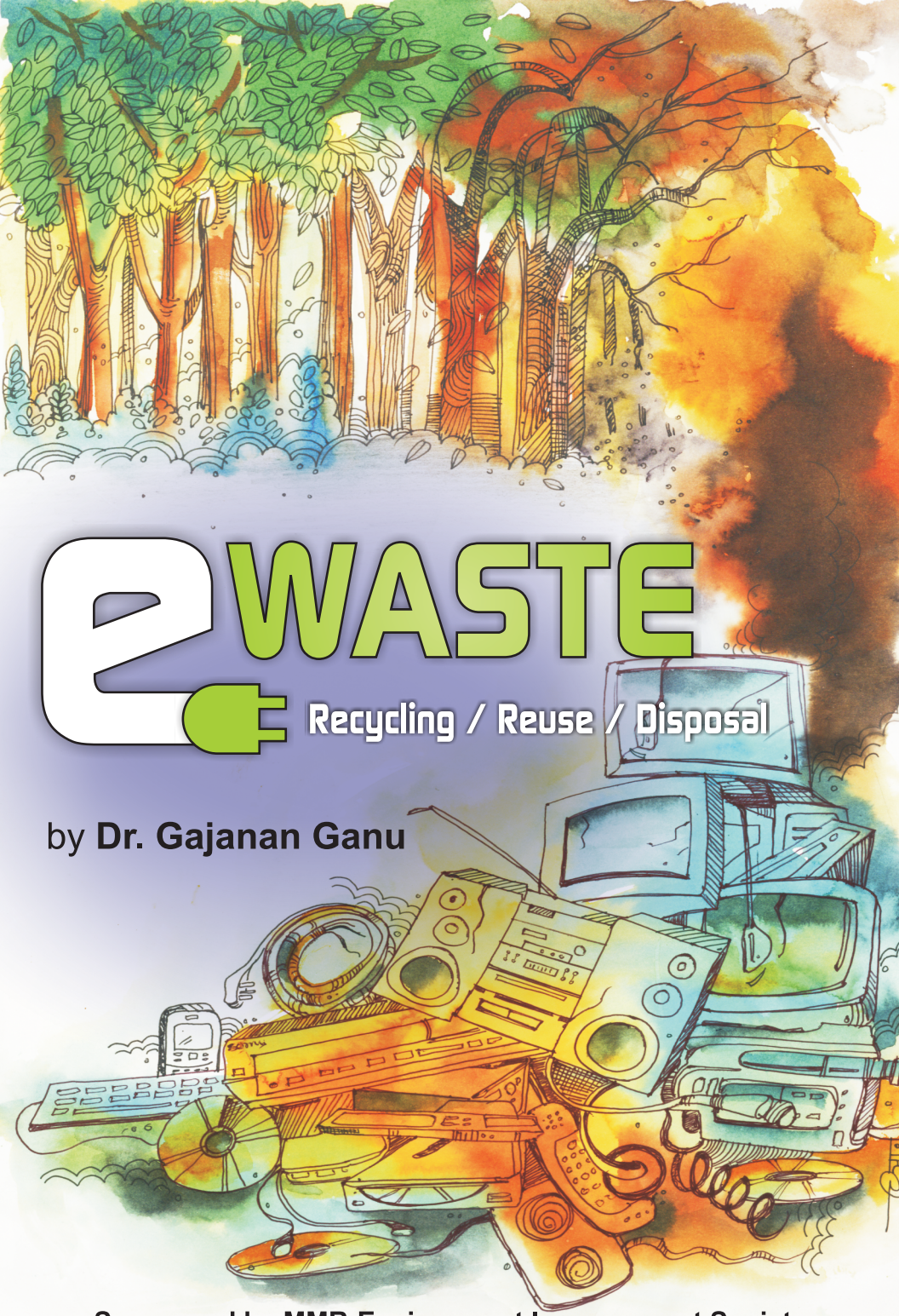


e-WASTE

Recycling / Reuse / Disposal

by **Dr. Gajanan Ganu**

Sponsored by MMR-Environment Improvement Society



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E-Waste
Recycling / Reuse / Disposal

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Preface

Since antiquity we are devotees of Nature. Aayurveda, the great scripture, tells us how we can have a healthy life if we maintain equilibrium with main five principle media, namely earth, water, radiance, air and the heavens. (Pruthvi, Jal', Tej, Vayu and Aakash) of the nature. This is what we call "Environment". Any deviation of those media principles from the equilibrium affects us. We suffer. The factor responsible for this deviation is called a pollutant and the process is called "Environmental pollution".Since 1960 special types of pollutants have emerged from electrical and electronic wastes (together called as E waste) which are hazardous and toxic. This is affecting all the above media, at a very fast rate.

With an intention to educate the common reader about i) the general prevalent polluting agents and ii) the most threatening types of pollutants generated in large scale from the EW, that are responsible for environmental deterioration and our health decay, a project regarding 'Booklet on Electronics Waste' was proposed to MMR-Environment Improvement Society. The Board of Governors approved this project for financial assistance,

EW is a major source of toxins and carcinogens. The rate of daily accumulation of this EW is very high all over the world. Every attempt with respect to A) Various types of pollutants generated by EW B) EW management measures e.g. collection, storage, dismantling, sorting, separating, recovery, segregation and disposal of hazardous materials C) stakeholders such as manufacturers, users policy makers etc. involved with EW & D) how EW, if treated properly can be a source for secondary raw materials e.g. copper, silver, gold metals and plastics, are explained. Some self practiced laboratory procedures, for the recovery of gold from EW are explained.

I am very much indebted to MMR-Environment Improvement Society for the sponsorship and timely guidance given during writing of this book. I take this opportunity to thank all those persons who encouraged and helped me directly and indirectly - during library reference search, writing, typing and final submission of this booklet in this form.

Thanking again
Gajanan M. Ganu

Chapter 1 - General

The natural complex factors e.g. air, water, land and every thing that affects an organism during it's life time is collectively known as the environment. Human activities done for normal, safe and healthy existance have impacts on these factors. Due to increasing rate of population and changing life styles, our demands for food, water, minerals, energy, living amenities and status comforts are increasing. Due to such ever increasing resource consumption and subsequent generation of waste full of pollutants, the natural healthy equilibrium between man and environment is disturbed and we have to suffer.

1.1 Our environment - Components of environment

Environmental science is the science of the inter relations among all the biotic & abiotic components on the earth including air, water, plants, organisms, and their mutual aggregate impacts. Atmosphere, hydrosphere, Lithosphere, Geosphere (earth) and Biosphere are the components of environment. Atmosphere is air surrounding the earth, Hydrosphere pertains to earth's water. We are concerned with the ground water. Lithosphere is outer layer of earth. Geosphere concerns the next part of the earth, named as soil. Biosphere is the region where all living organisms dwell. When all these components of environment remain in equilibrium, life is enjoyable.

1.2 Environmental degradation

Our environment is clean and simple so long as it is in the balanced state and in perfect equilibrium with human lifestyle. Environment becomes complex when the key problems such as a) global warming b) ozone depletion c) acid rain and the most important d) man's activities e.g. • Uncontrolled population growth • rapid consumption of natural resources • Little or no emphasis on air, water, soil pollution prevention and waste management • Shrinking of ground water stock. • Inadequate public health and sanitation care • forestation. • Rapid Industrialization • Scarcity of water, food, shelter etc.

1.3 Ecology

Ecology – Science and engineering when combined becomes technology. This leads to growth. Technology is used by interweaving ecology and environment together. So ecology concerns with mutual interactions and relationship between the living organisms and all above factors governing the environment. The specific environmental atmosphere in which a particular class of organisms lives is called 'habitat'. The reasons of unhealthy habitats or polluted environment are that mentioned above. So many other kinds of pollutants e.g. noise, food, metal, thermal, radiation, smell / odour etc. also contribute to the pollution. Ecosystem accounts for the population explosion leading to the depletion of resources. Diseases producing pollutants like viruses and bacteria are generated by natural forces as well as by human activities .

1.4 Atmosphere

Composition of atmosphere : Atmosphere of the earth is a layer of a mixture of many gases surrounding us and is retained there by earth's gravity. Atmosphere protects life on Earth by absorbing ultraviolet solar radiations and cooling the surface. This way the temperature extremes between day and night are maintained. Atmosphere is mainly composed of Nitrogen (78.1%), Oxygen (21%), and Argon (0.9%). They are the major gases . The remaining gases are referred to as trace gases. They include the greenhouse gases such as watervapour (1.3%), carbondioxide (0.03%), methane, nitrous oxide and ozone.

Component layers in atmosphere: Earth's atmosphere can be divided into five main zones/layers,on basis of the altitude in km, they are 1) upto 10km.is called **Troposphere,** the zone close to earth, is important zone for living world. 2) 10 to 50 km is **Stratosphere** 3) 50 to 150 km is **Mesosphere** 4) 150 to 400 km is **Thermosphere** and the 5) **Exosphere** the outer most layer of the earth's atmosphere.(see figure 1.1).Due to the continuous variations in temperature (between minus 50 to plus50) , pressure (between 100 to 10 atm.) in Troposphere we find changes in velocity and direction of the wind. This have definite impacts on the various human activities. This atmosphere belt becomes thinner

and thinner with increasing altitude. Boundries among these gases in the atmosphere and the outer space are not demarked or defined.

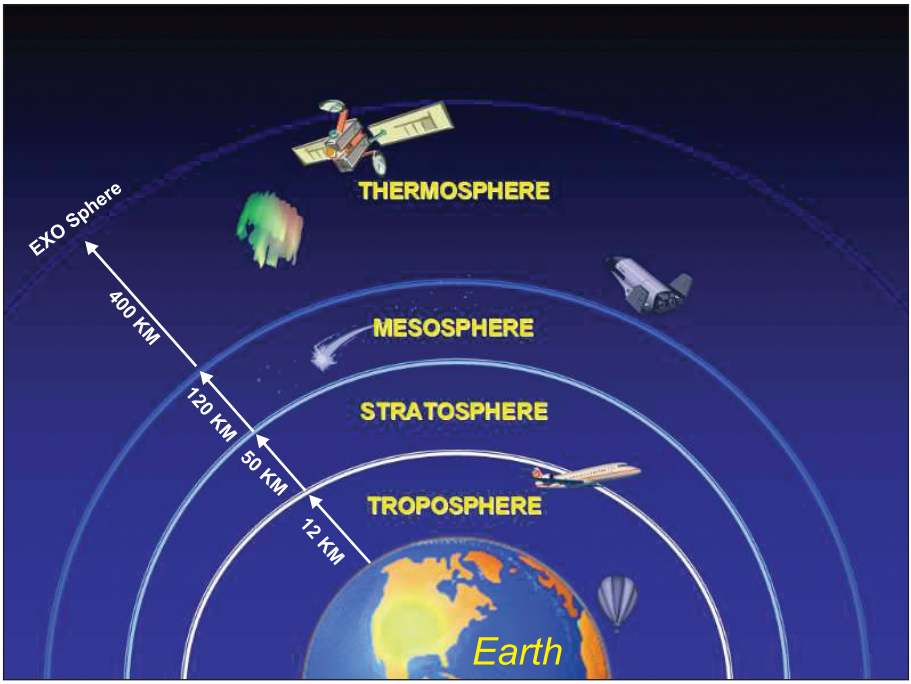


Figure 1.1 : Earth and layers of Atmosphere

1.5 Pollution

Pollution is defined as an unfavourable alteration of the environment due to the presence of agents, called as pollutants , that are produced by natural changes and / or human activities during his life cycle. Environmental Pollution makes living uncomfortable. The interactions of all types of pollutants produced in atmosphere have adverse effects on us. Pollutants produce synergistic effects. Once pollutants are released in any medium e.g. air ; water and soil , they are slowly transported to other media through diffusion processes. Thus entire atmosphere is polluted. Environmental pollution has been classified into different groups. Such as (a) air pollution (b) water pollution (c) soil pollution and (d) specific pollution from different sources and agencies, identified as noise, pesticides, food, metals, thermal, plastics etc.

1.5.1 Air pollution

Atmosphere plays a significant role in global processes supporting life on earth. Tropospherr serves as an efficient heat reservoir.

Stratosphere contains Ozone gas. It is the most important component.

Along with, there are also highly reactive gas species such as O^{+2}, NO^{+} and O^{-4}. They protect earth by absorption of short wave radiations of the Sun. Oxygen absorbs ultra violet radiation and is transformed to ozone (O_3), by photochemical reactions. When carbon dioxide (CO_2) limit exceeds, we get what is called as "Greenhouse effect" i.e. warming up of troposphere When oxides of nitrogen e.g. NO – Nox undergo photochemical reactions, they produce NO_2 and NO_3. These reaction products are condensed on innumerable minute particulates suspended in atmosphere that promote precipitation or rain formation including the acid rain. These colloidal particulates are called aerosols. Ozone layer, acid rains and the Greenhouse effect lead to global warming. Among the various types of pollution, air pollution is of great significance.

Particulate matter (PM): They are finely divided airborn solid particulates suspended in the atmospheric water e.g. acid mist . They may be classified as primary or secondary particulate matter depending on the compounds and processes involved during their formation. Primary PM is emitted at the emision source e.g. the smoke stack of electrical power plants. Secondary PM (SPM) formation results from a series of physical and chemical reactions involving formation of different gases such as ammonia, oxides of carbon, sulphur and nitrogen etc. According to the environmental conditions PM is seen as 1) Aerosol - are smaller than 1micron. 2) Condensation Aerosol –Aerosol formed by condensation of vapour 3) Dispersion Aerosol –dispersion of dust 4) Fog – minute water droplets 5) Haze – decreased visibility due to suspended particles 6) Mist– suspended liquid particles smaller than 10 microns.7) suspended solid particles in the range 0.1-1.0 microns. 8) Smoke particles resulting from incomplete combustion of any matter, e.g. petrol, coke and coal. Suspended PM is worst among all the pollutants. Auto exhaust causes serious air pollution due to emission of

oxides of carbon, sulphur, nitrogen and benzopyrene . This is a serious air pollutant as it has carcinogenic properties causing lung cancer. Photochemical smog, produced by the combination of smoke and fog contributes several pollutants to air e.g carbon monoxide, carbon dioxide, nitrous oxide, nitric oxide, sulphur dioxide, hydrocarbons etc. The thermal power plants are responsible for extensive air pollution. The size and the concentration of PM in the environment, determine the health damage. All respiratory sufferings are linked to SPM and also have adverse effects on vegetation and visibility….

1.5.1.1 Greenhouse effect:

Various human activities including i) industrial and domestic burning of coal and coke fossil fuels ii) air , sea & land transport activities -are increasing the percentage of CO_2. This anthropogenic increase of CO_2 is consumed by trees through the process of photosynthesis. During day time more trees will take in more CO_2 generated by humana activities, at the same time they would release equivalent oxygen by photosynthesis. The photosynthesis maintains the freshness of air. Consequently, due to this cycle of inhalation and exhalation of CO_2 by the plants and living organisms, the equilibrium is maintained in air. This leads to 'grow more trees' philosophy. This kind of effect is usually termed as “Greenhouse effect”. We are surviving on earth due to this effect.

Basic mechanism (Figure 1.2): The earth receives energy from the Sun in the form of light energy .This is absorbed at the earth's surface and re- radiated in the atmosphere as thermal radiations and warming increases .The persentage contribution by four major gases to the green house effect on earth are *watervapour 36–70% *CO_2 9–26% * methane 4- 8% * Ozone 3–7%. Clouds also absorb and emit infra red radiations . Strengthening of the green effect through human activities is known as enhanced greenhouse effect, which attributwes to increased atmospheric CO_2 levels.

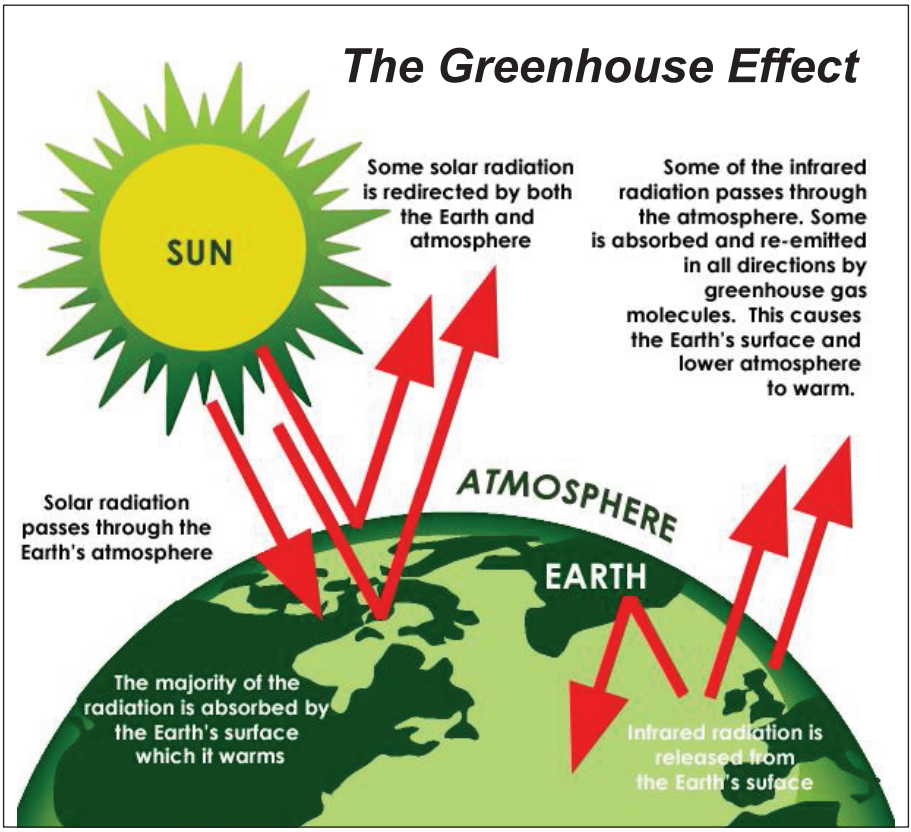


Figure 1.2 : Greenhouse Effect

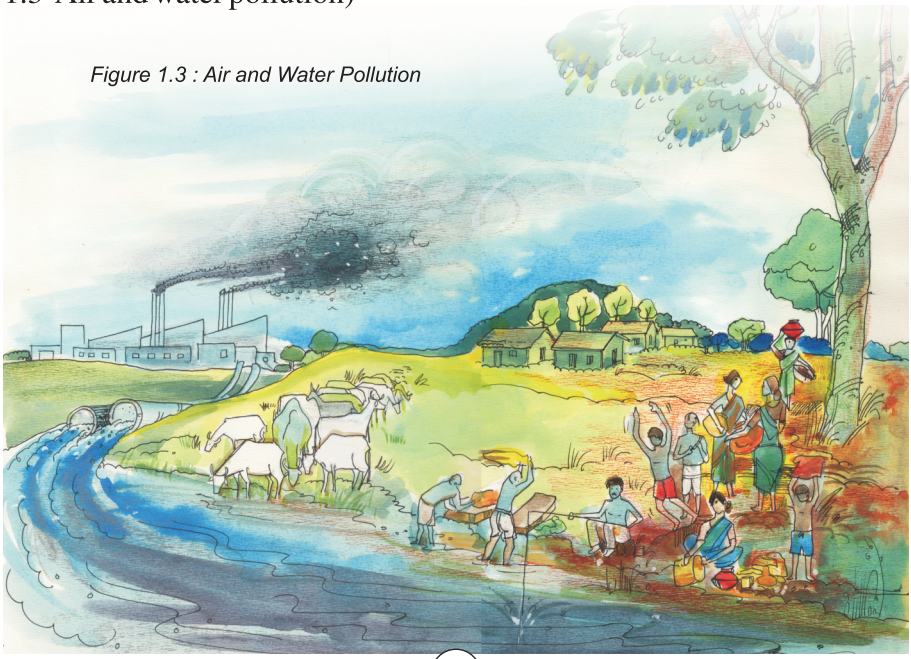
1.5.1.2 Global effect of Ozone

Ozone plays a vital role in the atmosphere. Ozone gas absorbs biologically damaging ultra violet radiation. Such absorption generates heat. Ozone controls temperature of the atmosphere. It is observed that a hole through ozone layer is created by the gases such as fluorocarbons or chlorofluorocarbons (CFC), formed by chlorine, fluorine, bromine, carbon and hydrogen based chemicals. Those gases are responsible for depletion of ozone layer in the atmosphere.

1.5.2 Water pollution

Out of the total volume of water present on the earth, 97% is found in the sea. Out of remaining water, 0.8% occurs in polar ice water that emerges on the surface of earth as river or lake water. As per the natural principles of water cycle, this water is in constant circulation by evaporation, precipitation, percolation and run off. The ground water is mainly used for domestic purposes. In all the times since ancient times entire civilizations have been established and disappeared due to excellent water availability or scarcity e.g. The Indus civilization. Water has excellent physical and chemical properties. It is the best solvent on the earth. Has high dielectric constant and surface tension, is colourless, odourless and tasteless liquid having maximum density at 4^{o} C. has high heat of evaporation and fusion of ice. Unfortunately the fresh water or ground water on which we survive, gets polluted through several agencies and therefore , can not be used as such for drinking purposes. The agencies adding contaminations and pullutants to fresh water are domestic sewage, industrial effluents, plant nutrients, holy bathing, washings, dead animals, organic and inorganic materials, sediments, various viruses. Bacteria etc. All together spoil the quality of water. (Fig. 1.3 Air and water pollution)

Figure 1.3 : Air and Water Pollution



1.5.3 Land / soil pollution

Municipal solid waste (MSW) contains any thing that has become useless e.g. paper, glass, cloth, plastics, metals, hazardous materials e.g. batteries, inorganic & organic acids, corrosives leached out from metal, WEEE components, explosives, highly toxic organic solvents, microorganisms, plants, hospital waste, etc. all together produce stinking smell and creat land / soil pollution. (Fig. 1.4 Land / soil pollution)

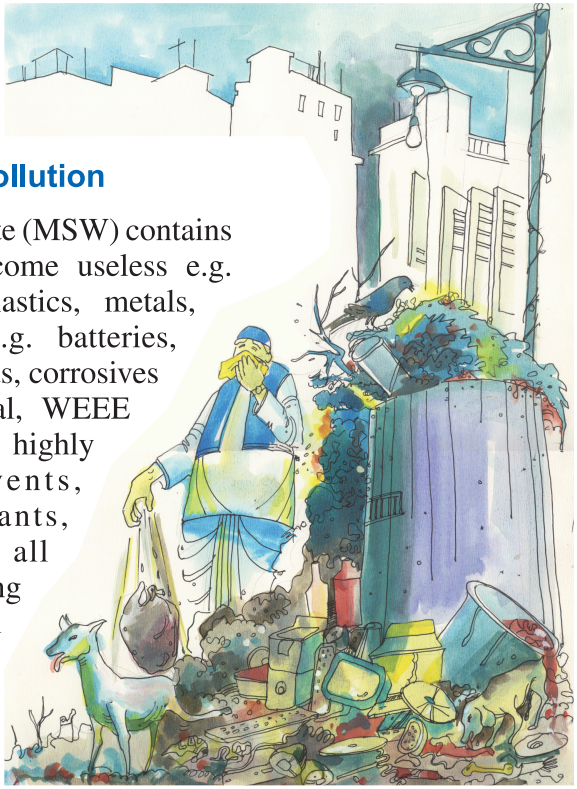


Figure 1.4 : Land Pollution due to MSW

1.6 Sources of Atmospheric pollutants

Atmosphere plays a significant role in supporting life on earth. It nurtures the earth and protects it from the hostile environment. It provides CO_2 for plants and O_2 for us. The chemistry of the ozone layer, the acid rains and the greenhouse effect all together lead to the global warming and are the three giant trouble shooters of environment. Air, water and land are the sources of atmospheric pollutants. Natural forces and man's activities together pollute the atmosphere. Air pollution is of great significance as it causes immediate health problems. The obninoxous gases of carbon, nitrogen, sulphur and benzopyrene from industries, vehicles lead to the acute atmospheric pollution. SPM is worst among atmospheric pollutants: pesticides, food, metal elements,

thermal, radiation, smell / odour are also pollutants of different types. They do not fall under any of the abve categories but still affect us, and can not be ignored.

Flyash: It is the waste mass from any type of power plant. In India 60 power plants produce 30 million tonnes of flyash. Air, water and soil pollution is increased due to this and develops big problem of disposal.

1.7 Dispersion of pollutants in the atmosphere

The ecology and environment are closely related. Polluting agents once are generated in any form do not remain there for a long time. Due to temperature changes and in presence of moisture most of the polluting agents decompose and putrefy the garbage that vaporize producing odour. As long as the polluting agents and the media in which they are reactive, they will keep on dispersing to other media through diffusion due to temperature gradient, wind and rain.

1.8 Role of E-Waste

Due to the tremendous demand for handy, miniaturised EEE e.g. lap top computers, IT instruments etc. the number of failures of such devices is also increasing. Such EEEs , when their use ful life is over, are thrown as high tech trash. Their repairs are economically infeasible. Disposal of WEEEs has become an issue of global concern in this century.

Annual generation of e-waste in India is approximately 1,46,000 tonnes per year (1 ton is equivalent to 0.94 tonnes). When disposal of WEEE is thought ,the greatest problem is that, complete degradation of plastics and metallic elements in this Ewaste require thousands of years, and during that period it will continuously release all types of known pollutants in atmosphere, described above.. It is almost impossible to eliminate all the pollutants in WEEEs and solve the problems of environmental pollution. WEEE is polluting our oceans, soil and atmosphere at a very high speed. The general possible methods of disposal of WEEE through reuse, recycle, recovery and ultimate elimination of pollutants is described in brief in the following chapters.

Chapter 2: Basics of E-Waste

Since 1978, there is growing awareness of environmental pollution , it's monitoring and control. In the second half of the 20th century, the yearly rate of accumulation of discarded electrical and electronic devices, known as **High tech trash,** started increasing so high that their disposal became impossible. By the end of 20th century this trash is declared as a confirmed modern polluting monster. There has been a gradual knowledgeable decline in our natural resources resulting in quality of our environment. This trash is spreading all types of toxic pollutants in the atmosphere affecting the environment and our health .

We use electricity for multitude of purposes such as lighting, heating, cooling, entertainment, unit operations etc. On an average a family of four members consumes per year about 1500 kilowatts hour electrical energy. Business companies and industries, some of them working in three shifts, use heavy machines for production. Computers and communication equipments are on continuously. Mumbai consumes maximum of the total electrical power produced in the country. Ultimately all these electrical and electronic equipments will be added to high tech trash once their useful life is over.

2.1 Definition of E-Waste

All appliances running on electricity and have ended their useful life are called as E-Waste / ew / E scrap /high tech trash or WEEE (Waste Electrical Electronic Equipment).

2.2 WEEE Sources/Categories (Domestic, Office, Industry & Public Services)

Sources of E waste can be categorized as i) domestic ii) office iii) industrial and iv) public service sectors. Electrical power supplying materials e.g. cables, distribution boards, switches, fuses, connectors, and relevent components are common items in all the sources mentioned above. Some representative components such as cables and connectors used for sophisticated EEE in general are shown in figure 2.1.



Figure 2.1 : Some common components in electrical and electronic devices. (A) Power cables (B) Connectors

i) Domestic: Toys, sewing machines, lighting bulbs, tube lights, fans, kitchen appliances e.g. mixers, grinders, ovens, microwave ovens, toasters, power tools, entertainment equipments such as sound recording / reproducing machines, radios, telephones, mobiles, shavers, video games, hair dryers, chandelers, festoons, electronic musicle key boards, TVs, home theatres, computers, printers, refrigerators, laptop, DVD players etc.

ii) Office: Most of the EEE mentioned in i) above are common..Only that the number of EEE is higher and they are of higher capacity. e.g. IT and telecommunication systems, air conditioners, fans, water coolers etc.

iii) Industries: Almost all industries use small, medium to high power electric motors for production of high precision ancillary electrical, electronic or mechanical products. Such machines do operations such as crushing, grinding, mixing, tableting, packing, injection moulding, casting, dispensing etc. All of them having electronically controlled devices.

iv) Public services: Include hospitals, hotels, clubs, cinema halls, railway stations, air ports, bus stations, gardens, drama theatres etc. All such places require special lighting, signalling, audio, video systems. Hospitals require well equipped operation theatres. Cinema shooting studios require special EEEs for lighting and audio systems. All condemned sophisticated EEEs add to WEEEs.

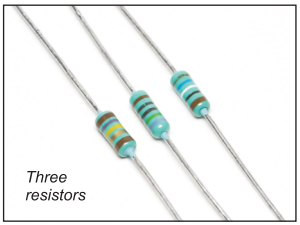
2.3 Components of E-waste

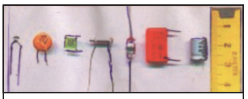
(A) Categories

Basic: There are some basic components, which are common in all electronic equipments. The components are packed in a discrete forms. Such components are fixed by soldering on the printed circuit board

(PCB) at their respective places to perform particular functions in the circuit to get a expected devices such as amplifier, radio receiver or oscillator. Components are insulated and mechanically stabilized. They may be passive or active. Passive components such as resistors, inductors do not require power to operate and so do not have gain or directionality. In net work analysis they are called as elements. Active components have gain or directionality, e.g. semi conductors and vacuum tubes.

Some typical common basic electronic components are i) Resistor - is a two terminal e-component. It produces a voltage proportional to the strength of the current passing through it. Practical resistors are made from carbon, ceramics powder, thick films , resistance wire ; made from alloys of different metals such as nickel, chromium etc. Resistance wires are used as heating elements for ovens and furnaces. ii) Capacitors / condensers - this component stores electric charge which is released when required. Simple capacitor consists of two metal plates separated by non conducting material or a dielectric matter such as glass, mica, oil, paraffin, paper, tantalum, air etc. iii) Inductors iv) Semiconductors v) Diodes vi) Transistors vii) Transformer - transfers required electrical energy from one circuit to another viii) Thick film and thin film components ix) Integrated circuit (IC), Microwave (MIC), Monolithic (MMIC). x) Copper cladded Printed Circuit Boards (PCB) made from phenolic, epoxy resin, fibre glass, ceramics etc. PCBs are of 2-6 mm thick insulating substrates on which the required electronic circuits are screen printed. xi)Batteries are the most important E-components used for supplying wide range of direct current (dc) to almost all E devices. There are two types of batteries namely primary and secondary. Primary batteries irreversibly transform chemical energy to electrical energy. When the initial chemical energy is exhausted they are thrown. Secondary batteries can be recharged. (See figure 2.2 and 2.3). Figure 2.2 Electronic components - resistors, capacitors, Figure 2.3 Various batteries, capacitors, and a typical working printed circuit board with various active and passive E-components.





Capacitor materials. From Left: multilayer ceramic, ceramic disc, multilayer polyester film, tubular ceramic, polystyrene, metalized polyester film, aluminum electrolytic. Major scale divisions are in centimetres.

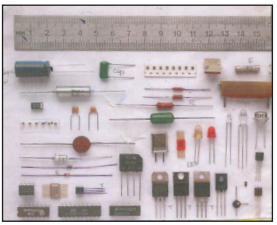
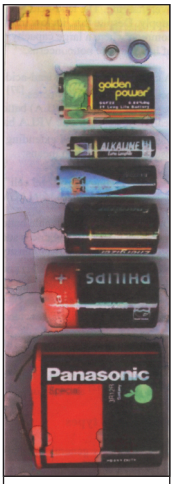
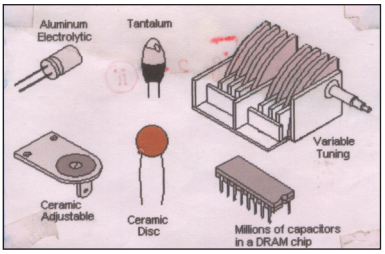


Figure 2.2 : Electronic Components

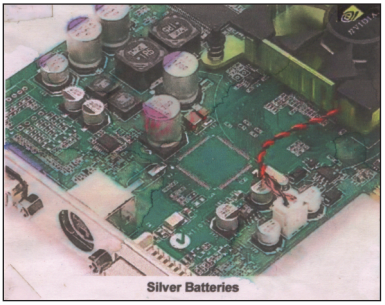
(i)



From top to bottom: SR41/AG3, SR44/AG13 (button cells), a 9-volt PP3 battery, an AAA cell, an AA cell, A C cell, A D cell, and a large 3R12. (Ruler in centimeters)



(ii)



(iii)

Figure 2.3 : Some more E. components (i) Batteries (ii) Capacitors (iii) Typical working printed circuit board, with various E components

(B) Materials of construction: The components of EEE are fabricated from varieties of metals ,non metals and insulators having specific properties. Elements like Lead, Tin, Copper, silicon, Beryllium, Carbon, Iron and Aluminium are used in large quantities. Elements like Cadmium, Mercury, Thallium are in small proportions. Elements like Americium, Antimony, Arsenic, Bismuth, Boron, Cobalt, Gold, Indium, Palladium, Platinum, Rhodium, Selenium. Gallium, Silver are in still smaller proportion or in traces. The main function of supplying electrical power to all components and circuits is done by the copper metal. Almost entire copper can be recovered from the WEEE. Prevention of any short circuiting in the discrete components, PCBs, and entire casing of the

equipment is the prime function of insulators. Among insulators we have rubber, epoxy resins, fibre glass, PVC, thermo setting polymers / and plastics, papers, ceramics etc. that are successfully used. In illuminating category we have halogen, incandescent, fluorescent and other types of lamps. Lamps are blown out from molten mixtures of various silicates. There are special polymers of plastics used for shielding of numerous active and passive e-components and bodies of EEEs. There is a special class of polymers called as fire retarded polymers. External body frames of costly TV sets computers and sophisticated EEEs are moulded from such fire retarded polymers.

C) Harmful, Hazardous, Toxic e-component: In WEEE the most harmful and hazardous components are the monitor of the computers and screens of TVs. These are the Cathode Ray Tubes (CRT).They have high contents of carcinogens (cancer producing chemicals) such as lead, barium, phosphor and other heavy metals. Secondly the insulating materials such as rubber, plastics and various polymers including the flame retardants are carcinogens and toxic in nature. Thirdly all types of batteries contain hazardous metals e.g. zinc, mercury, cadmium, nickel. silver etc. Button batteries contain mercury & silver .Then there are about ten most common metals found in WEEE, that are harmful pollutants. Out of them four important metals namely Lead, Mercury, Cadmium and Arsenic are posing to be the greatest hazardous pollutants to human health .

All four metals are characterized as Persistent Bioaccumulative Toxic (PBTs).

Lead - concentration of lead in house hold dust is as such, many times greater than in earth's crust. Lead being ductile and easy to work was widely used in plumbing, printing, soldering, jewellary casting etc.. Lead has subtle effects on nervous system and kidney, high blood pressure, deficity in memory and learning abilities. Murcury - Mercury vapors in humid atmosphere are converted in to organometallic -methyl mercury. This salt of mercury is more toxic than elemental mercury. Mercury vapors emitted from the amalgam, used to fill the dental cavities, results in sufferings like multiple sclerosis, arthritis, mental disorders. Mercury containing components in EW, are temperature

measuring and controlling devices, switches, batteries, blood pressure cuffs, button batteries etc. Cadmium - A carcinogen, which accumulates in kidneys resulting in it's failure, painful stone forming. brittle bones. Ni-Cd batteries are a major source of nickel & cadmium. There are six nutrient metals in EW. They are useful only if they are in small doses (up to 20 ppm.). They are iron, copper, chromium, nickel, selenium and zinc In excess they are PBTs and toxic Antimony, Beryllium are also PBTs.

Volatile Organic Chemicals (VOC):- Sources of VOCs are almost ubiquitous i.e. unavoidable. Paints, thinners, strippers, varnishes and turpentine are all found in WEEEs. They are the top most contributors to VOCs in air pollution. All paints and polishes, aerosol sprays, waxes are VOCs.

D) Plastics: Innumerable types of plastic resin polymers are used in EEE fabrication. Normally six types of resins are used. They are– Polyethylene terephthalate (PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), low density poly ethylene (LDPE), poly propylene (PP), poly styrene (PS). Plastics are massively accumulating. Enormous quantities of such plastic debris is floating in the ocean. Birds, mammals, fish and sea turtles die because of entanglement in these floating plastics. No marine organisms can biodegrade plastic . WEEE full of hazardous and toxic materials are clogging the landfills. There are three families of persistent bioaccumulative and toxic organic chemicals. i) Poly chlorinated ii) poly brominated - fire retardants and iii) poly fluorinated perfluoro octane sulfonates. They are used to insulate E-components. They are non flamable even at high temperatures

Chapter 3: E-Waste disposal

Due to the present need of advanced technology in developing and marketing sophisticated electronic equipments, more and more people are purchasing such instrument. Result is that the rate of accumulation of EW is increasing tremendously. Thousands of tonnes of WEEE along with the highly toxic pollutants are released by countries all over the world every day. Various studies were carried out by different organizations to identify the quantum of WEEEs in India .The figures declared are as follows. Approximately 500,000 tonnes of EW is collected every year in India. Maharashtra state tops the list of highest collector of WEEE in India. The number is 20,300 + tonnes of EW. Out of this, Mumbai alone generates 11,500 tonnes (1ton is equivalent to 0.94 tonnes) of WEEE. The highest among the cities in India. (MPCB* report). Almost 50 % of the total computers sold, are the products from the secondary market. They are reassembled on old pieces. The remaining market share is covered by multinational manufacturers (nearly 28-30%), Indian branded are 20-22%. Significantly discarded EE appliances in the form of donations ,gifts for reuse and / or for reassembling are exported by developed countries to developing countries including India. The documents on a container though declare that the contents are innocuous plastics, packaging wastes etc. the customs officer found tonnes of broken computer monitors and other electronic waste. All this adds to trash, containing thousands of old computers, TVs, refrigerators, discarded mobile phones etc.

Composition: A typical 27 kg. desk top computer contains following items in kg. plastic 6.26 , lead 1.72 , silica 6.8, aluminium 3.86, iron 5.58, copper 1.91, nickel 0.23., zinc 0.6 kg .We are facing the problem of EW disposal.

Management of Ewaste in India is different from that in other countries. Cultural diversity and economic disparities make this management more complex. Some important reasons are • rapidly increase in EW volumes are often disguised as second hand computer donations towards simply as metal scrap. • No accurate estimate of the quantity of EW generated and recycled. • Low level of awareness

* MPCB - *Maharashtra Pollution Control Board.*

amongst manufacturers, users and common people-of the hazards and toxins involved in conventional methods of EW recycling & disposal. • Wide spread unorganised EW recycling e.g. Using rudimentary techniques in leaching and open air burning. • Cherry pickers recycle and recover precious metals from EW using improper hazardous operations. What happens to our EW is briefly described in the following.....

3.1 Collection

Collection of WEEE from houses, offices, industries and MSW, is an ever growing trade. As such all types of EEEs are durable and can be repaired. and reused. Many a times it is less expensive to buy new EEEs, than to waste time and money in fault finding , removing and replacing parts.

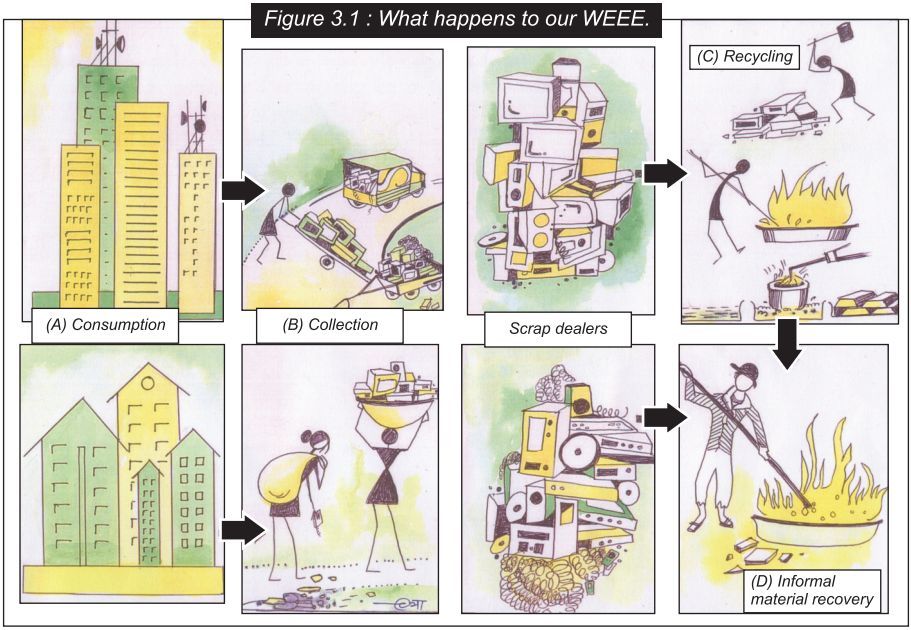
In most cases WEEEs become sources of secondary raw materials e.g. copper, silver, gold, aluminium, noblemetals, nickel, iron, lead, cadmium, mercury, glass, plastics, etc.

In Mumbai a complex EW (bhangar) handling infra structure has been developed by local solid dry waste dealers. They are popularly called as Kabadiwallas. The process used by them for EW recycling is traditional. The unit operations are as follows i) Rag pickers walk along every house, society, corporate buildings on lanes and roads of definite municipal wards ii) pick up all sorts of EW in big plastic carry bags, paying about 10-15 Rs./ kg. iii) Heavy items e.g. computer monitors (for Rs 200 /monitor) are loaded on hand cart / three wheelers / truck. All the E-waste collected is brought to middle man's shop iv) Accounts (secrets) are settled in hard cash v) Middle men bring this heterogeneous EW load to one of the godowns in slums vi) Here appropriate gradation and separation of various items is done by hands vii) Specific lots are taken by specific recyclers / reusers / disposers etc. (See figure 3.1). This WEEEs recycling system is purely market driven.

3.2 Segregation

Once the entire EW is collected, is sent to central godowns in slums. Here the lots are segregated item wise e.g. PCBs, computer, TVs, cables, connectors, transformers, mobiles, domestic appliances, plastics, glass. Hazardous and toxic items are removed manually. At present TVs and computers are the main things in WEEEs. They are generated locally as well as received as gifts ,through imports. It is useful as only metal scrap.

Figure 3.1 : What happens to our WEEE.



3.3 Classification of Ewaste:

Ewaste is classified into Organic, inorganic, degradable, non degradable, metals & non metals.

Organic-Organic matter is composed of carbon, hydrogen, nitrogen and other elements like sulphur. Hundreds of organic matter that are based on polycyclic aromatic hydrocarbons persist in the atmosphere undecomposed for several years and are extremely toxic to organisms, They are oxygen demanding and therefore there is reduction in the dissolved oxygen in moisture and water. Due to this, lives of aquatic

plants and organisms are threatened. Biodegradable substances are destroyed by many aquatic creatures. Exposure to hydrocarbons affects developments of marine organisms. The organic contents of EW such as paper, plastic based substrates of PCBs, thermakol, waxes, dielectrics. lacquers. etc. are mostly petroleum based materials that are not easily biodegraded. Such materials trap plants, fish and other creatures & kill them. Entire garbage collects on the sea shore. Here the garbage when is decomposed causes foul odours by fermentation, attract flies, mosquitoes, various bacteria and viruses that spread all types of diseases. All petroleum based components of EW are considered as hazardous wastes and should be segregated and disposed off separately .

Inorganic: EEEs contain many types of inorganic elements. Some important ino. pollutants are – PBTs (Hg, Cd, Pb, As), nitrates, halides (Cl - , Br - , I -). They are easily soluble in water and are leached out from EW. Fluorides cause fluorosis, affecting teeth and bones. Arsenic poisoning results in arsenicosis (skindiseases) gangrenous ulsers, leprosy. If halogeneted water is consumed by ladies, may lead to miscarriage and “blue baby syndrome" in infants. E-waste contains many toxic and hazardous materials, as already mentioned before. Pollutants are harmful to living beings and plants.

Degradeble / nondegradeble: Most of the items in discarded EEEs contain toxic and hazarduos organic compounds . that require millions of years to disintegrate. Naturally the soil and the ocean mutually regulate the balance between biochemical cycles and climate. But when the WEEEs are dumped without treatments the entire atmosphere is polluted severely. Marine pollution results mainly due to dead birds and fish because of non bio degradeable EW.

Degradeble materials are those which are destroyed by bacteria, although the time required is very long. Some common items and the time taken for them to degeneration are as follows. Thin paper, card board 15 – 30 days, cotton cloth 2-5 months, wool 12 months , metal (corrosion) e.g. aluminium, tin 100- 500 years Plastics 1 million years. Nondegradeable- They are inert to entire class of microorganisms. The immediate effect is pollution.

Out of 114 chemical elements in standard Periodic table ,there are 80 metals. Out of them only 18 metals are toxic in ppm level also .WEEEs are the important sources of these 18 metals. Toxic manifestations caused by these metals are tremor, renal disorders, gastric problems, anemia, dermatitis, jaundice etc.. Among the toxic nonmetals we have boron, carbon, nitrogen, phosphorous, sulphur and halides. Organometallic compounds involving PBTs are used in semiconductors, batteries and Ics.

The words Toxic and Hazardous pollutants are not synonymous. Toxic pollutants are those that can threaten harms to human health or environment to warrant limitations in applications. Hazardous waste are defined as those substances which when discharged present reasonable danger to public health. Toxic materials can produce injury, mutinogensity and carcinigencity, while hazardous materials will lead to injury if wrongly handled. Toxicity refers to intrinsic properties while hazardous words encompass the potential for injury. Hazardous material may be toxic, flammable, reactive, corrosive, irrigative or radioactive. Most of the EW components are hazardous.

3.4 Recycling / Reuse / Incineration

The recycling operations adopted by Kabadis are extremely harmful and have negative impact on the workers health. Hundreds of men, women and children residing in Mumbai's slums are working in highly polluted atmosphere where informal recycling activities of EW. are carried out. The EW management is done through the conventional steps. The important activities included are i) Source or primitive collection- individually and in groups ii) Dismantling / breaking iii) Segregation / sorting iv) Reduction / repairing v) recycling / reusing vi) Diverting the selected material to other streams vii) Composting viii)Burning. All these operations are mismanaged and carried out in slum's open air full of smoke and stinking smell of musty, stuffy EW components. After unloading WEEEs collected from various parts of Mumbai through hand carts, three wheelers, gunny bags, trucks etc. are arranged in small hills, for further operations such as cutting / shredding / hammering / tearing / pulling / desoldering and lastly burning and leaching for extracting metal. The operations are carried out day and

night continuously. On burning cables, wires, PCBs, connectors for recovery of copper etc. in open places, plastics; rubber and other insulating material escape in air as acrid lingering smoke full of poisionous gases and fumes of carcinogens, neurotoxins, dioxins and furans and the metals remain as residue. Dioxins are a group of polyhalogenated compounds which are considered as the most severe pollutants. These enter the human bodies during respiration and accumulate. Furan is a heterocyclic organic compound evolved during burning of polymers and papers / wood. Furan is toxic and volatile which escapes in air at Mumbai's ambient temperature (30 to 35°C). All new EEEs are packed and sold in varieties of packing materials such as steel, tin, aluminium containers and nonmetal materials such as thermokol, plastics, moulded blocks,bags etc. Almost all of them are non biodegradable. They add up to trash waste, once EEEs are removed from them.

Source reduction involves altering i) the design ii) material of construction iii) manufacturing processes, aiming at reduction in the quantity and toxicity from the main stream. Items such as paper, glass, plasics and metal are sorted and diverted for recycling. They are brought back as secondary source of raw materials. Discarded but repairable electronic items have extremely high cost differentials. A simple repairable Laptop can be worth hundreds of rupees, while an imported CRT is extremely difficult and expensive to recycle. and therefore large quantities of TVs and computers are typically sold to developing countries like India, having very high repair capabilities and high raw material demand. The result is - High accumulation of EW.

The important steps to be followed should be based on the principles of Three R R R (3RS) i.e. Reduce, Reuse and Recycle

R1- Reduce: The amount of toxicity which is proportional to the quantity of EW garbage / trash at the sources. All such hills of EW can be reduced by reduction in E-waste generation through i) back yard and composting ii)both sides writing of papers. iii) purchasing durable long lasting , repairable ecofriendly and sturdy EE goods. Source reduction prevents emissions of many green house gaseous pollutants, saves energy and reduces quantity of land fills. **R2- Reuse:** This involves

repairing the gadgets and reusing, donating or selling. This is an alternative to recycling. **R3- Recycle:** Recycling can produce valuable secondary source for raw materials .This diverts tonnes of EW away from disposal. By practice, toxic and carcinogens producing polymers like polychlorinated biphenyls, capacitors, transformers, diodes, cables, PVC coated components are easily identified and removed manually in the first stage. Shredders are used for cutting identified areas in PCBs. Magnetic materials are removed using magnets. Non ferrous metals and plastics are separated, processed and ultimately burnt. Halogenated plastic polymers, resins get easily leached out in hot water this creates disposal problems. Conventional recycling, composting via land filling is often followed.

Various techniques of EW disposal: Once the various EW components for reuse and recycling are sorted out, the remaining material should be disposed off in an ecofriendly way. Majority of EW land up on open dumping areas. Conventionally waste disposal mechanism and techniques adopted are-

Open dumping: Solid E-wastes remained after all treatments of recycling is dumped in low lying open areas in the out skirts of the town. These are uncovered pits and become collective camps of flies, insects, mosquitoes, bees, rhodents etc. together producing obnoxious odours full of bacterias and viruses which produce diseases

Modern landfills are designed to protect migration of pollutants from such area to the environment.

Incineration: Burning of solid waste at a very high temperature (about1800^0 C) in closed systems, is called incineration. Optional technologies for E-waste disposal are i) Plasma arc destruction ii) Biotechnology iii) Molten salt destruction iv) Super heated water etc.

Fly ash: During incineration some metallo organic chemicals are formed. This ash contains dioxins and furans which pollute atmosphere. The collected ash can be used in road paving or is mixed with cement and tiles .

"We can reduce, but can not eliminate waste."

3.5 Actors- Importers, Traders, Disassemblers, Recyclers and their roles:

Asia is the largest EEE manufacturing centre in the world. Here maximum WEEEs are returned when they die. By the mid -1980s EW carrying the lucrative promise of the precious metals embedded in PCBs began freely pouring in India. The actors in Ew are the Importers, Traders, Disassemblers, Recyclers and Users. The problems and challenges of managing EW in India are becoming more and more difficult. The main reasons are i) They are not legally organized. ii) They have low level of awareness of the quantity of EW generated and recycled. iii) They are not educated about the hazards involved during every stage in disassembling, assembling, recycling and disposing WEEEs. iv)They are unaware of the tremendous increase in rate of accumulation of EW volume every day vi) Kabadis, who are the prominent actors in the business of EW are still adopting rudimentary techniques of recycling, burning, leaching and disposing it in open air without paying any attention towards the environmental and health damage. vi) The actors are unaware of the substantial losses of material value and precious metals because of their unscientific ways of handling EW.

Chapter 4: Impacts

Any pollutant once released from any source pollutes the air, water, and soil of our environment. A major reason that we care about a pollutant is that it is toxic to us above certain ppm level. When any foreign particle enters our body it is either digested or distroyed by bio chemical reactions. If not, otherwise it accumulates in the body and affects us through toxins produced as by products of the reactions between our body cells and the foreign particulates. As far as pollutants released from EW are concerned we can say that E-wastes, are families of 209 halogenated (i.e chlorine, bromine, fluorine based) chemicals in the components of E-waste..Most of these halogenated polymers are toxic. Non toxic particle becomes toxic at a high enough dose.

4.1 Air pollution:

Air born pollutants enter our body through inhalation. Unless we deliberately inhale any pollutant in gaseous state the toxic matter can not enter our body. e.g. an gaseous anesthetic Ethyl ether, when inhaled, immediately makes the patient unconscious. Hot metal fumes, particulates in smoke or aerosol spray can be dangerous. There are numerous gaseous pollutants such as carbon monoxide, ozone, sulphur dioxide, nitrogen oxides, PM, lead, organic solvents present in atmosphere. Carbon monoxide is pervasive and accounts for more than 50% air pollution. It is produced due to the incomplete combustion of carbon. This gas is colourless, odourless and flammable. Carbon dioxide is the end product of combustion and much less toxic. Sulphur dioxide ,oxides of nitrogen get transformed to aerosols in the atmosphere. Inhaled pollutants prevent oxygen circulation to body tissues. Oxides of nitrogen during photochemical reactions produce nitrous and nitric anions. They are injurious to health. Size and concentration of PM in the atmosphere together determine the health damage of the people residing in the particular area in the city. All respiratory sufferings are linked to PM. Air visibility and vegetation are affected by PM concentration in the atmosphere. Mumbai emits highest sulphur dioxide. Burning of WEEEs produce all the gases mentioned above in the atmosphere. They are the major sources of air pollutants. Gases such as fluocarbons /

chlorofluorocarbons (CFC) etc. formed because of the reactions of chlorine, fluorine, bromine, carbon and sulphur based gases evolved during burning of plastic compounds from EW including refrigerators, airconditioners, foamblowing, degreasing electrical contacts and solvents for resins are responsible for depletion of the ozone layer in the atmosphere Depletion of ozone concentration leads to skin cancer, eye irritations and problems pertaining to immune systems. Some of the major physiological toxic effects of various air pollutants on human health are tabulated in Table 4.1.Air pollutants directly affect us and the environment. Eventually they get deposited on to soil and water and again affect us.

Table 4.1- Physiological effects of EW air pollutants on human health.

Pollutants	**Effects on human health**
Carbon monoxide	Circulatory systems, Cardiovascular diseases
Nitrous oxide	Respiratory problems , eye irritation.
Ozone	Coughing, chest pain
Sulphur dioxide	Respiratory disorders, chronic diseases
Suspended particles	Breathing, circulatory, olfactory systems
Peroxy Acetyl Nitrite	Eye irritation, burning, sneezing, cough & cold

4.2 Water pollution

Before discussing the impact of EW on water pollution it is absolutely necessary to understand the electrochemical reactions between metals and water.

Electro chemical Cell formation in WEEEs.: As long as the EEEs whether in working or dead conditions and are stored in racks cup boards do not pollute the environment . Now when such devices are broken and thrown for disposal in open land filling, it comes in contact with

moisture. EW is full of several metal elements and alloys. Such components are covered by water film immediately. At that place innumerable minute electrochemical cells are formed. In such cells a metal which is more positive(as per the standard electrochemical potential series) becomes anode, contaminated water film acts as an electrolyte and other metal in contact becomes the cathode. Electro Motive Force (EMF) is developed across the two electrodes, and we get a working cell. Anode (+ pole) metal of this cell dissolves , positively charged metal ions from anode travel through water film and deposit on cathode. This is corrosion. All types of electro-chemical reactions ,such as dissolution of anode, contamination of water, evolution of gases (hydrogen at cathode and oxygen at anode), formation of acids and alkalies, leaching of metals etc. are continuously operative till EMF becomes zero. The result is the release of all types of corrosion products, noxious gases and toxic chemicals. Thus a single entity from EW can release and spread maximum quantities of pollutants in air, water and land. That is why this trash is declared as a confirmed modern polluting monster.

The quality of drinking water: has been the most important factor in ascertaining the human welfare. There are two extensive categories of water pollution. They are A) point sources : Here disease causing pollutants like living creatures, microbes, viruses, parasites, bacteria, pathogens, which are already thriving water since antiquity and B) non point sources :Here pollutants enter the water through various agencies like municipal and industrial effluents. The major agencies are WEEEs. which are full of all types hazardous, toxic, inorganic / organic compounds and plastics.

Soil pollution: Air and water pollutants are deposited on to soil too and may acidify soil. High metal levels in EW, release the by products of electrochemical reactions to soil first. This liquid spoils the soil . Later on they enter the water as lieachates and air in gaseous form. Soil pollution spoils its ability to be farmed.

4.3 Other hazards

Plastics: The amount of plastics discarded from EW is increasing. Recycling plastics ,though environmentally valuable, poses challenges. Firstly, there is the difficulty of collecting and segregating many different types of plastics. Secondly it is more difficult to recover plastics from all WEEE products, such as casings of computers and TVs. The new products produced from such polymers are of low value and not compatible. Such waste is non biodegradable, yet it is disposed off in landfills by injecting it into underground wells or mixing it with MSW and clogging landfills. Dumping metal drums containing hazardous waste on to lands usually at rural sites return back to ground level after few years and the land soil becomes permanently hazardous. Plastics are long time hazards for creatures. This waste creates an environment full of hazards. The greatest hazards is usually to the workers handling ew. Hundreds of ladies and children work hard day and night under one shade having primitive conditions. Their assigned duties are - i) hammering & breaking WEEEs ii) hand sorting E-components iii) - burning cables for recovery of metals iv) leaching in strong acids etc. All operations are carried out without any type of protection against physical injury, chemical accidents or the smoke. All of the workers have the problems such as finger cuts that are never healed (contact dermatitis). All these are the major hazards in this business. When EW containing metals and hazardous organic chemicals are burnt / incinerated, the metals still remain in ash. This ash is still hazardous, although its volume is much reduced. When solutions of hazardous metals are neutralised by acids or alkalies and treated with reducing agents hazardous metals are precipitated and removed by filtration. The remaining EW solution may no longer be hazardous. Often these hazards arise due to improper recycling and disposal processes used.

4.4 Occupational safety

Inventory study of Manufacturers' Association for Information Technology (MAIT) done in the year 2007 revealed that i) India generated 3.3 lakh tonnes (expected to reach to +4.7 tonnes by 2011)of EW. ii) there was alarming concentration of dioxins in the surrounding areas in which open burning of EW was practiced. The concentration was 30 times more than that prescribed by Swiss Federal laboratories guide lines. The workers and residents who inhaled these toxins, caused an increased risk of cancer. All the hazards can be avoided if proper processes for recycling and disposal of WEEEs are followed. For example i) CRTs have high contents of carcinogens. Breaking, recycling and disposal processes should be carried out in controlled environment with necessary safety precautions. ii) halogenated plastics used as flame retardants produce persistent gases like dioxins and furans which are hazardous fumes. iii) when PCBs, cables and PVC enclosed components are burnt to recover copper & other metals also release dioxins as the result of catalytic reaction between metals and polymers.

4.5 Health Hazards

One of the most widely used method of disposing EW is land filling. This is prone to production of hazardous and corrosive chemicals for hundreds of years. Rain water ,and ground water leach the elements such as As, Hg, Cd, Pb, Si etc. from this EW. This metal extracts are acidic or basic in nature and release poisionous and hazardous salts, affecting all the organisms and the plant kingdom. These corrosion processes go on for hundreds of years in the soil. This contaminates all the ground water sources e.g. rivers, wells, springs. These water pollutants affect our vital organs e.g. brain, heart, lungs, kidneys, liver etc. due to insufficient supply of oxygen resulting in breathing problems, leading to various diseases and death. Table 4.1 shows a few hazardously polluting elements in E-waste and their impacts.

Table 4.1 Some hazardous components in EW and their impacts.

EW components	Contents	Health Impacts
Insulators, fire retardants, Cables, Printing wiring boards Polymers of plastics	TBBA-Tetra Bromo Bisphenols-A PVC (Poly Vinyl Chloride)	Long term period injuries to health. Fumes acutely poisonous .
Condensers, Transformers	PCB (Poly chlorinated Biphenyls)	causes cancer, effects on Immune systems.
PCB, polymers enclosed Coolingunit, Insulation foam	PBB (Poly Brominated Pisphenol) PBDE- (PBDiphenyl Ethers) CFC (Chlorofluoro Carbon)	Reproductive, nervous endocrine systems. and other health problems. Toxic combusion products
Metal (heavy) - As, Ba, Be, Cr, Ga As, Pb, Li, Hg, Ni, Cd,	Light emitting diodes, CRT, power boxes, silicon rectifiers screens, batteries, photo copying machines, fluorescent lamps	acutely poisonous, injurious to health, on long term allergic reactions affecting eyes & skin.
Organic substances toner dust.	condensers, liquid crystal display toner cartridges, lazer printers.	Toxic when inhaled health problems cancer.

Chapter 5: Current scenario of e-waste

In a grim reminder of the increasing environmental and health hazards in India's urban centres a new study by TOXICS ALERT Link, an environmental group, revealed that these centres are not just the generators of e-waste in the country but also , that the rate at which they are throwing away WEEE, is far higher than believed so far. All individuals, offices, institutions, shops etc. who are using, manufacturing, assembling, repairing, buying and selling any type of EE devices are responsible for the pollution due to WEEE.

5.1 Statusquo of Mumbai

Mumbai, the financial nerve centre of India, is a city of dreams attracting millians from all over India. Mumbai has posh vertical multy storied housing societies, hutment dwellers, innumerable over crowded slums, luxury cars, over crowded trains, buses, crampy industrial estates, beaches full of garbage. There is outburst of population, severe scarcity of land, shelter, water, energy, food etc. About 300 families of minimum four members each, are coming in Mumbai everyday. Almost 30% of the population in Mumbai are living in slums. About 50% live in chawls, lower income co op societies, roads, under flyover bridges, 15% live in middle class societies having 1BHK flats and remaining in modern hifi societies. The city generates 2,225 millian litres of sewage /day which flows directly in to the Arabian sea. Attempts by Bruhan Mumbai Nagar Palika to dispose off sewage have been in vain due to shortage of land and facilities for secondary treatment. Mumbai generates 19000 tonnes of EW / year.

5.2 Role of stakeholders

(policy makers, Manufacturers, users, recyclers and disposers.):

All individuals, offices, institutions, shops etc. who are using, manufacturing, assembling, repairing, buying and selling any type of EEEs are responsible for the pollution due to WEEE and therefore can be considered and included in the class of stake holders. Let us study about some of them.

5.2.1 Manufacturers

Mumbai Metropolitan has many EEE manufacturing and assembling units. Santacruz Electronics Export Processing Zone (SEEPZ) has a dedicated industrial area for manufacturing and is a home for several electronic product manufacturers as well as intimidate ancillary industries such as, PCB manufacturing units and export of several types of electronic items. SEEPZ remains attractive for hardware manufacturing houses and large importers of computer equipments. Another industrial areas fully concentrated with e manufacturers are in Navi Mumbai, Thane Belapur road, MIDC Electronic Park Mhaphe etc. Here there are numerous units that manufacture PCBs, and various E-components for other companies. Most of them not having the services for recycling and disposal of E-waste. Although they are not having appropriate houses for storing E-waste and manufactured defective items, they have to store that high tech waste. They can not dispose that through local scrap channel. Once they procure an ISO 14001 certification then only they can dispose E-waste through official recyclers. Manufacturers who have manufacturing facilities and generate production waste ,as well as the importers and brand owners of EE products, are the real key stockholders, especially in the context of Extended Producer Responsibility (EPR) which is the new paradigm in waste management.

5.2.2 Users

Corporate users are those who individually generate large quantities of E-waste annually. Currently business people either donate their discarded but working and repairable equipments to charitable organisms or auction that as scrap. However, custom bonded goods, especially in the case of IT companies, are to be stored untill cleared by the authorities for disposal as scrap. Individual house hold consumers generate small quantities of E-waste but the total volume is huge. Toxic links estimates that individual house hold percentage to be 22 % of junk computers. Such computers are exchanged for new appliances, or sold to scrap collectors.

Relevant organizations - National Association of software & service companies (NASSCOM), Toxic Link etc.

5.2.3 Recyclers

Formal E-waste recyclers are in a nascent stage, with the first ones being established in Bangalore. Currently, the collection, dismentaling and recovery are done entirely by a well established network in the formal sectors. Even though the sector creates substantial value add especially by collecting and repairing disused equipment, some recovery processes employed are extremely dangerous.

WEEE hot spots in Mumbai:- Mumbai has a large scrap trade net work. There are specialized buyers and recyclers of WEEE. The prime areas that handle E-waste in and around Mumbai are Saki Naka, Safed pul, Andheri-Kurla road, Jari Mari Industrial area, Ghatkopar, Kurla, Kamathi Pura, Grant Road, Jogeshwari, Goregaon, Malad and so many remote slums. All are fast emerging as the focal points of E-waste. Here all kinds of E-waste items are handled, bought and sold. Figure 5.1 shows the map of Mumbai and prime slums handling WEEE. All are fast emerging as the focal points.



Figure 5.1 : Map of Mumbai showing locations of slums

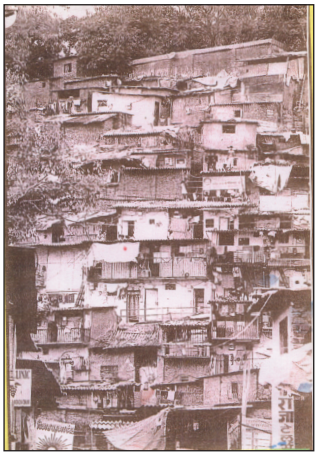


Figure 5.2 : Structure of Mumbai's typical slums e.g. Dharavi, Multy storied slum on Worli Hill



Figure 5.3 : A pile of electronic waste stored by a kabadi

Electronic Procedure's Responsibility (EPR) is an environment policy approach where a producers' responsibility for a product is extended to the post consumer stage of the product's life cycle including it's final disposal. Producer Responsibility Organizations (PROs) are commonly formed to assume the collective responsibility of the industry as a hole, to reduce the complexibility for each manufacturer.

Relevent organizations - Manufacturer's Assn of IT (MAIT), Consumer Electronics & Television Manufacturers' Assn. (CETMA), Telecom Equipment Manu. Assn, (TEMA), Electronic industries Assn. of India (ELCINA).

5.2.4 Policy makers & Legislatures

Government authorities Policymakers and Legislatures and the persons concerned with drafting and implementing environmental legislation are important stake holders at both the national and state level. The primary objective is to protect human health and the environment from the potential hazards of E-waste disposal, resource recovery etc. Resource recovery means that, the treatment processes would yield, for example methane gas, compost etc. The Government of India, Ministry of Environment and forest considers it necessary to regulate environmentally sound management of E-waste which are generated .

5.3 Regulatory environments-Handling rules- recycling guide lines

E-waste contains valuable materials such as plastics, metals and non metals. In the absence of suitable techniques and protective measures, recycling of EW using prevailing open air methods, such as demanufacturing, disassembling, burning in open places which are full of alarming concentrations of toxic emission of dioxins vapors. Dioxins are extremely harmful and have negative impacts on the workers health posing serious health and environmental hazards. All the operations are purely market driven. Various unit operations done by local kabadis while disposing WEEE are shown in figure 5.4 which is self explanatory. As discussed earlier rag pickers and E-waste dealers adapt business

focused on the reuse of the components and extraction of precious metal e.g. Pt, Cu, Ag, Au, Rh, Pd, etc. as secondary source of raw material. Health problems of the workers and residents in and around slums are due to the lack of regulatory environmental checks, proper facilities, equipments and training of workers while dealing with WEEE. The Basel conventions states that - Parties shall take the appropriate measures to ensure that the hazardous and non hazardous components in E-waste are not allowed to be treated together. What so ever the E-waste end up in land fills should not harm natural habitats, wild life, human health, soil and ground water.

The Draft Rules are divided and explained under seven chapters of different headings.

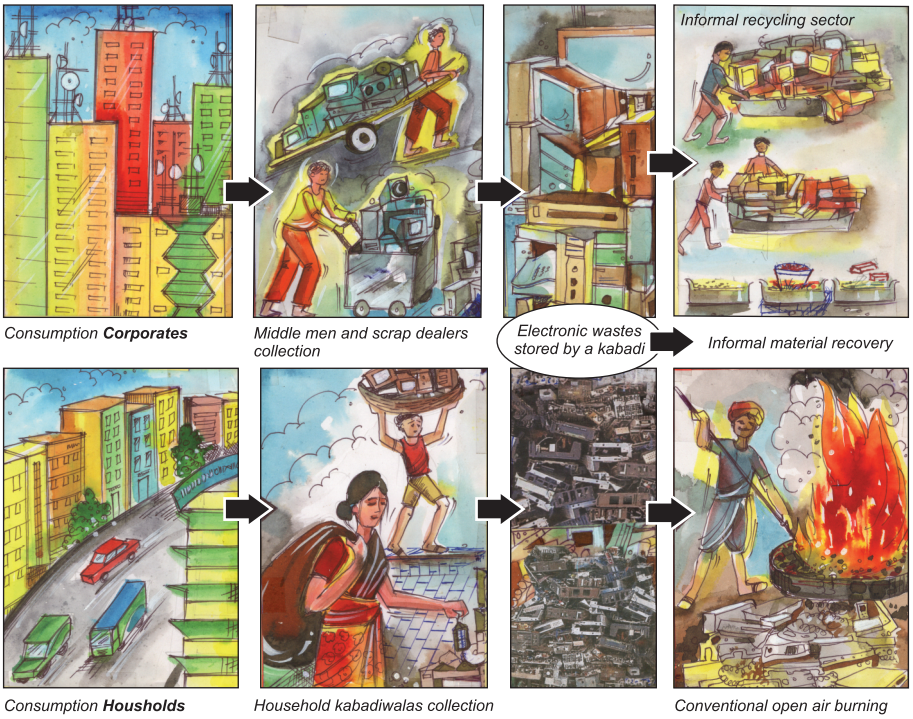


Figure 5.4 : WEEE disposal in slums

5.4 National Initiatives

As we are increasingly relying on EEEs', it is very important that they have as little impact on the environment as possible. The mandate of national task force is to identify, plan and implement all issues related to E-waste. The Govt. of India has re-iterated its commitment to minimization and control of E-waste w.r.t. hazards, both nationally and internationally. A ratification of the convention obliges India to mind the problems of transboundary movement, recycling and disposal of dangerous E - waste. Hon. Supreme court has ordered that the import of WEEE is banned in the country. The current awareness levels regarding the existance and dangers of E-waste are extremely low, partly because the E-waste being generated is not as large as in developed countries. However, urgent measures are to be taken now to make common public aware of E-waste. In order to a) regulate environmentally sound management b) protect the environment and human health from potentially harmful effects of E-wastes which are generated and to facilitate reuse, refurbishment and recovery of useful materials by environmentally sound recycling, thereby, reducing the waste destined for final disposal, and to provide incentives for reduction in the use of hazardous substances by adopting green design… the Central Government has proposed the following DRAFT RULES (Published in 2010).

Chapter I GENERAL: Describes E-waste; Management and Handling Rules will come into force from 2010. They will be applicable to every manufacturer, importer, dealer, collection centre, refurbisher, dismantler, recycler, auctioneer, consumer, Definitions and meanings of each specific word in E-waste.

Chapter II RESPONSIBILITIES: Describes the responsibilities of i) a producer i.e. Extended Producer Responsibility (EPR), Individual Producer Responsibility(IPR) and the meanings of the EPR, IPR. How every producer shall create awareness of the hazards of EEE through different agencies to the user of the equipment etc. ii) dealer iii) collection centre iv) consumer /bulk consumer v) dismantler vi) recycler vii) designated various authorities. The responsibilities of the various authorities are given in Schedule 2 of these rules

Chapter III - Describes the procedure details about Seeking Authorization for handling E-waste. Every producer, collection centre, dismanteller and recycler of E-waste shall submit an application for authorization in form-1

Every authorised person shall maintain the record of E-waste handled by them in form-2,They shall file annual returns in form-3 to the State pollution control Board / Committee on or before 30th June every year file annual return

Chapter IV - Procedure for Registration of Recycling E-waste is the subject matter of this chapter. Every person desirous of recycling E-waste has to apply in form-4.

Chapter V - Describes about procedure for Import & Export of E-Waste. No import of used electrical and electronic equipments shall be allowed foe recycling or disposal.

Chapter VI - The producer of EEE shall comply with the European Union (EU) Directive dated 27/1/2003.The directive pertains to the Reduction in the use of hazardous substances (RoHS) in the manufacture of EEE.

Chapter VII - Describes Miscellaneous matters such as i) Transportation of E-waste. ii) Liability of the producer collection centre, transporter, dismantler and recycler of E-waste will be liable for any damage caused to the environment, human health. iii) Information Management:- An agency designated shall maintain a system for computerized information and tracking of E-waste.

Then there are two schedules. First schedule (A) explains the various categories of E-waste generated from used EEE. And schedule (B) various Govt. authority and corresponding duties.

5.5 Some important things TO DO & NOT TO DO

"Do 'S"

- Reuse a maximum of your obsolete equipment on- site
- Store E-waste separately from other wastes * Keep track of the E-waste generated.
- Inform your employees and friends to dispose of E-waste and it's treatment.
- Encourage them to give / sell e-waste through authorised recyclers.
- Adopt a-- green purchase policy, buy from brands providing a take back service.
- It is important to know what happens to EW, during down stream flow
- Put pressure on all the stake holders, including State and Central Pollution Boards to take appropriate measures for handling, storage and disposal of E-waste.
- Donate automatic toys and games to social clubs working for poor children

"Don'ts"

- Not to sell E-waste to scrap dealers
- Not to dump E-waste with other types of wastes.
- Don't aim at making money out of your E-waste.
- Don't expect others to take care of your E-waste. You are responsible for it's ultimate disposal.

Chapter 6: Recovery of precious metals

E-waste disposal processing techniques usually involve following steps i) Dismentling the equipment ii) desoldering and detaching the components iii) segregating them in to different groups such as metal frames, power supplying cables, batteries, PCBs, plastic material of various types and polymer properties, resistors, capacitors(condensors), inductors, connectors, transistors, transformers, chips, diodes, Fets, ICs, recording heads, scanners, readers, writers, metal parts, dielectric ceramics, microprocessors, components containing precious metals, metallized PCBs, switches, etc. This is entirely done manually by hands. This is affordable only in countries where the awareness w.r.t. health hazards and safety standards are neglected and labour is cheap. The centres where the E-waste treatment has to be carried out, the standard facilities such as 1) sealed and enclosed sophisticated machines like mechanical shredding, hopper conveyors, separating, segregating, screening, granulating, magnetic separators, must be operative. Once this is done plastic recyclers and metal smelters can get their required raw material easily.

Recycling precious metals:- Maximizing the returns of precious metals e.g. Platinum, Palladium, Rhdium Irridium Silver and mainly Gold from E-waste, means knowing something about segregating E-scrap, methods of assaying, separating and refining of such metals among other activities. Knowledge of reclaiming such metals from solid E-scrap as well as from aqueous solutions such as drag outs, rinses, strippers, and main spent plating solutions preserved and stored in bulk lots in plating shops, is also required. A sizable monitory returns can be gained from many of the E-components, such as PCBs, Transistors, Diodes, Waveguides, Silver batteries, Blanking scrap, Punchings, Brazing alloys, Cladded bi-metal parts, Contacts, relays, Switches and connectors. Some of them are shown in figures 6.1 & 6.2. All of those are high priced commodities.

6.1Recovery of Gold from plating shop's solutions:

Before processing recycling and recovery of gold from solutions such as drag outs, rinses and main spent plating solution ,it is important to note that the main Electrolyte, used for plating gold on items like conductor tracks on PCBs, connectors, transistors, diodes etc. contains gold of maximum purity (not less than 999.9 % gold) .When certain precalculated weight of gold is deposited from this electrolyte , it is discarded and freshly prepared electrolyte is used.

This discarded electrolyte is mixed with other solutions, such as rinses and dragouts. Gold recovery from such solutions is done using many procedures including Ion exchange method, Reverse Osmosis, Electrodialysis, Electroless plating, Precipitating or cementation methods of precipitating gold using reducing chemicals.

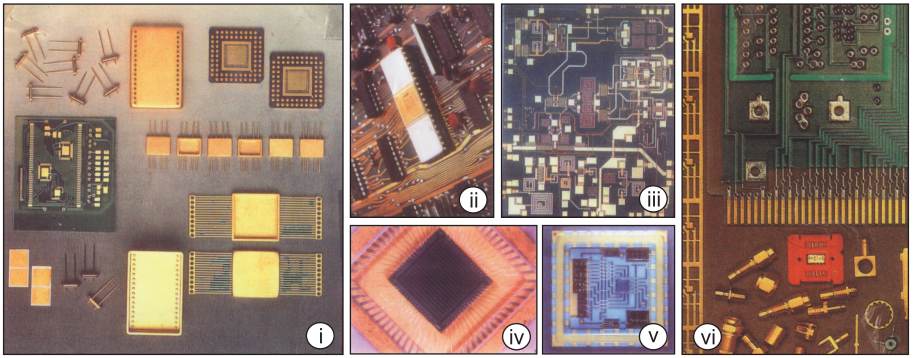


Figure 6.1 : Various gold plated E components and devices

i) Ceramic Substrates & Packages ii) Entirely gold plated electronic device iii) Monolithic Microwave Integrated Circuit iv) Gold bonded wires of silicon chip housed in ceramic package v) Wire bonded MMIC vi) Gold Plated circuit tracks and components

6.2 Recovery of Gold from Gold plated e-components.

Electronic instruments are required to be used in deep sea, land and space environments having extreme variations in atmospheric conditions such as humidity and temperatures. Those instruments must be long living and reliable. Due to natural properties such as a) excellent electrical conductivity and b) inertness to oxidation (corrosion) gold is widely used in electronics and telecommunication industries. Electrical and electronic circuit tracks, relays, switches, reed switches, and several

functional components that are often used so many times, are gold plated to achieve maximum efficiency. Figure 6.1 shows a typical PCB on which gold plated circuit tracks and general components are shown. This entire gold, if recovered, can be used as secondary source of gold.

Recovery of gold from (a) rejected PCBs: The shredded pieces of PCBs are digested with 10 % nitric acid for about one hour. This removes solder metal alloys by chemical dissolution. The pieces are digested in a mixture of Sulphuric (100-200) : Nitric Acid (10-20) and Hydrochloric (15-35) acids, grams / litre. To this, appropriate volume of Sulphur dioxide or Hydrazins sulphate ($N_2 H_4$, H_2SO_4) are added when you get precipitate of gold. The remained PCB is washed well. Ppt. is filtered, washed and dried .

Recovery of Gold from (b) Used electrical contacts : Wherever low voltage surfaces ,with out any tendency to form oxide film or formation of polymer friction ,are required the only choice is the gold plated substrates. This has served the test of time. Since last five decades maximum quantities of gold are being used for this purposes. As the thickness of gold deposition required on copper is up to 5-10 microns (1000 microns = 1 millimeter) only, gold can not be recovered easily and is economically not feasible. In such cases the copper base can be dissolved with relative ease in dilute nitric acid. The remaining residue contains about 94% gold as a very fine thin film.

Recovery of Gold from (c) Solutions and Sludges : Because of the wide applications of electroplated gold components in electronic industries, for every specific property achievement, the composition of bath used for gold plating is different. Apart from the main salt of gold (e.g. Gold potassium cyanide, gold sulphite etc.) other different chemical salts including citrates, phosphates, borates, phosphonates of metals as silver, cadmium, nickel, cobalt, arsenic, tin, palladium, platinum, indium, etc. are also added as additives for obtaining bright, hard, plating etc. Many of the proprietary gold plating compositions contain cyanides. The cyanides from such solutions need to be destroyed before gold recovery process is carried out. One of the most popular way of removing cyanides from the solutions is - Bring the Ph of this solution

to 12. Treat this warm solution with sodium hypochlorite (NaOCl). Now to this solution add any suitable borohydride (K or Na) or reducing agent, or finely powdered Zinc or aluminium metal at 70 – 80°C temperature. Precipitated Gold is filtered and refined.

6.3 Bench scale Gold refining procedure:

Because the purposes of gold deposited, on various components in the circuits, have different functions to do, the rejections collected during fabrication and ultimate scrap collected in WEEE has to be categorized and segregated carefully. The gold refining procedure described here is based on traditional and ancient wet chemical method. The method consist of the following steps.

(1) Any combustible material present is completely burnt in a 500ml. pyrex glass beaker as follows. Weigh 50g. scrap pieces, (not bigger than 10 mm. sieve,) in the beaker. To this add about 10 ml. of alcohol as the fuel. Mix well using a glass rod. Ignite the mass. This addition of alcohol and igniton is repeated three to four times .

(2) After complete combustion a strong bar magnet is rotated in this dried powder. This removes any iron particles present in the beaker.

(3) Grind the mass to finer powder in pestle and mortor.

(4) Transfer this powder to 500 ml pyrex glass beaker

(5) Preparation of Aqua Regia (AR) solution - To one volume of concentrated Nitric acid in a 250 ml pyrex glass beaker add slowly 3.5 volume of concentrated Hydrochloric acid. Cover this partly with a watch glass. Allow to stant for about 3o minutes.

(6) To the gold scrap in (*4*) above add slowly the aqua regia solution from (*5*) above. This needs slow swirling of the mixture with glass rod in order to keep the reaction going on. Brown coloured fumes of gas accompanied with minute bubbles of solution evolve. When bubbling of the solution subsides add a little hydrochloric acid.Heat slowly. When no

more brown coloured fumes evolve, cool the solution. Allow some time to settle the heavy matter at the bottom.

(7) Pour off the clear liquid in to another beaker, with out disturbing the solid undissolved matter remained at the bottom. Set aside the beaker containing the clear brown solution. Add mor aqua regia solution to the beaker containing solid mass. Warm. Reaction will restart. Repeat this addition of AR and process of dissolution till the solution is apparently clear. Cool and filter. Filtrate is usually clear and greenish in colour. The residue on the filter paper is white. It is the silver chloride. The green colour of the filtrate is due to the presence of copper and nickel.

(8) This clear greenish solution always contains excess nitric acid. This is to be completely removed as follows. This is achieved by boiling the solution to near dryness, with occasional additions of hydrochloric acid. Add few ml. sulphuric acid near the end. Add water to this solution to get clear gold chloride solution.

(9) Sodium bisulphite ($NaHSO_3$) treatment :- Nitric acid can be eliminated from the main Gold chloride solution as follows. Prepare 40% solution of $NaHSO_3$ in water. Add this solution slowly to the solution obtained in (8). Stir this solution during additions.

(10) Precipitation of gold - Gold is precipitated by adding ferrous sulphate to the solution obtained in (8). The end of precipitation of entire gold is tested as follows. Add a few drops of $NaHSO_3$ to the solution. If evolution of sulphur dioxide gas starts you get distinct smell of burning sulphur. Allow this solution to stand for several hours (even over night). Fine particles of gold accumulate at the bottom Filter.

(11) Melting of Gold:- Transfer the gold powder with the filter paper to the silica crucible. Spread borax powder, used as flux, Heat on gas burner. Gold melts. Transfer it in a suitable mould.

Notes

About the author



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- Retired, on superannuation after 35 yrs. of continuous service on the level of Research Faculty (Project/Research Scientist) at The **Indian Institute of Technology, Powai, Mumbai.**
  - Twenty three years in Electro Chemical Technology Section of Chemical Engineering Department.
  - Twelve years in Advanced Centre for Research in Electronics.
- Author of 78 Scientific, Technical, Research papers / articles that were presented and published in National and international conferences and Journals .
- Main Areas of work :
  i) Industrial Electrochemical processes
  ii) Metal Finishing
  iii) Electrochemical Technology in Fabrication of Gold plated Electronic components and circuits
- Recipient of National Scientific achievement award for the year 2006 by **Swatantrya Veer Savarkar National Trust.**
- Hobbies :
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