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Environmentally Sound Electronic Waste Treatment Technologies - An Analysis

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ABSTRACT

E-waste comprises of wastes generated from used electronic devices and household appliances which are not fit for their original intended use and are destined for recovery, recycling or disposal. . The environmentally sound management is needed to solve the problems related to the electronic waste. . The use of environmentally sound technologies needs to be encouraged in order to increase efficiency in processes, maximize recovery of materials and conserve energy subsequently reducing waste generation. This study focuses on the major environmentally sound management of electronic waste.

KEYWORDS :

Introduction

Electrical and electronic equipment contain different hazardous materials which are harmful to human health and the environment if not disposed of carefully. While some naturally occurring substances are harmless in nature, their use in the manufacture of electronic equipment often results in compounds which are hazardous. The environmentally sound management is needed to solve the problems related to the electronic waste.

Environmentally sound recycling refers to recycling without leading to adverse impact on environment and health. E-waste recycling in India is mostly carried out in the informal or the unorganized sector that use polluting technologies leading to extensive environmental degradation and adverse effects on health of the workers engaged in recycling activity. The use of environmentally sound technologies needs to be encouraged in order to increase efficiency in processes, maximize recovery of materials and conserve energy subsequently reducing waste generation. The policy shall enable access to such technologies and make the informal sector accountable

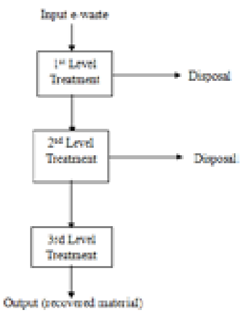
Environmentally Sound E-Waste Treatment Technologies

Environmentally sound E-waste treatment technologies are used at three levels as described below:

1. First level treatment
2. Second level treatment
3. Third level treatment

All the three levels of e-waste treatment are based on material flow. The material flows from 1st level to 3rd level treatment. Each level treatment consists of unit operations, where e-waste is treated and output of first level treatment serves as input to second level treatment. After the third level treatment, the residues are disposed of either in Treatment Storage Disposal Facility (TSDF) or incinerated. The efficiency 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 the figure Environmentally Sound E-waste Treatment Technologies (EST) at each level of treatment is described in terms of input, unit operations, output and emissions.



1) Environmentally sound E-waste treatment in First Level

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 : Removal of all liquids and Gases
2. Dismantling -manual/mechanized breaking
3. Segregation

All the three unit operations are dry processes, which do not require usage of water.

Output:
1. Segregated hazardous wastes like Chloro Fluoro Carbons (CFC), Mercury (Hg) Switches, batteries and capacitors
2. Decontaminated e-waste consisting of segregated non-hazardous E-waste like plastic, Cathode Ray Tube Cathode Ray Tube, circuit board and cables

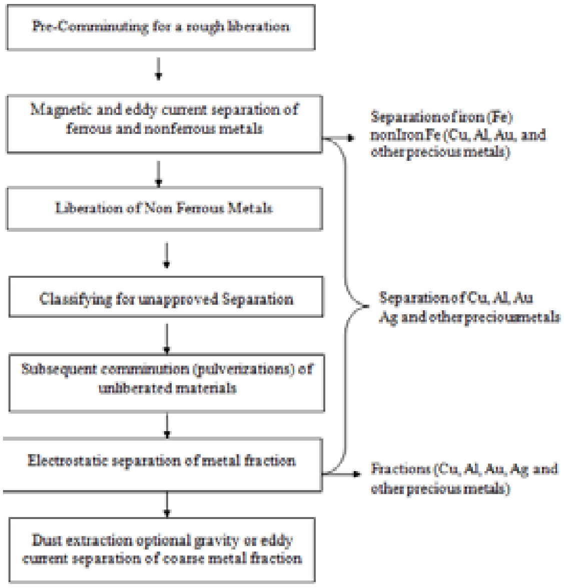
2) Environmentally sound E-waste treatment in Second Level

Input:
Decontaminated E-waste consisting segregated non hazardous e-waste like plastic, Cathod Ray Tube, 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) Cathode Ray Tube treatment consisting of separation of funnels and screen glass.
   (ii) Electromagnetic separation.
   (iii) Eddy current separation.
   (iv) Density separation using water.

The two major unit operations are hammering and shredding. The major objective of these two unit operations is size reduction. The third unit operation consists of special treatment processes. Electromagnetic and eddy current separation utilizes properties of different 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 first level treatment, plastic mixture and plastic with flame retardants after second level treatment, glass and lead are separated during this treatment. The efficiency of this treatment determines the recovery rate of metal and segregated E-waste fractions for third level treatment.



The salient features of this treatment technology and process are given below.

- The proposed technology for sorting, treatment, including recycling and disposal of E-waste is fully based on dry process using mechanical operations.
- The pre-comminuting stage includes separation of Plastic, Cathode Ray Tube and remaining non Cathode Ray Tube 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.
- A heavy-duty hammer mill grinds the material to achieve separation of inert materials and metals.
- 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 classified into different non-metal fractions, electrostatic separation and pulverization.
- 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 to recover fractions of Copper (Cu), Aluminum (Al), residual fractions containing Gold (Au), Silver (Au) and other precious metals. This results in recovery of clean metallic concentrates, which are sold for further refining to smelters. Sometimes water may be used for separation at last stage.
- Electric conductivity-based separation separates materials of different electric conductivity (or resistivity) mainly different fractions of non-ferrous metals from electronic 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.
- The efficacy 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:
  1. Particle size
  2. Particle shape
  3. Feeding rate/ RPM
  4. Optimum operations
- Particle shape is dependent on comminuting and separation. Since hammer mills and screens will be used in the proposed technology, the variations are expected to be the same as that of Best Available Technology (BAT).
- The feeding rate can be optimized based on the speed and width of the conveyor.

Cathode Ray Tube Treatment Technology

The salient features of Cathode Ray Tube treatment technology are given below.

1. Cathode Ray Tube 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**

A NiChrome wire or ribbon is wrapped round a Cathode Ray Tube and electrically heated for at least 30 seconds to causes a thermal differential across the thickness of the glass. The area is then cooled (e.g. with a water-soaked sponge) to create thermal stress which results in a crack. When this is lightly tapped, the screen separates from the funnel section.

- **Thermal Shock**

The Cathode Ray Tube is subjected to localized heat followed by cold air. This creates stress at the frit line where the leaded funnel glass is joined to the unleaded panel glass and the tube comes apart.

- **Laser Cutting**

A laser beam is focused inside and this heats up the glass. It is immediately followed by a cold water spray that cools the surface of the glass and causes it to crack along the cut line.

- **Diamond Wire Method**

In this method, a wire with a very small diameter, which is embedded with industrial diamond, is used to cut the glass as the Cathode Ray Tube is passed through the cutting plane.

- **Diamond Saw Separation**

Diamond saw separation uses either wet or dry process. Wet saw separation involves rotating the Cathode Ray Tube in an enclosure while one or more saw blades cut through the Cathod Ray Tube around its entire circumference. Coolant is sprayed on to the surface of the saw blades as they cut. This is to control temperature and prevent warping.

Water - Jet Separation

This technology uses a high-pressure spray of water containing abrasive, directed at the surface to be cut. The water is focused through a single or double nozzle-spraying configuration set at a specific distance.

3) Environmentally sound E-waste treatment in Third Level

The third level E-waste treatment is carried out mainly to recover ferrous, nonferrous metals, plastics and other items of economic value. The major recovery operations are focused on ferrous and non ferrous metal recovery, which is either geographically carried out at different places or at one place in an integrated facility. The following sections describe the unit operations, processes, available technology and environmental implications.

Input/ Output and Unit Operations

Plastic Recycling

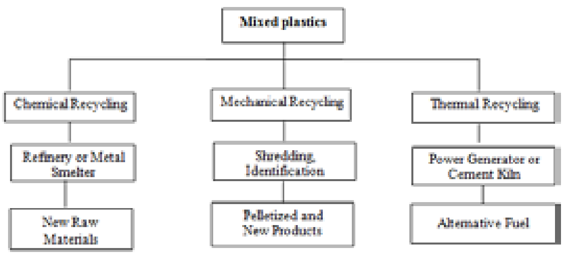
There are three different types of plastic recycling options i.e. chemical recycling, mechanical recycling and thermal recycling. In chemical recycling process, waste plastics are used as raw materials for petrochemical processes in a metal smelter. In mechanical recycling process, shredding and identification process is used to make new plastic product. In thermal recycling process, plastics are used as alternative fuel.

The two major types of plastic resins, which are used in electronics, are "thermo sets" and "thermoplastics". Thermo sets are shredded and recycled because they cannot be re-melted and formed into new products, while thermoplastics can be re-melted and formed into new products.

Mechanical Recycling Process

The first step is sorting process, where contaminated plastics such as laminated and or painted plastics are removed. The methods, which may be used for sorting, are grinding, cryogenic method, abrasion/ abrasive technique, solvent stripping method and high temperature aqueous based paint removal method. Any of the method is used for removal of paints and coating from waste plastics.

Recycling options for managing plastics from end-of-life Electronics



Shear-shredder and hammer mills are generally used for size reduction and liberation of metals (coarse fraction) followed by granulation and milling for further size reduction. Granulators use a fixed screen or grate to control particle size, while hammer mills allow particles between hammers and the walls to exit the mills.

Magnetic separators are used for ferrous metals separation, while eddy current separators are used for non ferrous metals separation. Air separation system is used to separate light fractions such as paper, labels and films. Resin identification can be carried out by using a number of techniques like turboelectric separator, high speed accelerator and X-ray fluorescence spectroscopy.

In hydro cyclones separation technique, plastic fractions are separated using density separation technique, which is made more effective by enhancing material wettability. In turboelectric separation technique, plastic resins are separated on the basis of surface charge transfer phenomena. Different plastic resins are mixed and contact one another in a rotating drum to allow charging. Negatively charged particles are pulled towards the positive electrode and positively charged particles are pulled towards negative electrode. This technique has been found to be most effective for materials with a particle size between 2-4 mm. In high accelerator separation technique, a high speed accelerator is used to de-laminate shredded plastic waste, which is further separated by air classification, sieve and electrostatics. X-ray fluorescence spectroscopy is effective in identifying heavy metals as well as flame retardants.

Chemical Recycling Process

This process was developed by the Association of Plastic Manufacturers in Europe (APME). The different steps in this process are given below.

1. Mixed plastic waste is first de-polymerized at about 350-400°C and dehalogenated (Br and Cl). This step also includes removal of metals.
2. In hydrogenation unit 1, the remaining polymer chains from depolymerized unit are cracked at temperatures between 350-400° C and hydrogenated at pressure greater than 100 bar. After hydrogenation, the liquid product is subjected to distillation and left over inert material is collected in the bottom of distillation column as residue, hydrogenation bitumen.
3. In hydrogenation unit 2, high quality products like off gas and sync rude are obtained by hydro-treatment, which are sent to petrochemical process.

Thermal Recycling Process

In thermal recycling process, plastics are used as fuel for energy recovery. Since plastics have high calorific value, which is equivalent to or greater than coal, they can be combusted to produce heat energy in cement kilns. Association of Plastic Manufacturers in Europe (APME) has found thermal recycling of plastic as the most environmentally sound option for managing E-waste plastic fraction.

(i) Metals Recycling

Metals recycling have been described below in terms of lead recycling, copper recycling and precious metals recycling. After sorting of metal fractions at second level e-waste treatment, they are sent to metal recovery facilities. These metal recovery facilities use the following processes to recover metals.

(ii) Lead Recovery

Reverberatory furnace and blast furnace are used to recover lead from e-waste fraction. The process involves the following steps.

- A reverberatory furnace is charged with lead containing materials and reluctant. In this furnace, the reduction of lead compounds is carried out to produce lead bullion and slag. Lead bullion is 99.9% while slag contains 60-70% wt. % lead and a soft (pure) lead product.
- Slag in reverberatory furnace is continuously tapped onto a slag caster. It consists of a thin, fluid layer on top of the heavier lead layer in the furnace.
- Lead bullion is tapped from the furnace when the metal level builds up to a height that only small amounts of lead appear in the slag.
- Lead is recovered from the slag by charging it in blast furnace along with other lead containing materials and fluxing agents like iron and limestone.
- Hard lead is recovered from the blast furnace, which contains 75-85 wt. % Pb and 15-25 wt. % Sb. Slag contains 1-3% lead. Slag contains calcium oxide (CaO), Silicon Dioxide (SiO2) and Ferrous Oxide (FeO).
- Flue gas emissions from reverberatory furnace are collected by bag house and feedback into the furnace to recover lead. Slag from blast furnace is disposed of in hazardous waste landfill sites.

(iii) Copper Recycling

The copper recycling process involves the following steps.

(i) E-waste fraction containing copper (Cu) is fed into a blast furnace, which are reduced by scrap iron and plastics to produce "black copper". Black copper contains 70-85 wt. % copper.
(ii) The black copper is fed into converter and oxidized using air or enriched oxygen to produce blister copper having 95 wt. % purity. Tin (Sn), lead (Pb) and zinc (Zn) are removed, while Iron Fe is remove das slag.
(iii) Blister copper and scrap copper (Cu) are melted and reduced by coke or wood or waste plastic in anode furnace. Other less noble metal are oxidized and removed from blister copper. Sulfur is also removed from the anode furnace
(iv) Recovered anode copper is further purified in electrolytic process where it is dissolved in H2SO4 electrolyte with other elements such as Nickal (Ni), Zinc (Zn) and Iron (Fe). The pure copper 99.99 wt. %) is deposited on the cathodes.
(v) The by-products of copper recovery process and slag are reused for roof shingles, sand blasting and ballasts for railroads. The anode slime from electrolytic process is used for precious metal recovery. The entire secondary recovery of Copper (Cu) uses only one-sixth of the energy that would be required to produce Copper (Cu) from ore.
(vi) Precious Metals Recovery The anode slime from copper electrolytic process is used for precious metal recovery. The process involves the following steps.

1. Anode slime is leached by pressure.
2. The leached residue is then dried and, after the addition of fluxes, smelted in a precious metals furnace. Selenium is recovered during smelting.
3. The remaining material from smelter is caste into anode and undergoes electrolysis to form high-purity silver cathode and anode gold slime.
4. The anode gold slime is further leached and high purity gold, palladium and platinum sludge are recovered.

Environmental Impacts of the First, Second and Third level E-Waste Treatment System

In order to assess environmental impacts of e-waste treatment, an example of environmental impacts of entire Swiss take back and recycling system has been described by comparing it with a baseline system. Swiss take back recycling system included take back, collection, sorting, transportation, dismantling and secondary material processing steps. The baseline system included e-waste disposal by incineration in Municipal Waste Incineration plant (MSWI) and primary production of raw material. The impacts have been assessed with respect to environmental attributes like acidification, climate change, eutrophication, photochemical oxidation, and ozone and resources depletion.

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