MODULE 2:WATER TECHNOLOGY AND E- WASTE MANAGEMENT

Water Technology: Introduction, Potable water- specifications as per WHO standards.
Water purification: Membrane filtration - Reverse osmosis. Cellulose based water filters. Membrane Separation-Electrodialysis. Drinking water treatment-UV treatment. Graphene membranes for water filtration. Softening of water by ion exchange method.
E-Waste Management: Introduction, sources of e-waste, Toxic materials used in manufacturing electronic and electrical products. Methods of disposal. Extraction of copper and from E-waste. Role of stake holders in environmental management of E-waste (producers, consumers, recyclers, and statutory bodies).

WATER TECHNOLOGY

Water is abundant in nature, and it covers 71% of the earth surface. The different sources of water are rain, river, lake, sea and underground water.

1. Physical impurities	2. Chemical impurities	3. Bacterial impurities
(a) Suspended impurities	(a) Dissolved salts	
(b) Colloidal impurities	(b) Dissolved gases	

Potable water: Potable water, also known as drinking water, comes from surface and ground sources and is treated to levels that that meet state and federal standards for consumption.

Water Parameters: specifications as per WHO standards

1. ***Hardness:*** Water described as "hard" contains high amounts of calcium and magnesium, which are naturally found in the Earth's crust. Total hardness is the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter (mg/L). water's hardness based on these concentrations of calcium carbonate:
   - Soft 0 - 17.1
   - Slightly hard 17.1 - 60
   - Moderately hard 60 - 120
   - Hard 120 - 180
   - Very hard 180 & over

2. ***pH:*** pH is an important indicator of chemical, physical, and biological changes in a waterbody and plays a critical role in chemical processes in natural waters. pH values are on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acidic, and those with a pH above 7.0 are considered basic. The pH scale is logarithmic, meaning that every one-unit

change in pH represents a ten-fold change in acidity. In other words, pH 6.0 is ten times more acidic than pH 7.0; pH 5.0 is one hundred times more acidic than pH 7.0.Excessively high and low pHs can be detrimental for the use of water. High pH causes a bitter taste, water pipes and water-using appliances become encrusted with deposits, and it depresses the effectiveness of the disinfection of chlorine, thereby causing the need for additional chlorine when pH is high. Low-pH water will corrode or dissolve metals and other substances.

3. ***Alkalinity***:Alkalinity is water's capacity to resist acidic changes in pH, essentially alkalinity is water's ability to neutralize acid. This ability is referred to as a buffering capacity. The most well-known alkalinity components are bicarbonate, carbonate, and hydroxide, respectively. These compounds are obtained from the decomposition of minerals in the soil or the atmosphere. High alkalinity gives a bitter taste to water. At the same time, however, the major concern about water alkalinity is related to the reactions that may occur between alkalinity and certain cations in water. The resulting sediment can lead to clogging of pipes and other water supply network accessories.
4. ***Turbidity***: turbidity is the cloudiness of water. It is a measure of the ability of light to pass through water. It is caused by suspended material such as clay, silt, organic material, plankton, and other particulate materials in water. Turbidity in drinking water is esthetically unacceptable, which makes the water look unappetizing.Water can be classified by the amount of TDS per liter as follows:freshwater: <1500 mg/L TDS;brackish water: 1500–5000 mg/L TDS;saline water: >5000 mg/L TDS.

Potable water- specifications as per WHO standards:

S. No.	Parameters	Standard Value	Permisible values
1	pH	6.5 – 8.5	No relaxation
2	Turbidity (NTU)	1	5
3	Total Dissolved Solids (mg/L)	500	2000
4	Total Hardness (as $CaCO_3$, mg/L)	200	600
5	Sulphates (mg/L)	200	400
6	Magnisium (mg/L)	30	No relaxation
7	Nitrate (mg/L)	45	No relaxation
8	Chloride (mg/L)	250	1000
9	Residual Free Chlorine, (mg/L)	0.2	1
10	Calcium (mg/L)	75	200
11	Total Alkalinity (as $CaCO_3$, mg/L)	200	600

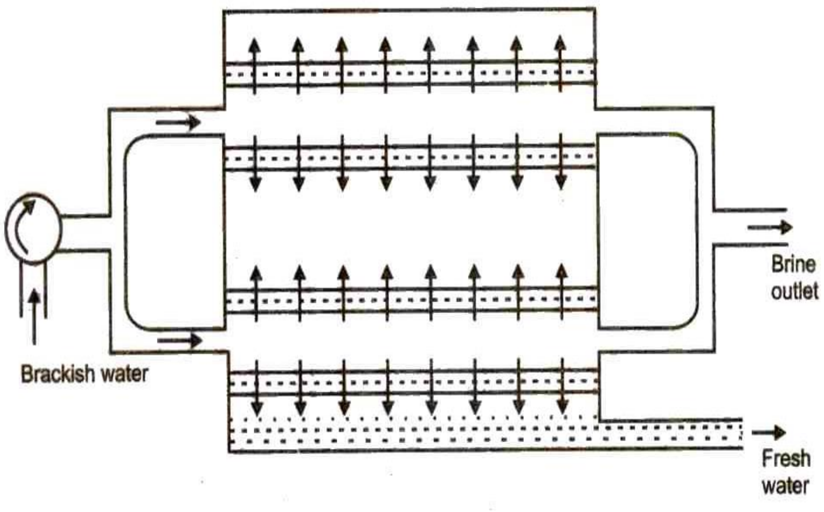
WHO produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting, in developing and developed countries worldwide. The quality of drinking water is a powerful environmental determinant of health. Assurance of drinking water safety is a foundation for the prevention and control of waterborne diseases.

Water Purification

Membrane filtration - Reverse osmosis:

Working Principle: The phenomenon of movement of water molecule from a region of lower concentration to a region of higher concentration in the presence of a semipermeable membrane and by the application of pressure (> Osmotic Pressure) is known as **Reverse Osmosis.**

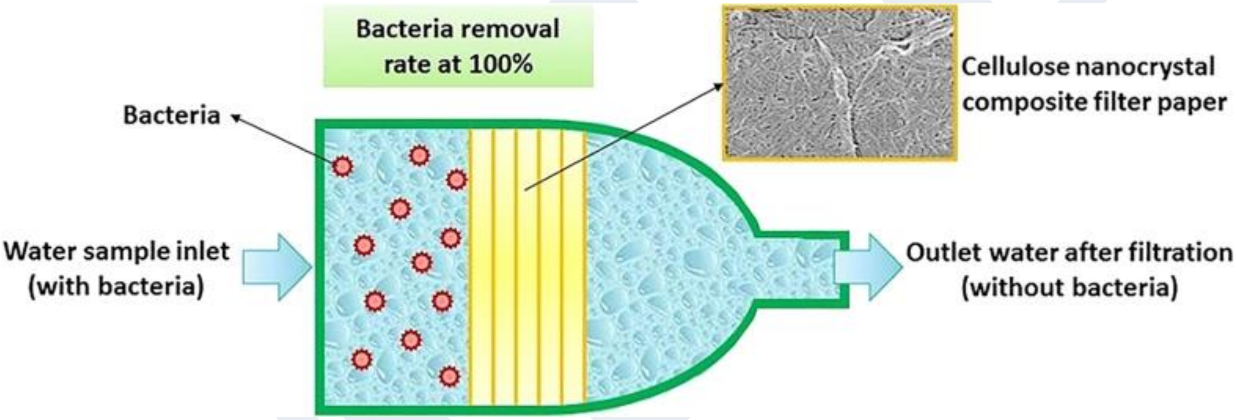
A series of tubes made up of porous material is lined on the inside with extremely thin film of cellulose acetate semi-permeable membrane. These tubes are arranged in parallel array in fresh water. Brackish water is pumped continuously at high pressure (>25atm) through these tubes. Water flows from brackish water into fresh water. The flow of water is proportional to applied pressure which in turn depends on the characteristics of the film. The film may rupture under excessive pressure. Further, greater the number of tubes, larger is the surface area, & more production of fresh water Concentrated brine & fresh water are withdrawn through their respective outlets. This method, however, has not yet been used on large scale production of fresh water. The technique has not passed beyond the pilot plant & is only successful in the recovery of fresh water from brackish water.Reverse Osmosis is capable of removing up to 99%+ of the dissolved salts (ions), particles, colloids, organics, bacteria and pyrogens from the contaminated water.



Reverse osmosis method for desalination

Cellulose based water filters

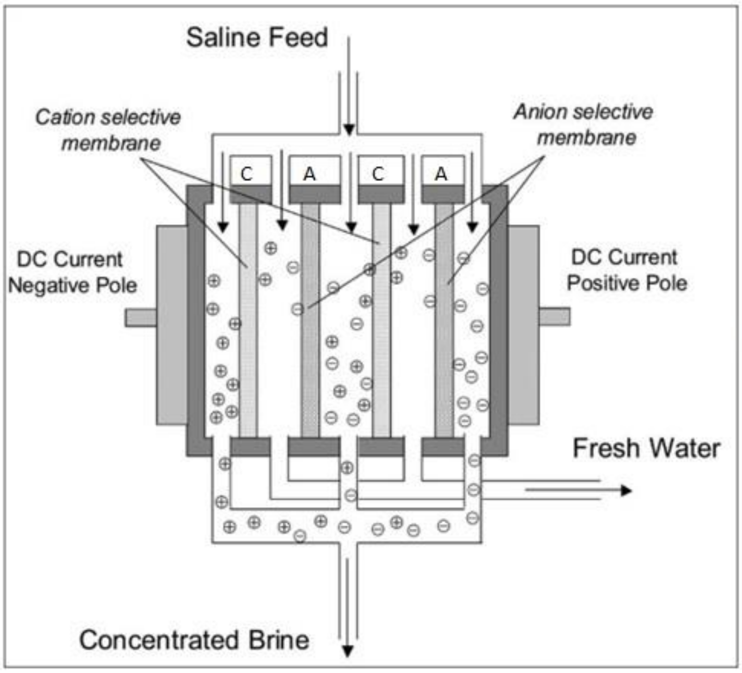
Working principle: Wood-based cellulose pulp fibers are used in disposable everyday filters. Cellulose based water filters functions by trapping contaminants within a matrix of fibers. Microfiltration uses membranes with a pore size less than 0.5 µm to physically remove bacteria from water. Cellulose is a polymer made up of glucose subunits. Filters based on cellulose pulp fibers do usually have large pores that facilitate water percolation, but they do not sufficiently remove bacteria through size exclusion. i.e., Cellulose filter papers work by trapping particulates within a random matrix of cellulose fibers. Cellulose-based water filters are filters made from cellulose, a carbohydrate polymer found in plant cell walls. They are used to remove impurities and contaminants from water and are an alternative to traditional synthetic polymer filters. The high mechanical strength and hydrophilic properties of cellulose make it an ideal material for water filtration. Cellulose filters can effectively remove particles, pathogens, and other contaminants from water, making it safer.They are also an environmentally friendly alternative to traditional filters, as they are biodegradable and can be produced from renewable resources.



<u>Membrane Separation-Electrodialysis:</u>

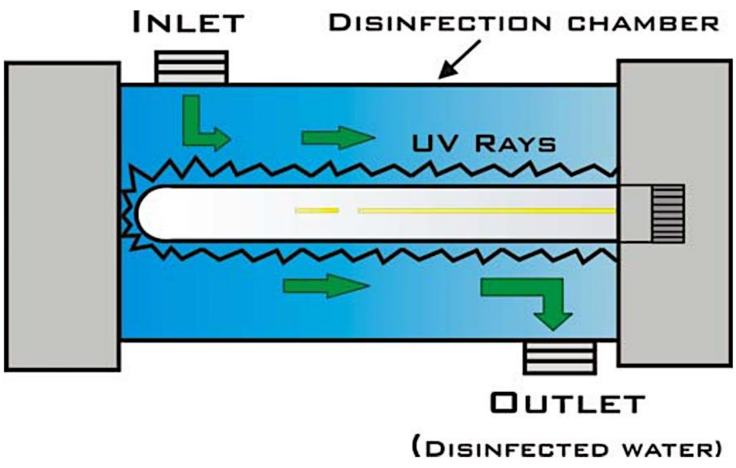
Working Principle: Electrodialysis process is based on the principle that the ions migrate towards oppositely charged electrodes when an emf is applied. The direction of ions movement is further made specific by using ion-selective permeable membranes. The cation membranes are permeable to only cations while anion membranes are permeable to only anions. The process thus yields pure water by decreasing salt concentration.The process of decreasing the salt concentration of salts in saline water using ion-selective membranes under the influence of an applied emf is called as 'electrodialysis'.

An electrodialysis cell consists of a series of alternative cation & anion permeable membranes (C &A).The anode is placed near the anion permeable membrane while the cathode is placed near the cation permeable membrane. A suitable emf depending on the level of salts in brine is applied across the two electrodes immersed in brine. Under the influence of applied emf, sodium ions (Na^+) move through the cation permeable membrane (C) while anions (Cl^-) move through the anion permeable membrane (A) from each compartment of 'CA'. The net result is the depletion of salt content in the 'CA' compartments & an increase in salt concentration in compartments 'AC'. The fresh water produced in ion depleted compartments (CA) is collected & pumped off. The concentrated brine produced in ion concentration compartments, is discharged through the outlet.



Drinking water treatment-UV treatment:

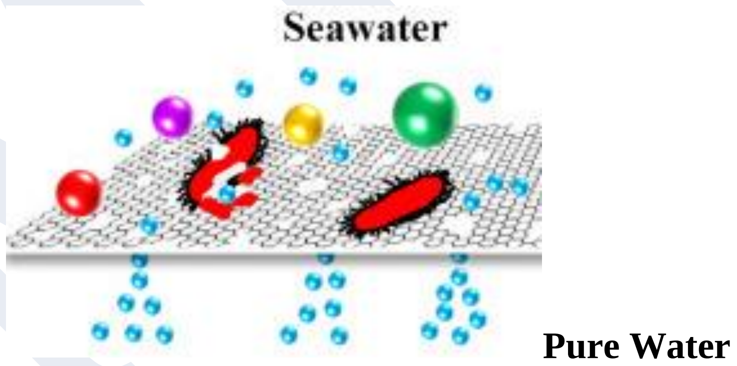
Working principle: UV treatment method is used in many water purification systems to control bacteria. UV energy is found in the electromagnetic spectrum, between the visible light and x-rays and can best be described as invisible radiation. UV light occurs with the wavelength ranging from 200 to 390 nm. The most effective wavelength frequency, from the point of view of microbiology disinfection, is 254 nm as this is where the optimum energy intensity is found. Typical UV disinfection systems involve the flow of water through a vessel containing a UV lamp. As the water passes through this vessel, microorganisms are exposed to intense UV light energy, which causes damage to genetic molecules (nucleic acids: DNA & RNA) needed for reproductive functions. In order to kill microorganisms, the UV rays must actually strike the cell. UV energy penetrates the outer cell membrane, passes through the cell body, and disrupts its DNA preventing reproduction. This damage prevents the microorganism from multiplying or replicating in a human or animal hist. The microorganisms cannot multiply, and hence no infection occurs. Disinfection of water is achieved when UV light causes microbial inactivation.



Graphene membranes for water filtration:

Graphene is a pure form of carbon made up of flat, staked carbon atoms with atom thickness. Graphene aims in removal of solids, bacteria, algae, and inorganic compounds. Graphene is naturally hydrophobic and repel water. When narrow pores are made in graphene, water permeation occurs. This allows only water to pass through and block all the contaminants. Graphene can be used to make light weight, environmentally friendly and energy efficient water filters and desalinators.

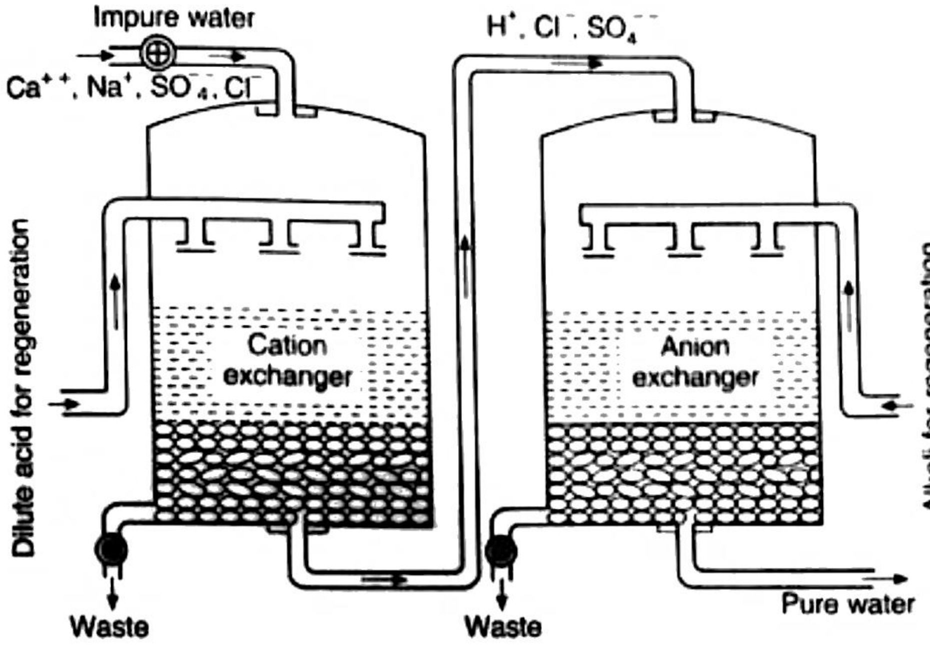
In desalination, the graphene membrane with sub nanometer pores acts as an RO membrane. In this process salt water is subjected to a high pressure and passed through the graphene membrane. The saline water is divided into two categories: (a) water molecules that passes through the membrane and (b) salt ions that will be blocked in the membrane.



Softening of water by ion exchange method:

An efficient way to soften water is to remove all the associated metal ions and their counter anions from water. This is accomplished with the efficient synthetic ion exchange resins. The utility of ion exchange resin rests with its ability to be used and reused, high efficiency, economical cost, and long useful life.

Working Principle: In ion exchange process the impure water is passed through cation exchange resin and anion exchange resin. Cation exchange resin is capable of exchanging cations present in water for H^+ ions, i.e., when the water passes through the cation exchanger, the cations present in water as impurities are retained by the resin and H^+ ions are released into water. Anion exchanger resin is capable of exchanging anions present in water for OH^- ions, i.e., when water passes through the anion exchanger, the anions present in the water are retained by the resin and OH^- ions are released into water.



Ion exchanger

i. ***Function of cation exchanger:*** Commercially significant cation exchange resins are sulfonated copolymers of styrene and divinyl benzene. They are represented as RH, and they exchange cations present in water.

$$RH + Na^+ \rightarrow RNa + H^+$$
$$RH + K^+ \rightarrow RK + H^+$$

The water coming out of cation exchange resin is acidic as H^+ ions are introduced into the water in place of metal ions.

ii. ***Function of anion exchanger:*** The anion exchanger resins are copolymers of styrene and divinyl benzene containing active quaternary amino groups. These resins are represented as ROH, and they exchange anions present in water for OH^- ions.

$$ROH + Cl^- \rightarrow RCl + OH^-$$
$$2ROH + SO_4^{2-} \rightarrow R_2SO_4 + 2OH^-$$

As OH- are introduced into acidic water, neutralization reaction takes place.

$$H^+ + OH^- \rightarrow H_2O$$

As cations are replaced by H^+ ions and anions by OH^- ions, the net reaction is introduction of water in place of metal salts present in water.

iii. ***Regeneration*** :When the resins get exhausted, they can be regenerated by passing HCl and NaOH solutions through cation and anion exchange resins respectively

In cation exchanger:

$$RNa + HCl \rightarrow RH + NaCl$$

In anion exchanger :

$$RCl + NaOH \rightarrow ROH + NaCl$$

E-WASTE

All electronics and electrical items which is discarded on completion of their useful life together is called as E-waste.

Sources of E-Waste:

i. Computer peripherals: monitor, keyboard, mouse, motherboard, laptops, CDs etc.

ii. Telecommunication device: phones, cell phones, routers, pagers, fax machine etc.

iii. Household appliances: washing machines, vacuum cleaners, toasters, drying machines, refrigerators, irons, air conditioners etc.

iv. Industrial electronics: sensors, medical device, automobile device etc.

v. Electrical devices: switches, wires, bulbs etc.

Composition

i. E-waste contains about 65% of iron, steel, and other metallic materials including costly metals like platinum, gold, silver, and toxic metals like lead mercury, cadmium, chromium etc.

ii. E-waste contains about 21% of polymeric non biodegrable materials including PVC (poly vinyl chlorides), polychlorinated biphenyl and brominated flame-retardant plastics.

iii. E-waste also contains about 11.8 % of CRT (Cathode Ray Tube) and LCD screen and other materials like glass and ceramics.

Toxic materials used in manufacturing electronic and electrical products:

Toxic materials used in manufacturing electronic and electrical products are hazardous. Hazardous substances are toxic and can affect the quality of ecosystem and have harmful effects on human health. These include.

1. Heavy metals like Cd, Cr, Pb and Hg

2. Organic compounds like CFC (chlorofluorocarbons), polyacyclic aromatic hydrocarbons, (PAHs), Poly chlorinated biphenyls(PCBs) etc.

Constituents	sources	Health effect
Lead	Solder in printed circuit board, glass, gaskets in computer monitor panel	Damage to central and peripheral nervous system, blood system, kidney damage, effect the brain development of children
Cadmium	Chip resistors and semiconductors	Accumulate in kidney and liver, causes nerval damage
Mercury	Relays and switches, printed circuit board	Chronic damage to brain and respiratory system.
Plastic including PVC	Circuit board, cabinets and cables	Burning produces dioxin. It causes reproductive and development problem. Immune system damage
Beryllium	fond in motherboard	carcinogenic and causes lung cancer, skin diseases

Methods of disposal:

- Recycling: Many items of e-waste can be dismantled and their component parts repurposed into new products. E-waste recycling techniques can recover precious metals from circuit boards and be melted down to make new devices or used for other products such as jewellery.
- Reuse: By far, the most environmentally friendly e-waste disposal technique is for, where possible, devices to be reused. Many charities will gladly accept old electronic devices that can then be refurbished and redistributed to people in more disadvantaged communities.

Recycling and Recovery of e-waste

In e-waste, among various components metals contribute to the significant economic value and efforts are focused on extracting the metals during recycling operation.

Pyrometallurgy

Pyrometallurgy process is used to extract pure nonferrous and precious metals from e-waste. The methods require high temperature to reduce /extract metals. Smelting, incineration, combustion, pyrolysis, and molten salt process are the main pyrometallurgical methods employed for recovery of metals of e-waste .

(a) ***Smelting:*** Copper smelting is commonly used for recovery of nonferrous metal fractions from e-waste. The processed scrap after preliminary stage contains mainly Iron, Aluminium, Copper, Lead, Tin, antimony, Zinc and precious metals as metallic constituents. The mixture is fed to high temperature furnace of copper smelters. The copper metal is converted to liquid copper. The impure copper undergoes electro refining process to get pure copper (99.99 %). The precious and valuable metals like Au, Pt, Lead, Tin and antimony are recovered from sludge with high recovery rates of 90% using hydrometallurgical process. Here iron, silicon and Aluminium are not recovered but are collected as slag.

(b) ***Combustion:*** It is a low technology, low-cost method which focuses on recovery of precious metals. The e-waste is subjected to open burning in uncontrolled manner which releases all sorts of pollutants into atmosphere. The method is highly dangerous for the environment and also increases the health risk of all the workers involved in it.

(c) ***Incineration:*** It is a controlled combustion of waste with suitable emission units. The incinerator has two connected furnaces. In first furnace e-waste is burnt at temperature 800^oC and in second furnace for gaseous products of the first incinerator are further oxidised at 1110^oC. Heavy metals and fly ash are collected at the bottom. Hydrometallurgical process is used for further recovery of metals. These methods are not advisable due to pollutant gas emission and low metal recycling performance.

(d) ***Pyrolysis:*** Pyrolysis is a thermal decomposition of e-waste at higher temperature in an oxygen free environment. During pyrolysis irreversible thermal decomposition reactions takes place leading to the formation of low molecular weight products (gases and Liquids) at temperature between 450^oC and 1100^oC. The gases, chars and oils produced have an economic value and can be used as fuel. The metallic components can be separated by separation. The process also involves release of toxic halogens along with flue gases into atmosphere.

(e) ***Molten salt Process****:* In this method inorganic salts such as potassium chloride (KCl)-sodium chloride (NaCl) are used at different temperature between 300^0C and 1100^oC in a furnace depending upon the requirement. E-waste is fed with the salt and salt is melted at desired temperature in an inert atmosphere. The organic part decomposes in salt forming carbonate and silicates and gets trapped in salt. Halogens are converted to alkali metal halides which remain in molten salt. Molten salts dissolve glasses, oxides and to destruct plastics present in wastes without oxidizing the most valuable metals. This method is efficient for recovering a copper-rich metallic fraction. A large quantity of hydrogen is produced and might be used as fuel gas. The metallic component is collected at the bottom of the furnace after removing the molten salt by washing with hot water. The metal is further processed to get pure metal.

Extraction ofCu from E-waste:

There are 3 stages in metal recovery by hydrometallurgy method.

1. Pretreatment stage
2. Chemical treatment stage
3. Metal recovery stage

Stage 1: Pre-treatment stage:- In the pre-treatment step, e waste is manually dismantled to separate various fractions like metals, ceramics, plastics, papers, and wood. The technique such as gravity separation, electrostatic separation, magnetic separation, and eddy current separation are used to separate metals from other fractions.

Stage 2: Chemical treatment stage:- In this method metals are leached into solutions by treating with appropriate chemical reagents. Several leaching agents such as thiosulfate, alkaline cyanide, and many acids such as hydrochloric acid, sulphuric acid and nitric acids can be used to leach copper into solution. Acid leaching is the most common method used to extract copper. H_2SO_4/HNO_3 in the presence of oxidizing agent H_2O_2 is used in the process.

$$Cu + \frac{1}{2}O_2 + 2H^+ \rightarrow Cu^{2+} + H_2O$$

Stage 3: Metal recovery stage:- In the last step metal is recovered from leach solution. Varieties of methods like electro deposition, solvent extraction, ion exchange, adsorption, precipitation and cementation are used to recover metals from leached solution. Copper metal can be recovered by electro deposition method. Pure copper metal is taken as cathode and inert anode are dipped in leaching solution. When current is applied, copper is electrodeposited on cathode.

Role of stake holders in environmental management of E-waste (producers, consumers, recyclers, and statutory bodies):

The e-waste management program is designed by statutory government regulatory bodies. The members of the body frame the policies and execute it for protection of the environment. To achieve the plan of management of e-waste a green tax is collected from consumer through manufacturer. Penalties are implied on manufacturer and consumers when green tax is not paid. Manufacturing units must support the agenda of e-waste management by doing dismantling processing of e-waste, management of scarp materials and reselling of recycled materials. Consumer must pay green and must be aware of importance of e-waste management. All stakeholders must effectively work in tandem form for effective e-waste management.

There are four stakeholders in environmental management of e-waste. They are as follows.

1. Statutory Government Regulatory bodies.
2. Producers (Manufacturing units).

3. Recyclers (Recycling units and collection units)
4. Consumers.

1. ***Statutory government Regulatory bodies:*** The statutory bodies play a Vitol role in management of e-waste. Main roles are:
   (a) To collect the green tax from consumer through producer.
   (b) Apply extra charges on producers (manufacturing units) in form of penalty when no proper recycling is assured from manufacturing units.
   (c) Provide incentives in form of subsidy to recyclers and collectors when recycling of e-waste is done properly.
   (d) To conduct programs of awareness in the society about importance of e-waste recycling in reduction of hazardous substances.

2. ***Producers (Manufacturing units):***
   (a) The accountability to collect green tax.
   (b) Charging an additional amount on consumer during sell of e-products and returning it with interest at the time of exchange of e-product.
   (c) Forming the group of manufactures who monitor and encourage the recycling of e-waste.
   (d) Bearing the transportation cost and collection fees to ease collection process.
   (e) Purchase the recycling material at fixed value and using of recycled e-waste during manufacturing.
   (f) Giving discount to consumer on the basis of e-waste generated from gadget.

3. ***Recyclers (Recycling units &Collection Units):***
   (a) The accountability of recycling units is dismantling, recycling processing of e-waste materials, management of scarp materials and reselling of recycling materials.
   (b) Establish collection units and group of people who can ensure return back of products by consumer in exchange offer or directly approach consumer for door-to door collection.
   (c) Collect the e-waste from the collection units, dealer, or retailer.
   (d) Providing incentives when proper collection of e-waste assured by collection units.

4. ***Consumer:***
   (a) The accountability to pay green taxes.
   (b) Develop self-awareness on e-waste management and involve in awareness programs.
   (c) Returning back of e-waste to collection units.