STUDY AND DEVELOPMENT OF A SUSTAINABLE AND EFFICIENT E-WASTE MANAGEMENT SYSTEM TO MITIGATE THE THREAT OF ENVIRONMENTAL POLLUTION

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Abstract— **The act of extensive, reckless and haphazard disposal of e-waste for monetary gains mostly, coupled with governments inefficiency and unorthodox systematic control of it in any society is without a doubt extremely dangerous and harmful to the society`s public health and economy as a whole. The untreated e- waste poses enormous threat to public health and the quality of life of the people in general. It also shatters and renders the environment inexplicably unproductive. In addition, it is the socially and economically weaker sections of the society, who suffer the most in these situations. With the number of the souls purchasing electrical and electronic goods increasing manifolds, many areas are being used as a dumping ground for e-wastes, and weaknesses in governmental waste management processes has made WEEE become a serious dilemma. Previously the environmental and sustainability management of e-waste has received low priority. Lack of financial resources, institutional weaknesses, improper choice of technology and public unawareness towards WEEEM are some of the factors that contributed to the upward slide of seeing E-Waste as a problem. In this paper, the problem of e-waste, sources, composition and its treatment as related to waste have been critically examined.**

Keywords— **landfilling, incineration, environmentally sound techniques, unit operations, CRT technology, sustainability.**

INTRODUCTION

In general E-waste can be defined as old, end of life electronic and electrical(EEE) or waste generated from any equipment running on electricity or battery becomes unfit for their originally intended use or have crossed their expiry date. Computers, servers, mainframes, monitors, compact discs (CDs), printers, scanners, copiers, calculators, fax machines, battery cells, cellular phones, transceivers, TVs, iPods, medical apparatus, washing machines, refrigerators, and air conditioners are examples of e-waste (when unfit for use). These electronic equipments get fast replaced with newer models due to the rapid technology advancements and production of newer electronic equipment. This has led to an exponential increase in e-waste generation. People tend to switch over to the newer models and the life of products has also decreased.

e.g. the telecom sector liberalization during the last decade resulted in the preference of mobile telecom services over fixed lines. Consequently, the usage of fixed lines dropped by about 75% in the same time period. As a result, these fixed line telephone sets, which were over 30 million units were either disposed unconventionally or stockpiled. Electronic waste as such is emerging as a serious public health and environmental issue in India. India is the "fifth largest electronic waste producer in the world"; approximately 2 million tons of e-waste are generated annually and an undisclosed amount of e-waste is imported from other countries around the world. Annually, computer devices contribute about 70% of e-waste, 12% comes from the telecommunication industry, 8% from medical equipment and 7% from electric appliances. The government, public sector companies, and private sector companies generate approximately 75% of total electronic waste, with the contribution of households being merely a 16%. E-waste is growing at a compound annual growth rate (CAGR) of about 30 per cent in the country. ASSOCHAM, one of the apex trade associations of India, estimated that e-waste generation was 1.8 MT per annum in 2016 and would reach 5.2 MT per annum by 2020.

MAJOR SOURCES

WEEE CATEGORY	SWISS ODREE	EU
Household Appliance	Washing machines, dryers, refrigerators, coffee machines, iron, toasters, vacuum cleaners, air conditioners, etc	Large household appliances: Washing machines, refrigerators, air conditioners, dryers, etc Small household appliances: Vacuum cleaners, iron, coffee machines, toasters, etc
Office, Information and Communication Equipment	PCs, Laptops, Mobiles, Telephones, Fax Machines, Copiers, Printers etc.	PCs, Laptops, Mobiles, Telephones, Fax Machines, Copiers, Printers etc.
Entertainment and Consumer Electronics	Televisions, VCR/DVD/CD players, Hi-Fi sets, radios, etc	Televisions, VCR/DVD/CD players, Hi-Fi sets, radios, etc
Lightning Equipment	Fluorescent tubes, sodium lamps etc. (Except: Bulbs, Halogen Bulbs)	Fluorescent tubes, sodium lamps etc. (Except: Bulbs, Halogen Bulbs)
Electric and Electronic Tools	Drills, Electric saws, Sewing Machines, Lawn Mowers etc. (Except: large stationary tools/machines)	Drills, Electric saws, Sewing Machines, Lawn Mowers etc. (Except: large stationary tools/machines)
Toys, Leisure, Sports and Recreational Equipment	Electric train sets, coin slot machines, treadmills, etc	Electric train sets, coin slot machines, treadmills, etc
Medical Instruments and Equipment Surveillance and Control Equipment Automatic Issuing Machines	Medical Instruments and Equipment Surveillance and Control Equipment Automatic Issuing Machines	Medical Instruments and Equipment Surveillance and Control Equipment Automatic Issuing Machines

COMPONENTS OF E-WASTE

E-waste is broadly classified into three main categories, viz. large household appliances, IT and Telecom and consumer equipment. Refrigerator and washing machine represent large household appliances, personal computer monitor and laptop represent IT and Telecom, while television represents consumer equipment. Each of these e-waste items has been classified with respect to twenty six common components, which could be found in them and these components form the "building blocks" of each item. . These components are metal, motor/compressor, cooling, plastic, insulation, glass, (Liquid Crystal Display) LCD, rubber, wiring/ electrical, concrete, transformer, magnetron, textile, circuit board, fluorescent lamp, incandescent lamp, heating element, thermostat, BFR-containing plastic, batteries, fluorocarbons (CFC/HCFC/HFC/HC), external electric cables, refractory ceramic fibers, radioactive substances and electrolyte capacitors.

COMPOSITION OF E-WASTE

Composition of e-waste is very diverse and varies in products across various categories. It consists of more than 1000 different substances, which are further classified as "hazardous" and "non-hazardous" materials. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitutes almost 50% of the e-waste followed by plastics (21%), non ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminium and precious metals e.g. silver, gold, platinum, palladium etc. The presence of elements like lead, mercury, arsenic, cadmium, selenium and hexavalent chromium and flame retardants beyond threshold quantities in e-waste classifies them as hazardous waste.

Possible Hazardous Substances in Components of E-waste

Component	Possible hazardous content
Metal	
Motor/compressor	
Cooling	Ozone Depleting Substances (ODS)
Plastic	Phthalate plasticizer, brominated flame retardants (BFR)
Insulation	Insulation ODS in foam, asbestos, refractory ceramic fiber
Glass	
Cathode Ray Tube	Lead, Antimony, Mercury, Phosphor
Liquid Crystal Display	Mercury
Rubber	Phthalate plasticizer, BFR
Wiring / electrical	Phthalate plasticizer, BFR, Lead
Concrete	
Transformer	
Circuit Board	Lead, Beryllium, Antimony, BFR
Fluorescent lamp	Mercury, Phosphorous, Flame retardants
Incandescent lamp	
Heating element	
Thermostat	Mercury
BFR-containing plastic	BFRs
Batteries	Lead, Lithium, Cadmium, Mercury
CFC,HCFC,HFC,HC	ODS
External electric cables	BFRs, plasticizers
Electrolyte capacitors	Glycol, other unknown substances

Out of the substances mentioned above , the cause of most concern are the heavy metals like lead, mercury, cadmium and chromium(VI), halogenated substances (e.g. CFCs), polychlorinated biphenyls, plastics and circuit boards that contain brominated flame retardants (BFRs). BFR can give rise to dioxins and furans during incineration. Other materials and substances that can be present include arsenic, asbestos, nickel and copper. These substances may act as catalysts to increase the formation of dioxins during incineration Different professional researchers have shown that electrical and electronic appliances possess valuable elements as well. These elements are originally found and extracted from the earths crust.

HEALTH EFFECTS OF SOME CONSTITUENTS IN E-WASTE

Almost all e-wastes possess certain kind of recyclable material, including plastic, glass, and metals; but due to lack of proper disposal facilities and techniques these materials are not retrieved for other purposes. If e-waste is dismantled and processed in a hafazard manner, its toxic constituents can wreak havoc on the human body. Processes such as dismantling components, wet chemical processing, and incineration are used to dispose off the waste which result in direct exposure and inhalation of harmful chemicals.

WEEE Source	Element Composition	Health Effect
Chip resistor and semi- conductor	Cadmium (Cd)	Neural damage Accumulation in kidney and liver, which can cause breakdown of these organs Teratogenic Toxic irreversible effect in Human
Solder in printed circuit boards, glass panels and gasket in motherboards	Lead(Pb)	Damages the central periphery nervous systems and kidney Affects brain development in children
Relays, switches and printed circuit boards	Mercury(Hg)	Severe and chronic brain damage Respiratory and skin disorder as a result of bioaccumulation in fishes consumed
Plastic housing of electronic equipment and circuit boards	Brominated flame retardants(BFR)	Disrupts the function of the endocrine system
Front panels of CRTs	Barium(Ba)	Muscle weakness Liver, heart and spleen damage
Motherboards	Beryllium(Be)	Carcinogenic effect Skin disease such as wart Chronic beryllium disease or beryllicosis
Computer and cabling housing	Plastic including PVC	Dioxins causes Reproductive and developmental problem Interference with regulatory hormones Immune system damage
Corrosion protection of untreated and galvanized steel plates, decorator or hardener for steel housing	Hexavalent chromium IV (Cr)	DNA damage Asthmatic bronchitis

The health hazards posed by these inappropriate recycling methods as well as improper and unsustainable management of WEEE as tabled in table 8 is really horrible. Many cases of the above mentioned diseases and effects in the table have been reported in developing nations such as China, India, Nigeria and Ghana, where people make living through collecting, recycling and reselling of recycled materials.

ASSESSMENT OF HAZARDOUSNESS OF E-WASTE

The hazardous nature of e-waste is determined by identifying the e-waste category item (identification includes the waste items and year of manufacture), identifying the e-waste composition or its components, identifying possible hazardous content in the e-waste and identifying whether the e-waste component is hazardous or the entire e-waste item is hazardous.

RECYCLING, REUSE AND RECOVERY OPTIONS

Sustainable business development as a phenomenon centers on the 3R, which are "recovery, reuse and recycle". Recycling is a means of treating e-waste, which involves processing the waste material to recover materials (Kofoworola 2007, 2). Schaik and Reuter (2009, 194.), states that the recycling principles and dynamics are the same for all e-waste materials, however the difference is the composition of each item as well as the toxic elements it contains. There are two set of views that comes up, during recycling process, the first set is "to shred-or-not-to-shred", whereas the second is "the environment and the economic values"

Recycling could be either manual or automated. In both methods, there are set out processes they follow. It requires infrastructure in order to be effective in the treatment and valuable material recovery processes. This set of processes is described below:

STEP 1: DISASSEMBLY AND SEGREGATION

Disassembly is further clasified into two. One involves the removal of hazardous products and other high or low grade including component, part, or group of parts, or a sub-assembly from a product, which is known as partial disassembly. Other involves the separation of a product into all of its components. This is also called as complete disassembly. Disassembly may be manual, semi-automated or automated. It can also be classified into destructive and non-destructive methods. The non-destructive recovers the various disassembled parts for reuse, whereas the destructive disassembles deals with the total separation of each material type for recycling processes. However, the issues with the feasibility of the non-destructive disassembly is the rate of speed of technological changes in products and their respective designs with the addition of lot of functionalities. Morever, the method whereby the valuable materials are soldered nowadays makes it also impossible to use the non-destructive method to recover valuable According to Chatterjee & Kumar (2009, 5.), the dissembled materials are classified into three main categories, which are first, small and large structural metal parts and heat sinks. Second, refers to the small and large structural plastic parts. Third, refers to printed circuit boards with IC chips, electronic components and connectors.

Segregation is a process in which the dissembled materials are further cllasified into various categories with respect to their constituent materials The dissembled components from the computer are further segregated into various groups for convenience in further recycling process. The segregation process also makes it easier for the recycler to know the type of method to apply to particular group regarding the material recovery purposes.

STEP 2: SHREDDING, PULVERIZATION AND CRUSHING

These processes are done to make homogenous mixture of different categories, and hence, to primarily assess the various saleable metals present. During the shredding process, the materials are broken down into a smaller size or sizes to allow the downstream separation equipment performance efficiency in material recovery The idea of pulverization is to increase the metal separation from plastics to which it is normally adhered to. During this process, particles are separated with their different types of metal components, and also metals are liberated from plastics parts of individual components and laminate.

The crushing is the further compression and breaking down of plastics and metals into smaller sizes.

STEP 3: VALUATION FOR METAL CONTENT

This process needs professional manpower with adequate instrumental analyzing facilities, whereby the homogenous shredded and pulverized powder full of valuable metals is subjected to analysis. Valuation of metal content applies methods such as, "atomic absorption spectroscopy (AAS)" or "inductively coupled plasma (ICP)" or "atomic emission spectroscopy (AES)", in the identification of the economical values of the metal contents. These methods are used in the determination of elemental components of a sample by its electromagnetic or mass spectrum

AAS is a method whereby the presence of metals in liquid or solid samples is detected through the application of ultraviolet light on the defined sample.

ICP is an analytical technique used for the detection of trace of metals in an environmental sample. The main goal of ICP is to get elements to emit characteristics wavelength light, which can then be measured (CEE 2011).

AES uses quantitative measurement of optical emission from excited atoms to determine analyte concentration (Elchem 2011).

STEP 4: METAL RECOVERY

This is the main goal of recycling, in which after the valuation metal content phase, the samples are then seperated into various groups and different types of suitable recovery techniques matching each group characteristic is applied. For example, the magnetic separation is used for iron, nickel and Cobalt. In addition, eddy current is used for aluminums. The end result in this step is recovery of valuable materials.

TREATMENT & DISPOSAL OF E-WASTE

Sustainable waste disposal is a major issue which requires a great deal of care in planning and implementation. The reason is because it involves the processing of e-waste by rendering it innocuous and also the final removal of it without harmful effect to both humans and the environment Disposal is the end process of WEEEM. There are various issues to be taken into consideration when planning waste disposal facility. Issue such as waste types, type of residue from the waste that needs disposal, the level of the toxics in the waste, the destination to be used as a dispose site, the availability of the land or site for construction of waste disposal facilities, the right design for waste disposal facility with respect to the waste decomposition process and byproducts, and the involvement of the right stakeholders.

Taking these points into consideration provides a firm base for designing an efficient waste management system. Further, it provides a destination for scientific and technological experiments on the classes of wastes disposed. In addition, it makes the WEEEM safe and sustainable. In both developed and developing nations, there are several types of disposal methods. However, the most common ones and sustainable ones used in developed nations are scientific landfilling and incineration for energy generation. While in developing nations such as India, where the necessary infrastructure is relatively low or unavailable, the most common methods are open field dumping, haphazard landfilling, and open burning.

SANITARY LANDFILLING:

It is a type of waste disposal in which refuse is buried in between layers of dirt so as to refill or reclaim low-lying ground (Freedictionary 2011). This is a common method and often put to use in disused or abandoned quarries, burrow pits, mining voids and in erosion sites. The efficiency of a landfill is determined by its design, management and mission it aims to achieve A properly designed and well managed landfill can be an effecient hygienic and in-expensive method. Contrary to it, a poorly designed and poorly managed one can create several environmental problems like breeding ground for diseases, pollution and eyesore. It is necessary to note that landfill has a byproduct, in the form of gas. This gas is mostly composed of carbon dioxide and methane which contribute significantly to greenhouse gas emission, air pollution and acidic rain water. The acidic nature of methane could prove disastorous to vegetation. In some landfills, a gas extraction system is constructed to counter this problem. Morever, it is also necessary to note that landfill is prone to leaking. Harmful and deadly materials like mercury could leach from the landfill into the soil or ground water. Further, when landfill gets overloaded, burning approach is applied to reduce the waste volume, thereby exhaling toxins into the surrounding atmosphere. However, considering the toxic substance in EEE, landfill is not a suitable disposal method. In many European countries regulations has been put in place to prevent electronic waste being dumped into landfill due to its hazardous content

Various surveys, studies and investigations have reported that degradation processes in landfills are very cumborsome and run over a wide time span. Currently, it is not possible to quantify environmental impacts from E-waste in landfills for the following reasons:

1) Landfills contain mixtures of various waste streams

2) Emission of pollutants from landfills can be delayed for many years

One of the studies on landfills revealed that the environmental risks from landfilling of e-waste cannot be ignored because the conditions in a landfill site are different from a native soil, particularly concerning the leaching behavior of metals. Further it is known that cadmium and mercury are emitted in diffuse form or via the landfill gas combustion plant. Although the risks cannot be quantified and traced back to e-waste, landfilling does not appear to be an environmentally suitable treatment technique for materials, which are volatile and not biologically degradable (Cd, Hg, CFC), persistent (PCB) or with unknown behaviour in a landfill site (brominated flame retardants). As a result of the complex material mixture in e-waste, it is not possible to exclude environmental (long-term) risks.

INCINERATION:

It involves thermal destruction of waste or method of destruction of waste by converting the organic material into carbon dioxide and water with the help of fire. Advantage of incineration of e-waste is the decrease in waste volume and the utilization of the energy content of combustible materials. Certain plants remove iron from the slag for recycling. Using incineration some environmentally hazardous organic substances are transformed into less hazardous compounds. Disadvantage of incineration is the emission of gases escaping fluegas cleaning and the large amount of residues from gas cleaning and combustion. This method if improperly managed can release poisonous heavy metals such as lead, mercury, cadmium and ashes into the air. Mercury released into the air can bio accumulates in the food chain, particularly fish, which could eventually be consumed by livestock and the general public. However, modern incinerators are equipped with state-of-art technology devices to check air pollution and capture pollutants and toxics from emitting into the air. Unlike other method, incineration major benefit is that it thermally destroys the waste rather than disposing or storing it. Furthermore, there is no research study or comparable data available, which indicates the impact of e-waste emissions into the overall performance of municipal waste incineration plants. Waste incineration plants contribute significantly to the annual emissions of cadmium and mercury. Morever, heavy metals which are not emitted into the air are converted to slag and exhaust gas residues and can reenter the environment on disposal. Therefore, e-waste incineration will increase these emissions, if no reduction measures like removal of heavy metals from are taken.

ENVIRONMENTALLY SOUND E-WASTE TREATMENT TECHNOLOGIES

Environmentally sound E-waste treatment technologies (EST) are technologies and techniques capable of reducing environmental damage through processes and materials that generate fewer potentially damaging substances, recover such substances from emissions prior to discharge, or utilize or recycle production residues. EST encompasses technologies which have the potential for drastically improved environmental performance relative to other technologies. In general these technologies help in-

*protecting the environment and ecosystem

*are comparatively less polluting

*use resources in a sustainable and judicious manner

*try to recycle more of the wastes and products

*cater all residual wastes in a more environmentally friendly way as compared to the technologies for which they are substitutes.

Moreover, Environmentally Sound Technologies are not "individual individual technologies, but total systems that include technical know-how, procedures, goods and services, as well as equipment and organizational and managerial procedures". This needs both the human resource development (including gender relevant issues) and local capacity building aspects of technology choices. There is also the necessity to ensure that ESTs are compatible with nationally determined socio-economic, cultural and environmental priorities and development goals. In the complicated relationship between development and the environment, , technology provides a link between human action and the natural resource base. Faced with limited global natural resources, the population must strive to achieve more sustainable forms of development. As a result, the application of new, resource efficient ESTs has become critical for both development and the environment. Technology cannot be used to compensate for or mitigate the deep-rooted social causes of environmental issues or the negative impacts of political and social policies, but the necessity for sustainable development in the today's world is real. The availability of ESTs via cooperative technology transfer is largely dependent on political willingness at the international level to follow an innovative environmental agenda as we approach the new utopia.

The dynamics of technological transition will not be constrained to a single technology for developed countries and another for developing countries. Instead, cutting-edge and traditional technologies will exist together throughout the globe. In order for developing countries to make the most use of ESTs, they must improve their ability to access, analyse and select technologies based on their own requirements and development priorities, and then adapt these technologies to specific local conditions. Technology in its new role, will play a very important role on the path towards sustainability.

Environmentally sound E-waste treatment technologies (EST) are put to use at three levels as illustrated below:

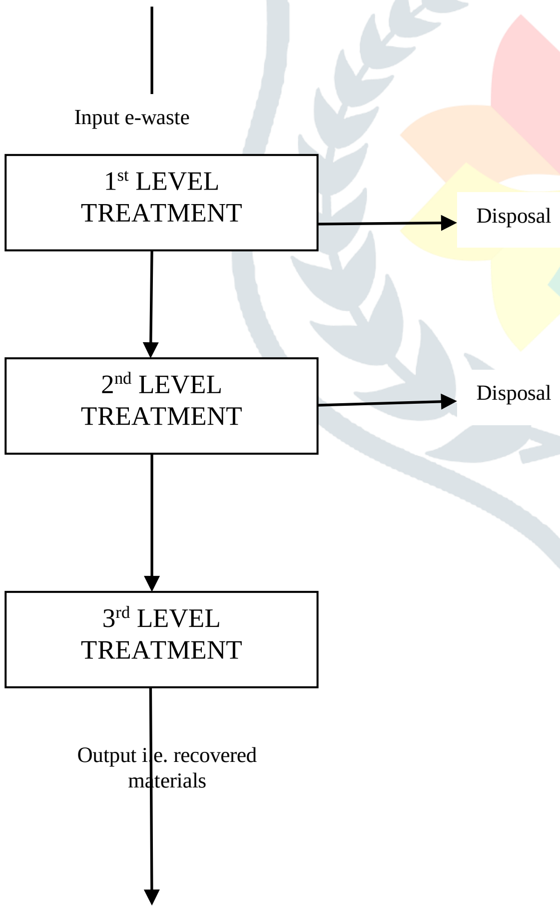
1. 1ST LEVEL TREATMENT

2. 2ND LEVEL TREATMENT

3. 3RD LEVEL TREATMENT

ANALYSIS

All the three levels of e-waste treatment are entrenched on material flow. The material flows from 1stlevel to 3rd level treatment. Each level treatment is compromised of unit operations, where e-waste is treated and output of 1stlevel treatment serves as input to 2ndlevel treatment. After the third level treatment, the residues are disposed of either in Treatment, Storage, Disposal Facility (TSDF) or incinerated. The effectiveness of operations at first and second level determines the quantity of residues going to TSDF or incineration. The simplified version of all the three treatments is shown in figure 8. EST at each level of treatment is illustrated in terms of input, unit operations, output and emissions.



Simplified Version of EST for E-waste

EST FOR 1ST LEVEL TREATMENT

INPUT: E-waste items like tv, refrigerator and personal computers (pc)

UNIT OPERATIONS:

There are three units operations at first level of e-waste treatment.

1. Decontamination - The initial treatment step is to decontaminate e-waste and make it nonhazardous. It involves removal of all types of liquids and gases (if any)under negative pressure, their recovery and storage.

2. Dismantling - Manual/mechanized breaking

3. Segregation - Components are seperated into hazardous and nonhazardous components of e-waste fractions to be sent for 3rd level treatment.

All these unit operations are dry processes and do not require usage of water.

OUTPUT:

1. Segregated hazardous wastes such as CFC, Hg Switches, batteries and capacitors

2. Decontaminated e-waste composing of segregated non-hazardous e-waste like plastic, CRT, circuit board and cables

EMISSIONS: The emissions that come out of 1st level treatment is given in table

Emissions from 1st level E-waste treatment

Emissions	Dismantling	Segregation
Air	√ (fugitive)	X
Water	X	X
Noise	√	√
Land/ Soil Contamination due to spillage	√	√
Generation of hazardous waste	√	√

EST FOR 2ND LEVEL TREATMENT

INPUT: Decontaminated E-waste consisting segregated non hazardous e-waste like plastic, CRT, circuit board and cables.

UNIT OPERATIONS:

There are three unit operations at second level of E-waste treatment.

1. Hammering

2. Shredding

3. Special treatment Processes comprising of

(i) CRT treatment consisting of separation of funnels and screen glass.

(ii) Electromagnetic separation

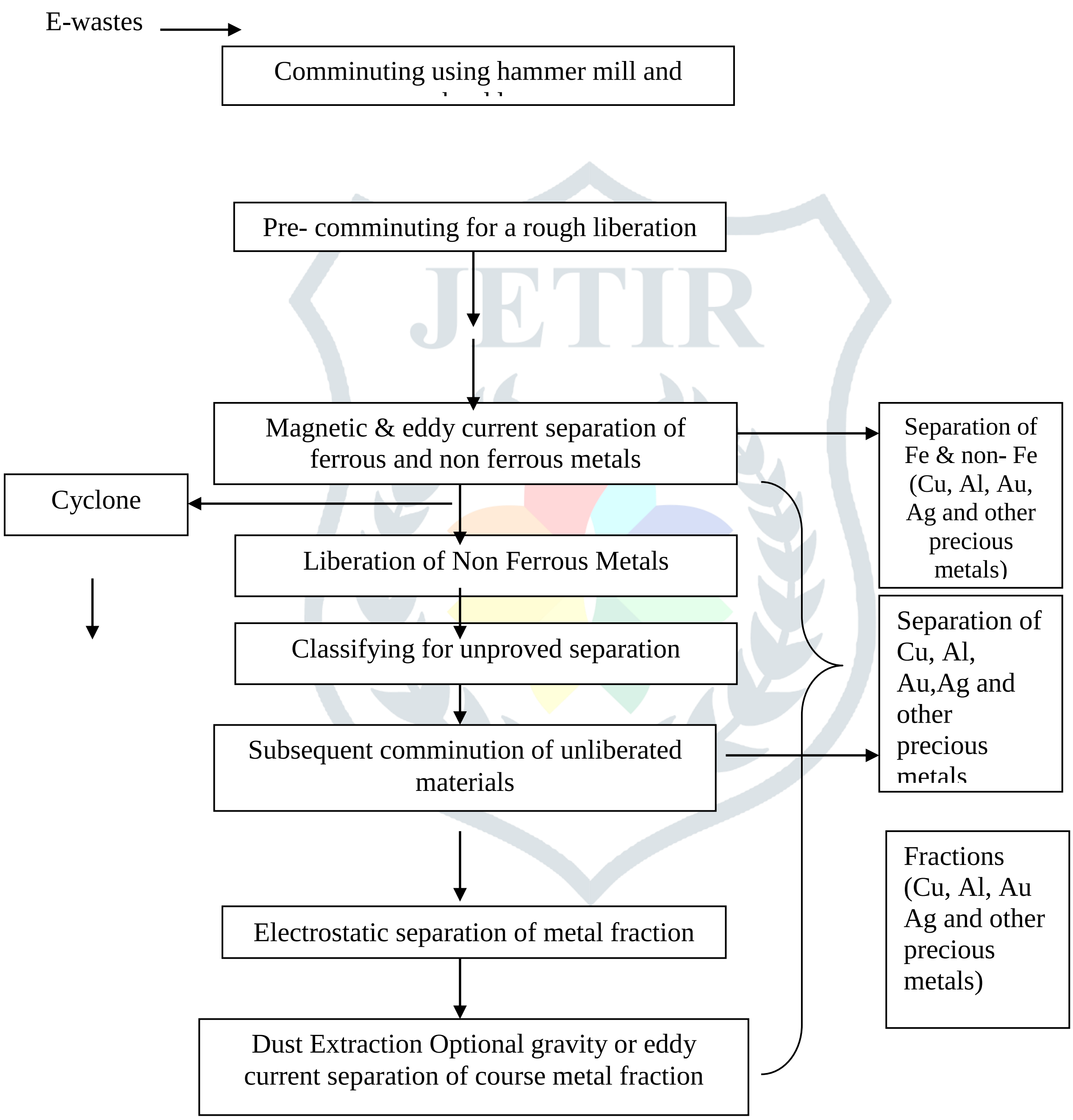
(iii) Eddy current separation

(iv) Density separation using water

The two basic unit operations are hammering and shredding. The main objective of these two unit operations is reduction in size. The third unit operation consists of special treatment processes. Electromagnetic and eddy current separation utilizes properties of various elements like electrical conductivity, magnetic properties and density to separate ferrous, non ferrous metal and precious metal fractions. Plastic fractions consisting of sorted plastic after 1stlevel treatment, plastic mixture and plastic with flame retardants after second level treatment, glass and lead are separated during this treatment. The effectiveness of this treatment determines the recovery rate of metal and segregated-waste fractions for third level treatment. The simplified version of this treatment technology showing combination of all three unit operations is given in figure below:

1. The technology for sorting, treatment, including recycling and disposal of E-waste is fully entrenched on dry process using mechanical operations.

2. The pre-comminuting stage includes separation of Plastic, CRT and remaining non CRT based e-waste. Equipments like hammer mill and shear shredder will be used at comminuting stage to cut and pulverize e-waste and prepare it as a feedstock to magnetic and eddy current separation.



Process Flow Chart of Non CRT Based E-Waste Treatment

3. A heavy-duty hammer mill grinds the material to achieve separation of inert materials and metals.

4. After separation of metals from inert material, metal fraction consisting of ferrous and non-ferrous metals are subjected to magnetic current separation. After separation of Ferrous containing fraction, Non-ferrous fraction is divided into several non-metal fractions, electrostatic separation and pulverization.

5. The ground material is then screened and de dusted subsequently followed by separation of valuable metal fraction using electrostatic, gravimetric separation and eddy current separation technologies fractions of copper (Cu), aluminum (Al), residual fractions containing gold (Au), silver (Ag) and other precious metals. This results in recovery of clean metallic concentrates, which are sold for further refining to smelters. In some cases, water may be used for separation at last stage.

6. Electric conductivity-based separation separates materials of different electric conductivity (or resistivity) mainly different fractions of non-ferrous metals from E-waste. Eddy current separation technique has been used based on electrical conductivity for non ferrous metal separation from e-waste. Its operability is based on the use of rare earth permanent magnets. When a conductive particle is exposed to an alternating magnetic field, eddy currents will be induced in that object, generating a magnetic field to oppose the magnetic field. The interactions between the magnetic field and the induced eddy currents lead to the appearance of electro dynamic actions upon conductive non-ferrous particles and are responsible for the separation process.

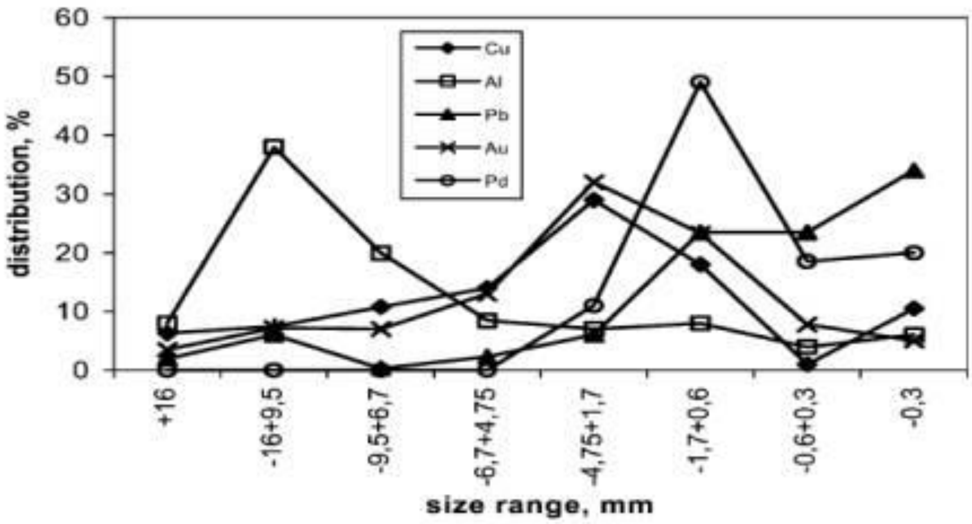
7. The efficiency of the recycling system is dependent on the expected yields/output of the recycling system. The expected yields/ output from the recycling system are dependent on the optimization of separation parameters. These parameters are given below

Particle size

Particle shape

Feeding rate/ RPM

Optimum operations



Non- ferrous Metal Distribution vs. Size Range for PC Scrap

Above figure shows the non- ferrous metal distribution (which forms the backbone of financial viability of recycling system) as a function of size range for PC scrap. It can be seen that aluminum is mainly distributed in the coarse fractions (+6.7 mm), but other metals are mainly distributed in the fine fractions (−5 mm). Size properties are essential for choosing an effective separation technique. Therefore, eddy current separator is best for granular nonferrous materials having size greater than 5mm. The eddy current separation will ensure better separation of Al fraction in comparison to fraction containing Cu, Ag and Au.

Particle shape is dependent on comminuting and separation.

9. The feeding rate can be optimized based on the speed and width of the conveyor.

CRT TREATMENT TECHNOLOGY

The salient features of CRT treatment technology are given below.

1. CRT is manually removed from plastic/ wooden casing.

2. Picture tube is split and the funnel section is then lifted off the screen section and the internal metal mask can be lifted to facilitate internal phosphor coating.

3. Internal phosphor coating is removed by using an abrasive wire brush and a strong vacuum system to clean the inside and recover the coating. The extracted air is cleaned through an air filter system to collect the phosphor dust.

Different types of splitting technology used are given below.

NiChrome hot wire cutting

Thermal shock

Laser cutting

Diamond wire method

Diamond saw separation

Water-jet separatio

OUTPUT: The output from the 2nd level treatment technology is given below.

Ferrous metal scrap (secondary raw material)

Non ferrous metal scrap, mainly copper and aluminum

Precious metal scrap mainly silver, gold, & palladium

Plastic consisting of sorted plastic, plastic with flame retardants and plastic mixture

Glass fraction (secondary raw material)

Lead (secondary raw material)

EMISSIONS: The emissions coming out of 2nd level treatment is given in table below:

Emissions from 2ndLevel E-wastes Treatment

Unit Operations / Emissions	**Dismantling**	**Shredding**	**Special Treatment Process**			
			CRT	**Electro-magnetic**	**Eddy Current**	**Density Separation**
Air	√(fugitive)	√ (fugitive)	X	√ (fugitive)	√ (fugitive)	X
Water	X	X	√	X	X	
Noise	√	√	√	√	√	X
Land/ Soil Contamination due to spillage	√	√	√	√	√	√
Generation of hazardous waste	√	√	√	X	X	X

EST FOR 3RD LEVEL TREATMENT

The hazardous material separated during the 1st level treatment and the output from the 2ndlevel is subjected to the 3rd level treatment. This facility does not always exist with the first two treatment locations, but may be located at different places. The treatment includes recycle /recovery of valuable materials using processes like smelting, refining etc.

Input/ WEEE Residues	**Unit Operation/ Disposal/ Recycling Technique**	**Output**
Sorted Plastic	Recycling	Plastic Product
Plastic Mixture	Energy Recovery/ Incineration	Energy Recovery
Plastic Mixture with BFR	Incineration	Energy Recovery
CRT	Breaking/ Recycling	Glass Cullet
Lead bearing residue	Secondary Lead Smelter	Lead
Ferrous metal scrap	Secondary steel/ iron recycling	Iron
Non Ferrous metal Scrap	Secondary copper and aluminum smelting	Copper/ Aluminum
Precious Metals	Au/ Ag separation	Gold/ Silver
Batteries (Lead, Acid/ Nickel metal Hydride (Ni-MH) and Li – ion	Lead recovery and smelting remelting and separation	Lead
CFC	Recovery/ Reuse and Incineration	CFC/ Energy recovery
Oil	Recovery/ Reuse and Incineration	Oil recovery/ energy
Capacitors	Incineration	Energy recovery
Mercury	Separation and Distillation	Mercury

Input, Output and Unit Operations at 3rd Level Treatment

CONCLUSION

Electronic and electrical equipments can no longer be avoided in today's world. So is the case of waste electronic and electrical equipments as well. As long as this is a necessary evil, it has to be best managed to mitigate its adverse impacts on environment. Through innovative changes in product design under EPR, use of environmentally friendly substitutes for hazardous substances, these impacts can be minimised. A legal framework has to be put in place for enforcing EPR, RoHS for attaining this cherished goal. Adoption of environmentally sound technologies for recycling and reuse of e-waste along with EPR and RoHS offers workable solution for environmentally sound management of e-waste. Also Government must ensure availability of sufficient funds for executing various reduce recycle and recovery works in a time bound manner so as to mitigate the sufferings of the common masses due to recuriing devastation caused by E-Waste just the same way as was explicitly demonstrated by their counterparts in American and European countries, fallin which due to any indecisiveness time will only be wasted in cosmetic works just for public consumption, till the this E-Waste monster strikes us very soon and that too with a big bang.

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