E-waste Management and its statistics all around the world

E-waste management is one of the burning topics in sustainability as it is concerned with the energy, culture, technology, economy, human health, waste management, international affairs, policies, and ecosystem health. This is a multidisciplinary topic which is complex in nature.

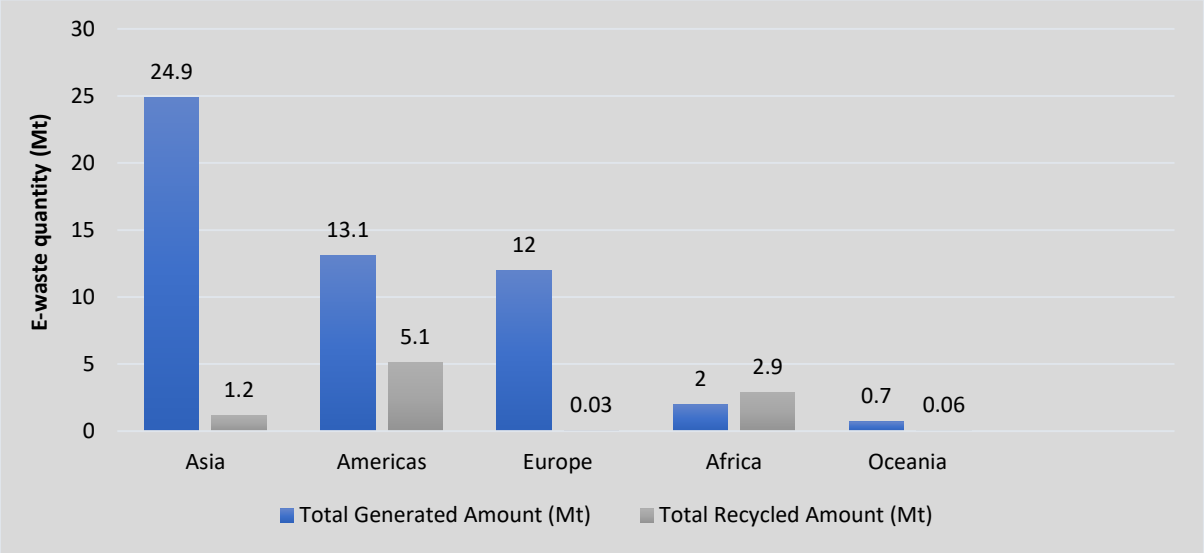
The waste electronic products called as e-waste or WEEE (Waste of Electronic and Electrical Equipment) is basically all components and consumables derived from electronic devices and equipment. It comes with any function and in any sizes which is not desired by consumers anymore[1-S]. According to GEM-2020, e-waste generation had reached 53.6 Mt in 2019 and expected to reach 74.7 Mt till 2030. If e-waste generation in 2005 is considered as minimum of nearly 20 Mt as a reference, then worldwide e-waste generation has increased up to 168% between the years 2005 and 2019 whereas the population was increased by around 17.9% only in the same years. This is clearly showing that the generation of e-waste is way higher than the population. The e-waste properly recycled or collected was 9.3 Mt i.e. 17.4% in 2019.

The remaining e-waste and its effects are undocumented and differ in middle or low- and high-income countries. Fig. 3 is depicting the highest e-waste generating regions on a global scale along with its recycling rates. The graph is clearly representing that there is a wide gap between generation and formal recycling of e-waste. Asia is the largest e-waste generating continents of all followed by Americas, Europe, Africa and Oceania. Asia generated nearly 24.9 Mt in 2019 which is around 46% of total e-waste generated. The highest contribution that Asia is making to e-waste generation is may be because of the significant contribution from India and China owing to the booming economies of them. It can be assumed that Asia will be leaving other continents behind in future considering its huge population and further increase in the per capita income of India, China and other developing countries. The data further shows the European nations are in frontlines of recycling and collecting their e-waste.

India is world's third biggest contributor of e-waste, by producing ~3.2million tonnes of e-waste in a year. According to Environmental Performance Index 2018, out of 180 countries India ranks 177th and is among the least 5 countries [8]. There are 65 cities in India which generates more than 60% of the total e-waste. Mumbai followed by Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat and Nagpur are among the top ten cities in the generation of e-waste [32]. As per the study by ASSOCHAM-KPMG titled "Electronic waste management in India" mobile, telephones and computer equipment are the principle electronic waste generators. According to a report by Business Line (Radheshyam Jadhav), around 78% of electronic waste in India is not being disposed of properly by the government, only 22.7% out of total 10,14,961.21 tonnes generated was collected, recycled and disposed-off, in 2019-20. In the year 2018-19, only about 21.35% was handled while in 2017-18 it was just 9.79%.

The report provided by Ministry of Environment shows that there is total 468 authorized recyclers/dismantlers in 22 states with a processing capacity of 13,85,932.22 tonnes annually. Maharashtra has the highest number of authorized recycling units – 116,

followed by Uttar Pradesh, Haryana, Tamil Nadu, and Uttarakhand. The limited number of recycling and dismantling units and their concentration in cities is one of the issues that need attention, and it is one of the major reasons that all e-waste generated is not recycled properly. For this reason, it goes to the informal sectors or unauthorized recycling units. These unauthorized recycling centres do not only extract out valuable metals but also pose environmental threats by dumping toxic metals in the ground like Lead and Mercury. It is usually given to the rag pickers who pay some amount to the people from whom they are collecting. After the collection, activities like segregation, dismantling, disposal etc., which are mostly carried out by the informal sectors are done. It is a great source of income for rag pickers as well as for middlemen and scrap dealers. But most of this work is done by unskilled labours and they do not take proper safety measures. Lack of appropriate technology and infrastructure are the main reasons behind not properly doing the disposal. Hence, implementation of proper e-waste management system is required in India [32].



E-waste – An opportunity for economic growth

This solid waste is the fastest growing waste category because of the increasing market penetration, the replacement markets, high obsolescence rate, innovation in technology [1-H]. However, this serves an opportunity for the sustainable growth. Every year we consume enormous amount of gold and silver for the production of new electronic items. According to EPA (environmental Protection agency) 1million cell phones can recover 10 tons of copper, 0.01 tons of palladium, and 0.025 tons of gold [2]. Value of raw materials present in e-waste in 2019 was estimated to be around $57 billion. E-waste represents a potential hub for extracting different types of materials like metals, glass, plastics etc. which can be further used in manufacturing of products and reduces the use of virgin raw materials.

It is considered as a secondary resource which is easily available on the surface of earth and can be recovered using the urban mining technique i.e., bioleaching, also reducing pressure on natural resources. Secondary resources do not require complicated processes and deep mining techniques for its recovery which further reduces the need to mine virgin raw metals, unlike primary resources. Urban mining promotes the concept of circular economy (CE) in all three aspects of environment, economy and social benefits. Unlike linear economy, circular economy helps in

reintroduction of raw materials recovered from used products back into economy which not only reduces the waste but also uses the raw materials in a more sustainable way. It has also been reported that urban mining has the potential to replace the materials required in different sectors like micro and macroelements in agriculture, metals in making electrical products, ornamental industry etc.

But as per the report of Global e-waste monitor 2020, recycling sector is confronted with various challenges in recycling of materials which mainly includes treatment and handling cost, toxic emissions, disposal of hazardous and unwanted remains, heterogeneity of waste and less international collaboration. The recycling of materials does not look like a feasible solution if we do not improve our collection and recycling practices. In order to avoid the use and release of hazardous materials into the environment several legislations and initiatives have already been initiated, discussed in Table. These policies, legislations and initiatives provide a legal framework within boundaries to control, reduce and prevent any damage to humankind and environment. Although, they have banned the use of any harmful substances and are replacing them with safer alternatives, products that were manufactured in past with hazardous composition also needs to be treated adequately in order to avoid the risks they can pose on environment and human health. As technological innovations are increasing at a speeding rate day by day and this has led to the increase in the amount of WEEE. Therefore, recycling of the WEEE following the circular economy approach is the only sustainable way that will keep us up the technological innovations thereby not exploiting our mother nature.

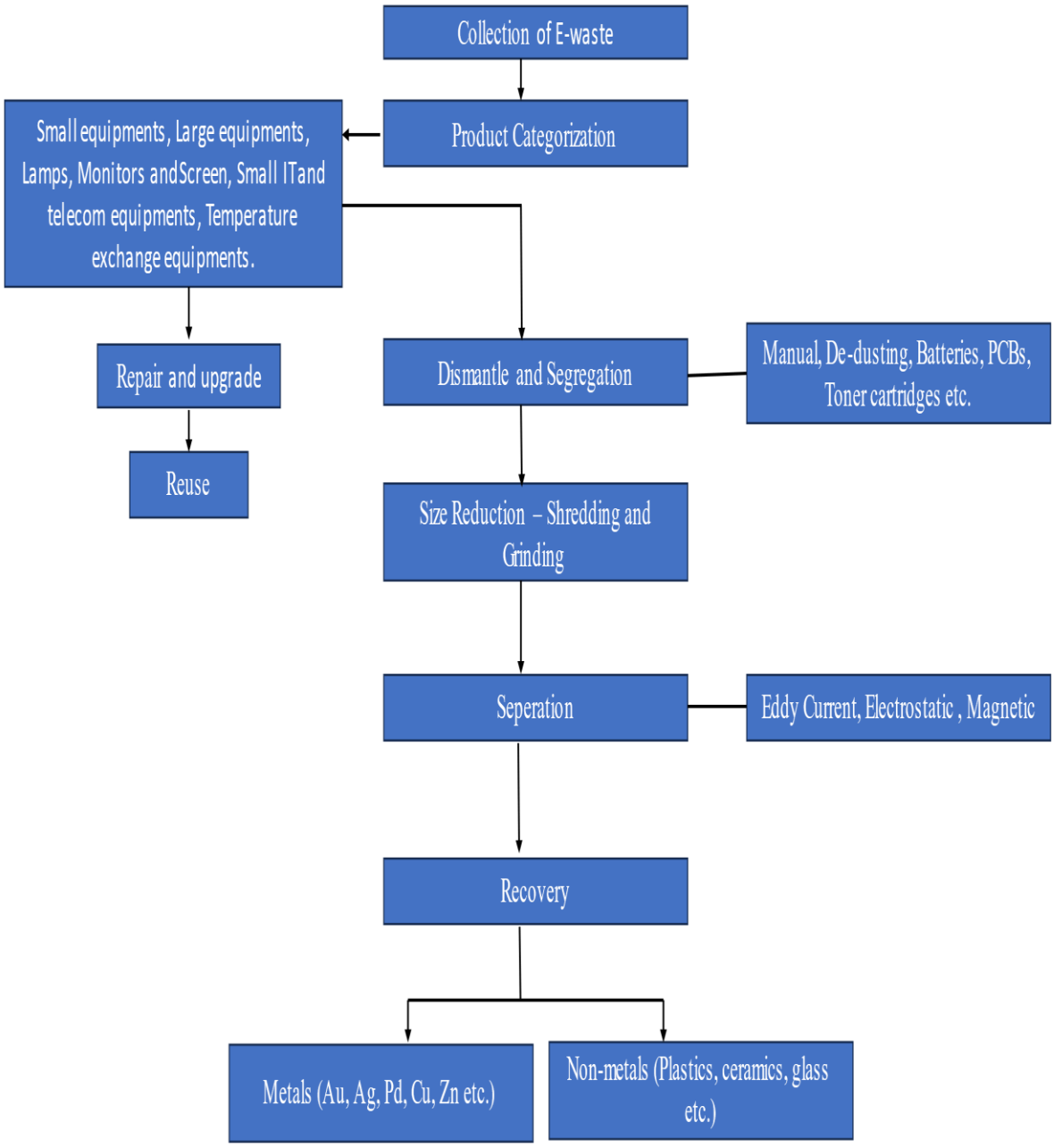


Fig. Recycling of e-waste.

Representation of initiatives, organizations and legislations to manage e-waste.

Initiatives	Organizations	Legislations and Acts
Basel Convention – 1992	IETC (International Environmental Technology Center)	Air Act - 1981
The European Union from WEEE Directives - 2003	PACE (The Partnership for Action on Computing types of equipment)	Water Act - 1974
Bamako Convention - 1998	Global E-waste Monitor	Environmental Protection Act – 1986

Waigani Convention - 2001	GPWM (Global Partnership for Waste Management)	Hazardous Waste Rules – 2008
StEP (Solving the E-Waste Problem) - 2007	IEMN (International E-waste Monitoring Network)	Batteries Rules – 2011
GESP (Global E-Waste Statistics Partnership) - 2017		E-waste Rules – 2011
RoHS (Restriction of Hazardous Substances) - 2003		E-waste Rules – 2016
		E-waste Rules - 2018

Impact of E-waste on Human health and Environment.

Generation of e-waste has a very strong connection with human health and environment. Generally, it occurs in two ways – first is by contamination in food chains and the second is direct exposure to recycling areas. The inappropriate management of e-waste leads to the pollution of environment which in turn affects human health [1] and our surroundings as the toxic metals leach into the water, soil, and atmosphere. These toxic metals include Hg, Pb, Sn etc. that gives rise to several life-threatening diseases like respiratory disorders, birth defects, cancer, neurological disorders etc [11].

E-waste affects human in various ways such as its exposure may result in changing cellular function as well as expression, can have effects on thyroid glands, may also result in changing psychological behaviour and temperament, affects lung function. People working in e-waste recycling areas had higher DNA damage in comparison to control areas. Leachates of e-waste have toxic effects on plant and bacterial cell and acts on mammalian cells too as a genotoxic compound. They are taken up by the cells which brings alteration in the pH both outside and inside, which might alters the DNA structure and impact enzymes too [9,12,13]. A fetus inside mother womb can also be affected by the metal toxicity during pregnancy which may result in low cognitive skills and respiratory disorders after birth. Bio-concentration of toxic metals from e-waste inside human causes muscular and physical degeneration, that may result in multiple sclerosis, Alzheimer's disease, muscular dystrophy and Parkinson's disease [9.14,15].

Metals like Cu, Zn, Fe, B, Ni, Co, P, K, Mg plays a vital role in biochemical and physiological processes like photosynthesis, redox reaction in mitochondria and chloroplast, nitrogen fixation, chlorophyll biosynthesis, sugar metabolism, DNA synthesis and protein modifications. At higher amount, heavy metals results in severe toxicity in plants. The effects on plants generally include chlorosis, lower biomass accumulation, inhibition of photosynthesis and growth, altered nutrient assimilation and water balance and senescence that eventually causes death of plant [17]. Microbial diversity plays a vital role in plant nutrients recycling, plant pests' control, noxious chemicals detoxification, soil structure maintenance and plant growth and are major indices in investigating the soil quality [19,20]. The findings show that improper management of e-waste may show results in altering microbial community. Microorganisms are the major driver in biological cycles and have a decisive role in

functioning of almost all ecosystems. Microbes' metabolic activities are significantly prone to subtle changes in environment [9].

The heavy metals in soil also carry a risk of being transferred to the groundwater as well as to food chain affecting plants and humans. In causing damage to water bodies including groundwater waste electronic products are of great concern. Majority of factories and industries are built in close proximity to water sources, hazardous metals seep into the ground thereby polluting the water present deep in aquifers. After this, the water becomes unsafe for drinking and other purposes. The toxic components present in waste electronic products reacts with the groundwater and results in disturbing the chloride levels, conductivity, pH, turbidity, and TDS (total dissolved solids) that may affect the health of adults and children [9]. The loads of heavy metals have inhibitory effects on development of organisms residing in water like fish, zooplanktons and phytoplanktons. Hence, it is important to assess the influence of heavy metals on soils and take steps to treat it before it spreads its toxicity to higher level in food chain [21].

Conclusion

E-waste is undoubtedly causing a huge damage to people and surrounding because of its toxicity. In the beginning e-waste appeared in the developed countries and further moved to other developing nations. It is causing life threatening diseases in human beings and plants and directly contributing to the increase in the rate of pollution. The article reveals that how growing technology and increasing demands of consumers is contributing to accumulation of e-waste on a global scale. Several legislations and approaches have already been addressed which can help in managing this hazardous stream of waste. Any one technique or approach may not be perfect but in concert they can create a broader impact. Interaction of several approaches can dive to create a proper e-waste management. Above all the concepts, studies and approaches, no matter what is being introduced and implemented there will be no change if people do not become aware about it, everything hinges on the mindset of people. They must accept the introduced management ways and adhere to them.