Quantifying E-waste Generation and Management: An Empirical Analysis

Shahela[1], Suchitra.G[2], B Beulah Aswini[3], Pramod Kumar Jha[4]

[1]JRF, CAS DRDO, Hyderabad, Telangana, India
[2]JRF, CAS DRDO, Hyderabad, Telangana, India
[3]Technical Officer-C, CAS DRDO, Hyderabad, Telangana, India
[4]Scientist F, CAS DRDO, Hyderabad, Telangana, India

Abstract - *One of the fastest-growing waste streams in the nation is electronic waste (E-waste). Because of the expansion of the information and communication technology (ICT) industry, there has been a significant increase in the use of electronic devices. Due to its quick obsolescence and subsequent improvements, consumers are being obliged to throw away old devices, which contribute a sizable volume of e-waste on the earth. E-waste is growing in India at a 10% annual rate. Inefficient and dangerous methods are generally used in the market to recycle e-waste. Appropriate legislative actions and technological solutions that are reasonably priced, ecologically benign, and economically viable are needed to address the issue.*

This study offers an empirical examination of the methods used to control e-waste. To evaluate the contemporary e-waste management infrastructure, surveys were used to get the primary data, and academic journals, government papers, and other pertinent sources were used to gather the secondary data. The investigation demonstrates that the current methods for managing e-waste are insufficient, with the majority of it being dumped in landfills, burned, or illegally transferred to underdeveloped nations. The issues experienced in India are also discussed, along with the management system and recycling procedures for handling E-waste.

This paper emphasizes the necessity for immediate action and the negative effects of insufficient e-waste management on the environment, human health, and socio-economic factors. To improve e-waste management methods, the report suggests business sector involvement, regulatory measures, and awareness campaigns. By offering a thorough examination of e-waste creation and management techniques in India, this study adds to the body of knowledge on the management of electronic trash.

Keywords: **E-waste, Empirical analysis, Take back, Refurbish, Recycling, Landfills.**

1. INTRODUCTION

E-waste is a complex and hazardous waste stream, containing a range of toxic and valuable materials such as lead, mercury, cadmium, gold, and copper, which pose significant environmental and health risks if not properly managed. The management of e-waste is a pressing environmental challenge that requires urgent attention from all stakeholders, including governments, industry, civil society, and individuals. This study aims to provide insights into the challenges and opportunities associated with e-waste management and the need for a comprehensive approach that involves all stakeholders.

The findings of the study contribute to the literature on e-waste management by providing a detailed analysis of e-waste management practices in our country. It emphasizes the urgent need for collective action to address the growing e-waste crisis and the need for a comprehensive and integrated approach to e-waste management.

1.1 Scenario of e-waste in India

India is one of the up surging economies globally, with rapid industrialization and urbanization leading to a significant increase in e-waste generation. A significant part of the e-waste generated in India is managed by the informal sector, which includes waste pickers, scrap dealers, and dismantlers. The forecast of the e-waste generated and recycled from 2020 to 2030 from various sources is predicted as shown in figure 1.

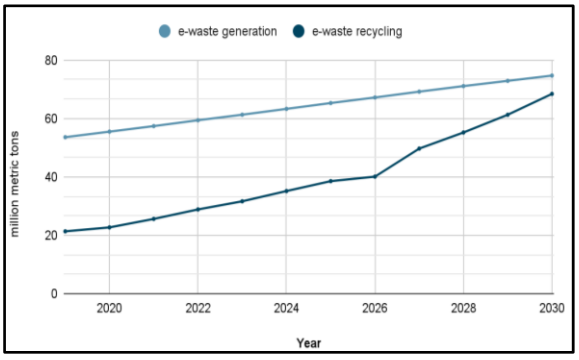

Fig -1: Graphical representation of e-waste generation and recycling

There is an urgency for e-waste management because, when imprecise, unscientific methods are used to recover useful components, e-waste components may pose serious health concerns and environmental harm. To protect natural resources, it is important to promote recycling of all precious and useful materials from e-waste. The majority of developing nations are struggling with the rapidly expanding e-waste issues, and they need reliable e-waste management solutions for end-of-life ICT goods to prevent threats to the environment and people.

ITU (International Telecommunication Union) has acknowledged that many developing nations' WEEE (Waste Electrical and Electronic Equipment) policies are insufficient since they leave out important subjects and important stakeholders, such as the informal sector.

1.2 Challenges associated with the e-waste management

(i) Lack of Awareness: Many people dispose of their electronic waste with regular trash because they are unaware of the harmful effects it has on the environment and human health.

(ii) Informal Sector: Informal workers use hazardous methods, such as open burning or acid stripping, to extract valuable metals from e-waste, which exposes them to health risks.

(iii) Lack of Infrastructure: There is a lack of proper infrastructure, including collection centers, transportation facilities, and recycling units, for e-waste management. This results in a significant amount of e-waste ending up in landfills or being dumped in unauthorized areas.

(iv) Inadequate Regulation: The existing laws and regulations related to e-waste management in India are insufficient and poorly enforced. This has led to illegal imports of e-waste and inadequate monitoring of e-waste recycling units.

(v)Limited Resources: The limited resources and funding available for e-waste management pose a significant challenge in India. The cost of setting up and maintaining e-waste management infrastructure is high, and the revenue generated from e-waste recycling is relatively low.

Addressing these challenges requires a multi-stakeholder approach, including government, industry, civil society, and the public, to create awareness, promote responsible e-waste management practices, and develop a sustainable e-waste management system in India.

1.3 Tactics involved in e-waste management

Here are some steps that can be taken for e-waste regulation as shown in figure 2.

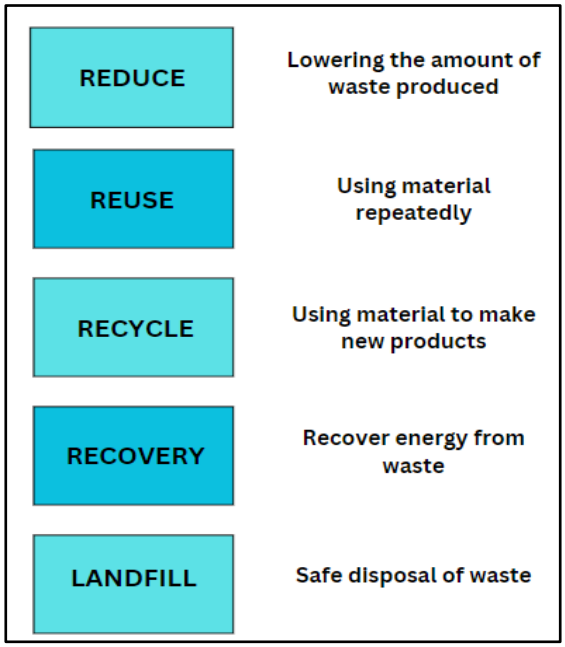

Fig -2: E-waste management hierarchy

a. Reducing e-waste generation: One way to reduce e-waste is by implementing a circular economy approach in the industry sector. This involves designing products that can be easily repaired, upgraded, and recycled.

b. Implementing a take-back program: Many industries have established take-back programs, where they collect old devices from consumers and recycle them. This helps to ensure that e-waste is handled responsibly and prevents it from ending up in landfills.

c. Disposing of e-waste responsibly: It is important to dispose of e-waste in an environmentally responsible way. This involves ensuring that it is collected and transported safely, and is recycled or disposed of in a way that minimizes harm to the environment.

d. Educating consumers: Consumers need to be educated about the importance of responsible e-waste management. This can be done through public awareness campaigns, product labeling, and information on company websites.

e. Working with suppliers: Industries should work with their suppliers to ensure that they are also implementing responsible e-waste management practices. This can include requiring suppliers to use environmentally friendly materials in their products and to implement take-back programs.

Overall, e-waste management is a complex issue that requires collaboration between different industries, consumers, and government regulators by working with certified e-waste recyclers. By implementing responsible e-waste management practices, we can help to protect the environment and human health thus, promoting a more sustainable future.

2. SOURCES OF E-WASTE

Manufacturer sources for e-waste: According to surveys, roughly 50% of PCs sold across the nation come mostly from the second-hand market and are rebuilt using used parts. MNCs (30%) and Indian brands (20%) account for the remaining market share. Manufacturers are not the only ones who produce a lot of e-waste. The waste is made up of damaged motherboards, CRTs, IC chips, and other production-related accessories. It also covers faulty computers covered by a guarantee that were bought as replacements from customers.

Consumer: Indian households are responsible for producing about 22% of garbage computers. Exchanging from shops or giving the outdated computers to friends or family are common methods of getting rid of them. In India, 78% of all installed PCs are in the business sector. The surplus computers from the commercial sector are frequently sold at auction or occasionally given to charitable organizations or educational institutions for reuse.

E-waste import: Although it is illegal to import e-waste, studies indicate that a significant amount of e-waste is being brought in from abroad. Since the ministry of the environment lacks information on the import of e-waste, it is impossible to completely control borders.

2.1 Risk Assessment

Risk assessment is a methodical technique used to identify potential risks associated with waste management. Communication skills regarding environmental risk are crucial for effective collaborations between the public, businesses, stakeholders, and state authorities. All stakeholders must be informed of the risk assessment policy in order to promote public participation in environmental decision-making. They must strive to ensure that trash is thrown away consistently, safely, and without damaging the environment or the health of the general public. A productive collaboration is a continual process that needs to be evaluated on a regular basis.

a) Identifying hazards is the process of locating and defining the potential threats.

b) Exposure assessment is the process of determining the exposure paths and channels from a source to a person.

c) The outcomes of risk variables include exposure analyses and chemical toxicity information.

2.2 Recycling of E-waste

Recycling e-waste from various sources is an important step towards responsible e-waste management. Here are some ways that e-waste from industries can be recycled:

a. Collection: The first step in recycling e-waste is to collect it from industries. This can be done through take-back programs, collection events, or through partnerships with e-waste recycling companies.

b. Sorting: After collection, it is sorted into different categories based on the type of material, such as metal, plastic, glass, and circuit boards.

c. Dismantling: Once sorted, it is dismantled into individual parts, such as batteries, chips, and wires.

d. Shredding: The dismantled parts are then shredded into small pieces.

e. Separation: The shredded material is separated into different categories using various techniques such as magnetic or eddy current separation.

f. Refining: The separated material is then refined and processed to recover valuable metals such as gold, silver, copper, and aluminum.

g. Disposal: Any material that cannot be recycled is disposed of safely, following local regulations and guidelines.

2.3 Elements of e-waste

The different components of an e-waste management system include:

- Life Cycle Assessment (LCA)
- Material Flow Analysis (MFA)
- Multi-Criteria Analysis (MCA) and
- Extended Producer Responsibility (EPR)

LCA is a tool used to reduce the issues caused by e-waste and design environmentally friendly electronic equipment. In India, it is used to make decisions about how to handle garbage related to computers.

MFA is used to analyze the flow of gold and copper from the recycling of personal computers in India as well as to regulate the flow of e-waste in the environment.

MCA is a tool for locating potential locations for e-waste recycling facilities.

EPR is a policy that ensures that electronic components are still accountable to their producers after they reach the end of their useful lives. [1]

3. MANAGEMENT OF E-WASTE

3.1 Existing management processes

The Government of India has adopted a number of initiatives to manage e-waste, including:

- E-Parisaraa is the first technologically advanced recycling facility built to reduce e-waste pollution and recover metals.
- Trishyiraya Recycling recycles e-waste and has received certification from the Indian government.
- Plug-into E-cycling is the process of recycling and recovery. This aids in lowering atmospheric greenhouse gas emissions.
- Installations of e-bins in Bangalore City - According to Jhariya et al. (2014), e-bins are put in place to educate city residents about e-waste.[2]

3.2 Initiatives of Department of Information Technology (DIT)

In order to meet the pressing demand for reasonably priced environmentally friendly technology, the Department of Information technology (DIT) is actively involved in encouraging Research & Development (R&D). Their goal is to create recycling technologies for all sorts of e-waste that will result in fewer landfills and absolutely no emissions into the air, land, or water. To make recycling a financially viable enterprise, precious resources must be recovered and plastics must be reused. Numerous R&D initiatives have been started in Indian national institutions. Such initiatives include:

a. *Harnessing rare metals from printed circuit boards (PCBs):*

The authorized recycler, E-Parisaraa Pvt. Ltd., of Bangalore, is actively taking part in it at C-MET, (Centre for Materials for Electronics Technology), in Hyderabad. The project's objective is to create methods for depopulating, separating, and treating components that are ecologically friendly as well as a way for recovering metals from depopulated PCBs.

b. Development of technological solutions for electronic waste recycling and reuse:

In this project, indigenous technology has been developed at the National Metallurgical Laboratory in Jamshedpur, which has a 90% recovery rate for metals in e-waste. The procedure doesn't produce any hazardous effluents or toxic gases. As a result, it would lessen the environmental risks associated with e-waste recycling facilities. This process has successfully recycled waste up to a pilot scale of around one Metric Tonnes (MT) of e- waste.

c. Novel recovery and conversion of plastics from WEEE (Waste Electrical and Electronic Equipment) to modernized products:

It is put into practice at the Central Institute of Plastics Engineering & Technology (CIPET), Bhubaneswar. The seven groups of plastics that make up plastic e-waste are polycarbonate (PC), polypropylene (PP), polyvinyl chloride (PVC), nylons, epoxy, phenolic, and polyesters. The project intends to reduce the amount of plastic trash that accumulates in society by creating value-added items from these waste plastics.

d. The creation of lead-free X-ray absorption coatings for CRT TVs (cathode ray tubes):

It was implemented at C-MET, Pune, India, in March 2011 where the ecologically benign phospho-silicate glass composite/phosphate composite is used as an X-ray absorption coating in place of the harmful lead found in CRT glass shell.

3.3 How to start an E-waste program?

Starting an e-waste management program in an organization can have a positive impact on the environment, reduce potential health risks, and promote sustainability. Here is the man oeuvre to get started:

Conducting a Waste Audit: A waste audit is conducted to assess the type and quantity of e-waste generated by an organization. This helps to identify areas that require improvement and create a baseline for future waste reduction efforts.

Creating an E-waste Policy: A policy outlining the proper disposal and management of electronic waste is made. The policy should include guidelines for employees on how to handle e-waste, instructions on how to dispose of it responsibly and how the organization handles e-waste.

Identifying a Recycling Partner: A reputable e-waste recycling partner to handle the collection and disposal of e-waste is identified. We have to make sure the recycling partner is certified and follows all the necessary regulations and guidelines for responsible e-waste management.

Educating Employees: Employees are trained on the importance of e-waste management and the proper disposal methods. Regular training sessions, providing resources such as posters, emails, or newsletters are conducted to promote responsible e-waste management practices.

Implementing a Collection Program: An e-waste collection program within the organization is implemented. Set up collection bins in designated areas are arranged so that employees can easily dispose of their e-waste. Guidelines and instructions on what types of electronics are accepted and how to prepare the items for disposal are provided.

Tracking Progress: We have to keep track of the amount of e-waste collected and the progress made in reducing e-waste. Using this data, we measure the success of the program and identify areas for improvement.

Considering Refurbishment: Refurbishing can help extend the life of the devices and reduce the amount of e-waste generated by the organization.

Take back programs: These are designed to encourage the proper disposal of e-waste by allowing consumers to return their old or unwanted electronics to the manufacturer or retailer for recycling or proper disposal. Startups like Cashify recycle the products from multibrands.

3.4 Processing techniques of E-waste

The initial step in the processing of electronic waste is the manual dismantling of the items into their component pieces (metal frames, circuit boards) which is followed by automatic shredding machinery. The recycling machinery has a system in place to collect dust and is completely enclosed. Screens and scrubbers are used to capture some pollutants, such as glass. Eddy currents are used to remove ferrous metals from plastic, and CRT glass is recycled into lead wheel weights, ammunition.

A few of the valuable metals sold to smelters for recycling are palladium, gold, silver, and copper. To reduce the risk to the environment, harmful smoke and gases are captured and treated.

The methods listed below can be used to securely recover all of the essential elements.

S. No	E-Waste Component	Process Used	Potential Environmental Hazard	Proposed Solution
1	Plastic Waste (plastic products like casing, cover)	Shredding and melting	Air emission of brominated dioxins, heavy metals and hydrocarbons	Usage of biodegradable plastic
2	PCB (metals like gold, copper etc)	Desoldering , acid bath open burning	Air emission of heavy metals like tin, lead, cadmium, mercury inhalation.	Usage of silicon chips instead of PCB
3	Miscellaneous Waste (Broken glass waste)	Chemical stripping by nitric acid, hydrochloric acid	Tin and lead contamination to surface and groundwater	Urban mining Prevent it in the first place
4	Liquid Waste (Chemicals, acid stripping waste)	Sewerage system	Acidification of surrounding areas	Physical separation

Table -1: Impact on the environment during the processing of various E-waste & our proposed solution.

3.5 Establishing management strategies for a circular economy (CE)

In the long run, CE is a theory that reduces the consumption of electricity and electronic devices (EEE). This includes the 7′R systems, which emphasize social, economic, and environmental factors: reduce, reuse, renew, repair, recycle, retrieve and redesign. The processes are slowed down by a number of factors, including inadequate collection mechanisms, subpar technology, a lack of training for the unorganized sector, and a lack of funding. Figure 3 shows how this CE concept plans methods, policies, and models for waste removal through recycling and product optimization. This CE concept works towards sustainable, renewable, and cleaner technologies. It is necessary for different sectors (governments, corporations, and consumers) to work together for the control of e-waste. As a result, it encourages locating improved chances for developmental interventions to enhance e-waste management and create a satisfying professional economy.

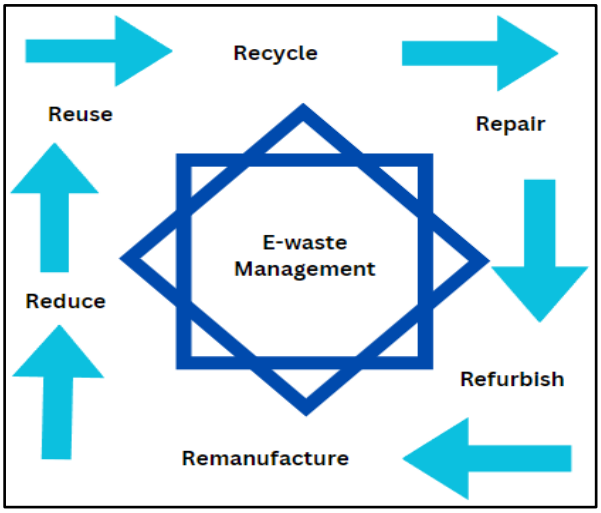

Fig -3: Concept of a CE in e-waste management

4. ADVANTAGES OF E-WASTE RECYCLING

(i) Reusing the basic materials from the past generation of electronics is the primary practical answer to the growing e-waste problem. This prevents the disposal of dangerous e-waste from causing air or water pollution.

(ii) Recycling lowers energy use, which in turn lowers greenhouse gas emissions. The demand for virgin materials is decreased when recycled materials are used to create new items.

(iii) Reinstalling the waste plastic from the printers, which is produced as a byproduct, allows for the production of new 3D printed items.

(iv) Because of the current surge in interest in 3D printing technology, few 3D printers are designed to produce waste that can be easily recycled and lower the amount of dangerous pollutants in the atmosphere.

5. FUTURE OUTLOOK

Innovative ways of E-waste management

We can maximize an object's utility and control our digital garbage with the help of cutting-edge waste management solutions. Reusing, recycling, or reducing waste are three options for doing this. All of this is relevant on a personal level. On the other hand, managing garbage at an industrial scale requires sophisticated technology and long-term planning. There are many creative options available, including:

Robotic E- waste Monitoring Systems

Waste management companies can monitor the amount of rubbish gathered in containers with the use of IoT (Internet of Things) e-waste monitoring systems. They use this information to create e-waste disposal routes, ensuring that e-waste collecting vehicles take an economical and timesaving path. As a result, electronic trash disposal will be moved to a special online space, improving convenience and effectiveness.

Buy-Back & Exchange Programs

Garbage is building up because processing e-waste is cumbersome. However, it is essential that electronic waste be recycled through innovative e-waste management techniques as our mineral wealth declines. Buy-back programmes pay in cash when consumers deposit outdated digital products. Any type of portable electronic device, such as a phone, computer, tablet, etc., might come under this category.

E-waste Management to Achieve Climate Sustainability Goals

It is challenging to recover metals from e-waste; for instance, the global cobalt recovery rate is only 30%. However, batteries for laptops, smartphones, and electric vehicles are in significant demand for this metal. Less energy is required to melt down metals from recycled ore than from fresh ore. Additionally, extracting gold from outdated technology produces 80% less carbon dioxide per unit of gold than mining it from the earth. As a consequence, increasing the amount of scrap materials used to make electronic products could considerably help us achieve our sustainability goals for the environment.

6. CONCLUSION

E-waste is increasing at a rapid rate in India due to many reasons like expansion of the electronics sector and globalization that has increased the import of electronic items in the country. The e-waste is detrimental for the ecosystem. The toxic substances present in e-waste can cause serious damage to human health and other living organisms in the ecosystem. Even though management systems and strategies exist to handle the task of safe disposal of the e-waste, still there are various challenges faced by the system for their successful implementation. There are various recycling processes that have been discussed in this paper, which are not only helpful in removing toxic substances from the waste but also helpful in recovering valuable metals which might ultimately create substantive business opportunities in a developing nation like India. Also, by the year 2030 e-waste recycling can match the generated e-waste and will help to become waste neutral which will be a very welcome step.

REFERENCES

[1] White paper on electronic waste management approaches.https://www.nqr.gov.in/sites/default/files/File%202_waste%20mgt.pdf

[2] https://timesofindia.indiatimes.com/city/bengaluru/bengaluru-gets-first-e-waste-bin-on-roadside/articleshow/61706915.cms

[3] Reference paper on e-waste in India.]https://www.meity.gov.in/writereaddata/files/EWaste_Sep11_892011.pdf

[4] https://pubs.acs.org/doi/10.1021/es303166s.

[5] https://www.yourarticlelibrary.com/waste-management/e-waste-sources-constituent-materials-and-problem-created-by-e-waste-notes/123

[6] https://www.wipo.int/wipo_magazine/en/2014/03/article_0001.html

[7] https://www.psa.gov.in/challenge-event/initiatives-e-waste-management/3738.

[8] https://www.inderscienceonline.com/doi/abs/10.1504/IJPQM.2019.101934.

BIOGRAPHIES

[1] **Smt Shahela** is presently working as a JRF at DRDO, CAS, Hyderabad. She has 1.5 years of work experience in the field of IT & Cybersecurity. She has published four papers in the field of cybersecurity. She is certified as CISSP-Certified Information Systems Security Professional and ISO 27001 lead auditor.

[2] **Smt G.Suchitra** is presently working at DRDO, CAS, Hyderabad as a JRF. She has 2 years of work experience in the field of computer science. She is certified as CISSP-Certified Information Systems Security Professional.

[3] **Smt B.Beulah Aswini** is presently working as a Technical Officer-C in DRDO, CAS, Hyderabad. She has 22 years of experience in the field of embedded systems and published three research papers in Cybersecurity. She is certified as an internal auditor on ISO 27001.

[4] **Sri Pramod Kumar Jha**, Scientist-F is presently working as a Technology Director, ITCS&AI at CAS DRDO Hyderabad. He has done his M Tech in Manufacturing Management from BITS Pilani. He has also obtained a couple of PG Diplomas and certifications in the areas of Operations and Project Management, Public Procurement etc. He has more than 22 years of research and techno-managerial experience in the areas of Information Technology management and cyber security. He has published more than 20 research papers, articles in various journals and conferences.