgy, and bio-leaching. Pyro-metallurgy involves changing the physical and chemical composition of the E-waste scrap by thermal treatment. It incorporates numerous sub processes such as calcining, roasting, smelting and refining and hence this method proves to be a bit uneconomical. The technique used in hydro-metallurgy is chemical leaching by using different ligands or acids like cyanide, halide, thiourea, sulphuric acid and others. Refining of electronic products may also carried by hydrometallurgical etching by using various chlorides and other organic solvents. Bioleaching is a method in which micro-organisms are used to accelerate rate of leaching from metallic mineral source. There are two types of mechanisms that may be used for the purpose. Direct action mechanism in which minerals are directly oxidized by microorganisms and the indirect action mechanism which involves oxidation of minerals and simultaneous rejuvenation of ferric ions by microorganisms. These processes are based on scientific studies and have been adopted after successful experimentation. Therefore, E-waste recycling in properly organized treatment plants ensures safety of human health and environment. They are also much more efficient as compared to the unorganized sector and provide 99% recovery of precious and special metals from various electronic components.

V RECOMMENDATIONS

(a) Recommendations For Industrial Sector

E-waste is a relatively new type of waste product in comparison to any other waste. Recycling and efficient treatment is a separate solution. Manufacturers should use innovative designing techniques that can allow the users to upgrade all kinds of electronic products in relevance to latest technological advancements. This will motivate them to use the product for a much longer time.

The future production of electronic items should come up with some technological advancement which allows easier dismantling and recovery of the basic components of any electronic product. Such advancement will increase rate of refurbishing of electronic products and subsequently reduce E-waste recycling.

The use hazardous metals and traditional printed circuit boards should be avoided. These come up with fire inhibitors and require a large amount of soldering and fabrication. Instead, manufacturer should motivate the utilization of thick film technologies and ceramic printed boards. This will reduce soldering material and provide easy dismantling to obtain useful raw materials. Design Improvisation is essential for the outer casings and body cover as well. Electronic manufacturing should avoid using traditional paints as they reduce the plastic impact resistance which significantly affects recycling and remolding of electronic plastic. Use of water based paints can certainly solve this problem.

Apart from that, the present production techniques uses different kind of plastics such as High Impact Polystyrene (HIPS), Acrylonitrile-Butadiene Styrene (ABS), Polypropylene (PP) and others for manufacturing a single electronic product only. This makes the recycling process complex and tedious. Future production must make efforts to minimize this variation in fabrication of electronic products.

(b) Recommendations For Government Agencies

The government waste management legislations must motivate the researchers to evolve sustainable E-waste disposal ideas that can counter this problem and are economically feasible. The latest discussion is about incorporation of E-waste plastic residues in road construction. Therefore, various institutional agencies should promote and finance such innovative ideas.

Government legislations need to be more stringent in order to improve the working and co-ordination of centre and state pollution control boards. This will help to channelize the structural framework, minimize the financial leakage and achieve the desired recycling targets.

Various environmental and health management government initiatives such as Swatch Bharat Abhiyaan should create awareness among consumers about all the possible choices of E-waste recycling.

At the same time agencies should make E-waste collection easier for the recycling units. One alternative is to send pre-paid mail services to the consumer thus motivating them to bring their obsolete electronic products to recycling units.

Another initiative can be installation of self-serving automatic E-waste collection booths at various places. These should be capable of receiving E-waste, evaluate the waste electronic product and providing the evaluated money to the consumer instantaneously.

ecoATM company is one such example which provides this service to people. If this initiative is supported by the government and allowed to flourish in society, it can surely dominate the interference of unorganized sector (Kabariwala's) and contribute to the aim of sustainable disposal of E-waste products.

Currently only limited number of investors have invested in organized E-waste recycling sector. The probable reasons are lack of awareness about economic aspects, value contribution towards sustainable development and assurance of constant useful material feed. Government schemes such as Make in India, Stand up India and others should setup a suitable framework to enlighten the investors about all these aspects. This will surely attract the investors to step in the business of eco-friendly E-waste recycling.

The upcoming E-waste management legislations should try to integrate the unorganized and organized E-waste recycling sectors. The unorganized sector has vey strong collection and accumulation network. It also comprises millions of experienced workers who can easily handle the treatment technologies.

(c) Recommendations For Consumers

The most effective mitigation for E-waste management would be to minimize E-waste generation at the consumer end. People should know about this emerging hazard and realize their responsibility to avoid unnecessary E-waste generation. Before discarding any electronic product, consumer should check whether it can be reused or if it can be donated. This will ensure a much longer life span of these items.

At last if the electronic product becomes completely obsolete or waste, consumer must seek for all possible ways for organized E-waste recycling of their product. Discarded E-waste should not be mixed with other solid household waste because it becomes a tedious task to segregate it at later stages.

People should understand the process of sustainable E-waste disposal and make efforts to deliver the segregated E-waste at authorized centers rather than giving it to local scrap collectors to make easy money.

Mostly consumers who use electronic products are literate; therefore they may use internet sources to encourage free cyclic use of electronic products. People can make groups on various social networking platforms and in this way the discarded electronic product from one user can become useful for another.

Consumer should promote use of eco-friendly electronic products. This means that they should purchase products which are manufactured by using environment friendly raw materials.

VI CONCLUSION

Unorganized E-waste recycling exposes people to various chronic diseases. The illiterate or unskilled labor is usually unaware of the consequent occupational hazards. Rate of E-waste generation is greater in developed countries in comparison to the developing

countries. In the present scenario, organized E-waste recycling legislations in the developed nations are very strong thereby making the process expensive for the investors. Despite the clear guidelines of Basel convention, these constraints have encouraged illegal exports of E-waste items to various developing countries. E-waste handling and management legislations which are already prevailing in India have proved to be insufficient in implementing enforcements on unorganized E-waste recycling sector. The upcoming regulations should focus on improved implementation and better integration of center and state pollution control agencies. Government and various non-profitable agencies must be vigilant to enforce Extended Producer Responsibility (EPR) and reduction in use of hazardous substances. Further, it is essential to integrate unorganized and organized E-waste recycling sector in order to access all financial benefits of E-waste recycling but with an environmentally sound mechanism. Although present E-waste management is a problematic issue but with combined efforts of the government, industrialists and consumers it can be easily sorted.

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