Chapter 8
Waste From Electrical and Electronic Equipment

Waste from electrical and electronic equipment (WEEE) implies discarded electrical and electronic equipment (EEE). While WEEE includes non-electronic goods, E-waste includes waste from only electronic goods. Some literature does not make differentiation between the two.

The electronic business is the world's fastest and largest growing manufacturing industry (Radha 2002; DIT 2003) and so is WEEE the most rapidly growing waste stream (Widmer et al. 2005; BAN and SVTC 2002) in the world. It is a crisis born from toxic components of the waste posing threat to environmental and human health. WEEE is harmful and valuable as it contains large quantities of environmental contaminants and valuable materials (Morf et al. 2007; Robinson 2009). Whilst e-waste recycling in developing nations is market-driven, it is driven by principles of extended producer responsibility (EPR) in the developed nations.

As per e-waste (Management and Handling) Rules 2011 of India:

> 'e-waste' means waste electrical and electronic equipment, whole or in part or rejects from their manufacturing process, which is intended to be discarded.

As per the Waste Electrical and Electronic Equipment Regulations 2006 of the UK :

> "waste electrical and electronic equipment" means electrical or electronic equipment which is waste within the meaning of Article 1(a) of Directive 2006/12/EC, including all components, subassemblies and consumables which are part of the product at the time of discarding.

The Basel convention calls on all nations to lessen export of hazardous wastes to the least amount and, tackle their waste problems within national borders.

WEEE recycling sector is largely unregulated. However WEEE recycling operations in India, China, and Ghana have been well recorded (BAN and SVTC 2002; Brigden et al. 2005, 2008).

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The production of EEE is the fastest-growing due to intense marketing, technological innovation, and intense replacement process. Brett (2009) estimated that every year, about 20–25 million tonnes of WEEE are produced globally. But UNEP estimated the world's production at 20–50 million tonnes annually (UNEP 2006). The contribution of an item to WEEE production depends on the number of units in service, the mass of the item, and its average lifespan. Figure 8.1 shows reasons for generation of WEEE.

Presence of heavy metals (like mercury, cadmium, and lead), flame retardants (like pentabromophenol, polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol-A (TBBPA), etc.) and other harmful chemicals in WEEE is a major health and environmental concern.

8.1 Significance

The hazardousness of WEEE is well recognized (Oyuna et al. 2011). WEEE contains over 1,000 different substances (BAN and SVTC 2002) and handling of these wastes causes pollution and affects human health especially in the developing world. The potential negative health and environmental impact of improper handling and treatment of WEEE is well documented (Fishbein 2002; Puckett et al. 2003; Ramesha and Ravi 2009; NEP 2006).

Many developing countries which do not have proper solid waste management systems often neglect the hazardous WEEE thrown along with domestic non-hazardous waste. Such practice increases quantum of hazardous waste as non-hazard waste would br contaminate with chemicals like mercury. Figure 8.2 shows consequences of improper disposal of WEEE.

Even though WEEE collection and recovery have gained significance in Europe in the past 15 years, detailed studies quantifying the environmental loads are still rare (Wäger et al. 2011). Cobbing (2008) estimated that mobile telephones, computers and television sets would account 5.5 million tonnes of WEEE in 2010, which would rise to 9.8 million tonnes in 2015.

Estimated WEEE generation to be 1—3 % of the world's municipal waste generation of 1,636 million tonnes per annum, whereas in rich countries, WEEE may constitute about 8 % by volume (Widmer et al. 2005). The fraction of plastics in EEE has continuously increased from about 14 to 18 % in 1992, 22 % in 2000 and estimated 23 % in 2005 (APME 2001). The plastics from WEEE from Europe were estimated to be 20.6 % in 2008 (Huisman et al. 2008). Different literature draws different destination to WEEE. Most discarded WEEE go out with domestic waste and do not receive particular treatment (Ladou and Lovegrove 2008). Electronic equipment which is of no use to the original buyer ultimately exports some WEEE to poor nations (Puckett et al. 2005). In fact, 80 % of WEEE collected is exported to poor nations according to Schmidt (2006). Old functional electronic goods are frequently transported to developing nations with electronic equipment that are not functioning (Ladou and Lovegrove 2008).

Obsolete technology		Due to fast growing technology (hardware and software) old electronic goods become obsolete, e.g., electronic storage device like floppy discs are no more in use and new computer will not have drives to insert them making many of unused floopy becoming waste.
End of Life		Electronic goods usually have a life time of 5 to 10 years after which it will malfunction or stop functioning. End of life of cells, printer drum and cartridge may expire within few weeks from the date of using them.
Energy inefficiency		Most of the old electric and electronic goods are energy inefficient and hence are discarded to save energy.
Damage		Damage to electrical and electronic goods accidentally or intentionally will result in E-waste.
Discontinuing manufacturing Goods, consumables and spare part		Many manufacturer intentionally discontinue manufacturing some of their products and spare parts to create new market to their new products. This would result in discarding equipments even in good condition due to absence of conumables like printer cardridge.
Out of fashion		With invention and design of new equipments, old equipment looks out of fashion and out dated. Hence the user of old equipment will switchover to new equipment. Such rapid changes are seen dominantly with respect to mobile phones.

Fig. 8.1 Reasons for generation of WEEE

Increase in quantity of hazardous waste		Entry of WEEE into waste will increase toxicity and hence hazardous nature of the entire waste into which it enters increasing the hazardousness of the waste
Biomagnifications and entry of chemicals in food chain		Entry of WEEE into environment will increase toxicity and will lead to biomagnification in living organisms and enters human food through dairy, polutry and meat.
Increase in Sharps		Broken glass, plastic and teared metal will increase the sharp objects in waste leading to increased risk of injury.
Contamination		Presence of heavy metals like residual lead in the heap of lead-acid batteries will reach surface/groundwater leading to contamination of water/soil

Fig. 8.2 Consequences of improper disposal of WEEE

8.2 Characteristics and Quantity

The rapid rate of technological change, the high dependence of electronic and electric goods in everyday life and drop in prices has created huge market for EEE. Global quantities of WEEE are increasing across the globe (Ongondo et al. 2011). According to many, there is a drop in the lifespan of electronic and electrical goods and illegal transboundary movement of WEEE (Brigden et al. 2005; Cobbing 2008; Deutsche Umwelthilfe 2007; Puckett et al. 2003).

Due to the inadequate data in many countries flows of WEEE is not quantified. Furthermore, such assessments are expensive and very complex. The substitute of CRT monitors with LCD will decrease the lead in WEEE (Puckett et al. 2005) but, LCD displays will have mercury (Mester et al. 2005), indium, zinc and tin (Li et al. 2009). Rechargeable batteries contain nickel metal hydride (NiMeH), lithium ion, nickel cadmium (Ni–Cd).

WEEE contains a numerous hazardous material including heavy metals (like cadmium, mercury, lead, etc.,) flame retardants (like pentabromophenol, TBBPA, PBDEs, etc.). Mercury is used in switches and relays, gas discharge lamps and batteries (NEWMOA 2008). Batteries with mercury and rechargeable batteries with cadmium, lithium and lead are of concern from environmental point of view (EPS Canada 2006). PCBs contain lead, antimony, beryllium, cadmium, brominated flame retardants, copper, gold, silver, mercury and palladium etc. (AEA 2004; EPS Canada 2006; OECD 2003). Lead acid batteries are commonly used in mobile phones, portable (notebook/laptop) computers, portable power tools, video cameras, etc.

Iron and steel account for nearly half of the total weight of WEEE. Plastics represent about 21 % of WEEE and non-ferrous metals represent about 13 % (Widmer et al. 2005). An older polychrome CRT can contain 2–3 kg of lead, whereas a more recent CRT usually contains less than one kg of lead. The electron gun of the CRT contains barium and barium compounds (OECD 2003). Fluorescent phosphors containing zinc, a cadmium and rare earth metal, is coated on the interior of CRT panel. Figure 8.3 shows composition of desktop computer with CRT.

A notebook PC display can have nearly 0.5 g of liquid crystals whereas mobile phone display can have nearly 0.5 mg. Liquid crystals are implanted between layers of electrical control elements and glasses. About 250 substances are used for making about a thousand marketed liquid crystals. Past studies have not confirmed carcinogenic potential even though the materials used for liquid crystals cause acute oral toxicity, corrosiveness, irritant to the skin (AEA 2004).

Polyvinylchloride (PVC) is the widely used plastic in electrical and electronic goods which are known to emit dioxins and furans during combustion at temperature less than 1,200 °C. Brominated flame retardant (BFR)s are used in some plastics to reduce the flammability and are found in many electronic goods (Birnbaum and Staskal 2004).

It is estimated that worldwide, 20–50 million tonnes of WEEE is disposed annually with the Asian nations disposing off about 12 million tonnes (Greenpeace NA). Total quantity of WEEE generated globally is estimated by UNU (2007) to be 40 million metric tonnes per year. As per the studies conducted by Dalrymple et al. (2007) the EU countries discard about 6.5 million tonnes of WEEE per year with nearly 16–28 % growth every 5 years. Discarded quantity of WEEE in the EU could be as high as 12 million tonnes by 2015 (Goosey 2004). WEEE makes up to 1.5 % of the domestic residual waste in Germany (Dimitrakakis et al. 2009). The amount of WEEE from Germany is between 1 and 1.4 million tonnes/year. In 2006, 1.8 million tonnes WEEE is generated by German market (FEA 2008) and about 750 K tonnes WEEE is reported as returned (Janz and Bilitewski 2009).

WEEE is one among the fastest increasing waste streams in the UK (POST 2007) with about 940 K tonnes of domestic WEEE disposed in 2003 (Dalrymple et al. 2007). Ketai et al. (2008) estimated that around 4 K tonnes of WEEE are disposed throughout the world every hour out of which 80 % is exported to Asia. Every year, households dispose about one million tonnes of WEEE. In 2009,

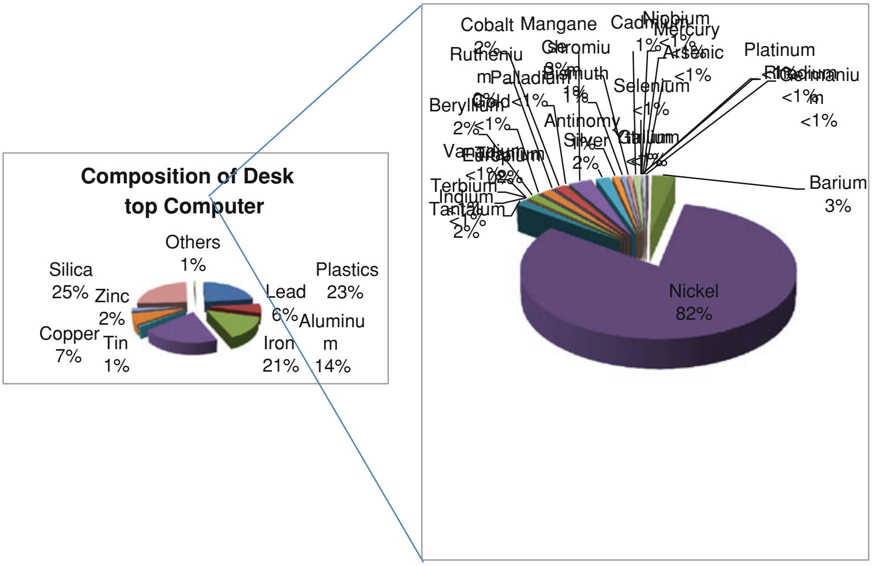


Fig. 8.3 Composition of desktop computer with CRT

about 1.5 million tonnes of EEE was placed in the UK market and about 454 K tonnes of WEEE was collected (Environment Agency 2010).

WEEE accounted for nearly 2.6 % of the overall municipal solid waste stream in Switzerland, during the year 2003 (Khetriwal et al. 2009) and processed about 40,000 tons of WEEE during 2004 (Streicher-Porte 2006).

The 1980s saw a surge in electronic good consumption in China (Yang et al. 2008) and after two decades these goods would have reached the end of their useful lives (Li et al. 2006). As per Schluep et al. (2009), about 2.4 million tonnes of EEE were put in the market of China in 2007 and 2.2 million tonnes of WEEE were produced. According to Xinhua News Agency (2010) about 40 million mobile phones, 25 million TVs, 12 million computers, 10 million washing machines, 6 million printers, 5.4 million refrigerators and 1 million air conditioners were thrown out in 2009.

As on 2011 China was the largest producer, consumer and exporter of electronic and electrical goods and it generated 1.7 million tons of WEEE in 2006 (Xinwen et al. 2011). The figure is expected to reach to nearly 5.4 million tons by 2015 (Yang 2008). Increase in domestic EEE consumption results in corresponding, time-delayed increase in WEEE (He et al. 2006; Liu et al. 2006a). China receives nearly 70 % of all exported WEEE (Liu et al. 2006b), while remarkable quantities are also received by Pakistan, India, Vietnam, Malaysia, Philippines, Ghana and Nigeria (Puckett et al. 2005) and probably to Mexico and Brazil too. As per Schmidt (2006) about 500 shipping containers with electronic goods are transported through Lagos every month. As per Wang et al. (2009) obsolete Personal computers would reach 93.36 million units, absolute TVs would reach

74.31 million units and air-conditioners would reach and 63.9 million units in 2012. China is receiving continuously e-waste from US, Europe and other Asian countries (Puckett et al. 2002; Terazono et al. 2004; Hosoda 2007). Electronics industry is main economic driver of China (Manhart 2007) and is growing fast since 1980s (Yang 2008).

People rarely discard their used EEE in many developing countries even when they are broken or out of date due to a perception that the items could be useful in the future. Most of the times the EEE will be repaired and used for many years unlike the developed countries where the EEEs are disposed of as soon as new attractive EEE goods appear in the market. Another reason for not disposing is lengthy procedure to be followed in many of the government organisations and universities where the absolute and unused electronic goods remain for long time even when they are not used.

As per Jinglei et al. (2009) China is the largest exporter of EEE and also the largest importer of WEEE in the world importing about 35 million tonnes of WEEE from developed nations. As per Yang et al. (2008) it is not apparent how much WEEE is imported into China.

In another developing country, India, the situation is not different either. In addition to illegal imports, domestic WEEE is generated significantly in India (Sepúlveda et al. 2010) with about 50 K tonnes of WEEE imported per year (Manomaivibool 2009). The amount of EEE in the Indian market during 2007 was about 823.6 K tonnes and WEEE generated was about 439 K tonnes (Schluep et al. 2009). Even though some of the used goods are reused, most of the imports are intended for the backyard recycling (Manomaivibool 2009). Common practice in India is to import WEEE as ‘‘reusable’’ products, ‘‘mixed cable scrap’’ or ‘‘mixed metal scrap’’ (Manomaivibool 2009).

About half of the End of Life (EoL) EEE are exported to Asian nations like China, Philippines, Afghanistan, Malaysia and Cambodia as second-hand goods (Shinkuma and Huong 2009; Yoshida and Terazono 2010).

Except in South Africa, WEEE recycling in Africa is rare (Nnorom and Osibanjo 2008). Growth in information and communications in the past decade and import of about 15–45 K tonnes/annum of the unusable computer hardware are two major contributing factors of WEEE in Nigeria which are burnt to reduce the waste quantity (Osibanjo and Nnorom 2007). Schluep et al. (2009) estimated that the quantity of EEE that entered South African market in 2007 was 99 K tonnes per year. Access to the EEE in the last decade has risen in South Africa with nearly 1.5 million computers entering its market every year (Lombard and Widmer 2005). Senegal is importing new and second-hand computers (Rochat and Laissaoui 2008). About 15 % of the computers imported to the nation are used in Uganda. An estimated 5.4 K tonnes of EEE was put in the market of Kenya in 2007 and about 7.4 K tonnes of WEEE were produced in the same year (Schluep et al. 2009).

Brazil generated 679 K tonnes of WEEE 2006 whereas Mexico generated about 28 K tonnes of IT waste in Mexico. Colombia generated about 6–9 K tonnes of computer waste in 2007 whereas Peru generated about 7.3 K tonnes per annum and Chile, generated about 7 K tonnes WEEE in the same year (Silva et al. 2008). As per the Environment Protection Agency of the USA, about 235 million units were accumulated in 2007 (EPA NA). Canada produced about 86 K tonnes of WEEE in 2002 (Environment Canada 2003).

The global WEEE will change with economies and technologies are developed as the total number of computers and other electronic goods are strongly correlated with a country's GDP.

8.3 Material Recovery, Treatment and Disposal

Once WEEE is transported to a materials recovery facility (MRF) the wastes are sorted. The sorted items can be divided into reusable or recyclable categories. There is huge evidence that the repair which was practiced in the USA during two decades ago is now not economical. As per the US EPA (2000) TV repair industry in the USA employed 588,000 people in 1997. But as per Hai-Yong and Schoenung (2005), there is a decline in the industry. Hence the MRFs receive huge quantities of WEEE wherein valuable components are segregated and sold.

Recycling activity contain the following main steps: (a) disassembly, (b) upgrading, and (c) refining (Cui and Forssberg 2003). Figure 8.4 shows a schematic diagram of the steps at a materials recovery facility. Figure 8.5 shows process diagram for disposing of CRT. Some facilities may skip some steps depending on sophistication of unit. Some of the WEEE recycling and disposal activities in the developing world are highly polluting engendering human health. Such polluting activities involve burning of wires and other electronic component to segregate metals, manual crushing of electronic/electrical goods and cells (Table 8.1 and 8.2) for recovery of metals, manual segregation of plastic, glass and other components, and immersion of electrical and electronic goods in chemicals manual.

The magnitude of material recovery at a MRF depends on the size of the facility as well as the target electronic products (IAER 2003). The market for recovered material varies from country to country. More than 50 % of the WEEE from developed countries is exported to developing countries like China, India, and Pakistan as there is great demand in these countries for reuse and recycling of electronic components.

Disassembly is usually carried out manually to recover components like casings, CRTs, external cables, batteries, PCBs, etc. These components are tested and the components which are functioning are sent to secondary market like repair shops, electronic goods assemblers, and electronic goods servicing agencies.

Cathode ray tubes are main item in electronic recycling because of their volume, disposal limitations and recycling costs. Figure 8.6 shows typical storage and dismantling units.

A CRT consists of two main parts: (1) the glass components comprising of funnel glass, solder glass, panel glass, neck, and (2) The non-glass components

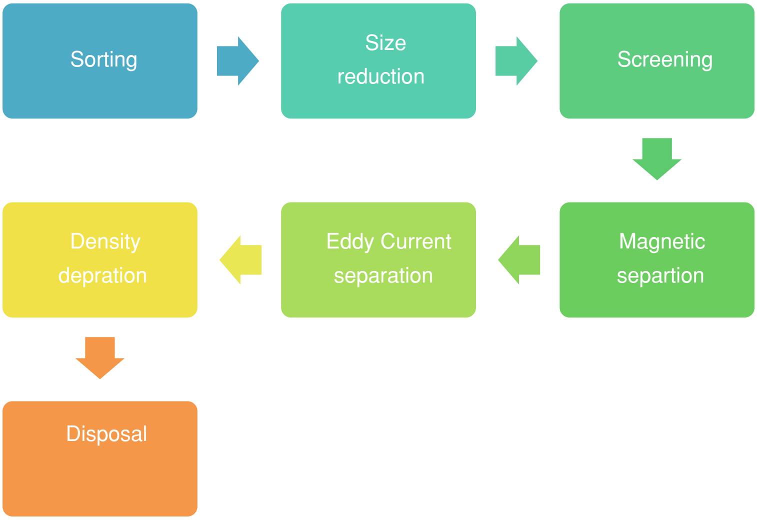


Fig. 8.4 Schematic diagram of steps at a materials recovery facility

Table 8.1 Commonly used rechargeable batteries

Type	Major components	Uses
Nickel–Cadmium (NiCad)	Nickel, Cadmium, Potassium Hydroxide	Power tools, cordless phones, professional radios
Nickel Metal Hydride	Nickel, some "Rare Earth" metals, Potassium Hydroxide	Power tools, cordless phones, professional radios
Lithium Ion	Lithium, cobalt oxide	Computers, cellular phones, digital cameras
Rechargeable Alkaline	Zinc, Manganese Dioxide, Potassium Hydroxide	Flashlights, radios, toys, remote controls, portable radios and televisions, garage door openers
Small sealed lead-acid	Lead, sulfuric acid	Alarm systems, emergency lighting. Some toys and other miscellaneous devices
Vanadium redox	Vanadium pentaxide	Electric vehicle
Lead acid Battery	Lead, lead oxide, sulphuric acid	Vehicle

comprising plastics, electron gun, steel, copper, phosphor coating. CRT glass consists of NaO, SiO_2, CaO, ZnO, BaO, K_2O, MgO, PbO.

There are two technologies available as on date for CRT recycling: (1) glass-to-glass recycling, and (2) glass-to-lead recycling.

In glass to glass recycling whole glass is ground without separation of funnel and panel glass. In the glass-to-lead recycling process, copper as well as lead in CRT glass are separated and recovered through a smelting process. Disassembly is

Table 8.2 Commonly used non-rechargeable batteries

Type	Major components	Uses
Carbon–Zinc or Zinc Carbon	Zinc, carbon, ammonium chloride	Flashlights, toys, remote controls clocks, and smoke detectors.
Alkaline Manganese	Zinc, manganese Dioxide, Potassium hydroxide	Flashlights, radios, toys, calculators, remote controls, portable radios and televisions
Alkaline Manganese button cells	Zinc, manganese Dioxide, Potassium hydroxide	Watches, calculators, toys, some cameras
Lithium	Lithium, Manganese Dioxide or Polycarbon monofluoride, solvent	Cameras, pagers, keyless locks
Aluminium Air	Aluminium	Military applications
Zinc Air	Zinc, carbon	Hearing aids, pagers
Mercuric Oxide button batteries	Mercuric oxide, Zinc, Potassium Hydroxide	Hearing aids, watches,
Mercuric oxide Battery larger	Mercuric oxide, Zinc, Potassium Hydroxide	Specialized industrial, medical, emergency equipment
Nickel oxyhydroxide battery	Nickel oxyhydroxide, manganese dioxide and graphite	Flashlights, radios, toys, calculators, remote controls, portable radios and televisions
Silver Oxide	Silver oxide, zinc, potassium hydroxide	Watches, calculators, toys, greeting cards, musical books

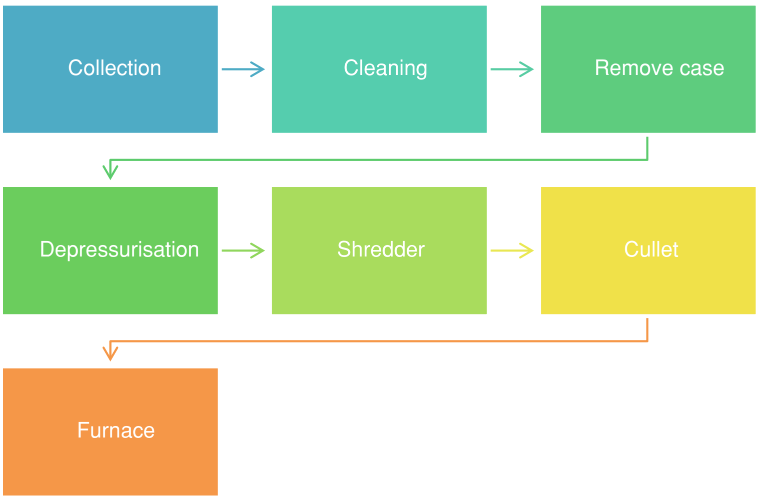


Fig. 8.5 Process diagram for disposing of CRTs

followed by upgrading and refining stages involving mechanical and metallurgical methods. Mechanical processes involves shredding or crushing process to obtain fractions based on their physical characteristics, like size, weight, density, shape, and magnetic and electrical properties.

Usual segregation processes involved are magnetic separation for ferrous parts, Eddy current separation for nonferrous materials.

A magnetic separator uses a permanent or electric magnet for separation of ferrous materials. The overhead belt magnet is the most widespread magnetic separation system. Shredded material particles are moved over the magnet on a conveyer belt where the ferrous metal pieces will adhere to due to magnetic attraction while the other material fraction are dropped into a non-ferrous material collection system/bin by gravity. Ferrous metal pieces remain attached to the belt which are carried away and dropped into a collection container/system when they are no longer influenced by the magnetic field.

Magnetic fraction which dominantly contains ferrous materials would be sent to a steel plant or foundry. Aluminium and copper fractions will be used in recycling industry of respective metals. Plastic fraction will be used in plastic recycling industry. In the case of plastics which cannot be melted they will be used in products like acoustic panels used for interior of auditorium or false ceiling. Crushed glass will be used by glass article manufacturers.

Eddy current separators are employed for non-ferrous metals from non-metallic fractions. When a non-ferrous metal passes above the separator, the magnets in the shell rotate at high velocity. This forms eddy currents in nonferrous metal which in turn create magnetic field around the nonferrous metals. The polarity of magnetic field will be the same as that of rotating magnet, causing nonferrous metals to be repelled away from magnet. Such repulsion results in the trajectory of the non-ferrous material greater than that of non-metal fraction, allowing the nonferrous and non-metal streams to be separated. The ratio of electrical conductivity and density of the material is main criteria for eddy separation. The materials with higher ratio of conductivity to density will be separated easily compared to those with lower ratios.

Aluminium is easily separated in eddy current separator. Stainless steel, glass and plastic have a zero value for conductivity-to-density ratio implying that these materials cannot be segregated by an eddy current separator. Non-ferrous metal embedded in a non-metallic substance (for example copper and aluminium wire embedded with insulation) cannot be separated using eddy current separator.

Plastics are coated/mixed with additives in order to make it flame-retardant. Presence of such additives acts as a barrier for recycling plastics. As the recyclers need a steady supply of the similar type of plastic, it will not be possible to meet such demands because each electronic good uses different types of resin/colour/additives.

The degree of environmental and health impacts vary greatly depending on the technology adopted in the treatment and disposal of WEEE. For example, the possible hazard associated with disassembly stage accidental spillages and releases of hazardous substances like mercury (Aucott et al. 2003). Similarly, the risks involved in handling of CRTs are the risk of implosion because of vacuum in the tubes and inhalation of phosphor coating of the CRT glass.

Fig. 8.6 Typical storage and dismantling units in WEEE processing units

Printed circuit board undergoes shredding, grinding to produce dusts of the material being shredded which includes plastics, ceramic, metals and silica (MJC 2004). As per the studies in a US based electronics recycling facility by Peters Michaud et al. (2003) concentration of cadmium and lead levels in air were found to be 0.27 and 1.4 μg/m^3, respectively. Presences of BFRs in the fine dust fraction recovered were reported by Morf et al. (2005) in the off-gas purification system in a Swiss recycling plant of WEEE. Studies by Takigami et al. (2006) in the air of a TV recycling unit revealed that concentrations of BFRs were higher than background levels.

The monitoring of dioxins and furans from combustion has been well documented (Funcke and Hemminghaus 1997; Sakai et al. 2001; Söderström and Marklund 2002; Tange and Drohmann 2005; Vehlow et al. 2000; Watanabe et al. 2008).

Figure 8.7 shows recycling options for managing plastics from end-of-life electronics. It is essential that the paint and coatings be removed failing which properties of recycled plastics would not fetch good economic returns. Chrome

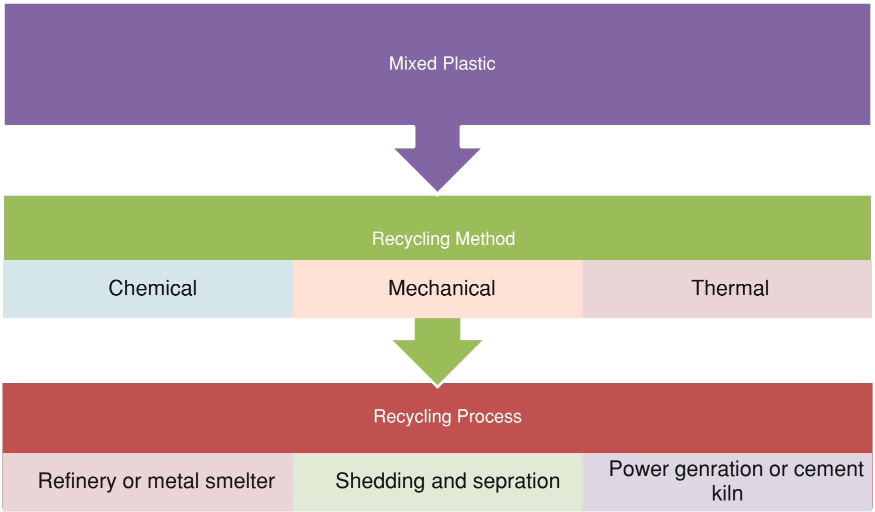


Fig. 8.7 Recycling options for managing plastics from end-of-life electronics

from plated plastics can be grinded and assisted with cryogenic methods to prevent the plating materials being embedded in plastic granules. Abrasive techniques, solvent stripping, high-temperature paint removal methods are the other methods employed for removing coating and paint from plastics (Biddle 1999; Plastic technology 1994).

A reverberatory furnace is usually employed for recovery of lead by charging the furnace with lead-containing materials wherein lead compounds will be converted into to metallic lead and other materials are oxidized to slag. Figure 8.8 shows a process for secondary lead recovery. Slag from a reverberatory furnace is charged to blast furnace with iron and limestone as fluxing agents to enhance furnace efficiency.

Copper is recovered in blast furnace wherein scrap with the copper is reduced by reducing agents like scrap iron and plastics. Figure 8.9 shows processes for secondary copper recovery. The product from the blast furnace called black copper is fed into the converter for oxidation. Blister form converter with copper purity of 95 % is fed into an anode furnace, wherein coke or wood or waste plastic is used as the reducing agent. The copper form anode furnace can be further purified in electrolytic refinery.

Precious metals like gold, silver, palladium and platinum are recovered in precious metal refineries. A schematic diagram of precious material recovery processes is shown in Fig. 8.10. Figure 8.11 shows manual segregation of larger fraction of copper pellets and plastic after shredding and screening. Not all WEEE processing plants will be able to recover costly metals like gold, platinum, etc. In such scenario the powdered metal will be sent to sophisticated plants which have recovery facility. The anode slime from the copper electrolysis is leached by

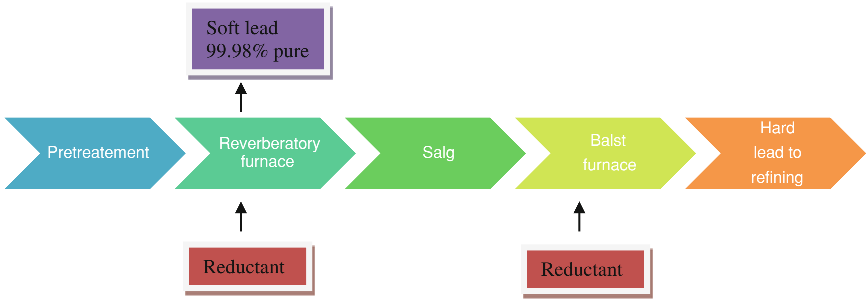
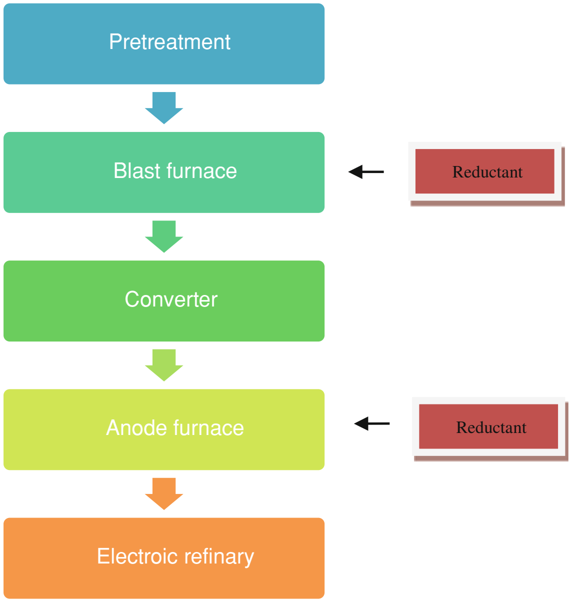


Fig. 8.8 Process for secondary lead recovery

Fig. 8.9 Processes for secondary copper recovery



pressure and the leach residue is smelted in precious metals furnace along with fluxes.

Metallurgical processes involve melting and electroplating. Hydrometallurgical treatment involves acid or caustic leaching of solid material followed by isolation and concentration. Major leaching solvents used for in hydrometallurgical treatment are sulphuric acid, hydrogen peroxide, aqua regia, thiourea, cynide leach solutions, nitric acid, sodium hydroxide, hydrochloric acid etc. (Antrekowitsch et al. 2006). Ion plating is environmental friendly as it avoids chemical solutions. Ion plating is sometimes employed at WEEE processing facilities. It is also called *ion assisted deposition* (IAD) or *ion vapour deposition* (IVD). Ion plating is a

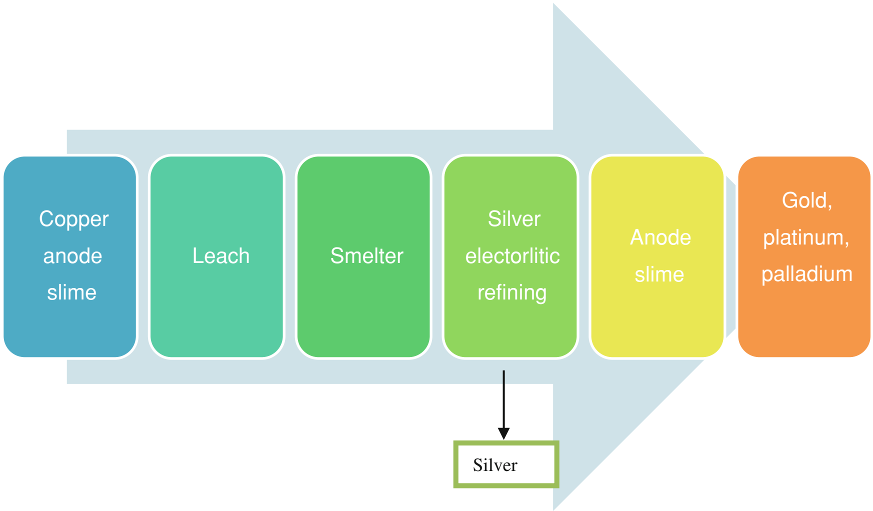


Fig. 8.10 Precious metals recovery process

Fig. 8.11 Manual segregation of larger fraction of copper pellets and plastic after shredding and screening

physical vapour deposition process wherein depositing material is vaporized and films of materials is deposited.

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