Emerging Technologies or Graveyard of Old Technology (E-waste) – A Question for Human Survival and Environmental Sustainability?

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Abstract

Our journey to Viksit Bharat is being powered by rapidly growing digitization and increased usage of electronic devices. With smart devices permeating every aspect of our lives, comes the mammoth task of managing the used electronic junk. India's e-waste volumes showed a meteoric rise of over 150.03% in six years, from 7 lacs metric tonnes in 2017-18 to 17 lacs metric tonnes in 2023-24, with an annual increase of 1.7 lacs metric tonnes. This rise is getting sharper with the advent of newer technologies, making the old ones obsolete. Compounding this large volume of e-waste is the fact that e-waste consists of several hazardous constituents. These toxic materials can potentially have a negative impact on human health and environment, if not properly managed. Many scientific groups and governments globally across the nations are trying to implement various variety of as well as systematic ways to address the problem of e-waste disposal to the environment and human health. This current article presents a compendium of major sources of E-waste, its constituents with special emphasis on E-waste scenarios in India. We also discuss the techniques of handling, processing, and recycling E-waste. This article mainly focuses on the growing menace of E-waste and covers the improvements needed to effectively tackle the issue.

Keywords: e-waste, Heavy metals, Extended Producer Responsibility (EPR)

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Introduction

"E-waste is made up of old or end-of-life electronic appliances such as computers, laptops, televisions, generators, DVDs, mobile phones, freezers, and other items that are typically discarded by their original owners due to their short lifespan".

Many years back the scientific community was fascinated by the electronic instruments and gadgets, which transformed their lives, and made their life very easier, comfortable as well as fast. But a rapid rise in consumerism combined with the need to up-grade technology in lesser time has led to product obsolescence at an alarming rate. All the end-of-life discarded and unused electronic appliances such as laptops, mobile phones, cameras, computers, memory devices, televisions, freezers, etc. discarded by their owners constitute what we now call as e-waste. It is now present in millions of tons in quantity all across the world and often containing large number of hazardous constituents, both organic and inorganic. These constituents cause environmental pollution and, more importantly, impacts human health negatively if not properly managed.

A systematic and proper segregation of e-waste from all other types and derivatives of waste like, biodegradable waste, plastic waste and recyclable materials is the need of hour. Different strategies need to be implemented for handling different constituents of e-waste. For example, hazardous substances like cadmium, lead, chromium, and antimony pose greater risk when handled with conventional methods, and require appropriate scientific approach to protect human health and environment. Valuable non-hazardous metals like ferrous metals, copper, and aluminum can be recycled. Many precious metals (PMs) like, gold, platinum, palladium, and silver, can be extracted by employing different techniques and be made available for use again. But currently, especially in developing countries recycling process is time consuming and often done in informal settings. The recycling is done using improper channels with untrained professional's handling the segregation and extraction. Even the recycling methods used are rudimentary at best. Unscientific handling (collection and managements for storage) of e-waste with lax environmental legislation are compounding this problem further. Even the Controlled land fillings (sanitary land filling) are also not in sufficient numbers in many developing countries. In many low-income, lower-middle-income, and middle-income countries garbage is collected in open dumps. These open dumps and landfills account for large percentage of e-waste

collected compounding the issue of e-waste management. Such E-waste open dumps will lead to pollute the environment through leaching into nearby soil and groundwater, and the surrounding air via emission thereby polluting all nearby air, soil, and water sources. A substantial number of valuable resources which can be extracted are lost through just disposals. Nevertheless, recycling under inferior conditions, we lose out on effectively extracting many recyclable components. Therefore, it is safe to say that formal e-waste recycling is the best way to manage e-waste. However, recent estimates suggest that currently only about 17.4 % (9.3 Mt) of the global e-waste generated in 2019 has been recycled by the formal sector, leaving the flow of rest 82.6% (44.3 Mt) e-waste to be proceeded in unsafe informal settings. This suggests that most of the e-waste, particularly in mid-lowerand lower-income countries is managed via the informal sector.

It cannot be denied that newer electronic items are the future of communications and technology, so the growing problem of e waste is our reality. Thereby it becomes essential to establish a balance between the negative impact of E-waste on the environment and human health, and resource reimbursement (financial). For achieving this goal, a multi-directional approach is required which can holistically solve the e-waste menace while also assisting the global economy and resource conservation. Many groups and governments across different nations are already implementing a variety of ways to tackle the issues of E-waste and threat it poses to the environment and human health, but the actual results are yet to be seen. The scientific community all over the world is also engaged in finding direct methods which are more effective and not much costly to dispose of these E-waste items. Recent advances by Chinese groups are commendable effort in that direction, where they have demonstrated methods to extract gold out of used phones etc. faster and cheaper. Hopefully this kind of research is extended and promoted for other components of E-waste to make the recycling process economically viable with minimal impact on the environment.

This article does not claim to be fully exclusive or exhaustive, but aims to provide a brief report on the current trends in global e-waste generation (types and sources). Also, it sheds light on the latest approaches being followed in e-waste recycling for the basic and fundamental understanding of the concept. The aim is to provide first-hand information to the researchers, scientific community and also general public to spread awareness regarding the grim and ever-

growing problem of E-waste. We also discuss environmental and occupational health concerns along with the opportunities and constraints in effective e-waste management.

E-Waste Sources

The electrical appliances and other form of e-waste have posted a biggest challenge before the human race in present times. The big heaps of unprocessed e-waste are becoming a common sight at the outskirts of most of our metro cities. The not so proper collections and disposal of e-waste due to lack of awareness, lax laws and insufficient techniques also (non-availability of technology or funds) is now becoming a major problem in across cities. There is significant deficit in knowledge regarding how to properly dispose used electronic items. The current practice is just to offload our old electronic appliances to our local "kabadivala". There are no formal channels to dispose of our old appliances. Since the segregation is done via informal channels, tt is also tough to estimate the amount of e-waste we are actually generating across different cities as there is authentic data or ground reports available. However, we do have some informal estimates and we can try to understand the different sources of e-waste, especially in India. By knowing that we can try to formulate steps specifically for each category to reduce, reuse and recycle the generated e-waste.

Household sources: Household appliances that mainly include E-waste from personal computers, freezers, generators, etc. come in this particular category. But these are not the major contributor of e-waste in developing countries as people often use their household appliances for longer duration and discard them when they reach end of their shelf life. However, this source is also increasing with the growing trend people changing their smart phones and laptops frequently.

Service/Business sector E-waste: This sector consists of different government departments, as well as public and private sector offices, MNCs, etc. Since all the offices etc use up-to-date computers and other electronic devices, making this sector is the main benefactor for the E-waste production. As per the survey, they are subjected to around 79% of total installed computers which is the highest in all the sectors. These sectors update their systems often to match with technological advances and lead of discarding of old products frequently.

***Manufacturers and Retailer's E-waste*:** PCs, Integrated chips, motherboards, cathode ray tubes (CRTs), and a wide variety of peripheral goods are manufactured in industry in large number every year. The waste generated from discarded goods, CRTs etc. are second major contributor in electronic waste.

Imports of E-waste:For developing economies like India, it is believed that importing garbage is a profitable business. The primary objective of importing old electronics from developed countries is to recover different precious metals that are mainly found in the electronic trash. This includes steel, silver, gold, titanium, copper, tin, mercury, cadmium, etc. present in large amounts. These commodities can provide useful raw materials that can be used for the production of new products. Many small scale industries, extract different kinds of plastics and other materials from the trash products. However, trade of export and import of electronic waste products has become an important contributor in the E- waste as the remaining left-overs are just dumped as garbage.

India is now said to be the 3rd largest e-waste producer in the world after USA and China, as reported on world environment day. India is approximately producing 2.27 million's tons of e-waste every year. The e-waste accumulated from domestic and unorganized industrial section, is many a times not segregated at source. It gets into our water, soil and air. Extremely hazardous and toxic and hazardous elements such as lead, chromium, mercury, cadmium, nickel etc. enter our food chain due to improper disposal of e-waste. These elements are a potential threat causing serious damage to our vital organs and can even cause fatality. A city like Ghanzau can be mentioned as typical example that how the city like it is experiencing the brunt of e-waste. Here the big heaps and mountains of e-waste with components containing heavy metals and several other hazardous components in it have damaged the environment. Let's now look at the steps or processes followed for e-waste management.

E-Waste Disposal

Here we discuss some different methods being used to dispose of e-waste since past few decades. Each of these methods has their shortcoming with several environmental issues. We need to improve upon these methods to make them more effective with minimal cost to their environment.

Landfills: This method refers to the practice of digging a massive hole in the ground in open area and filling it with waste. Once filled they are then covered back up with soil. While some of the pits are lined with clay or some plastic or with a leachate basin to prevent toxic organic waste from leeching into the neighboring environment. Still some materials such as heavy metals including cadmium, lead, and mercury inevitably find their way into the soil and groundwater, leading to contamination. In developing countries, often the landfills are massive pits without any lining and cause leachate poisoning to soil and water. It is the worst method, yet the most commonly employed method for waste disposal.

Acid Bath: This method involves soaking electronic circuits in powerful acidic solution such sulphuric, hydrochloric, or nitric acid solutions which extracts metals from the electronic pathways. The metals can then be collected and used for manufacturing newer products. However, handling acidic solution in improper way itself is an issue in developing countries. Besides that highly hazardous acid waste also needs to be very carefully disposed off in order to prevent it from getting into local water sources. So essentially, we end up trading one waste disposal issue for another. In often cases, the poor and under-privileged members of our society are employed by un-organized sector for this method without any necessary protective measures, making it a humanitarian issue as well.

Incineration: A very crude e-waste disposal method which is just burning the waste at extremely high temperature in an incinerator. Though, this method provides twin benefits of significantly reducing our waste volume and generating energy that can be further used for other applications. But, the process of simply burning the electronic waste can produces vast quantities of toxic gases – including cadmium and mercury fumes – which are then released into the atmosphere leading to air pollution.

Recycle and Reuse: Many items of e-waste can be dismantled and their component parts be reused into new products. Currently the process is time consuming and not economically favorable. The recycling efforts are also not keeping up with the increase of e-waste on a global scale.

Advanced Methods: There are several the advanced e-waste treatment methods being used as well including. high pressure compaction (applying high pressure to significantly reduce the waste volume), cement solidification, thermal treatment (pyrolysis gasification etc), organic

dissolution (using eutectic solvents to dissolve and recover valuable metals), plasma coupled acid leaching and substrate-oxidation are the most prominent one.

Inspite of many efforts and processes available, a vast majority of the e-waste produced is still not being properly collected and handled in an environmentally responsible way. Most of the time, the electronic flows are not systematically or consistently documented in most of the countries. The lack of information on e-waste that is being collected and recycled points to the fact that the majority of our generated e-waste is being managed outside of the official regulated collection channels.

E-waste management scenario in India

India has been one of the first country in South Asian region to have special E-waste laws in place since 2011. The outlined E-Waste Handling Rules makes proper guidelines for garbage transportation, handling and recycling. Another powerful tool of extended producer responsibility has also been introduced (EPR). It is a well-known policy tool which would require producers to take financial and physical responsibility for handling their manufactured products' disposal once they reach the end of their useful lives. In 2016, these regulations were later upgraded to further establish a 'Producer Responsibility Organization' (PRO) to monitor and help with electronic trash collection and recycling. However, the sad reality is still heaps of garbage on city outskirts and exploitation of poor by unorganized sector for garbage collection (kabadivalas) and extractions. It has provided no relief or solution but has ended up filling the coffers of big corporate and businesses through corruption.

We need to strengthen our pollution Control Board at both central and state levels to implement appropriate waste handling and disposal procedures. Strict rules ought to be formulated for the producers to clarify and specifically mention the procedures for the collection, storage and processing of E-waste (especially at source if E-waste is commercially generated). Strict monitoring at all levels of administration is also necessary in order enable local government authorities to dispose of abandoned electronic trash in a safer and secure manner.

Methods to Prevent E-Waste Damage

One of the basic methods to get rid of this e-waste is a three-step agenda i.e., to reduce, reuse and re-cycle the materials or constituents of electric components, especially the materials like computers and batteries. These three basic methods are in actual methods which are indeed needed to be adopted as policy measures to prevent e-waste pollution by lesser usage, re-usage for lesser utilization and effective as well as multiple utilization of resources by recycling. These are explained below:

a. **Reduce:** The first major step is to reduce the usage of materials, appliances and gadgets, especially materials like single use plastic. The e-waste production could be reduced with the better utilization tactics.
b. **Reuse:** The re-usages can reduce the sheer volume of e-waste being generated globally.
c. **Re-cycle:** The e-waste can be recycled and used again as it is possible to extract and refine the valuable metals. Three major steps of the reverse logistic for E-waste recycling are:

   1. Disassembly: Selective disassembly to specifically separate hazardous or valuable components for special treatment.

   2. Upgrading: Mechanical processing and/or metallurgical processing to increase the amount of desirable materials extract.

   3. Refining: purifying the recovered materials using chemical (metallurgical) processing to make them acceptable for the original use. This step is the most crucial as different processes need to employed to extract different component. A lot of new research is on-going in this area to find cheaper and environmentally sustainable ways of extracting and refining different materials from e waste components.

It is prudent to identify and implement environment cleaner production design, EPR, Strict standards and proper labeling, proper guidelines for segregation, storage and recycling, to deal with the E-waste caused problems and bringing up the sustainability. Encouraging academicians and researchers to propose newer methods for e-waste management can help in finding novel ways to tackle this menace. Strategies to generate citizen awareness about the

necessity of sorting and recycling waste can prove to be significant in reducing the waste management issue.

Conclusion and Future Prospects

The new technologies which are helping us and making our lives for convenient and easy (with electronics and instruments) and posing a rosy picture at front are leaving behind big heaps and mountains of ugly and deteriorating picture. We need to introspect and understand that the new technologies are turning into debris our environment and health. It can be stated that is the new innovating technological electronic instruments really helping us or instead creating a never ending graveyard of old technologies, which are increasing which each passing day and at an unprecedented fast pace. Here two most important lessons need to be learnt. First, we need to measure the damages and destruction which it has inflicted on our environment. Thus, a systematic study, especially in affected areas need to be carried out to access the impact of e-waste on our soil, air and water by detecting the content of pollutants (mainly heavy metals which are major constituents of e-waste). Secondly, we need to focus on reduce, reuse and recycle. Now the major part of emphasis here should be on the proper recycling and disposal of e-waste. Can the science and Physics in future really provide affordable, effective and practical resolution for the containment and disposal of e-waste is the question of current times? One should note that the answer to this question is critical because it is related to the survival of the future generations of human race.

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