

REVIEW ARTICLE

DEGRADATION OF E-WASTE USING BIOLOGICAL TECHNIQUES**Ashwini.M¹, Renuka devi K.P^{2*}, Nandhini.S³, Srinivasan.J⁴**

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ABSTRACT

Electronic gadgets are user friendly and it makes life simple and handier. Upgradation in life style and update in electronic gadgets results in deposition of electronic waste. E-waste is a well-known name for electronic waste, which is near to the end life. The electronic gadgets consist of many hazardous chemicals and metals. Great care should be taken when it is disposed into the environment because it may release many toxic elements to affect human and cause health issues. Many part of their e-waste products can be refurbished or recycled by physical method but it is carcinogenic to workers due to release of toxic metals. Also the e-waste can be degraded with chemical and biological method. In chemical method electronic waste are degraded using acid are costly and it have many disadvantages. Biological methods are considered as an effective remedy to degrade electronic waste because it is less expensive, eco friendly to treat the e-waste. Biological source such as microorganism, earthworm and plants are considered as valuable alternative to degrade electronic waste.

KEY WORDS: E-waste, Heavy metals, Degradation, Microorganism, Carcinogenic.

INTRODUCTION

Electronic Gadgets are meant to make our lives happier and simpler. The electronic gadgets include televisions, computers, mobile phones and etc. The electronic gadgets are made up of metals and plastics. They contain toxic substances which cause environmental and health problems. It contains more than 1000 different substance,which could fall under hazardous and non-hazardous. Apart from that it consists of ferrous and non-ferrous substances, wood, printed boards, rubber and other items. In E-waste iron and steel constitute are about 50%, plastics around 21%, non-ferrous metals around 13%, cadmium a 17% and aluminium were 12%.

Disposal of electronic gadgets are known as electronic waste or E-Waste. It is the fastest growing municipal waste because of its short lifespan, technical advancement, marketing methods and compatibility (Coby Wonget *al.*, 2007). It produces 3-5% of waste growth rate annually. Their disposal and recycle becomes a health night mare. E-Waste can be classified as any electrical powered appliance that has been reached its end of life. E-Waste has been accumulating over many years, It cause environmental and health problems. So there is a needof awareness regarding its impact on environment and the causes associated with the E-Waste management.

TV and computers are normally containing toxic substances such as mercury, lead, chromium, poly vinyl chloride and phosphor compounds. Whereas Nickel, Beryllium and Zinc can be present in circuit board. Because of the presence of these metal substances recycle and disposal of E-Waste becomes an important matter. We can segregate the e-waste as brown, white and grey goods. It has been prove that brown and white goods were less toxic when compared to grey goods. (Santhanam *et al.*, 2013)

Table-1 Types of Goods (Santhanam *et al.*, 2013)

White goods	House hold appliances
Brown goods	TVs, camcorders, cameras
Grey goods	Computers, printers, scanners, fax machines, mobile phones

People are unfamiliar about the potential negative impacts of rapidly increasing use of computers, TV and monitors. When these waste products are disposed in landfills or incinerated it cause health issue due to the hazardous metals. The electronic wastes are disposed without proper treatment they result in elevated risk of neurological disorders and cancer.

E-WASTE:

Development in technology, falling prices, and modern life style has resulted in a fast-growing surplus of electronic waste around the globe. An estimated 50 million tons of E-waste are produced each year in the world. The Environmental Protection Agency estimates that only 15-20% of e-waste is recycled, the rest of these electronics go directly into landfills and incinerators. E-waste contains heavy metals such as Pb, Cr, Hg, Cd, Be,As, Co, Ni, and

Zn. Heavy metals are naturally occur by earth’s crust. Metal pollution level increase due to industrial and human activities, which results in balance and biochemical level of heavy metal in the environment (Varshini., 2015). U. S .Environment Protection Agency and International Agency for Research on Cancer has been classified this heavy metals to be human carcinogenic, due to the toxicity effect (Fauziah *et al.*, 2017). China, USA, Japan, India, Germany, Brazil, Russia, France, Indonesia and Italy are denoted as a Top e-waste producing countries. Among top 5 countries India produce around 2million tons of e-waste annually (Menaka *et al.*, 2019).

Table-2 Electronic waste and its composition (Santhanam *et al.*, 2013)

WEEE-90%	% OF E-WASTE
Household	42%
IT equipment	33.9%
Consumer electronics	13.7%
Telecommunication components	12%
Biomedical components	7%
Other components	6%

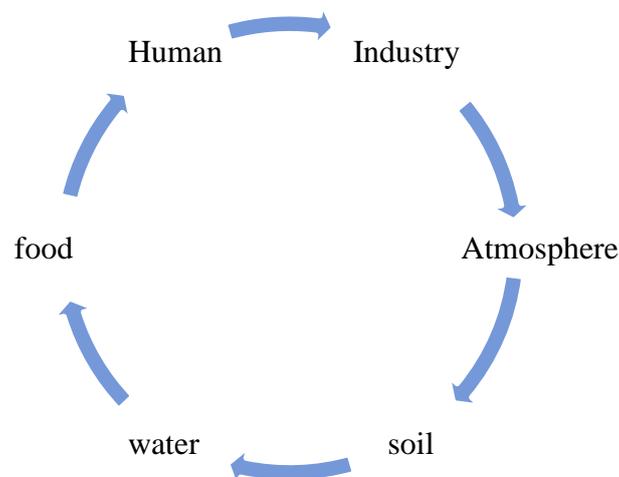


Fig-1 Cycling process of electronic waste (Vani *et al.*, 2015)

Table-3E-waste source and components (Cayumil *et al.*, 2016) (Willner *et al.*, 2013) (Kousar *et al.*, 2013)

SOURCE	METAL COMPONENTS
Batteries	Hg
Cell phones	Cu, Pb, Ni, Au, Pt, Ag
Circuit board	Be, Zn, Cd, Pb, Ni
Computer batteries	Cd
Copper wire	Cu
CRTs	Pb, Cd
Flat screen monitor	Hg
Monitor	Cd, PbO
PC	Pb, Hg, Cd
PCBs	Cd
Stainless steels	Cd, Cr, Zn
Switch	Hg
TV	Pb, Hg, Cd

LEAD:

Lead is an important fifth most widely used and studied metal. Electronic gadgets based on the concentration and period of exposure lead can cause wide range of effect in biological system such as gastrointestinal tract, chronic damage to CNS, kidney problem, and blood pressure (Gayatri *et al.*, 2016). Bioaccumulation of lead in human body leads to interferes with the functioning of mitochondria, swelling of brain, respiration problems, paralysis and eventually death (Akash *et al.*, 2013). Exposure to lead could occur through, drinking of contaminated water. Short time exposure can cause vomiting, diarrhoea. Lead has high impact on young children.

MERCURY:

Mercury is most toxic and most used in batteries, mining, agricultural, display screens and switches of electronic equipments. Exposure to methyl mercury depends upon the level and it occurs through aquatic food chain and eating contaminated food (Fabienne *et al.*, 2011). Methyl mercury is considered to be the highly toxic organic form. Mercury affects young children. High exposure to mercury can cause following problems in human body such as: nervous system, neurological disorder, insomnia, tumour, impaired memory, eye irritation.

CHROMIUM:

Chromium is greatly used most important industrial material. It is widely used in pigment manufacturing, vehicle, planting, food preservative and leather tanning. Cr (VI) is considered to be the most toxic form in its valence state. People can exposure to chromium through eating, breathing and skin exposure to chromium components. Uncontrolled release of Cr (VI) wastes has caused serious environmental pollution problems and health issues. When chromium enters to the human body it cause eye irritation, asthma, liver damage, and continuous exposure leads to DNA damage. (Dongyan *et al.*, 2013)

CADMIUM:

Cadmium present in rechargeable Ni-Cd-batteries, fluorescent layer (CRT screens), printer inks and toners, printed circuit boards and TV picture tubes. It is a potent oxidative agent. It enters inside the body through breathing. Cd can cause vomiting, lungs and kidney problems and weakness. Acutely poisonous and injurious to health on a long-term perspective. It inhibits DNA replication and makes the DNA more susceptible to nucleolytic attack resulting in single-strand DNA breaks (Katarina *et al.*, 2004).

ARSENIC:

Arsenic is released through volcanic activity, erosion of rocks, forest fires and human activity. The effect of arsenic on human health is depending on the dose and the period of exposure. Low level exposure can leads to nausea and vomiting, abnormal heart beat, cause problems to blood vessels, decrease production of the blood cells, and abnormal sensation in the hands and feet. High exposure can possibly cause death. (Obi *et al.*, 2017)

COPPER:

Copper is emitted into the environment through mining, smelting and refining of copper, industrial products such as wires, pipes, metal sheets and combustion of fossil fuel. Co- plays role in plants for the production of certain enzyme need for metabolicfunction. It enters into the body by food. Food source for copper is organ meat, nuts and beans. Copper at low level is good and necessary for metabolic function of human body when it reaches high concentration can leads to health complications such as anaemia and cause liver and kidney damages(Obietal., 2017).

NICKLE:

Nickel is one of the poisonous heavy metal bring into the environment through alloys, electroplating, Ni-Cd batteries, coins, stainless steels and CRTs. Route of exposure of Ni can be inhalation, oral and dermal. Nickel is advised as an essential trace component for living organisms and mammals. Ni in high concentration can cause head ache, vomiting, chest pain and dry cough. (Riden *et al.*, 2016).

IRON:

Plants need iron for the process of photosynthesis. It uptake by the plants through root. Enter intothe body through food chain. Excess irons accumulate in the human body can cause heart attack, diabetes,liver cirrhosis, arthritis (Vaniet *al.*, 2015).

ZINC:

Zinc is denoted as non-toxic specially uptake orally. Excessive concentration can leads to liverand kidney failure, diarrhoea, bloody urine, vomiting (Vani *et al.*, 2015).

BERYLLIUM:

Beryllium present in power supply boxes which contain silicon controlled rectifiers, mother board of computers Beamline components. It enters into the human body through Inhalation, people who working in the industries can expose to high level of Be,drinking water and Eating plants. Low concentration of Beryllium causeswelling of brain, breathing difficulties, high blood pressure, stomach irritation and liver and heart damages (Mohammad *et al.*, 2013). Beryllium has recently been classified as a human carcinogen because exposure to it can cause lung cancer.

BROMINATED FLAME RETARDANTS:

BFRs are added to TV, computers and plastics. BFRs released to environment through landfill. It accumulates in man and animal tissue through food chain. BFRs can cause problems such as disrupt endocrine system, hormonal disorders and increase the risk of cancer to digestive and lymphatic systems. (Mohammed *et al.*, 2013)

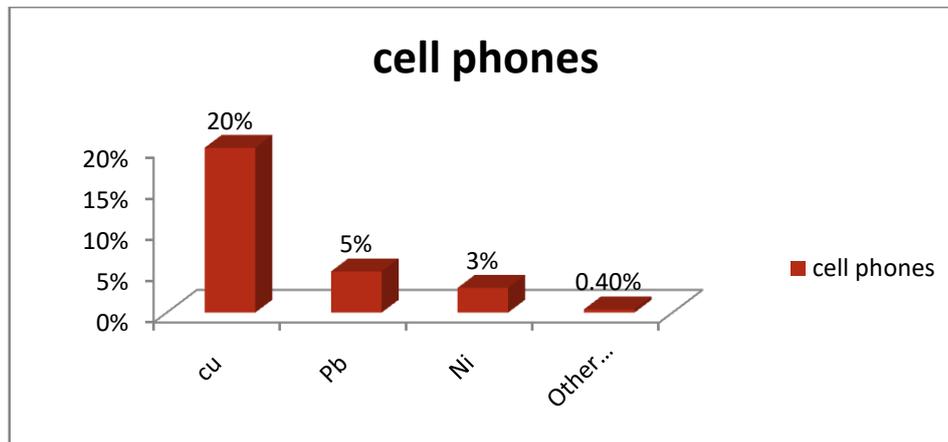


Fig-2 Comparison of metals present in PCBs and mobile phones. (Willner *et al.*, 2013)

INDIAN SENARIO:

In Indian scenario information technology (IT) industry is one of the major concerns of change in the economy. Due to digital revolution and life style changes the use of electronic gadgets are increased. Electronic gadgets are more comfort, cost effective, security, easy to exchange information, reduce our time and bring everything at our door steps. The increased use of electronic gadgets and its disposable onto the environment causes more toxic effect. There are two small e-waste dismantling facilities are functioning in Chennai and Bangalore. In India there is no large scale organization for treating e-waste. India generates upto 0.6million of electronic waste. The amount of e-waste generation in India is increased up to 0.2 million tons (Santhanam *et al.*, 2013).

65 cities are produce more than 60% of total e-waste generated in India. Ten states generate upto70% of e-waste. To avoid generation of e-waste in many companies are follow take back policy in this way the old electronic gadgets are recycled and reused by the company. Apple, Microsoft, Panasonic, Sony, Sony Eriksson, PCS, Philip for mobile take up where as WIPRO and HCL are take back the computers. HCL and WIPRO are denoted as a best take back practice branch in India. (Kouser *et al.*, 2013)

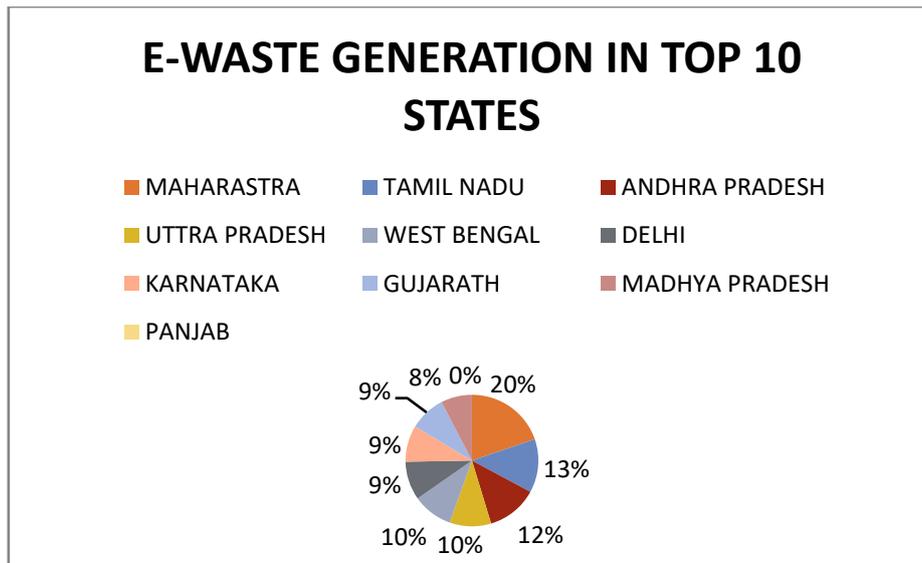


Fig-3 Top 10 E-waste Generating States (Kousar 2013)

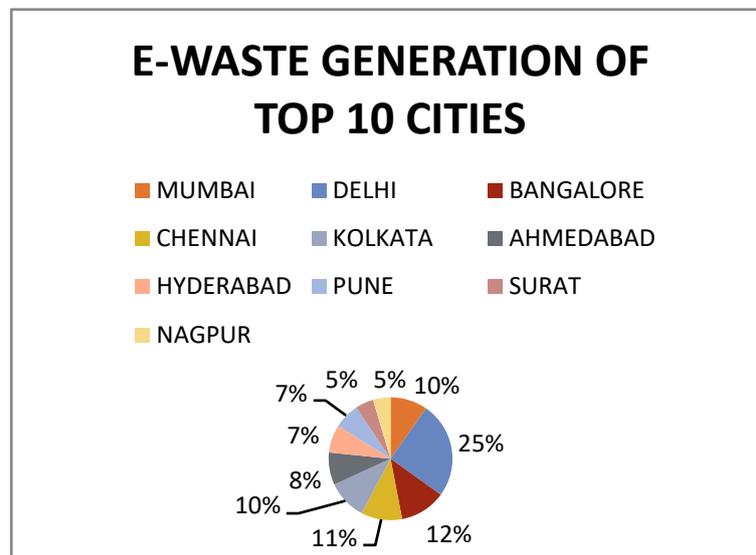


Fig-4 Top 10 E-waste Generating Cities (Kousar 2013)

LAWS IN INDIA:

- Electronic waste (management) amendment rules – 2018.
- Hazardous and other wastes management and transboundary movement rules - 2016.
- Draft hazardous material management handling and transboundary movement -2007.
- The Environment (production) Act – 1986.
- The air (prevention and control and pollution) Act – 1981.

- The water (prevention and control and pollution) Act – 1974. (Nivedita *et al.*, 2018)

METHODS TO DEGRADE THE E-WASTE

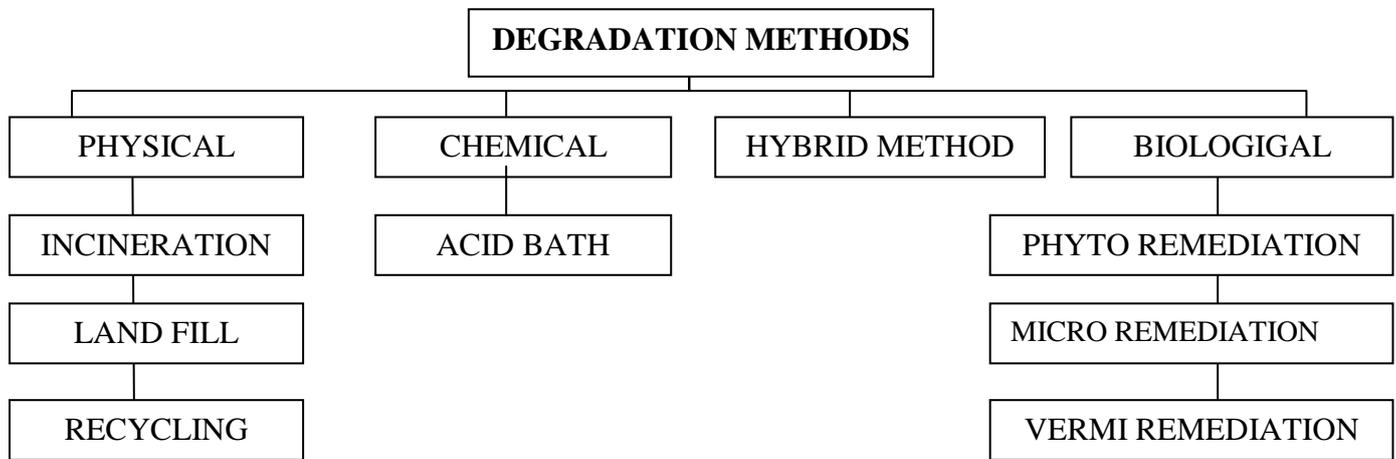


Fig 5: Degrading methods of e- waste(Shuchi *et al.*, 2014)

PHYSICAL METHOD:

Many disadvantages are associated with physical method such as it may pollute the environment and cause serious problems to human health. The physical methods are

1. Incineration refers to the thermal treatment of e-waste in specially designed incinerators. It is considered as a bad and unacceptable method of dispose the electronic waste in developing countries. (Mohammed *et al.*, 2013)
2. Land filling is the most common method. In this method the electronic wastes are buried in land by excavate and trenches.
3. Recycling is referred as recreation of electronic waste and it is carryout either by machine or by manual. (Mohammed *et al.*, 2013)

CHEMICAL METHOD:

Chemical method for degradation of electronic waste is done by either using acid or legend. Chemical method for degradation of electronic waste is done by either using acid or legend. Chemicals used in metals recovery process are nitric acid, sulphuric acid, hydrochloric acid, solution of H_2SO_4 and HNO_3 , sodium hypochlorite with acids (or) alkaline, cyanide, halides, thiourea or thiosulphate (Cayumil *et al.*, 2015).

1. Legends areget combine with metal, whereas acids are used to recover metals.
2. Acids are used to recover metals like Ag, Al, Ni, Cu, Au and Fe. It is an effective method, once the recovering process are gets over the acids are discharged into water bodies and pollute the water and soil by releasing toxicants.

BIOLOGICAL METHOD:

Biological method defined as using the biological sources, the metals presents in the e-wastes are degraded. Biological source such as microorganism, plant and earth worm are used to degrade the toxic metals.

1. Phyto remediation is a method by which the metal toxicants are absorbed. In this method plants are used to treat the heavy metals such as Cr, Cd, Ar, Zn, Ni, Pb, Hg etc.(Sharma *et al.*, 2013)Phyto remediation consists of 4 methods they are follow:
 - Phyto extraction is referred as a process in which plants can uptake high concentration of toxic metals. These metals are removing from plants through harvesting the plants and destroy them by burning or recycled by a process called Phyto mining. (Shuchi *et al.*, 2014)
 - Phyto volatilization is a process of transpiration of organic and inorganic metals and evaporation of metals to the environment. Phyto volatilization plant is cultivated tobacco (*Nicotiana Tobaccum*) which is used to remove mercury. (Mohammed *et al.*, 2013).
 - Phyto stabilization refers to stabilize or transform metals into lesser bio available forms. It is achieved through absorption and accumulation by roots. Phyto stabilization plant is white poplar (*Populus Alba*) removing Pb and Cd (Shuchi Patel *et al.*, 2014).
 - Rhizo filtration method metals are removed by absorption,precipitation and adsorption. Root of Indian mustard (*Brassica juncea*) can remove metals such as Cd, Cr, Cu, Ni, Pb and Zn, while the sunflower can remove Pb, U and Sr (Mohammed *et al.*, 2008).
2. Vermi remediation is the biological process in which the earth worm is used to absorb heavy metals. Earth worm are capable of absorb metals in their nature. It accumulates those absorbed metals in their tissue (Shuchi Patel *et al.*, 2014).

3. Hybrid technique is a method, which combine both biological and chemical leaching so that both will balance each other for an effective and improved method for metal recovery process in electronic waste (Santhanam *et al.*, 2013).
4. Micro remediation method uses various microorganisms to degrade electronic waste. In this method bacteria, fungi are plays an important role in degradation. (Mohammed *et al.*, 2013)Micro remediation process is carry out by the below mentioned ways.
 - Bioleaching is a process by which the solid metallic compounds are converted to solubility and extractable form by using microbes. Acidophilic group of bacteria play an effective role in bioleaching of heavy metals from the electronic waste. (Santhanam *et al.*, 2013) (Willner *et al.*, 2013)
 - Bio accumulation refers to the absorption of contaminants with microorganism and convert them into a biomass, this process required active metabolism. (Prakash *et al.*, 2012).
 - Bio sorption defined as the process of binding soluble contaminated metals to the surface of cellular structure. Bio sorption does not required active metabolism for absorb heavy metal toxicants. (Fabienne *et al.*, 2011)
 - Bio transformation is refers to the process in which chemical compounds are converted from one form to another form by chemical reaction. Due to this reaction chemical properties of the chemical are also changed. Transformation process is bone by direct enzymatic reduction method and indirect reduction method. (Prakash *et al.*, 2012)
 - Bio mineralization process the toxic metal ions combine with anions or legends to form precipitation. Legends and anions are produced from microorganism (Shuchi patel *et al.*, 2014).

Table 4: Metal Degrading microorganism

METAL	MICROORGANISM
Au	<i>Acidiphilum sp.</i> , <i>Chromobacterium sp.</i> , <i>Pseudomonas sp.</i> ,
Ag	<i>Chromobacterium sp.</i> , <i>Pseudomonas sp.</i> , <i>Bacillus sp.</i> , <i>Ferromicrobium sp.</i> ,
Cd	<i>Bacillus sp.</i> , <i>Acidithiobacillus sp.</i> , <i>Burkholderia sp.</i> , <i>Gamella sp.</i> , <i>Micrococcus sp.</i> , <i>Ochrobactrum sp.</i> ,
Cu	<i>Acidithiobacillus sp.</i> , <i>Aeromonas sp.</i> , <i>Chromobacterium sp.</i> , <i>Pseudomonas sp.</i> , <i>Sphingomonas sp.</i> ,
Cr	<i>Acidithiobacillus sp.</i> , <i>Gamella sp.</i> , <i>Micrococcus sp.</i> , <i>Pseudomonas sp.</i> ,
Fe	<i>Acidithiobacillus sp.</i> , <i>Geobacter daltonii sp.</i> , <i>Sphingomonas sp.</i> ,
Hg	<i>Bacillus sp.</i> , <i>E.coli</i> , <i>Pseudoduganella sp.</i> , <i>Lysobacter sp.</i> ,
Ni	<i>Acidithiobacillus sp.</i> , <i>Bacillus sp.</i> , <i>Chromobacterium sp.</i> , <i>Pseudomonas sp.</i> , <i>Sulfobacillus sp.</i> ,
Pb	<i>Bacillus sp.</i> , <i>Burkholderia sp.</i> , <i>Gamella sp.</i> , <i>Micrococcus sp.</i> , <i>Pseudomonas sp.</i> ,
Zn	<i>Acidithiobacillus sp.</i> , <i>Sphingomonas sp.</i> , <i>Sulfobacillus sp.</i> , <i>Geobacter daltonii sp.</i> ,

(Shuchi, 2014, Willner *et al.*, 2013, Mohammed *et al.*, 2013, Gayatri *et al.*, 2016, Katarina *et al.*, 2004, Clause 2000, Subhashree *et al.*, 2014, Karellova *et al.*, 2011, Dongyan *et al.*, 2013, Geremia *et al.*, 2018, Francois *et al.*, 2011, Lolo *et al.*, 2016, Virender *et al.*, 2010, Santhanam *et al.*, 2013.)

CONCLUSION

E-waste generation is globally increased due to life style changes, improved technical application, increased awareness about electronic gadgets and low cost. There is no awareness about electronic waste disposal method and improper handling of electronic waste

release toxic substance into the environment. The E-waste consists of various hazardous heavy metals such as Cd, Cr, Cu, Pb, Hg and etc. These heavy metals are highly toxic to human and environment. Due to its high toxic effect these heavy metals are denoted as human carcinogen.

Most of the E-waste is generated from the IT industry's because their usage of electronic gadgets is higher than other industries. To overcome the increased deposition of E-waste many companies are using various strategies to reuse and recycle the E-waste. Many companies are using take back policy to reduce the level of E-waste such as IBM introduce 100% reuse and recyclable computer, HP developed carbon-di-oxide for cleaning chips.

Many methods are available to treat E-waste. Physical methods are used to recycle and degrade e-waste but many problems are associated with this method. It may cause environmental problem such as release green house gas, air pollution, can cause serious health issues. Chemical degradation is also used to segregate metals from E-waste but it requires high cost, problems of depositing effluent from the E-waste digestion.

To overcome the above mentioned problems biological method is considered as a boon to reduce and degrade the heavy metals present in E-waste. Many advantages are there in biological method such as eco friendly, reduce green house gas emission and reduce environment pollution and it also avoid the risk to cause health problems in human.

In biological method microorganism, plants and earth worm are used to degrade metals. Many plants and microorganism are capable of absorb, leach and accumulate heavy metals in their surface and reduce the level of heavy metals in the environment. It will be a boon and effective method to degrade E-waste in future

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