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India's E-waste Challenge: Strategies for a Sustainable Future

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Abstract

Over the past few decades, there has been growing concern among scientists and diplomats about pollution stemming from municipal solid waste. However, in recent years, there has been a resurgence of concern regarding electronic waste (E-waste). E-waste has emerged as one of the fastest-growing pollutants globally, posing increasingly complex challenges day by day. Despite this, there have been limited efforts to address E-waste management comprehensively This issue affects the entire world, including both developed and developing countries like India and China. International and national agencies such as IAER, UNO, CAG, CPCB, and ELCINA have highlighted in their reports that up to 400 million tons of E-waste were generated worldwide by 2010, with 20-50 million tons being disposed of annually. According to ELCINA, India generated 4.34 lakh tons of E-waste by 2012, amounting to 0.800 million tons per day. Remarkably, only 10 states and 65 cities in India contribute to 70% of the nation's total E-waste Developing countries face immense challenges in managing E-waste, whether it's domestically generated or illegally imported. E-waste from the Americas, European Union, and Australia is illegally imported into countries like China, India, and other Asian nations. India, in particular, stands out as one of the largest importers of waste globally, often acquiring it as cheap raw material. According to the Indian customs department, around 50,000 tons of E-waste are illegally imported from the European Union (specifically Germany, Netherlands, and Denmark) every year. To effectively manage E-waste in developing countries like India, a shift in government attitudes, the enactment of appropriate legislation specifically targeting E-waste, control over electronic waste dumping, implementation of Extended Producer Responsibility (EPR), and the transfer of technology for sound E-waste recycling are crucial issues that need urgent attention.

Keywords:

Electronic Waste, E-waste Management, Developing Countries, Municipal Solid Waste Pollution, Extended Producers Responsibility (EPR), International Organization

Introduction

Throughout the 20th century, scientists and policymakers focused on combating various forms of pollution, including air, water, and soil contamination from municipal solid waste. This problem is projected to worsen, with estimates suggesting a potential rise to 2.2 billion tons of municipal solid waste generated annually by 2025 [1]. However, as the 21st century dawned, a new type of pollution emerged – electronic waste, or E-waste. This rapid growth coincides with the advancements in information and communication technology. Increased affordability, wider functionality of electronic devices, and shorter lifespans all contribute to a surge in E-waste generation The demand for electronic and electrical equipment (EEE) – laptops, mobile phones, refrigerators, LED TVs, and microprocessors – has skyrocketed in recent decades. Consequently, E-waste production has seen exponential growth. Estimates suggest 20 to 50 million tons of E-waste are generated globally each year, with an annual increase of 3 to 5% [19]

The objective of this review study is to document the extent of the generation and improper handling methods of the E-waste on the world transient economic.

Categories of E-waste

It can be categories on the basis of hazardous and non- hazardous waste and more than one thousand e-

No. Category	Label	Major electric and electronic equipment
1.Large household appliances	Large HH	Refrigerators, washing, cooking machines, electric fans, air conditioners.
2.Small household appliances	Small HH	Vacuum cleaners, irons, toasters, grinders, coffee machines, electric knives, clocks, watches
3.IT and telecommunications equipment	ICT	Mainframes, data processing, personal computers, laptops, notepads, Calculators, printers, copying equipment, telephones.
4. Consumer equipment	CE	Television and radio sets, video cameras, recorders, amplifiers.
5. Light equipment	Lighting	Luminaires for fluorescent lamps, straight or compact fluorescent lamps High-intensity discharge lamps, low-pressure sodium lamps.
6. Electrical and electronic tools	E&E tools	Drills, saws, sewing machines.
7. Toys, leisure, and sports equipment	Toys	Electric trains or car racing sets, computers for biking,
8. Medical devices	Medical equipment	Radiotherapy, cardiology and dialysis equipment, pulmonary ventilators.
9. Monitoring and control instruments	M&C	Smoke detectors, heating regulators, thermostats.
10. Automatic dispensers	Dispensers	Automatic dispensers for hot or cold drinks, solid products

Waste comes under this category (Wath *et.al*, 2010).According to the European Union electrical and electronic equipment available on the market have divided e-waste types into ten categories. The E-waste have a wide range so make it in the concept easy the e-waste divided into ten different categories on the basis label and size.

Generation of waste in developed and developing country

E-waste, the fastest-growing waste stream globally, is estimated to exceed 50 million metric tons annually. This explosive growth and the subsequent rise of the e-waste recycling market can be attributed largely to the rapid obsolescence within the electronics industry [5]. Consumer electronics are frequently replaced, often within a two-year timeframe. These discarded devices are then either thrown away or exported to developing nations where there's still a demand for used electronics.

The volume of electronic waste (e-waste) generated in developed nations such as the USA and the European Union (EU) has witnessed a significant surge over the past two decades. According to the Environmental Protection Agency (EPA), the EU annually produces 7X106 metric tons of e-waste, while the USA generates 5 X106 metric tons. This trend highlights e-waste, a category encompassing electronic and electrical equipment waste (WEEE), as one of the fastest-growing waste streams, already constituting approximately 8% of municipal waste. In emerging economies like India and China, the per capita production of e-waste remains relatively low at around 1 kilogram per year. However, this figure is escalating rapidly. Given their vast populations, the total e-waste output in these nations is expected to surpass that of Western countries in the near future. Furthermore, newly industrialized and developing countries are experiencing a rise in e-waste levels, partly due to the import of e-waste from developed nations. Research indicates that a significant portion, ranging from 50% to 80%, of e-waste generated in developed markets is being transported to emerging economies for purposes of reuse and recycling. This practice often infringes upon international regulations and standards.

The Growing Challenge of E-waste in India

E-waste, one of the fastest-growing pollutants globally, presents an increasingly complex challenge. The annual global generation of electronic waste (WEEE) is estimated to be around 40 million tons [3]. While developed countries grapple with 1-2% of their solid waste being e-waste, developing nations like India face a double threat. They already struggle with existing waste management issues, and a report by the United Nations Environment Programme (UNEP) in 2007 predicted a staggering 500% increase in e-waste from old computers in India by 2020.India's rapid growth as an IT hub and a modernizing lifestyle contribute significantly to its high e-waste generation rate. Estimates suggest that India generated approximately 1.46 million tons of e-waste annually in 2010 [4]. The Comptroller and Auditor General's (CAG) report further highlights that India produces around 4 lakh tonnes of e-waste each year.Government, public, and private sectors are the primary sources of e-waste in India, accounting for nearly 70% of the total. However, current e-waste management practices in this emerging economy are largely disorganized, potentially causing severe health and environmental consequences.

In India, Maharashtra state tops the rank among 10 states in E-waste generation

The Toxic Threat of E-waste

E-waste poses a significant challenge due to its complex composition. It's a mix of various components, somecontaining hazardous substances. Improper handling and mixing with municipal waste can have detrimental effects on human health and the environment [8]. The use of toxic materials in electronics manufacturing is a primary cause of widespread environmental damage from e-waste. Electronic equipment often contains hazardous materials like:

- **Lead and Cadmium:** Found in circuit boards, these elements can cause serious health problems like neurological damage and developmental issues in children.
- **Lead Oxide and Cadmium:** Present in monitor cathode ray tubes (CRTs), cables, and PVC cable insulation, these substances release highly toxic dioxins and furans when burned for copper extraction. Printed circuit boards, a ubiquitous component in all electronics, are particularly hazardous due to their lead content.

Pollutant	Occurrence
Arsenic	Semiconductors, diodes, microwaves, Light-emitting diodes, solar cells
Barium	Electron tubes, filler for plastic and rubber, lubricant additives
Brominated flame-proofing agent	Casing, circuit boards (plastic), cables and PVC cables
Cadmium	Batteries, pigments, solder, alloys, circuit boards, computer batteries, monitor cathode ray tubes (CRTs)
Chrome	Dyes/pigments, switches, solar
Cobalt	Insulators
Copper	Conducted in cables, copper ribbons, coils, circuitry, pigments
Lead	Lead rechargeable batteries, solar, transistors, lithium batteries, PVC, stabilizers, lasers, LEDs, thermoelectric elements, circuit boards
Liquid crystal	Displays
Lithium	Mobile telephones, photographic equipment, video equipment (batteries)
Mercury	Components in copper machines and steam irons; batteries in clocks and pocket calculators, switches, LCDs
Nickel	Alloys, batteries, relays, semiconductors, pigments
PCBs	Transformers, capacitors, softening agents for paint, glue, plastic
Selenium	Photoelectric cells, pigments, photocopiers, fax machines
Silver	Capacitors, switches, batteries, resistors
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances

Landfilling e-wastes can result in the leaching of lead into groundwater, posing environmental hazards. Additionally, crushing and burning cathode ray tubes (CRT) can release toxic fumes into the atmosphere, as documented in sources (10, 11). These electronic products often contain various types of rechargeable batteries, all of which harbor toxic substances that can contaminate the environment when

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incinerated or disposed of improperly in landfills. The presence of significant quantities of cadmium in landfill sites leads to substantial toxic contamination, particularly as cadmium can gradually leak into the surrounding soil, as noted in references (12, 13, 14, 15). Furthermore, electronic products' printed wiring boards and housings, containing brominated flame retardants due to the flammability of plastics, can have detrimental effects on human health and the environment, as several studies have indicated.

Techniques used to handle E-waste

There are four primary techniques commonly employed for handling e-waste, yet none has been deemed entirely satisfactory.

The **first** and widely used method involves storing e-waste in landfills, but this approach poses significant risks of leaching, especially in older or poorly maintained landfill sites.

The **second** method involves incineration or burning of e-waste, which unfortunately releases heavy metals like lead, cadmium, and mercury into the atmosphere.

The **third** and fourth methods focus on reusing and recycling e-waste. These methods are preferable as they extend the lifespan of products, leading to reduced waste generation over time. While these methods are prevalent worldwide, each has its drawbacks and limitations. For instance, landfilling contributes to a substantial portion, about 70%, of heavy metal contamination in the US and European Union from e-waste. Incineration, on the other hand, is a major source of dioxins in the US and Canadian environment.

The reuse of second-hand electronic goods in developing countries like India often faces challenges due to inadequate local facilities and expertise to handle them properly. While recycling seems like a safe method for managing e-waste, it can be misleading as it encompasses various practices such as dismantling, shredding, burning, and exporting, many of which are unregulated and can create additional hazards. The term "recycling" of hazardous wastes, even when done under optimal conditions, offers limited environmental benefits as it merely shifts the hazards into secondary products that will eventually require disposal. Some argue that unless products are redesigned to use nonhazardous materials, recycling may not be a genuine solution. However, recycling is not only environmentally beneficial but also a sound business practice. It is an important solution, especially considering that e-waste contains valuable and rare materials. Recycling involves reprocessing waste materials for their original purpose or for other purposes, contributing to sustainable resource management

Handling techniques for E-waste in the transient countries

In transient economies such as China and India, e-waste management utilizes more elaborate processes compared to processes used in developing nations, e.g. in Africa.

In both developing and emerging countries there is little awareness of the hazardous compounds being released during these practices. (modified the sentence)

More recently, developing countries like India have also created e-waste regulations. Nevertheless, most of developing countries do not control state of the art technologies (especially in recycling). As there is no separate collection of e-waste in India. The preferred practice to get rid of obsolete electronic items in India is to get them in exchange from retailers when purchasing a new item. Obsolete e-waste from the business sector is sold by auctions.

Regulation on e-waste is, worldwide, still in process. Differences on regulations can be observed comparing countries with asymmetric economic situation.

There are three main kinds of partnerships for the construction of sustainable innovation systems: a) collaborative projects; b) organizational learning systems; c) governance networks.

Developed and developing countries have different levels on technology development and legislation about e-wastes, but international regulation affects the competitiveness of their electronics industry equally.

In a few of the developed countries charge the fee from the consumers to cover costs of e-waste management, but in many developed countries this is not allowed.

Recommendation:

(1) Educating consumers about the dangers of dumping e-waste and the social benefits ofrecycling it properly;
(2) Making producers responsible for the endof-life of their products;
(3) Creating economic incentives to fosterrecycling;
(4) Passing regulations to ban the improper disposalof e-waste.

Conclusion

Solid waste management in India is already a significant challenge, further complicated by the influx of e-waste, including computer waste, televisions, and refrigerators. Academic institutions play a crucial role in addressing this issue, particularly through the development of clean technologies, life cycle analysis methods, eco-design techniques, and technologies for disassembling and recovering minerals from e-waste. There is an urgent need for a comprehensive assessment of the current and future e-waste scenario, including quantification, characteristics, existing disposal practices, and environmental impacts. Institutional infrastructures, encompassing e-waste collection, transportation, treatment, storage, recovery, and disposal, must be established at national and grassroots levels for environmentally sound e-waste management. Promoting the establishment of e-waste collection, exchange, and recycling centers through public-private partnerships is essential. Model facilities employing environmentally sound technologies for recycling and recovery should be set up, with strict licensing regulations for imported e-waste. Policy interventions should focus on developing e-waste regulations, controlling the import and export of e-waste, and holding producers accountable for designing long-lasting and recyclable products. Providing incentives to producers for eco-friendly product design, imposing collection and recycling targets, enforcing reporting requirements, and implementing deposit/refund schemes can encourage consumers to return electronic devices for proper disposal and reuse. Initiating awareness programs for consumers regarding product lifespan, recyclability, and reusability is also vital in promoting responsible e-waste management practices.

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