VOLUME 8 ISSUE 1 2022

ISSN 2454-3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 8, No. 1, 55-61 (2022)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Current Practices of Management/Handling of E-waste : A Review

Meshram Leena N., Naik Mayur S. and Pawar Prabhakar R.*

Department of Zoology, Mahatma Phule Arts, Science and Commerce College, Panvel, Raigad, Navi Mumbai 410206, India

**Corresponding Author*

Received: 20th November, 2021; **Accepted:** 2nd January, 2022; **Published online:** 7th January, 2022

https://doi.org/10.33745/ijzi.2022.v08i01.008

Abstract: Growth in the information technology and communication sectors, exponential use of the electronic equipment and faster up-gradation of electronic products have forced consumers to discard old electronic products as electronic waste (e-waste). Present review focuses on widely used methods for management/handling of e-waste with respect to disposal to landfill, incineration (pyrolysis), reuse/repair and recycling (dismantling, processing and end-processing) along with sustainable technologies used to reduce e-waste. It is recommended to integrate the informal sector with the formal sector in order to separately collect, effectively treat, dispose of e-waste along with divert it from conventional landfills and open burning. To reduce, reuse, refurbish, recovery and recycle are the current solution to minimize the e-waste.

Keywords: E-waste, Incineration, Landfill, Recycling, Reuse/repair, Sustainable management

Citation: Meshram Leena N., Naik Mayur S. and Pawar Prabhakar R.: Current practices of management/handling of e-waste : A review. Intern. J. Zool. Invest. 8 (1): 55-61, 2022.
https://doi.org/10.33745/ijzi.2022.v08i01.008

Introduction

Electrical and Electronic Equipment (EEE) refers to the equipments that are dependent on electric currents or electro-magnetic fields to be fully functional. Electronic and electrical products, such as refrigerators, washing machines, mobile phones, personal computers, printers, and television sets, are ubiquitous in the modern society (Zhang *et al.*, 2012). EEE has become a backbone of modern human society and considered as a symbol of a modern lifestyle, comfort, efficiency, and even prosperity in developing countries (Ghimire and Ariya, 2020). EEE has become an essential part of everyday life (Meshram and Pawar, 2021).

There is no standard definition of electronic waste (e-waste) but the most widely accepted definition is electric and electronic products that are unwanted, not working and nearing or at the end of their useful life. E-waste include all the components of electronic equipment, its subassemblies, and consumables which are the part of the product at the time it is discarded (Borthakur and Singh, 2012; Ghimire and Ariya, 2020). E-waste is also referred to as Waste electrical and electronic equipment (WEEE) or E-scrap or Technological waste. Rapid urbanization, advancements in science and technology, increased demand for consumer goods and higher purchasing capacity of middle-class families in developing countries are the driving forces responsible for exponential production of EEE (Wang *et al.*, 2020).

Unsustainable way to produce, consume and dispose e-waste, slow adoption of collection and recycling of e-waste, few repair options for EEE, rapid changes in technology and most common and wide use of gadget in schools, residences, offices and manufacturing industries is responsible for fast-growth of e-waste around the globe (Rao, 2014; Sankhla *et al.*, 2016; Forti *et al.*, 2020). Global e-waste generation is growing at a faster rate and it is expected to reach a whopping ~74.7 Mt by 2030 (Ghimire and Ariya, 2020). Due to the vast quantity of annual generation, e-waste has become a global concern over the past two decades (Wang *et al.*, 2020). According to Sthiannopkao and Wong (2013), an estimate of more than 40 million tons of e-waste is produced around the globe annually with a yearly growth rate of approximately 5 to 10 per cent.

A substantial proportion of e-waste produced in developed countries has been transferred to some developing countries (Wang *et al.*, 2020). The Guiyu town in China was one of the largest informal e-waste processing clusters in the world, processing millions of tons of e-waste annually, most of which were from developed countries. Diane *et al.* (2020) stated that Nigeria, Ghana, India, Pakistan, China, Kenya, Chile, Malaysia, Philippines, Dubai and Singapore have been identified as hotspot destinations of e-waste and serve as pre-distribution centres for e-waste coming from the EU and US to South Asian countries, mainly India and Pakistan.

E-waste consists of 54 product-centric categories and are grouped into six general categories such as temperature exchange/cooling and freezing equipment, screens and monitors, lamps, large equipment, small equipment and small IT and Telecommunication equipment (Balde *et al.*, 2015). Composition of e-waste is diverse and contains more than 1,000 different toxic and non-toxic substances (Hossain *et al.*, 2015). Kiddee *et al.* (2013) reported that toxic substances associated with e-waste toxic metals (Ba, Be, Cd, Co, Cr, Cu, Fe, Pb, Li, La, Hg, Mn, Mo, Ni, Ag and Cr(VI) and persistent organic pollutants (POPs) --dioxin, BFRs, PAHs, PCBs, polybrominated dibenzo-p-dioxins and PBDD/Fs, Polychlorinated dibenzo-p-dioxins and PCDD/Fs and PVC.

E-waste can be profitable if we repair and/or reuse it or recycle the usable materials that it contains. The basic principle of e-waste management includes collection, transportation, recycle, and disposal of the remaining waste with least negative implications on health, environment, and aesthetics of location (Ghimire and Ariya, 2020). Present review provides an overview of the current practices of e-waste handling with reference to disposal to landfills, incineration/pyrolysis, reuse/repair and recycling.

Review of Literature:

This article reviews the e-waste with respect to current practices of e-waste handling and methods of sustainable management. Review method adopted was based on the scientific literature survey from databases such as Scopus, MEDLINE, Web of Science and Science Direct. The keywords used for reviewing the literature were the ones that refer to the issues concerning the e-waste. For literature search, keyword "e-waste" is combined with methods of e-waste handling and sustainable management of e-waste.

Management of e-waste/Practices of e-waste handling:

Forti *et al.* (2020) reported that e-waste is usually managed by methods like:

- E-waste formally collected.
- E-waste in waste bins.
- E-waste collected outside of formal systems in countries with a developed (e-) waste management infrastructure.
- E-waste collected outside of formal systems in

countries with no developed (e-) waste management infrastructure.

The widely used methods for management/handling of e-waste include disposal to landfill, incineration (pyrolysis), reuse/repair and recycling (dismantling, processing and end-processing).

Disposal to Landfill:

In landfill disposal, either the waste is openly dumped or mining voids/borrow pits can be used to bury e-waste. It is one of the most widely used methods for the disposal of e-waste because of its ease of operation (Ghimire and Ariya, 2020). Sivakumaran (2013) recorded that e-wastes ending up as landfills are described as toxic time bomb. Landfills with e-waste contain a higher concentration of toxicity than landfills without e-waste.

Landfill disposal can cause leachate formation in landfill sites and change the site into wasteland, which cannot be exploited anytime soon in the future. E-waste from landfill release toxic metals (Pb, Al, As, Fe and Ni) and polyhalogenated organics (PBDEs) (Kiddee *et al.*, 2014). Leaching of wastes (batteries and electronic circuits) releases acids and toxic metals that can seriously harm health and the environment (Ghimire and Ariya, 2020). Metals do not disintegrate via physical processes, affect biogeochemical cycles, accumulate within organisms through the food chain and cause harm to our vital organs or even death. These pollutants may transport via soil and groundwater in and around dumping sites. Due to this, landfilling is considered an inappropriate e-waste disposal method (Kiddee *et al.*, 2013; Sivakumaran, 2013).

Eighteen heavy metals in the leachate of personal computers and CRTs in the simulated landfills were reported by Li *et al.* (2009). Guo *et al.* (2009) recorded presence of PBDEs and significantly higher concentrations of Pb, Al, As, Fe and Ni in leachates and groundwater collected from landfill sites in Australia. Also, leachability of PBDEs from e-waste in landfills in Australia was recorded by Hearn *et al.* (2011).

Incineration/Pyrolysis:

Incineration involves burning a combustible fraction of e-waste in order to obtain non-combustible fractions such as metals. It is a tedious, costly and not environmentally friendly process of e-waste management (Ghimire and Ariya, 2020). Incineration is a commonly used method in China, Africa, India and Pakistan (Sivakumaran, 2013).

Advantages of incineration/pyrolysis:

(Source: Borthakur and Singh, 2012; Sivakumaran, 2013; Ghimire and Ariya, 2020)

- Faster reaction rates.
- Easy to separate and recycle metals.
- Provide energy to self-sustain the process.
- Serve as energy or chemical source.
- Reduction of waste volume.
- Hazardous organic substances are converted into less hazardous compounds.

Disadvantages of incineration/pyrolysis:

(Source: Sivakumaran, 2013; Ghimire and Ariya, 2020)

- Highly toxic compounds such as PBDDs, PBDFs, PCDDs, PCDFs, fly ash, carbon oxides, hydrogen bromide, methane, ethylene, benzene, toluene, phenol, benzofuran, styrene, PAHs, bromophenols, etc. are released.
- Secondary pollution by heavy metals and BFRs leaching the groundwater.
- 'Bottom ash' (solid residues of incineration remnants) have significantly higher levels of Cu, Pb and Cd.
- Heating of plastic or PVC circuit board release PCA, PCDDs and PCDFs which are known carcinogens.

- Release of harmful gases such as carbon monoxide, sulfur dioxide, nitrogen oxides.

- Smoke consists of oxides of Sb, Pb, Tl, As, Cu, Mn, Hg and Ni.

Reuse/Repair:

Ghimire and Ariya (2020) stated that repairing/reusing instruments can be a good measure for sustainable waste management because it lowers the manufacturing volume of EEEs thereby reducing the amount of e-waste. Changes in product designs, technology, and wireless services often pose difficulties to upgrade or repair instruments (Wieser and Troger, 2018).

Refurbishment and reuse of e-waste has potential to renovate the used electrical and electronic equipment and to put them to their original use (Borthakur and Singh, 2012).

Recycling (Dismantling, Processing and End-processing):

Recycling helps to re-extract materials from e-waste, reduces carbon emission, and restricts many usable and/or hazardous substances to end up in landfills. E-waste can be a good source of recycled metals and can supplement the use of virgin materials for EEE production (Ghimire and Ariya, 2020). Taurino *et al.* (2010) stated that a complete characterization of the waste in terms of its materials, composition, hazardous substances present, physical properties (magnetic, density, electric conductivity, volume resistivity, specific gravity, shape, size, liberation properties, etc.) and chemical properties is required for an effective recycling of e-waste.

According to Borthakur and Singh (2012), recycle and recovery of e-waste includes the unit operations like dismantling, segregation of ferrous metal, non-ferrous metal and plastic by shredder process, refurbishment and reuse, recycling/recovery of valuable materials and treatment/disposal of dangerous materials and waste. Atin and Singh (2020) reported that recycling of e-waste primarily involves two stages, Manual collection (Sorting, separating and dismantling) and Mechanical processing (Shredding, grinding, etc.). Borthakur and Singh (2012) and Ghimire and Ariya (2020) documented that a typical recycling process includes dismantling, processing and end-processing.

Dismantling:

Dismantling includes removal of perilous substances (CFCs, Hg switches, PCB) and valuable substances (cable containing copper, steel, iron, precious metal containing parts etc.) from the e-waste (Borthakur and Singh, 2012). Dismantling can be either manual or mechanical for the separation of hazardous and valuable components (Ghimire and Ariya, 2020). According to Atin and Singh (2020), dismantling is a manual processing that involves sorting, separating, cleaning, emptying, dismantling and segregation for the purpose of de-pollution. Output of dismantling (hammering and shredding) is a reduction in size of e-waste (Vats and Singh, 2014b).

Huang *et al.* (2014) stated that in Ghana, e-waste recycling is performed by the informal sector using rudimentary methods (dismantling and open burning) to salvage copper and other metallic components by breaking electronic devices down to their individual components. According to Lundstedt (2011), during dismantling. simple hand tools (hammers, chisels or stones) are used to break electronic devices down to their individual components. Materials of no value are disposed of in a large area at the disposal sites. Such materials are piled up on the dump site and are periodically burned to reduce volume.

Manual dismantling of e-waste helps recover recyclable metals, plastics and components and segregate the hazardous components that need further treatment e.g. mercury and lead containing components (batteries, CRT-Glass and LCDs). Vats and Singh (2014b) reported that outputs of dismantling are air fugitive due to spillage and generation of hazardous waste.

Processing:

In processing, either a smasher is used to slowly break e-waste or a cross flow shredder is used to cut the scrap. In Europe where labor cost is high, mechanical processing of e-waste is preferred (Ghimire and Ariya, 2020). Mechanical processing is followed by sorting out hazardous and valuable materials. Further crushing and separation are performed using hammer mills, magnetic separation, sieves, eddy current separators etc. which produce metal concentrates that go to metal mills and plastics (Salhofer *et al.*, 2016). Guo *et al.* (2009) stated that processing of e-waste is an indoor activity and include processing of circuit boards, plastic chipping and melting.

End-processing:

In end-processing, fractions of ferrous, aluminium and copper/lead are sent to smelters. Ferrous fractions are diverted to steel plants to recover iron, aluminium fractions to aluminium smelters while copper/lead fractions, circuit boards, and other fractions containing precious metals are sent to integrated metal smelters. Hazardous and non-recyclable substances are sent for disposal (Ghimire and Ariya, 2020).

End-processing of e-waste involves the mechanical processing of fractions concentration (shredding, milling, grinding and segregation) and selective treatment (Atin and Singh, 2020). Mechanical processes such as shredding, grinding, magnetic and eddy current separation etc. are the primary requirement of recovery (Vats and Singh, 2014a).

Recycling of Plastics:

Recycling plastics is difficult because e-waste consists of more than 15 different polymers containing BFRs including PBBs/PBDEs (Taurino *et al.*, 2010; Ghimire and Ariya, 2020). Plastics have great potential and hardly 25% of plastics are being recycled since the presence of numerous polymers and additives made it very complex materials. Techniques like sieving, density separation, electrostatic separation and air-separation in combination with grinding, milling and granulation are used for separation of different products and quality of plastics (Vats and Singh, 2014a).

Kang and Schoenung (2005) stated that pyrolysis and depolymerisation techniques are used to transform plastics into oven gas and other chemicals. In Guiyu, China, plastics were disposed by burning and salt brine delamination. The recyclers ignited plastics and classified them into different categories by identifying their smell in burning. The chemicals used in both "gold washing" and plastics classification were directly discharged into the local waterways (Wang *et al.*, 2020).

Acid Baths/Acid Dissolution:

Sivakumaran (2013) reported that acid bath technique is mainly used for management of circuit boards to recover copper, lead, gold and silver. During acid baths, circuit boards are submerged into sulphuric acid for about 12 h to dissolve copper. The solution is then boiled to extract the copper sulphate by precipitation and remaining solution is added with scraped particles to remove the copper smudges. Acid dissolution occur using nitric acid or aqua regia to dissolve the precious metals. In 'urban mining', metals are recycled by extracting them from electronic waste. These include Gold, Silver, Palladium, Tin and others valuable metals (Ma, 2014).

Recycling of used Batteries:

Forti *et al.* (2020) reported that e-waste do not cover any kind of batteries, accumulators, or electrical components of vehicles. According to Ferronato and Torretta (2019), in Iran, almost 10,000 tons of household batteries were imported and most of them have been discarded in municipal solid waste (MSW) without any separation and sent to sanitary landfills. This safe disposal of used batteries in MSW stream implies the depletion of valuable resources along with health risk to environment and human.

China: The Global e-waste Capital:

China is the former largest e-waste recipient and now become a main global generator of e-waste. Its annual domestic e-waste generation reaches approximately 10.129 million tonnes. China has emerged as the largest e-waste producing country in 2019 (Wang *et al.*, 2020; Forti *et al.*, 2020). According to CHEARI (2019), China appeared as the global "e-waste capital" or "e-waste heaven" in the international media or NGO reports.

Guiyu: Global hub of e-waste recycling:

Guiyu, a coastal town with population of about 200,000 people and 52.17 km^2 area of Shantou city located in Guangdong province of China. More than 100,000 people and about 80% of families of Guiyu were involved in e-waste recycling to process about 150 to 300 million of e-waste annually. Specialized family workshops were involved in collection, sales and processing of e-waste along with trade of second-hand electronic components, extraction of raw materials and sales. Circuit boards baking (CBB), precious metal extraction and plastics disposal were the main sources of pollution in Guiyu (Wang *et al.*, 2020).

Ghimire and Ariya (2020) noted that sustainable technologies used to reduce e-waste include:

- Use of airborne nanoparticle for effective and efficient recycling of e-waste.
- Clay minerals and Kaolin nano and microtraps to remove and recycle e-waste components.
- Combination of bioreactors and nanotechnology for removal and recycling e-waste.

Conclusion

Management of e-waste is a great challenge for many developing countries. Present review recommends to integrate the informal sector with the formal sector in order to separately collect, effectively treat, dispose of e-waste along with divert it from conventional landfills and open burning. To reduce, reuse, refurbish, recovery and recycle is the current solution to minimize the e-waste. 'Thinking globally and acting locally' is a fundamental attitude to reduce such an environmental threat. Information campaigns, capacity building and awareness is critical to promote environment friendly e-waste management programmes.

Acknowledgements

Encouragement and support provided by Ganesh A. Thakur, Principal, Mahatma Phule Arts, Science and Commerce College, Panvel, Raigad, Navi Mumbai is gratefully acknowledged. Thanks are due to The Head, Department of Zoology and faculty members for healthy cooperation and fruitful discussion on the present study.

References

Atin B and Singh SG. (2020) E-waste management in India: Challenges and agenda. Centre Sci. Environ. New Delhi, pp. 62.

Balde CP, Kuehr R, Blumenthal K, Fondeur Gill S, Kern M, Micheli P, Magpantay E and Huisman J. (2015) E-waste statistics- Guidlines on classification, reporting and indicators, United Nations University, IAS-SCYCLE, Bonn, Germany. ISBN: 978-92-808-4553-2.

Borthakur A and Singh P. (2012) Electronic waste in India: Problems and policies. Int J Environ Sci. 3(1): 353-362.

CHEARI (China Household Electronics Appliance Research Institute) (2019) White Paper on the Development of WEEE Recycling Industry; China Household Electronics Appliance Research Institute (CHEARI): Beijing, China.

Diane P, Golnoush A, Lieselot B, Debashish C, Christian E, Mikhail E, Petr F, Hemda G, Khadijah I, Nadia GK, Mari L, Avtar M, Bradley WM, Antonio P Oluseun EP, Teodora R, Heinz R, Angela S, Yehuda S, Kiran RS, Fiona W, Benjamin PW and Ming HW. (2020). Global occurrence, chemical properties, and ecological impacts of e-wastes (IUPAC Technical Report). Pure Appl Chem. 92(11): 1733-1767.

Ferronato N and Vincenzo T. (2019) Waste mismanagement in developing countries: A review of global issues. Int J Environ Res Public Hlth. 16: 1060.

Forti V, Balde CP, Kuehr R and Bel G. (2020) The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) -co-hosted SCYCLE Programme, International Telecommunication Union (ITU) and International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. pp. 120. ISBN: 978-92-808-9115-7.

Ghimire Hand Parisa AA. (2020) E-wastes: Bridging the knowledge gaps in global production budgets, composition, recycling and sustainability implications. Sustain Chem. 1: 154-182.

Guo J, Guo J and Xu Z. (2009) Recycling of non-metallic fractions from waste printed circuit boards: A review. J Hazard Mater. 168: 567-590.

Guo Y, Changjiang H, Hong Z and Qiaoxiang D. (2009) Heavy metal contamination from electronic waste recycling at Guiyu, Southeastern China. J Environ Qual. 38:1617-1626.

Hearn LK, Thompson J, Kennedy K and Mueller J. (2011) Perfluorinated compounds and polybrominated diphenyl ethers in leachate from Australian landfill sites. In: 31st Int Symp Halogenated Persistent Organic Pollutants, Belgium.

Hossain MS, Sulala MZFAH and Toufiqur RM. (2015). E-waste: A challenge for sustainable development. J Hlth Poll. 9: 3-11.

Huang J, Philip NN, Desmond OA and Ebenezer M. (2014) E-Waste disposal effects on the aquatic environment: Accra, Ghana. In: Reviews of Environmental Contamination and Toxicology, (ed.) Whitacre D. M., Springer International Publishing Switzerland, pp. 229.

Kang HY and Schoenung JM. (2005) Electronics waste recycling: A review of U. S. infrastructure and technology options. Resour Conserv Recycl. 45: 368-400.

Kiddee P, Naidu R, Wong MH, Hearn L and Müller JF. (2014) Field investigation of the quality of fresh and aged leachates from selected landfills receiving e-waste in an arid climate. Waste Manag. 34: 2292–2304.

Kiddee P, Ravi N and Ming HW. (2013) Electronic waste management approaches: An overview. Waste Manag. 33: 1237-1250.

Li Y, Richardson JB, Mark BR, Niu X, Yang H, Li L and Jimenez A. (2009) Leaching of heavy metals from e-waste in simulated landfill columns. Waste Manag. 29: 2147-2150.

Lundstedt S. (2011) Recycling and disposal of electronic waste: health hazards and environmental impacts. Swedish Environ Protection Agency, Report 6417.

Ma HK. (2014) Eco-recycling of precious metal from e-waste. Conf. on electronics Recycling Asia, organized by World Recycling Forum on 11th to 14th Nov 2014, pp. 33.

Meshram LN and Pawar Prabhakar R. (2021) E-waste: sources, composition and impacts on environment and human health -A review. Uttar Pradesh J Zool. 42(23): 191-210.

Rao LN. (2014) Environmental impact of uncontrolled disposal of e-wastes. Int J Chem Tech Res. 6(2): 1343-1353.

Salhofer S, Steuer B, Ramusch R and Beigl P. (2016) WEEE management in Europe and China - A comparison. Waste Manag. 57: 27-35.

Sankhla MS, Mayuri K, Manisha N, Shriyash M, Gaurav P S, Chaturvedi B and Rajeev K. (2016) Effect of electronic waste on environmental and human health- A review. IOSR J Environl Sci Toxicol Food Technol. 10(9): 98-104.

Sivakumaran S. (2013) E-waste management, disposal and its impacts on the environment. Universal J Environ ResTechnol. 3(5): 531-537.

Sthiannopkao S and Wong MH. (2013) Handling e-waste in developed and developing countries: Initiatives, practices, and consequences. Sci Total Environ. 463-464: 1147-1153.

Taurino R, Pozzi P and Zanasi T. (2010) Facile characterization of polymer fractions from waste electrical and electronic equipment (WEEE) for mechanical recycling. Waste Manag. 30: 2601-2607.

Vats MC and Singh SK. (2014a) E-Waste characteristic and its disposal. Int J Ecol Sci Environ Engineer 1(2): 49-61.

Vats MC and Singh SK. (2014b) Status of e-waste in India- A review. Int J Innov Res Sci Engineer Technol. 3(10): 16917-16931.

Wang K, Junxi Q and Lixiong L. (2020) Understanding environmental pollutions of informal e-waste clustering in global south via multi-scalar regulatory frameworks: A case study of Guiyu Town, China. Int J Environ Res Public Hlth. 17: 2802.

Wieser H and Troger N. (2018) Exploring the inner loops of the circular economy: Replacement, repair, and reuse of mobile phones in Austria. J Clean Prod. 172: 3042-3055.

Zhang K, Jerald LS and Eddy YZ. (2012) E-waste recycling: Where does it go from here? Environ Sci Technol. 46: 10861-10867.