REVIEW ARTICLE

Indian Journal of Waste Management
Volume 9 Number 2, July - December 2025

Smart Boards as Emerging E-Waste: Challenges and Sustainable Management Strategies

Rohit Kumar Pal

HOW TO CITE THIS ARTICLE:

Rohit Kumar Pal. Smart Boards as Emerging E-Waste: Challenges and Sustainable Management Strategies. Ind. Jr. Waste Manag. 2025; 9(2): 53-60.

ABSTRACT

The proliferation of smart boards, interactive digital displays widely used in educational and corporate settings, has introduced significant advancements in communication and learning. However, their rapid adoption and relatively short lifespan contribute to the growing global electronic waste (e-waste) crisis. This review examines smart boards as an emerging source of e-waste, focusing on their composition, environmental and health impacts, and current management practices. Smart boards contain valuable materials like precious metals and hazardous substances such as lead, mercury, and brominated flame retardants, posing risks when improperly disposed of. The study highlights challenges in smart board disposal, including limited recycling infrastructure, lack of standardized regulations, and low public awareness. Sustainable solutions, such as eco-friendly design, advanced recycling technologies, and circular economy models, are proposed to mitigate these issues. By integrating green manufacturing and enhanced policy frameworks, this review aims to provide a roadmap for managing smart board e-waste effectively, ensuring environmental sustainability and public health protection.

KEYWORDS

• Smart Boards • Electronic Waste • E-Waste Management • Recycling • Hazardous Materials • Sustainability • Circular Economy

AUTHOR'S AFFILIATION:

Head of the Department, Biological & Environmental Sciences, R.I.C.E Education, Kolkata, West Bengal, India.

CORRESPONDING AUTHOR:

Rohit Kumar Pal, Head of the Department, Biological & Environmental Sciences, R.I.C.E Education, Kolkata, West Bengal, India.

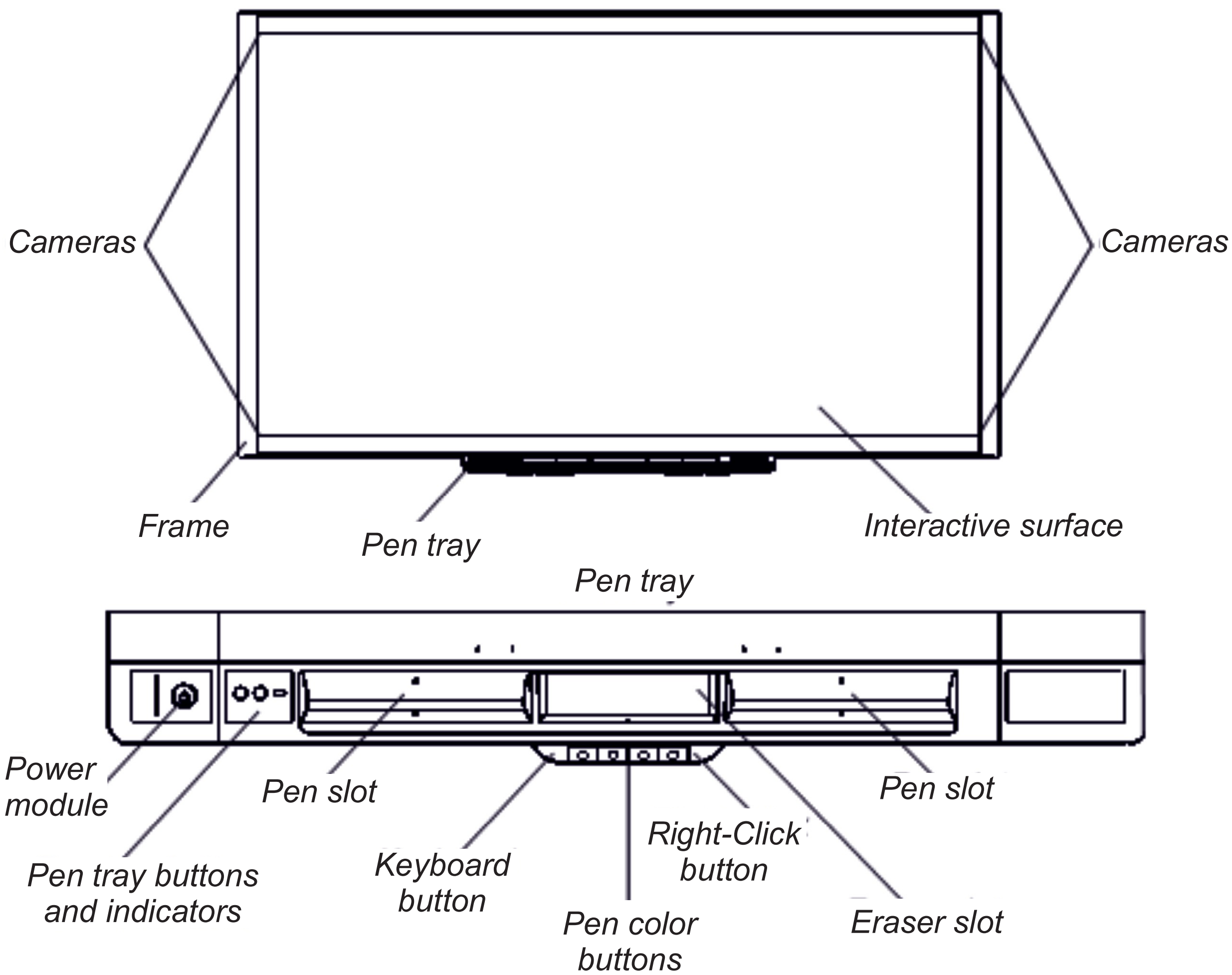
E-mail: rohitpal241@gmail.com

➤ **Received:** 11-07-2025 ➤ **Accepted:** 24-09-2025

INTRODUCTION

Smart boards, or interactive whiteboards, have transformed educational and professional environments by enabling dynamic, technology-driven interactions. These devices, which integrate touch-sensitive displays, microprocessors, and connectivity features, are increasingly prevalent in classrooms, boardrooms, and public spaces. However, their rapid obsolescence, driven by technological advancements and an average lifespan of 5–7 years, positions them as a significant contributor to electronic waste (e-waste).[1] In 2022, global e-waste reached 62 million tonnes, with only 22.3% recycled appropriately, highlighting the urgency of addressing emerging e-waste streams like smart boards.[2]

E-waste is one of the fastest-growing waste streams, increasing at a rate of 3–5% annually.[3] Smart boards, comprising printed circuit boards (PCBs), liquid crystal displays (LCDs), and plastic housings, contain both valuable and hazardous materials. Improper disposal releases toxic substances like lead, mercury, and brominated flame retardants into the environment, posing risks to human health and ecosystems.[4] This review synthesizes current knowledge on smart boards as e-waste, addressing their composition, environmental impacts, management challenges, and sustainable solutions, with a focus on fostering a circular economy.



Smart Board Design (*Source:* Smart Tech Support)

Composition of Smart Boards

Smart boards are complex assemblies of electronic components, including:

- **Printed Circuit Boards (PCBs):** Contain metals like copper (Cu), gold (Au), silver (Ag), and palladium (Pd), alongside hazardous elements such as lead (Pb) and cadmium (Cd).[5] PCBs constitute 30–50% metal and 50–70% non-metal fractions.[6]

- **Display Panels:** Typically LCD or LED screens, which may include mercury in backlighting and indium tin oxide coatings.[7]
- **Plastic Housings:** Often treated with brominated flame retardants, which are persistent organic pollutants.[8]
- **Batteries and Sensors:** Lithium-ion batteries and sensors may contain cobalt (Co) and nickel (Ni), adding to the hazardous waste profile.[9]

The monetary value of recoverable materials in e-waste, including smart boards, is estimated at $57 billion globally, yet only $10 billion is recovered sustainably.[1] The complex composition of smart boards necessitates specialized recycling processes to recover valuable materials while mitigating environmental risks.

ENVIRONMENTAL AND HEALTH IMPACTS

Improper disposal of smart boards, such as landfilling or incineration, releases hazardous substances into the environment. Lead and mercury can contaminate soil and groundwater, while burning releases dioxins and furans, contributing to air pollution and greenhouse gas emissions.[10] In 2019, e-waste contributed to 15 million tonnes of CO2 emissions due to unsustainable recycling practices.[1] Informal recycling, prevalent in developing countries, exposes workers often including children to toxic substances, leading to respiratory issues, neurological disorders, and increased cancer risks[11]

Children and pregnant women are particularly vulnerable to e-waste pollutants. For instance, lead exposure from e-waste can impair cognitive development in children, while mercury poses risks to fetal development.[12] In regions like South Asia and Sub-Saharan Africa, where 83% of e-waste remains undocumented, informal recycling exacerbates these risks.[6]

Current E-Waste Management Practices

E-waste management for smart boards faces several challenges:

1. **Limited Recycling Infrastructure:** Only 17.4% of global e-waste is formally collected and recycled, with developing countries recycling as little as 0.9–11.7%.[13] Smart boards, due to their size and complexity, are often processed inadequately.
2. **Regulatory Gaps:** While 78 countries have e-waste legislation, enforcement is weak, particularly in developing nations.[1] The Basel Convention regulates transboundary e-waste movement, but illegal exports to countries like India and Nigeria persist.[14]
3. **Low Public Awareness:** Many users are unaware of proper disposal methods, leading to household storage or improper disposal.[15]
4. **Technological Barriers:** Smart board recycling requires advanced disassembly and sorting technologies, which are costly and not widely available.[6]

Current recycling processes involve dismantling, upgrading, and refining stages.[16] Mechanical processes separate metals and non-metals, while hydrometallurgical and pyrometallurgical methods recover precious metals. However, these methods are energy-intensive and may generate secondary waste.[17]

Sustainable Management Strategies

To address the challenges of smart board e-waste, the following strategies are proposed:

1. Eco-Friendly Design

Green design principles, such as modular construction and biodegradable materials, can reduce the environmental footprint of smart boards. For example, using paper-based substrates instead of plastic reduces reliance on non-renewable resources.[18] Companies like Fairphone demonstrate the feasibility of designing electronics for end-of-life recyclability.[19]

2. Advanced Recycling Technologies

Innovations in recycling, such as bioleaching and smart disassembly using 3D image recognition, improve material recovery efficiency.[6] Bioleaching uses acidophilic bacteria to extract metals like copper and gold from PCBs, offering an eco-friendly alternative to chemical processes.[20] Smart sorting technologies enhance the accuracy of component identification, reducing waste.[6]

3. Circular Economy Models

A circular economy approach emphasizes reuse, repair, and recycling to extend the lifecycle of smart boards. Implementing take back programs and incentivizing repairs can reduce e-waste generation. For instance, pilot projects in Africa have shown that recycling can create jobs and recover valuable materials.[21]

4. Policy and Regulation

Strengthening global and national e-waste policies is critical. The European Union's Waste Electrical and Electronic Equipment (WEEE) Directive serves as a model, mandating producer responsibility and recycling targets.[22] Extending such frameworks to include specific guidelines for smart boards can enhance compliance and accountability.

5. Public Awareness and Education

Raising awareness about proper e-waste disposal is essential. Campaigns targeting educational institutions, where smart boards are prevalent, can promote responsible disposal practices. In India, initiatives by the Ministry of Environment and Forests have begun addressing e-waste awareness, though broader outreach is needed.[15]

6. Internet of Things (IoT) for Waste Management

IoT-based solutions, such as smart bins equipped with sensors, can optimize e-waste collection. For example, a Raspberry Pi-based system with ultrasonic sensors can monitor waste levels and alert authorities, improving collection efficiency.[23] Such technologies can be tailored for smart board disposal in institutional settings.

THE RECENT INSTALLATION OF SMART BOARD, ITS PROS AND CONS IN OUR ORGANIZATION

R.I.C.E Education, Kolkata, a premier institute renowned for preparing students for various job-related competitive exams such as SSC, WBPSC, WBCS, LIC, Railways, Banking, and UPSC, has recently taken a significant leap in modernizing its teaching methodologies by installing smart boards in its classrooms. Here I am working as a faculty member of Biology & Environmental Sciences for the last 8 years. This initiative aims to enhance the learning experience, making it more interactive and efficient. However, while introducing smart boards brings numerous advantages, it also presents challenges for teachers and students. Additionally, there are concerns regarding the health effects of prolonged exposure to digital screens and the environmental implications of electronic waste (e-waste) in the long run. Let's have a look, at the Pros and Cons of a smartboard.

Advantages of Smart Boards for Educators and Learners

1. Improved Learning Environment: Smart boards allow educators to deliver lessons engagingly through multimedia features like videos, animations, and interactive quizzes. This enhances the learning experience and aids students in understanding intricate ideas more efficiently.

2. Enhanced Visual Display: By showcasing high-definition images and diagrams, smart boards aid in elucidating complex topics such as mathematics and science more effectively than conventional chalkboards.

3. Interactive Teaching Techniques: Educators can utilize digital resources such as annotations, zoom features, and real-time examples to enhance student engagement in the learning experience.

4. Enhanced Accessibility: Smart boards facilitate the incorporation of online resources, enabling students to access a variety of educational materials, such as e-books and recorded lectures.

5. Effective Note-Taking: Learners can obtain digital notes straight from the smart board, lessening the requirement for handwritten notes and decreasing mistakes.

6. Time-Efficient: Educators can create engaging lesson plans ahead of time and access past lessons instantly, thus conserving precious time during class.

Cons of Smart Boards for Teachers and Students

1. Technical Issues and Maintenance: Smart boards are electronic devices that require regular maintenance and can sometimes malfunction, causing disruptions in the teaching process.

2. High Initial Cost: The installation and maintenance costs of smart boards are significantly higher compared to traditional blackboards and whiteboards, making it a costly investment.

3. Learning Curve for Teachers: Not all educators are tech-savvy. Many may require additional training to effectively use smart board features, which could be time-consuming.

4. Distraction for Students: While smart boards make learning interactive, excessive use of animations and online tools might divert students' attention from the core lesson.

5. Dependence on Electricity and Internet: Since smart boards rely on power and an internet connection, technical failures or network issues can hinder classroom activities.

Health issues related to smart board usage

The integration of smart boards into educational settings, such as R.I.C.E Education Kolkata, offers numerous benefits for interactive learning. However, it's essential to be aware of potential health implications associated with their usage:

1. Eye Strain and Digital Fatigue

Prolonged interaction with digital screens can lead to symptoms collectively known as digital eye strain or computer vision syndrome. These symptoms include dry eyes, headaches, blurred vision, and neck pain.

2. Blue Light Emission

Digital devices, including smart boards, emit blue light, which has raised concerns about its impact on eye health and sleep patterns. **Exposure to blue light, especially during evening hours, can disrupt the production of melatonin a hormone that regulates sleep leading to sleep disturbances.**

3. Postural Issues

Extended periods of interaction with smart boards may contribute to posture-related problems. Both teachers and students might experience discomfort due to prolonged standing or sitting in fixed positions, leading to **musculoskeletal issues over time.**

4. Electromagnetic Radiation Concerns

Smart boards, like other electronic devices, emit low levels of electromagnetic radiation. While current research indicates that the levels emitted by devices such as smart boards are generally considered safe, ongoing research continues to monitor any potential long-term effects.

Mitigation Strategies to Overcome Smartboard Issues

According to various doctors and ophthalmologists, to minimize potential health risks associated with smart board usage we may follow this

1. Implement the 20-20-20 Rule: Encourage users to take a 20-second break every 20 minutes by looking at something 20 feet away. This practice helps reduce eye strain.

2. Adjust Screen Settings: Reducing screen brightness and using blue light filters can alleviate discomfort.

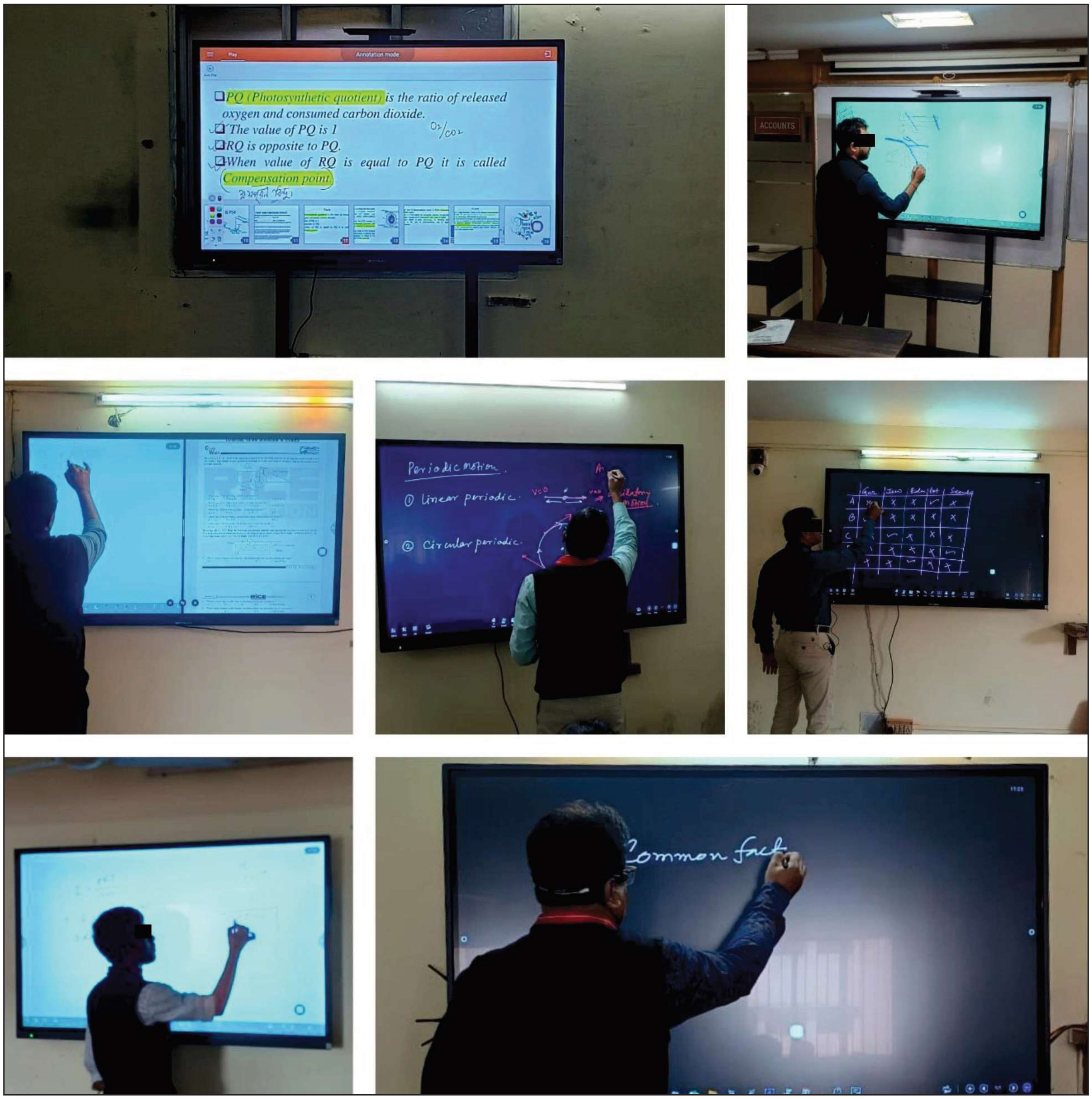
3. Promote Proper Posture: Ensure that classrooms are equipped with ergonomically designed furniture and that users are educated on maintaining proper posture during smart board interactions.

By acknowledging these potential health effects and implementing appropriate preventive measures, educational institutions can ensure that the advantages of smart board technology are harnessed effectively while safeguarding the well-being of both teachers and students.

SMART BOARDS AND FUTURE E-WASTE CONCERNS

With technological progress, electronic gadgets, such as smart boards, are likely to become outdated. When they become obsolete or dysfunctional, smart boards add to the increasing issue of electronic waste. If not managed properly, they may leak toxic substances like lead, mercury, and cadmium into the environment, creating significant ecological and health hazards. Organizations need to implement sustainable e-waste management strategies, including recycling and correct disposal, to alleviate these impacts.

Moreover, the introduction of smart boards at R.I.C.E Education, Kolkata signifies a forward-thinking move toward contemporary education, providing various advantages for engaging and effective learning. Nevertheless, in addition to these benefits, it is important to tackle the related challenges, such as technical dependencies, health issues, and environmental effects. Through the adoption of balanced teaching approaches, setting appropriate screen time limits, and encouraging responsible e-waste disposal, the institution can enhance the advantages of smart boards while reducing their disadvantages. Some glimpses are given below.



Images are taken during various class times at R.I.C.E Education

Other Case Studies

- **Canada:** Despite provincial e-waste regulations, only 20% of e-waste is recycled, with limited data on smart board disposal.[24] Private sector initiatives like e-Cycle Solutions show promise but lack scalability.
- **India:** India generated 380,000 tonnes of e-waste in 2007, with only 3% recycled formally.[15] Informal recycling dominates, posing health risks. Demonstration projects by the Department of Information Technology have recovered copper from PCBs, indicating potential for formal recycling.[15]
- **Africa:** A pilot project in Cape Town processed 60 metric tons of e-waste in 2008, generating $14,000 and creating 19 jobs, highlighting the economic benefits of recycling.[21]

FUTURE OUTLOOK

The projected growth of e-waste to 74.7 million tonnes by 2030 underscores the need for proactive measures [6]. For smart boards, future research should focus on:

- Developing biodegradable electronics to reduce hazardous waste.
- Scaling up smart disassembly and sorting technologies.
- Establishing global standards for e-waste management, including specific protocols for smart boards.
- Enhancing data collection on smart board disposal to inform policy.

Collaborative efforts among manufacturers, policymakers, and researchers are essential to transition to a sustainable, circular economy for electronics.

CONCLUSION

Smart boards represent an emerging e-waste challenge due to their complex composition and rapid obsolescence. Their disposal poses significant environmental and health risks, exacerbated by inadequate recycling infrastructure and regulatory gaps. By adopting eco-friendly design, advanced recycling technologies, circular economy models, and robust policies, the e-waste impact of smart boards can be mitigated. Public awareness and IoT-based solutions further enhance management strategies. As smart board adoption continues to grow, proactive measures are critical to ensure sustainability and protect human health and the environment.

REFERENCES

1. Shahabuddin M, Uddin MN, Chowdhury JI, Ahmed SF, Uddin MN, Mofijur M, Uddin MA. A review of the recent development, challenges, and opportunities of electronic waste (e-waste). International Journal of Environmental Science and Technology. 2023 Apr;20(4):4513-20.
2. World Health Organization. (2024). Electronic waste (e-waste). Retrieved from https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste)
3. Forti V, Baldé CP, Kuehr R, Bel G. The global e-waste monitor 2020. United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. 2020 Jul;120.
4. Kiddee P, Naidu R, Wong MH. Electronic waste management approaches: An overview. Waste management. 2013 May 1;33(5):1237-50.
5. Wath SB, Dutt PS, Chakrabarti T. E-waste scenario in India, its management and implications. Environmental monitoring and assessment. 2011 Jan;172:249-62.
6. Abdelbasir SM, Hassan SS, Kamel AH, El-Nasr RS. Status of electronic waste recycling techniques: a review. Environmental Science and Pollution Research. 2018 Jun;25:16533-47.
7. Cucchiella F, D'Adamo I, Koh SL, Rosa P. Recycling of WEEEs: An economic assessment of present and future e-waste streams. Renewable and sustainable energy reviews. 2015 Nov 1;51:263-72.
8. Matsukami H, Tue NM, Suzuki G, Someya M, Tuyen LH, Viet PH, Takahashi S, Tanabe S, Takigami H. Flame retardant emission from e-waste recycling operation in northern Vietnam: environmental occurrence of emerging organophosphorus esters used as alternatives for PBDEs. Science of the Total Environment. 2015 May 1;514:492-9.
9. Xia MC, Wang YP, Peng TJ, Shen L, Yu RL, Liu YD, Chen M, Li JK, Wu XL, Zeng WM. Recycling of metals from pretreated waste printed circuit boards effectively in stirred tank reactor by a moderately thermophilic culture. Journal of bioscience and bioengineering. 2017 Jun 1;123(6):714-21.
10. Graedel TE, Lifset RJ. Industrial ecology's first decade. Taking stock of industrial ecology. 2016:3-20.
11. Fawole AA, Orikpete OF, Ehiobu NN, Ewim DR. Climate change implications of electronic waste: strategies for sustainable management. Bulletin of the National Research Centre. 2023 Oct 13;47(1):147.
12. Perkins DN, Drisse MN, Nxele T, Sly PD. E-waste: a global hazard. Annals of global health. 2014 Jul 1;80(4):286-95.
13. Grant K, Goldizen FC, Sly PD, Brune MN, Neira M, van den Berg M, Norman RE. Health consequences of exposure to e-waste: a systematic review. The lancet global health. 2013 Dec 1;1(6):e350-61.
14. Meidl, R. A. (2023). Closing the loop on the world's fastest-growing waste stream:

Electronics. Baker Institute. Retrieved from - https://www.bakerinstitute.org/research/closing-loop-worlds-fastest-growing-waste-stream-electronics.

15. Ilankoon IM, Ghorbani Y, Chong MN, Herath G, Moyo T, Petersen J. E-waste in the international context–A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. Waste management. 2018 Dec 1;82:258-75.

16. Kishore J. E-waste management: as a challenge to public health in India. Indian Journal of Community Medicine. 2010 Jul 1;35(3):382-5.

17. Zhang S, Forssberg E. Mechanical recycling of electronics scrap-the current status and prospects. Waste Management & Research. 1998 Apr;16(2):119-28.

18. Huang J, Chen M, Chen H, Chen S, Sun Q. Leaching behavior of copper from waste printed circuit boards with Brønsted acidic ionic liquid. Waste management. 2014 Feb 1;34(2):483-8.

19. Ghulam ST, Abushammala H. Challenges and opportunities in the management of electronic waste and its impact on human health and environment. Sustainability. 2023 Jan 18;15(3):1837.

20. Pradeepkumar S. Studies on bioleaching and recovery of metals from printed circuit boards using acidophile and alkaliphile bacteria (Doctoral dissertation, Department of Civil Engineering, PEC, Pondicherry University).

21. Bhutta MK, Omar A, Yang X. Electronic Waste: A Growing Concern in Today's Environment. Economics Research International. 2011; 2011(1):474230.

22. European Commission. (2012). Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE). Official Journal of the European Union, L197, 38–71.

23. Susila N, Anand S, Elwin JG, Sujatha T. Technology-enabled smart waste collection and management system using iot. International Journal of Pure and Applied Mathematics. 2018;119(12):1283-95.

24. Habib K, Mohammadi E, Withanage SV. A first comprehensive estimate of electronic waste in Canada. Journal of Hazardous Materials. 2023 Apr 15;448:130865.