Impact of E-Waste Management and Recycling Challenges: Review

Vyshnavi Gogula[1], Belwin Edward[2], W J Praiselin[3], Jacob Raglend I[4].
[1,2,3,4] School of Electrical Engineering, Vellore Institute of Technology Vellore, Tamil Nadu, India.

Abstract-Due to its economic potential, increasing commercial prospects, and possible contribution to the SDG (Sustainable Development Goals) 2030 target, urban mining of these metals has lately acquired favour. Due to transboundary imports and exports, it is the fastest increasing solid waste stream worldwide. There are several hazardous substances in the massive volume of electronic garbage that presents a significant problem. E-waste, or garbage made up of old electronics, is a problem for both people and the planet. The majority of industrialised nations now have E-waste handling infrastructures in place. Strangely, emerging countries have a lot of problems and no good solutions. Other issues that have an impact on the E-waste value chain in India include a lack of data inventory and treatment choices. To ensure the safety of the E-waste supply chain, improve social conditions, reduce negative effects on the environment, and promote long-term growth. Life cycle assessment, biotransformation, and the "4R" approach are all viable options as well. It is crucial to transform the underground recycling economy into a transparent market. Challenges in India's E-Waste Management and Recycling System. Addressing these challenges will ensure the health and safety of e-waste collectors, recyclers, and manufacturers. India has very few regulations governing the recycling of E-waste at the grass roots level.

1. Introduction

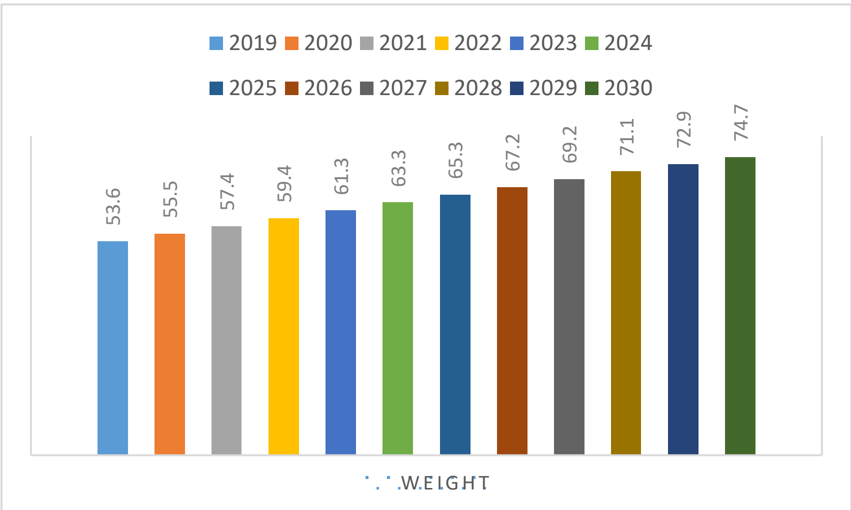

Fig. 1 WEEE generation between 2019 and 2030 [1]

WEEE, or "electronic waste," refers to unwanted electrical and electronic equipment (e-waste). E-waste encompasses a wide variety of electrical and digital gadgets, such as laptops, PDAs, video and audio devices (TVs, cameras), and more. The amount of electronic garbage produced every year has skyrocketed alongside the proliferation of IT equipment [1]. A considerable amount of electronic garbage is produced each year by a group of emerging and industrialised countries. Indian e-waste generation has increased from being one of the top five in 2018 to becoming the third largest in 2020 from being one of the top five [2].

In 2019, the world produced around 54 million metric tonnes of WEEE, up from 45 million metric tonnes in 2016 [3], with an average annual use of 7.3 kilogrammes per person. To get to 75 MT by 2030, annual growth in this generation rate is expected to be substantial. E-waste production was predicted to be 53.6 million metric tonnes in 2019, with just 17.4 percent of that total being recycled, according to the Global E-waste Monitor 2020 [4-5].

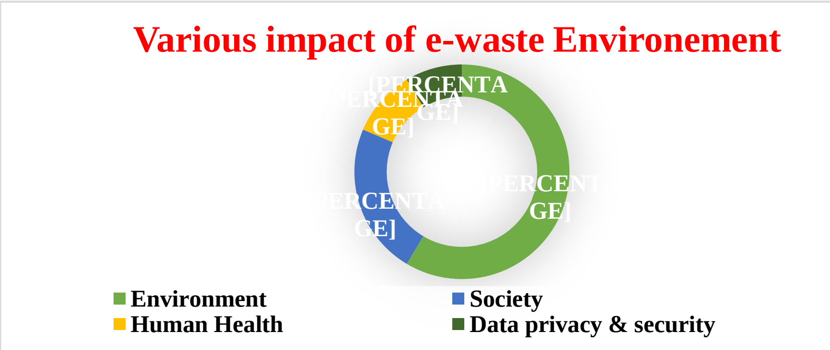

Fig. 2 various impacts of e-waste environment [6].

The risks to the privacy and security of electronic data held on these devices are considerable, and so are the environmental, health, and societal consequences of e-annual waste. Fig. 2. All of these issues stem from our current, ineffective, and contentious approach of dealing with e-waste. There is a growing need for effective e-waste management solutions due to the increasing volume of obsolete electronics.

1.1 Environment: The ecology could be endangered if e-waste isn't properly disposed of. Toxic chemicals discovered in electronic trash include heavy metals, chemical contaminants, and flame retardants. Negative environmental repercussions can be caused if e-waste is not properly handled. Heavy metals include cadmium, lead, nickel, and mercury. Cadmium can be found in a wide variety of electrical components, including switches, solder joints, and rechargeable batteries, to name just a few. Lead is used in batteries, electrical solders, and CRTs. In flat-screen televisions, circuit boards, switches and other components all contain mercury. Electronic equipment uses many heavy metals, such as barium, copper, and beryllium [7, 8-12]. They will pollute the environment if these metals are put in landfills. When they are burned, they also release carbon dioxide into the environment." It is possible for animals to accumulate toxic compounds due to the slower metabolism of some metals. Foods such as milk, eggs, and other dairy products can cause amplification or bio magnification in the human body [13-15]. Animals are unable to consume trace elements and heavy metals in the air, soil, and river water. Some of the most prevalent semiconductor parts in electronic devices rely on the use of the trace elements bismuth (indium), antimony (antimony), and tungsten (tungsten). It was discovered that e-waste disposal sites in the Northern Vietnamese region were polluting the environment with significant concentrations of harmful compounds. Inorganic pollutants, such as polybrominated diphenyl ethers and polychlorinated biphenyls (PCBs), also endanger our ecology. PCBs are released into the environment through a variety of sources, including printing ink, hydraulic fluids, and capacitor dielectrics. Chemicals may also be released from wire and cable coatings that contain PVC components after burning [16, 17]. PCBs were outlawed in the 1980s, but the devastation they inflicted on the environment before that time is still visible. The use of these substances has resulted in pollution. Furthermore, environmentally toxic flame retardants like PBDEs and TPP are used. They're used in the plastic housing and foams of electronic gadgets like monitors. Furthermore, allowing them to penetrate the ecosystem has negative implications. Some of these plastic containers leave behind some non-burned particles, which may wash away due to rain and result in rivers. Discharges of harmful compounds into the environment harm the ecosystem in two ways: by polluting it or by causing hazardous molecules to build up. E-waste must be transported, disposed of, and recycled in a defined manner because of this.

1.2 Human Health: E-waste is among the most harmful types of household hazardous waste. Electronic waste contains a wide range of hazardous substances that can harm human health. You can either get sick from eating or working with harmful chemicals in e-waste, or you can get sick from being exposed to them while in the e-waste industry directly. Toxic metals such as cadmium and mercury damage children's cognitive and behavioural development, as well as their renal, bone, and reproductive systems; this has been demonstrated to be the case. E-waste and hair samples from people working in these industries were the most common sources of copper, antimony, and bismuth [18]. Many organs, including the liver, kidneys, thyroid, central nervous system, and reproductive system, are negatively impacted by the toxic substances included in e-organic waste. The presence of hazardous flame retardants in this trash is cause for alarm for human health. These factors have an effect on the growth of the fetus's immune system, hormone levels, thyroid, memory, learning, and behaviour. As one of the few dangerous substances that might potentially destroy Deoxyribonucleic acid (DNA), people who live near electronic waste disposal sites should take precautions to avoid exposure to hexavalent chrome. Dust and chemicals released during e-waste breakdown, renovation, reformation, recovery, and sorting may harm the health of recyclers. The release of all toxic chemicals from electronic waste poses a threat to human health [19].

1.3 Society: It's easy to ignore the harm that e-waste causes to the environment and to human health. In areas where illicit and informal e-waste operations are common, this component is more directly associated with the harm that these operations do to children and young adults. With the help of international agreements, Ghana is addressing the issue of e-waste management. Slum children and young men, on the other hand, are employed as cheap labour disassembling and recycling machinery because the area has long been regarded as a place to dispose of unwanted electronic devices. As a result, young people are becoming increasingly involved in illegal electronic trash transactions [20]. As health threats and environmental dangers become more serious, public health concerns are on the rise as well. As a result, social and economic conditions have shifted. As a result of decreased agricultural output, food insecurity and poverty have increased. Because of this, many of these workers have turned to crime. As the amount of e-waste grows, so do the number of unlawful e-waste trades and crimes. Health issues are often more strongly associated with e-social waste's impact in these situations.

1.4 Data privacy and security: Personal information, private information, and institutional data can all be stored on electronic devices such as computers and mobile phones. Data on this can both be deleted/formatted and disposed of, or it can be thrown away as is with no data remaining. A lot of people don't know that they can restore data from these storage devices. This sensitive information can be accessed by anyone with ulterior intents or business interests [21]. This is seen as a gold mine for cyber criminals. It is possible to use this information to impersonate, crack passwords, blackmail, gain access to credit and debit card numbers, and more. Disposal of e-waste raises issues of national security as well. Toxic information contained in electronic waste may be misused by criminal organisations if it is shipped to another nation for disposal. Malware-infected electrical components imported from foreign countries pose a threat to national security because they can reveal sensitive data about manufacturers. Some electronic devices' components can be copied and their data can be accessed by someone who are not authorised to do so when reverse engineering [22]. Because of this, when dealing with electronic waste, privacy and security are the most crucial issues to consider.

Table. 1 Efforts and regulations aimed at reducing electronic waste [23].

Initiatives	Key feature
Basal convention	In 1992, it was endorsed as a way to prevent hazardous waste from being exported from producing countries. The accord is supported by 172 countries, but the United States has not ratified the treaty.
Bamako convention	E-waste imports are to be regulated more strictly than in the Basel Convention. Since 1998, it has been used in African Union countries.
EU WEE Directive	All EU members embraced the system in 2007 and began taking back ten categories of

	electrical items as part of the system's takeback methodology.
Restriction of Hazardous Substances Directive (RoSH)	Restrictions on the use of hazardous compounds are part of the EU WEEE directive. Endorsed by a number of countries, including China and India.
Solving the E-waste Problem (StEP)	United Nations agencies began promoting the reuse of recycled components in 2007 as a means of cutting down on trash output.
5Rs (Report, Reduce, Reuse, Recycle and Recover)	Japan was the spark that lit the fire. Take steps to reduce the amount of electronic waste you produce. Allows remanufacturing and recycling to take place in another country.

Table 1 lists a slew of worldwide organisations and projects that have taken steps to ensure proper monitoring and recycling. These initiatives and organisations are working together to educate the public about the dangers of e-waste and find solutions to the problem.

2. Impact of e-Waste in climatic changes: A review

Deepali Sinha Khetriwal et al. [24] used data from two countries, Switzerland and India, to help readers understand the current practises for disposing of end-of-life appliances. This included details on how countries fund their appliance collection and recycling systems, as well as the social and environmental implications of these practises. The problem has been solved at last. The longevity of a recycling system depends on its capability of adjusting to upcoming shifts in trash quantity and quality. Despite existing in the shadow economy, market-based systems may be more flexible than ones based on an intergenerational contract. More quantitative indicators are needed, as this paper mainly gives a qualitative assessment of environmental and social aspects of e-waste recycling. G. Gaidajis et al. looked examined the things that make up e-waste, as well as the current and projected production of e-waste, the potential environmental challenges linked with their disposal, and management techniques. Furthermore, we learned that ill-handling of e-waste products contributes significantly to pollution in economically developing nations. S.B. Wath et al. [25] conducted a study with the intention of presenting the composition and categorization of e-waste, as well as global and Indian e-waste scenarios, prospects for reclaiming and reusing as well as recycling and recovering materials from e-waste, and environmental and occupational hazards associated with e-waste. Last but not least, more attention should be paid to recycling and recovery options at levels 2 and 3 of treatment systems in order to enhance e-waste treatment and management. Concurrently, the country needs the implementation of innovative programmes and best practises like ARF and EPR. Petheeswari Vetrivel [26] has written about the dangers that e-waste poses to the environment and to human health, as well as the three main ways to deal with it: recycling, reusing, and reducing. Peeranart Kiddee et al. [27] reviewed the toxic compounds found in discarded electronics, their possible effects on the environment and human health, and the current treatment options available. Life Cycle Assessment (LCA), Material Flow Analysis (MFA), Multi Criteria Analysis (MCA), and Extended Producer Responsibility are only few of the methods created to deal with electronic waste (EPR). Mahesh C. Vats et al. [27, 28] analysed data to assess the current status of e-waste in India. In 2005, the country ranked 101 on the ESI (Environmental Sustainable Index), but only 66th in environmental governance; it has since been reported that the country's environmental governance could benefit from the infusion of FDI (Foreign Direct Investment) in the form of a PPP (People, Private Partnership) model for the treatment of electronic waste, since European countries possess the necessary technological know-how and India provides the necessary low-cost labour. Finally, we should be prepared with the most up-to-date infrastructure, awareness, and technology for e-waste treatment to face the new difficulties that the technological boom of the 21st century is predicted to bring. Opportunities worth millions of dollars can be swiftly unlocked by implementing 5R principles to reduce environmental loading in the country. According to Tansel et al. [29, 30], India and China face a double-edged sword in the shape of electronic trash, as they deal with both domestic production and illegal imports from wealthier countries. The cost of disposing of electronic trash has been shown to be somewhat attributable to its international transport.

Conclusion

Threats to the environment, human health, social welfare, and the privacy and security of personal data are just few of the many that electronic waste presents. Careful management of electronic trash is required to lessen its potentially harmful effects and the likelihood of illicit activity. E-waste must be managed and disposed of according to stringent laws and regulations. It's crucial to be knowledgeable about all aspects of e-waste, including the many crimes that could put people at risk from using it. In order to successfully recycle electronic waste over the long run, governments and regulatory agencies must provide the necessary infrastructure and encourage private sector engagement through financial support and other incentives. To stop the illegal dumping of electronics in the future, we need a mix of stricter laws, innovative technological solutions, and increased community accountability through education. It's possible that in the not-too-distant future, bio hydrometallurgy (i.e., bioleaching) strategies will play a pivotal role in metal recycling.

References

[1] Forti, V., Balde, C.P., Kuehr, R. and Bel, G., 2020. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential.

[2] India among top five nations in e-waste generation, says report, Financial Express, 04 June 2018, (2018).

[3]India third largest e-waste generator in the world, capacity limited to threat only few fourth of its waste. Times of India, 04 July 2020, (2020).

[4] Unger, N., Beigl, P. and Salhofer, S., 2017. Small waste electrical and electronic equipment–

from collection to secondary resource. *Österr Wasser-und Abfallw*.
[5]S. Mehta, The why and how of disposing electronic waste, Mongbay, 25 August 2020, (2020).
[6] Kapoor, N., Sulke, P.J. and Badiye, A., 2021. E-WASTE FORENSICS: AN OVERVIEW. Forensic Science International: Animals and Environments, p.100034.
[7]Sivaramanan, S., 2013. E-Waste Management, Disposal and Its Impacts on the Environment. Universal Journal of Environmental Research & Technology, 3(5).
[8] Hartwig, K. and MDes, A.D.P.D., 2016. DIGITAL WASTE & CYBER CRIME.
[9] A. Ashfaq, A. Khatoon, Environmental impacts and assessment of electronic waste management, Int. J. Curr. Microbiol. Appl. Sci. 3 (7) (2014) 772–779. ISSN: 2319- 7706.
[10] M.S. Sankhla, M. Kumari M, M. Nandan, S. Mohril, G.P. Singh, B. Chaturvedi, R. Kumar, Effect of electronic waste on environmental & human health – a review, IOSR J. Environ. Sci. Toxicol. Food Technol. 10 (9) (2016) 98–104, e-ISSN: 2319- 2402, p- ISSN: 2319-2399.
[11] J. Alghazo, O. Ouda, A. Elassanm, E-waste environmental and information security threat: GCC countries vulnerabilities, Euro-Mediterr. J. Environ. Integr. 3 (13) (2018) 13.
[12] B.S. Al-Anzi, A.A. Al-Burait, A. Thomas, C.S. Ong, Assessment and modeling of E-waste generation based on growth rate from different telecom companies in the State of Kuwait, Environ. Sci. Pollut. Res. 24 (35) (2017) 27160–27174.
[13] T. Sivakumar, G. Vijayaraghavan, A.V. Kumar, Global challenges in e-waste management: indian scenario, Int. J. Adv. Eng. Technol. 2 (4) (2011) 0976–3945 (E-ISSN).
[14] T. Udhayakumar T, Disposal methods of e-waste in India survey conducted in Chennai, Int. J. Appl. Environ. Sci. 12 (3) (2017) 505–512. ISSN 0973-6077.
[15] N.N. Ha, T. Agusa, K. Ramu, N.P. Tu, S. Murata, K.A. Bulbule, P. Parthasaraty, S. Takahashi, A. Subramanian, S. Tanabe, Contamination by trace elements at e-waste recycling sites in Bangalore, India, Chemosphere 76 (1) (2009) 9–15.
[16] N. Uchida, H. Matsukami H, M. Someya, N.M. Tue, L.H. Tuyen, P.H. Viet, S. Takahashi, S. Tanabe, G. Suzuki, Hazardous metals emissions from e-waste-processing sites in a village in northern Vietnam, Emerg. Contam. 4 (1) (2018) 11–21.
[17] J. Alghazo, O. Ouda, A. Elassanm, E-waste environmental and information security threat: GCC countries vulnerabilities, Euro-Mediterr. J. Environ. Integr. 3 (13) (2018) 13.
[18] P. Kiddee, R. Naidu R, M.H. Wong, Electronic waste management approaches: an overview, Waste Manag. 33 (2013) 1237–1250.
[19] K. Grant, F.C. Goldizen, P.D. Sly, M.N. Brune, M. Neira, M. Van de Berg, R. E. Norman, Health consequences of exposure to e-waste: a systematic review, Lancet Glob. Health 1 (6) (2013) e350–e361.
[20] A. Illes, Illegal shipment of e-waste from the EU: a case study on illegal e-waste export from the EU to China. A Study Compiled As Part of the EFFACE Project, IEEP,, London, 2015.
[21] Illicit trade in electrical and electronic waste (e-waste) from the world to the region. Transitional Organised Crime Treat Assessment- East Asia and the Pacific.
[22] Special Report. Recycling Electronic Waste. Initiative for Global Environmental Leadership (IGEL). Knowledge @ Whartone (2016).
[23] Thakur, P. and Kumar, S., 2021. Evaluation of e-waste status, management strategies, and legislations. International Journal of Environmental Science and Technology, pp.1-10.
[24] Sinha-Khetriwal, D., Kraeuchi, P. and Schwaninger, M., 2005. A comparison of electronic waste recycling in Switzerland and in India. Environmental Impact Assessment Review, 25(5), pp.492-504.

[25] Gaidajis, G., Angelakoglou, K. and Aktsoglou, D., 2010. E-waste: environmental problems and current management. Journal of Engineering Science and Technology Review, 3(1), pp.193-199.
[26] Wath, S.B., Dutt, P.S. and Chakrabarti, T., 2011. E-waste scenario in India, its management and implications. Environmental monitoring and assessment, 172(1), pp.249-262.
[27] Vetrivel, P., 2012. A Focus on E-Waste: Effects on Environment and Human Health. International Journal of Novel Trends In Pharmaceutical Sciences, 2(1), pp.47-51.
[28] Kiddee, P., Naidu, R. and Wong, M.H., 2013. Electronic waste management approaches: An overview. Waste management, 33(5), pp.1237-1250.
[29] Vats, M.C. and Singh, S.K., 2014. Status of e-waste in India-A review. transportation, 3(10).
[30] Tansel, B., 2017. From electronic consumer products to e-wastes: Global outlook, waste quantities, recycling challenges. Environment international, 98, pp.35-45.

Biographies

Gogula Vyshnavi was born in Andhra Pradesh, India, on January 24, 1994. She received her B.Tech degree in Electrical and Electronics Engineering from JNTU Anantapuramu in 2015. She received her M.Tech in Electrical Power System at the Department of Electrical and Electronic Engineering in Sree Vidyanikethan Engineering College, Andhra Pradesh, India. At present she is pursuing PhD in School of Electrical Engineering, VIT University, Tamil Nadu, and India. Her main research interest is power system protection, distributed generation, specifically detection and location faults in distribution system, high impedance faults, and E-waste management. Etc.,

Dr. J. Belwin Edward received his doctorate in Power Systems from Anna University in Chennai, India. Now, he works as a senior associate professor in the electrical engineering department at VIT in Vellore, India (an Institute of Eminence). He's presented over fifty of his works at various conferences and magazines. He has been in the academic field for over 18 years. His primary areas of study are home energy management, hybrid electric vehicles, power system optimization, and renewable energy systems.

W J Praiselin received a Bachelor of Engineering in Electrical and Electronics Engineering in 2013 from Udaya School of Engineering in Tamilnadu, India, and a Master of Engineering in Power Systems Engineering in 2015 from Francis Xavier Engineering College in Tamilnadu, India. She is a current Ph.D. student at VIT University in Vellore, India. Her areas of focus in academia are power systems, microgrid power quality improvement, control operations, FACTS devices, and the integration of renewable energy sources.

Dr. I. Jacob Raglend, Ph.D., earned a first-class Bachelor of Science in Electrical Engineering from The Indian Engineering College in 2000 and a first-class Master of Science in Power Systems Engineering from Annamalai University in 2001. He earned his doctorate in 2007 from the Electrical and Electronics Engineering Department at the Indian Institute of Technology in Roorkee, India. Currently he is the head of the Electrical Engineering Department at Vellore Institute of Technology (VIT) in India and a professor there. He has written roughly 80 articles for peer-reviewed journals, another 65 for conferences both domestic and abroad, and 13 for collections of essays. Twelve students have earned their doctorates under his tutelage, and another six are now enrolled. Volunteering at National and International Conferences as a Technical and Advisory Member He has served as the publication chair for five different IEEE International conferences and the organising chair for two different conferences. At Noorul Islam University, I served as the Associate Project Director for a student group working on a Nano Satellite. To serve as a reviewer for the journals Journal of Applied Soft Computing, International Journal of Energy Sector Management, and International Journal of Electric Power and Energy Systems. Some of the topics he covered in his lectures included the fundamentals of electrical engineering, power systems, AI, and soft computing. Unit Commitment, Economic Dispatch, Smart Grid, Power System Restructuring and Deregulation, Renewable Energy Integration, Internet of Things Applications, Artificial Intelligence Applications to the Power System, and FACTS are all areas of study that pique his interest.