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LIFE CYCLE ANALYSIS OF E-WASTE MANAGEMENT IN BENGALURU CITY

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ABSTRACT

Bengaluru is often referred to as the "Silicon Valley of India", because of the leading Information Technology companies present here. Electronic waste (e-waste) management in Bengaluru, India's technology hub, has become a critical concern due to the rapid proliferation of electronic devices. A life cycle analysis (LCA) of e-waste management in Bengaluru evaluates the environmental impacts associated with the entire life cycle of electronic products, from production and usage to disposal and recycling. The objective of conducting Lifecycle Analysis (LCA) of e-waste management in Bengaluru would be to assess and improve the environmental, social, and economic sustainability of the city's current e-waste handling systems. Given that Bengaluru is a major technology hub with a significant amount of electronic products being used, sold, and disposed of an LCA would offer valuable insights into how e-waste can be better managed to reduce negative impacts.

KEYWORDS : e-waste, sustainability, recycling

INTRODUCTION:

The rapid growth and advancement of technology has led to the usage of more and more electronic products. Electronic products have become integral part of the modern life. However, as these products become obsolete or reach the end of their useful life, they contribute to an increasingly critical global issue "electronic waste (e-waste)." E-waste refers to discarded electrical or electronic devices, such as smartphones, computers, televisions, and household appliances, (Hong et al.,2015) which are often discarded in landfills or improperly disposed of. It is also commonly known as waste electrical and electronic equipment (WEEE) (Perkins et al.,2014) or end-of-life (EOL) electronics. Electronic waste or 'e-waste' in general refers to electrical and electronic equipment (EEE) that has ceased to be of any value to its owners. European Union WEEE Directive 2002/96 (EU, 2002) which, is one of the earliest legislation in the world to have recognized this specialized waste stream. E-waste can be categorized as hazardous or non-hazardous waste under the Basel Convention. When in e-waste there is presence of toxic materials such as mercury, lead or brominated flame retardants e-waste is classified as hazardous waste according to the Basel Convention. E-waste may also contain precious metals such as gold, copper and nickel and rare materials of strategic value such as indium and palladium. These precious and heavy metals could be recovered, recycled and used as valuable source of secondary raw materials.

This e-waste contains a diverse range of materials. Most studies examine five categories of materials in e-waste viz. ferrous metals, non-ferrous metals, glass, plastics and others. Iron and steel account for almost half the total weight of WEEE, followed by plastics (21% of weight), and non-ferrous metals including precious metals (13%, of weight of which copper accounts for nearly 7%). It also contains around 2.7% of pollutants (Widmer et al., 2005). Nearly 60% of materials like iron, steel, glass and plastic along with recoverable valuable metals like gold in e-waste are recyclable.

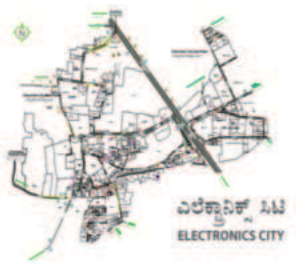
With the volume of e-waste growing at an alarming rate, managing it has become a major environmental and public health concern. According to estimates by the United Nations, the world generates approximately 50 million tons of e-waste annually, a figure that is expected to rise as technology continues to evolve. The improper disposal of e-waste can lead to severe environmental damage, including the release of toxic materials such as lead, mercury, and cadmium into the soil, water, and air. Furthermore, the improper handling of e-waste has serious human health implications, particularly in developing countries where much of the e-waste is exported for informal recycling.

Nnorom and Osibanjo (2008), conducted a study on Overview of Electronic Waste (E-Waste) Management Practices and E-Waste Recycling in Nigeria and assessed the impacts of informal e-waste recycling in Nigeria. The findings showed that informal recyclers often expose themselves to toxic chemicals, including lead and mercury, and that the lack of safety protocols in the informal sector increases both environmental pollution and human health risks. This emphasizes the need for formalizing e-waste recycling to reduce harmful practices. **Kuehr and Williams (2017)** in their book "Computers and Electronic Waste: How Recycling is Part of the Solution" provide an overview of the global e-waste situation and how LCA can help assess and reduce its impacts. They emphasize that most of the environmental damage from e-waste occurs during the end-of-life phase, particularly when e-waste is improperly disposed of in landfills or incinerated. **Awasthi et al. (2022)** in the study on Innovative Technologies in E-Waste Recycling: A Life Cycle Assessment Perspective analyzed the environmental performance of novel recycling technologies, including bioleaching and hydrometallurgical processes. These methods, while still in the developmental phase, showed promise for extracting metals from e-waste with lower energy consumption and reduced toxic emissions compared to traditional mechanical and pyrometallurgical methods. **Kaur et al. (2020)** conducted the study on Composition and Challenges in E-waste Management in India and suggest that improper disposal methods contribute to the release of hazardous substances like lead, mercury, and cadmium into the environment, highlighting the importance of proper treatment and recycling. **Singh et al. (2018)** in their study on Lifecycle Assessment of Mobile Phone Recycling in India: Resources, Conservation & Recycling, applied LCA to the recycling of mobile phones in India and found that formal recycling processes, despite being more energy-intensive, result in lower environmental impacts overall due to the recovery of valuable metals like gold and copper, reducing the need for mining. **Bisht et al. (2024)** in their study on Circular Economy and E-Waste Management in Karnataka: Challenges and Opportunities proposed that Karnataka's e-waste management system could benefit from innovations in urban mining, where valuable metals from e-waste are recovered and used in new products. They argued that urban mining could support local industries and reduce dependence on mining for precious metals, contributing to a more sustainable economic model. **Bakker et al. (2014)**, study focus on how designing products for greater durability, easy disassembly, and recyclability can reduce the volume of e-waste generated. Eco-design also incorporates the reduction of hazardous substances, making the recycling process less harmful to the environment. **Huisman et al. (2020)** argue that integrating circular economy principles into e-waste management systems can improve resource recovery and reduce landfill use. This approach is increasingly being adopted in Europe and is becoming a focus of global e-waste management strategies.

There are many studies conducted with respect to Life Cycle Analysis of e-Waste Management. These studies focus on the effects of e-waste on environment and human health, importance of recycling, circular economy, extended producer's responsibility, etc. Along with this the need of the hour is to identify several opportunities wherein Bengaluru can benefit from a more integrated approach that involves technological innovation, policy improvements, public awareness campaigns, formalizing informal recycling and greater industry collaboration to establish a more sustainable and efficient e-waste management system.

MATERIALS AND METHODS:

Some of the prominent IT/ITES areas in Bengaluru include Electronic City, Whitefield, Koramangala, Hosur Road, Indiranagara, Marathahalli. Majority of the companies are present especially in Electronic City and Whitefield area.



There are approximately 200 IT/ITES company campuses located in Electronic City, including main campuses of Infosys, Wipro, TCS, HCL, Tech Mahindra and Biocon etc. According to available sources there are approximately 57 companies listed as being located in the Whitefield area of Bangalore, including major players in software services, banking, manufacturing etc. like Accenture, Hewlett Packard, Tesco, Capgemini, Dell, Schneider Electric etc. Hence, these two areas were selected for the purpose of conducting the study of "Life Cycle Analysis of e-Waste in Bengaluru City).

Methodology For LCA:

- **Objective Setting:** The first step is to clearly define the goal of the LCA. In the case of e-waste management, the goal could be to assess the environmental impacts of different e-waste management strategies, compare the sustainability of recycling vs. disposal methods, or evaluate the efficiency of a specific management system in a region like Bengaluru.
- **Data Collection:** This step involves gathering data on all stages of the e-waste lifecycle, including:
- **E-Waste Generation:** Data on the quantity and types of e-waste produced (e.g., mobile phones, computers, TVs).
- **Collection:** Information about e-waste collection systems (formal and informal collection points, logistics, collection rates).
- **Transportation:** Data on transportation methods and fuel consumption for e-waste transfer.
- **Recycling And Treatment:** Data on the recycling technologies used, such as mechanical sorting, shredding, chemical processes, and metal recovery.
- **Disposal Methods:** Data on landfilling, incineration, or illegal dumping.
- **Material And Energy Flow:** Quantifying the flow of materials (e.g., precious metals, plastics) and energy (e.g., electricity for recycling processes).

Before starting the visit and survey, necessary permissions was obtained by Member Secretary, Karnataka State Pollution Control Board. The preliminary discussion was undertaken with the concerned officer (e-waste management section). A detailed overview of lifecycle analysis of e-waste management was provided by the officer. The guidelines followed by KSPCB was explained.

The research design included observation, case studies and surveys. For the purpose of study selected companies and recycling unit was taken up. Survey of households, Apartments, Repair shops, schools was conducted.

RESULT AND DISCUSSION:

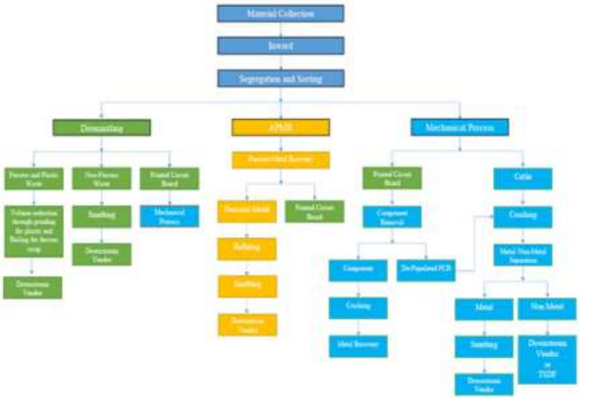
The survey result in table 1. shows that high percentage of people know what is the meaning of e-waste, but only a minimum percentage of them are aware about the negative effects of it on environment and human health. According to this study people should be given awareness about the proper disposal of e-waste. Children should be provided with the knowledge and awareness of the ill effects of the e-waste and proper management of e-waste.

Table 1. Survey Report With Respect To The E-waste Perception Among Public

No.	Questions	Yes	No	Not certain or Do not know
1	Do you know what the e waste meaning before the explanation	80%	15%	5%
2	Do you know the negative impacts of e waste on people health and environment	30%	35%	35%
3	Do you separate the e-waste to be recycled later	10%	90%	0
4	Do you need to enhance your knowledge about the e-waste effects	80%	0	20%
5	What do you do with your end life mobile or laptop? • It will be kept in the house for a long time without taking any action for disposal • When there are exchange offers it will be exchanged • Taken to repair or service centres to upgrade the products, in case if it is not able to repair or upgrade it will be sold to the repair shops for minimal amount			
6	What happens to the consumables like Refrigerator, Washing Machines, air conditioners etc? • When there are exchange offers it will be exchanged • Taken to repair or service centres in case if it is unrepairable it will be sold to the repair shops for minimal amount. • If it is in non-usable condition it will be given to scrap dealers for minimum amount			

Proper management of domestic e-waste produced, plays an important role in the effective management of e-waste. Just like the source separation of dry and wet waste e-waste separation at the sources also to be mandated. Some sort of the handholding should be given.

When it comes to the companies and manufacturing units, though there are legislatures, effective implementation of these policies have to be carried out. Though there are formal procedures for dismantling and recycling, it is learnt that only 30% of the recycling is done by the authorized dealers. Informal (include those recycling units without registration and licence from the concerned competent authorities, scrap dealers, kabadivalas etc.) sectors are mainly responsible for the improper disposal of the e-waste and unscientific methods of extraction of the valuable metals like use of burning process, acid washing etc. which may lead to spilling of the heavy metals and other chemical components present in the e-waste, which will have ill effects or negative effects on the soil, water, health. The e-waste will have negative impact only when it is dismantled in unscientific way, if not there will not be any ill effects.



The Process Flow Of The E-waste Recycling Followed By The Visited Unit

Resource Recovery and Recycling like precious metals recovery like gold, silver, palladium, copper, and rare earth elements can be reused as raw materials in the production of new electronics, reducing the need for mining (Singh et al.,2018). Plastic and Glass present in e-waste can be recycled into new products, reducing the need for raw material extraction and energy-intensive manufacturing processes. Recovery of Rare Earth Elements present in e-waste and in limited quantity, which are essential for the production of high-tech products like smartphones, electric vehicles, and renewable energy technologies can be reused.

Recycling e-waste conserves natural resources, as it reduces the need for mining and extraction of raw materials, which is often a resource- and energy-intensive process. Recycling materials from e-waste requires less energy compared to extracting raw materials from the earth. This results in energy savings and lower carbon emissions. Through the recovery and reuse of metals, plastics, and glass, e-waste management can lower the carbon footprint associated with the production of new electronic devices.

The process of recycling, repairing, and refurbishing e-waste creates jobs in the recycling sector, including labour for disassembly, sorting, and material recovery. E-waste management supports a circular economy model, where products are reused, refurbished, and recycled, creating economic value through sustainable business practices (Goyal et al.,2024) The development and implementation of advanced recycling technologies and systems for e-waste management can drive innovation and lead to the creation of new industries and business opportunities.

Proper e-waste disposal reduces the exposure of harmful chemicals and metals to both workers in informal e-waste sectors and communities living near landfills or informal recycling sites. Informal e-waste recycling practices, such as open burning or unprotected manual dismantling, can release dangerous toxins into the air and soil. Regulated, formal e-waste management systems reduce such health risks.

Many regions have implemented EPR laws, which require producers to take responsibility for the collection, recycling, and disposal of their products after they reach the end of their useful life. E-waste management ensures that companies meet these obligations. According to the 2022 E-Waste Management Rules, producers are required to collect and recycle at least 60% of the e-waste generated by their products, with a target to increase this to 80% by 2025, as part of their Extended Producer Responsibility (EPR) obligations; this target is implemented in a phased manner over several financial years. But, tracking the number of products manufactured and getting the exact numbers is not effective irrespective of stringent rules. The rules say that producers should collect and recycle at least 60% of the e-waste, when this is the obligation, they try to collect any brand e-waste, by this also the tracking of their own brand will not happen hence, exact production and disposal numbers are not obtained.

Companies are also facing the asset ownership issues, as many a time the companies will be working on client owned equipment. In such cases tracking the client asset ownership will be difficult. Also, tracking of the donated desktops / Laptops after the end of life period is also not happening effectively and difficult. By this also, keeping track of exact numbers of production and disposal count is difficult.

By the above discussion it can be deduced that, proper awareness should be created among the communities for proper e-waste management. And rules and laws has to be implemented effectively.

CONCLUSION:

The Life Cycle Analysis of e-waste management in Bengaluru highlights both the challenges and opportunities in addressing the city's e-waste problem. While the informal sector plays a key role in handling e-waste, it is fraught with environmental and health risks due to unregulated practices. Formal recycling, though more environmentally friendly, is not yet fully scaled to handle the volume of e-waste generated. There is an urgent need to enhance the infrastructure for formal e-waste recycling, ensuring that more e-waste is diverted from informal practices and properly processed to recover valuable resources and reduce environmental harm.

In conclusion, the proper management of e-waste in Bengaluru requires a collaborative approach between the government, private sector, and the public to improve both formal and informal recycling systems, enforce policies, and raise awareness. This will not only help mitigate environmental harm but also foster sustainable development in the city, turning e-waste into a valuable resource. Effective e-waste management is crucial for reducing environmental pollution, conserving resources, and ensuring public health and safety.

A comprehensive, multi-faceted approach is necessary to address the growing issue of e-waste. By enhancing formal recycling infrastructure, strengthening regulations, educating the public, incentivizing recycling, and supporting innovation, we can reduce the environmental and health impacts of e-waste while maximizing the recovery of valuable materials. A shift toward circular economy practices and sustainable consumption will ultimately reduce the overall volume of e-waste and create a more sustainable future for both the economy and the environment.

Effective e-waste management contributes to the United Nations Sustainable Development Goals (SDGs), particularly those focused on responsible consumption and production (SDG 12) and climate action (SDG 13). Corporate Social

Responsibility (CSR): For businesses, investing in e-waste management and promoting recycling programs demonstrates commitment to sustainability and social responsibility, which can enhance corporate reputation and customer loyalty.

Effective e-waste management plays a vital role in environmental conservation, resource recovery, job creation, and public health protection. By reducing pollution, conserving natural resources, and supporting the circular economy, e-waste management contributes to a more sustainable and responsible approach to dealing with the increasing volume of electronic waste. Additionally, as technology continues to evolve, e-waste management becomes an ever-more important practice to ensure that the growing waste stream is handled in a way that benefits both people and the planet.

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