IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

# A REVIEW OF THE EFFECTS OF ENVIRONMENTAL HEAVY METAL CONTAMINATION FROM ELECTRONIC WASTE ON HUMAN HEALTH

**[1]Akanksha Bansal, [2]Susan Verghese P., [3]Mahima Habil Massey, [4]David Daneesh Massey, [5]Rahul Singh**

[1]Research Scholar, [2]Professor, [3]Assistant Professor, [4]Assistant Professor, [5]Research Scholar

Department of Chemistry, St. John's College, Agra 282002

Department of Chemistry, St. John's College, Dr. Bhimrao Ambedkar Univerity, Agra, India

## ABSTRACT

Electronic waste or E-waste comprises old, end-of-life electronic appliances such as computers, laptops, TVs, DVD players, refrigerators, freezers, mobile phones, MP3 players, etc., disposed of by their original users. the categories of E-waste materials, major pollutants including ferrous/non-ferrous metals, plastics, glass, printed circuit boards, cement, ceramic, and rubber side, and some valuable metals (such as Cu, Ag, Au, Pt, Cd, Cr, Al, Li, Hg, Ni, etc.) Toxic elements from E-waste materials, released in the air, water, and soil, including As, Cd, Cr, Cd, Hg, and Pb, cause pollution. It contains many hazardous constituents that may negatively impact the environment and affect human health if not properly managed. Various organizations, bodies, and governments of many countries have adopted and developed environmentally sound options and strategies for E-waste management to tackle the ever-growing threat of E-waste to the environment and human health. This paper presents E-waste composition, categorization, Global and Indian E-waste scenarios, prospects of recoverable, recyclable, and hazardous materials found in the E-waste, Best Available Practices, recycling, and recovery processes followed, and their environmental and occupational hazards. Based on the discussion, various challenges for E-waste management particularly in India are delineated, and needed policy interventions were discussed.

**Keywords:** E-waste, Heavy Metals, Global Environment, Human Health, Global Economy.

## INTRODUCTION

Electronic waste or E-waste is a collaborative name for discarded electronic devices that enter the waste stream from various sources **[Mundada M.N. (2004)]**. E-waste team means discarded electrical, electronic devices, or equipment. Whenever an electronic or electrical factor or device whose working life has expired or been damaged, or is no longer used by people due to technological advancements, comes under E-waste. As we know, technology changes day by day due to which a large amount of electronic or electrical gadgets are turning into waste. Some of the common E-waste elements are mobile phones, computers, laptops, hard drives, fans, microwaves, DVDs, printers, lamps, Display units (CRT, LCD, LED monitors), processors (CPU, GPU, or APU chips), memory (DRAM or SRAM), and audio components have different useful lives.**[geeksfor geeks]**

**Definitions of electronic waste:**

*Source: Pic- E- waste [www.istockphoto.com]*

- ‘Electronic waste’ or ‘E-waste’ for short is a generic term embracing various forms of electric and electronic equipment that have ceased to be of any value to their owners. There is, as yet, no standard definition. Some selected definitions. In this article, we use the terms ‘WEEE’ and ‘E-waste’ synonymously and by the EU WEEE Directive. **[Needhidasan, S (2014)]**.
- “Electrical or electronic equipment which is waste.. including all components, sub-assemblies, and consumables, which are part of the product at the time of discarding. Directive 75/442/EEC, defines waste as any substance or object which the holder disposes of or is required to dispose of under the provisions of national law in force.”
- E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air *conditioners, cell phones, personal stereos, and consumer electronics to computers that have been discarded by their users. [**Puckett and Smith, (2002)**]
- Any appliance using an electric power supply that has reached its EOL [**OECD (2001)**].
- An electrically powered appliance that no longer satisfies the current owner for its original purpose [**Sinha, D. (2004)**].

- E-waste refers to the reverse supply chain which collects products no longer desired by a given consumer and refurbishes for other consumers, recycles, or otherwise processes wastes [**StEP (2005)**].
- **E-waste:** E-waste is defined as "an electrically powered appliance that no longer fulfills the current owner for its original purpose" throughout this essay. Common synonyms for "e-waste" include "e-junk" and "e-trash." Also extensively used is WEEE. Because it is the most widely used terminology, only the term "e-waste" is used in this paper.
- **Reuse:** Second-hand marketing of the product for use as it was originally intended.
- **Repair:** Repairing a broken item and getting it back in working order.
- **Refurbish:** An internal or exterior improvement to the equipment that is significant.
- **Remanufacture:** Disassembly and reuse of parts for the manufacture of a new appliance by the manufacturer **[ Lee, S. G. (2001)].**
- **Recover:** Recover waste material streams and turn them into secondary raw materials.
- **Recycle:** All processes, which close the material flow loops and bring the material back into circulation are considered to be 'recycling' in the broad sense **[ Haas, W. (2015)].**
- **Final Disposal:** Landfill or incinerate, with or without energy recovery **[ Jeswani, H. (2013)].**
- **Recyclate:** Secondary material after recycling [ **Sinha, D. (2004)**].

## E-WASTE SCENARIO

### International Scenario

The accelerated generation of E-waste with time happens to be the natural outcome of incremental penetration of IT in diverse spheres of day-to-day activities, adding up to the municipal solid waste stream. E-waste equals 1% of solid waste on average in developed countries and ranges from 0.01% to 1% in developing countries [**E-waste (2006)**], and the same is expected to inch up considerably shortly. Some of the developed countries such as the US, UK, Germany, Japan, and New Zealand have already developed advanced processing techniques for recycling E-waste and patented them, as well. The Union Meniere Company in Belgium [**Hageluken C (2006)**] and Boliden Mineral in Sweden [**Theo L. (1999)**] have, for quite some time, been operating recycling plants to process E-waste, while in China [**Li J, (1995), Huang K (2009), Wei L (2012), Zhang K (2012), Tong X (2015)**], Taiwan [**Lee CH (2000)**], and South Korea [**Lee JC (2007)**] proactive measures are being pursued to recycle metal from E-waste, but in India, no concrete or notable steps have been initiated so far in the large scale or a structured format. [**Das A (2009)**] developed a flow sheet using a combination of wet and dry processes to produce a rich concentrate with significantly high recoveries of metals from ground PCB powder.

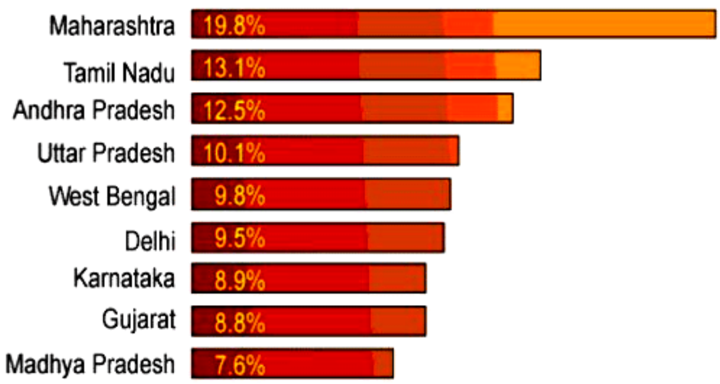
Every year, 20 to 50 million tons of electrical and electronic equipment waste are discarded worldwide and Asian countries discard an estimated 12 million tons [**Greenpeace (2005)**]. The share of the developing economies of China, India, etc., concerning the consumption of computers, in particular, is likely to surge ahead, surpassing 178 million in case of China and 80 million in case of India, out of the estimated 716 million new computer users' global total [**Greenpeace (2006)**]. E-waste produced in developed nations like the US and others is frequently exported for recycling in developing nations where labor is relatively inexpensive, aside from the possibility of ending up in a landfill. As a result, the pollution problem is intensifying quickly, especially in nations like China, India, and , posing a serious risk to human health and the environment.

The rampant approach of open-air burning of plastic wastes, toxic soldiers, river dumping of acids, and widespread dumping and landfill in general [**Puckett J (2002)**]. According to a report by the International Association of Electronics Recyclers, approximately 3 billion units or an average of 400 million units annually will be discarded in the remaining years of the current decade in the US alone, including 200 million televisions and 1 billion pieces of computer hardware. According to Basel Action Network (BAN), 75% of outdated electronics are on the verge of being scrapped soon even though consumers have been holding onto them in the hope that they still have some usable value while also being unsure of the disposal strategy to be used **[Puckett J (2005)].** Most of the electronic garbage that wealthy nations create is dumped in underdeveloped and developing countries. In their study, **[Ladou, J., and Lovegrove, S. (2008)]** examined discarded electronic devices such as computers, computer monitors, televisions, and mobile phones, collectively referred to as "E-waste". Currently, less than 10% of E-waste gets recycled. With the knowledge that it would do serious harm to the underprivileged areas where it will be disposed of, the United States and other rich nations export E-waste mostly to Asia. In most electronics devices marketed in the ED, a 2006 regulation prohibits the use of lead, mercury, cadmium, hexavalent chromium, and certain brominated flame retardants. Even though they only apply locally and only cover a small portion of the hazardous materials used in the production of electronics, the RoHS and WEEE directives from the EU are helpful solutions to the problem of E-waste. There is an urgent need for significantly stronger restrictions over the transboundary flow of E-waste and its recycling. EElectronicproduct producers must immediately assume accountability for their goods from production to EOL. Manufacturers must create safe goods that are easier to repair, update, and recycle, have longer useful lives, and won't expose people or the environment to dangerous substances. According to **[Van Yken, J. (2021)]**, E-waste is a global problem that is becoming greater. The entire worldwide output in 2019 was 53.6 million tonnes, and by 2030, it is anticipated to reach 74.7 million tonnes. This quick growth is mostly caused by increased electrical and electronic product use, shorter product life cycles, and limited repair choices. E-waste is categorized as a hazardous material and, if not properly collected and processed, can harm the environment. According to estimates, the entire economic worth of the recoverable materials in E-waste created in 2019 was anticipated to be US $57 billion. Only 17.4% of E-waste was recycled globally in 2019, despite the waste's intrinsic worth, which emphasizes the necessity to set up suitable recycling procedures at a regional level.

**National Scenario**

E-waste is not specifically or systematically collected in India, therefore it is impossible to determine how much of an environmental concern there is from the amount created and disposed of annually. According to the **[MAIT-GTZ (2007)]** research, 330,000 metric tonnes of E-waste (exclusively from computers, TVs, and mobile phones) were produced in 2007. A further 50,000 tonnes were dishonestly smuggled into the nation, most of which were mislabeled as contributions to organizations or scrap and were not identified as electronic junk, resulting in an annual E-waste production of around 380,000 metric tonnes. Only 19,000 tonnes of this were recycled, which was factually supported by the country's need for electronic device refurbishment and reuse as well as the subpar recycling infrastructure built up in the unrecognized industry with a profit-making objective. Generation of E-waste in India is estimated to far exceed 470,000 metric tonnes as of 2011, out of which Mumbai generates around 11,000 tonnes of E-waste, Delhi 9000 tonnes, Bengaluru 8000 tonnes, and Chennai 5000-6000 tonnes each year. Maharashtra State (including Mumbai city) alone produces 20,270 tonnes of E-waste annually [**MPCB (2007)**]. Maharashtra, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, and Madhya Pradesh are the top-ranking states in India in order of their primary participation in WEEE. Mumbai, Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat, and Nagpur are the key cities where WEEE is produced. This is because there are several information technology parks and businesses making electronic items located in these locations, which are mostly responsible for trash production.

Since the typical lifespan of a personal computer has been shortened to just two years, the Electronic




*Source: Pic. State-wise E-waste generation in India [ Sinha-Khetriwal (2005)]*

Industry Association (ELCINA) in India has estimated that by 2012, E-waste will have increased by an extraordinary 11 times. In emerging nations like India and China, the amount of garbage produced per person each year is still rather low, at less than 1 kg. The electronics hardware market in India will continue to expand thanks to products like laptops, washing machines, televisions, and refrigerators. It was determined that these four things created 1,46,180.00 tonnes of electronic garbage between 2004 and 2005, and by 2010 it was anticipated to surpass 16,00,000 tonnes [**CII(2006)**].

In India, the problem of E-waste generation and disposal is steadily attaining an alarming dimension with time. It has been reported that 900-1000 computers are dismantled every day in New Delhi alone. In 2005, about 1000 tonnes of plastics, the same equivalent of iron, 300 tonnes of Pb, 0.23 tons of Hg, 43 tonnes of Ni, and 350 tonnes of Cu were expected to be generated as E-waste in Bengaluru alone [**Beary H (2005)**]. In India, Maharashtra, Tamilnadu, and Andhra Pradesh head the list of E-waste-generating states. Cities such as Delhi, Chennai, Kolkata, and Bengaluru contribute significantly to E-waste generation as well. A study done by Toxics Link in 2007 [**Sinha S (2007)**] estimated that Mumbai alone produces 19,000 tonnes of WEEE annually. Another study done jointly by Toxics Link and the Centre for Quality Management Systems, Jabalpur University, and Kolkata estimates around 9000 tonnes of WEEE generation in the city of Kolkata [**Ghosh S (2007)**]. According to the findings of a field survey conducted in Chennai, a major city in India, to determine the typical usage and lifespan of personal computers (PCs), televisions (TVs), and mobile phones, the average household usage of PCs varies depending on the income class from 0.39 to 1.70 **[Ramesh S (2006)].** Although India's per-capita trash generation is still rather low, the country's overall absolute garbage generation is enormous and is increasing at an alarmingly rapid rate. Comparing the growth rates of PCs (20%) and TVs (18%), mobile phones' growth rate of 80% is significantly higher. About 50% of the population is aware of the environmental and health effects of EOL electronic products, according to the study's assessment of public knowledge of E-wastes and readiness to pay for E-waste disposal based on a structured questionnaire. The public's willingness to pay for E-waste management ranges from 3.4% to 5% of the cost of mobile phones, 3.94% to 5.95% for TVs, and from 3.57% to 5.92 % for the TV [**Joseph K. (2007)**]. According to research and analysis by **[Ha NN., (2009)]**, the recycling and disposal of E-waste in developing nations is giving rise to growing environmental and health problems. We analyzed trace elements (TEs) in soil, air dust, and human hair that were taken from E-waste recycling sites (a recycling facility and backyard recycling units) and the reference sites in Bangalore and Chennai, India, to determine the contamination status. The soil from E-waste recycling sites had greater concentrations of Cu, Zn, Ag, Cd, In, Sn, Sb, Hg, Pb, and Bi than the soil from reference locations. The amounts of Cu, Sb, Hg, and Pb in certain soils from E-waste sites surpassed the US Environmental Protection Agency's (EPA) recommended screening thresholds. In comparison to Chennai city levels, the air from the E-waste recycling plant has relatively higher concentrations of Cr, Mn, Co, Cu, In, Sn, Sb, Tl, Pb, and Bi. Male workers at E-waste recycling facilities have high concentrations of Cu, Mo, Ag, Cd, In, Sb, Tl, and Pb in their hair. Our findings imply that some TEs may contaminate the environment and people as a result of recycling and disposing of electronic trash. To our knowledge, this is the first investigation on TE contamination at Bangalore, India's E-waste recycling facility.

In modern systems, in developing countries, for which China, India, Pakistan, and Nigeria can be taken as examples, plastic cables are commonly burned to recover Cu and this is considered the least expensive means to recover Cu **[Blade (2017)]**. Valuable metals of circuit board parts are drained during an acidic wash and the utilized acid along with the metal parts leached down and dumped into the ground or water bodies a common practice in underdeveloped and developing countries **[Robinson (2009)]**. The nearby inhabitants might be unaware of the hazard of dumping toxic metal-contaminated waste. The official strategies and administrative rules of waste dumping in developing countries are much different from those of the developed world. However, importing E-waste materials is banned in developing countries, as the recycling of the waste by developing countries is costlier than the low-cost dumping of waste by developed countries **[Mehta (2019)]**. Many countries at present, have no standard or correct information on E-waste production. **[Abbas (2011)]**. There is no appropriate system to handle E-waste materials at the domestic level. In this way, individuals have to develop techniques to dispose of E-waste materials at the local level.

At this level, many people take part in the disassembling of E-waste materials, extracting the metals, and separating them, and by this means, they earn their living. In many countries open dumping and burning of E-waste are common practices **[(Umair (2015), Iqbal (2017) Akram R (2019)]**. **[Dave SR (2016)]** E-waste is a new type of garbage that has emerged as a result of the rapidly expanding availability and falling prices of modern electronic equipment including mobile phones, televisions, computers, and their peripherals as well as the rapid replacement of outmoded items. One of the issues facing the globe today that is quickly getting worse is "E-waste." The article gives a succinct overview of the current situation concerning the production of E-waste on a national and international scale, the risks to the environment and human health, the organizations and legal networks that are already in place to address this issue, and the current technologies for treating E-waste, specifically pyrometallurgy, hydrometallurgy, and bio-hydrometallurgy. It further explains why researchers are more interested in biohydrometallurgical approaches than traditional ones for recovering metals from E-waste. If a sustainable method of metal extraction from E-waste is created, it will help to protect the ecosystem's biotic and abiotic elements from the dangers of E-waste, preserve the high-grade metallic ores that are being consumed, supply the industries with the metals that were extracted, and provide for the preservation of the ores' diminishing high-grade ores. Additionally, the purity of base and precious metals in E-wastes is approximately 10 times higher than that of ore; therefore, if possible E-waste recycling processes are created and put into practice, the issue of pollution would be changed into a valuable metal resource.

**Generation of E-Waste:**

E-waste is created when electronic devices are abandoned, according to **[Chakraborty SC., (2022)]**. In recent decades, there has been tremendous growth in the production of E-waste. Nearly 2 metric tonnes (Mt) more of E-waste are produced annually on a global scale. In 2030, there will likely be 74 Mt of E-waste generated. As a result, E-waste poses a serious risk to the environment and releases toxic metals (including Pb, Hg, Ni, and Cd) into the environment, where they ultimately find their way into the soil, sediment, groundwater, and surface water. The environment's exposure to hazardous metals harms plant life, marine life, and human health. As a result, it is crucial to handle E-waste properly, which has become a global issue. In this regard, this analysis offers a thorough overview of the production, disposition, and cleanup of metals from E-waste. E-waste is mostly produced by household electrical equipment, which accounts for 50% of total E-waste output. The combination of biological, physical, and chemical processes has relatively high removal efficiency when compared to other remediation approaches, and they also have certain benefits over them. The biggest issue with managing E-waste is the quantity, which is always growing. The amount of E-waste, however, only makes up a minor portion of the total municipal solid waste (MSW). Because of differences in waste definitions, technical equipment utilized, consumer consumption habits, and variations in living standards throughout the world, data on E-waste creation may differ between areas of a country **[Andarani P (2014)].** Approximately 20-25 million tonnes of electronic trash are created globally each year, the majority of which is produced in developed nations like the United States (US) or European Union (EU) members. With an annual production of 3 million tonnes, the US leads the world in the generation of E-waste. China comes in second with 2.3 million tonnes produced annually. Among rising nations, Brazil produces the second-highest amount of E-waste **[Oliveira CRD, (2012)].** According to estimates, Malaysia produces between 0.8 and 1.3 kg of garbage per person per day, with an upward trend in E-waste production that reached 134,000 tonnes in 2009. Additionally, according to **[Malaysia (2009)]**, 1.1 million metric tonnes of E-waste would be produced there year by 2020. Between 2007 and 2020, the generation of E-waste from outdated computers will rise by 200-400% in China and South Africa and by 500% in India. China and India will have 1.5-2 times more television-related E-waste over this period, but by 2020, refrigerator-related E-waste in India would have doubled or tripled. 146,000 tonnes of E-waste are produced annually in India. However, these statistics only take into account the domestically produced E-waste and do not account for trash imports, both legal and illegal, which are significant in developing nations like China as well as India **[UNEP (2010)]**. The cause is that, under the guise of charity, an extensive amount of WEEE is brought into India from other nations without paying any duty **[Karla V (2004), Kimberley M (2007)]**. E-waste volume is growing at an annual average of 5 to 10% each year worldwide [**Robinson B (2009), Mmereki, D (2016)].**

**Growth of E-Waste:**

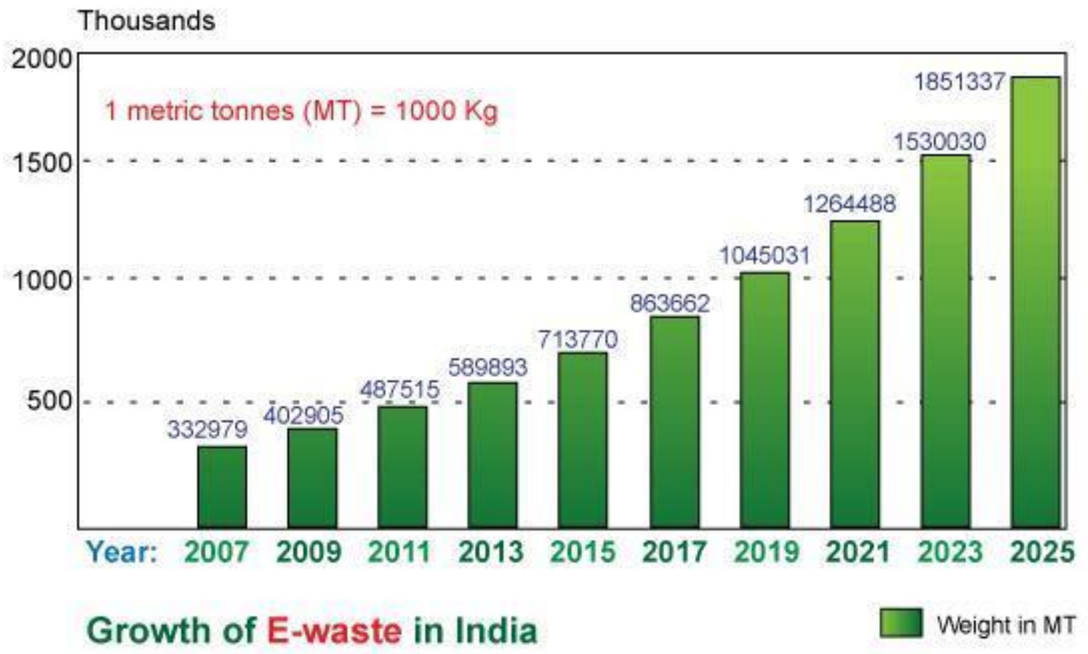
Electronic and electrical goods are largely classified under three major heads:

- ‘White goods’ comprise household appliances such as air conditioners, dishwashers, refrigerators, and washing machines.
- ‘Brown goods’ such as televisions, camcorders, and cameras.
- ‘Gray goods’ such as computers, printers, fax machines, scanners, etc. These gray goods are comparatively more complex to recycle due to their multi-layered configuration and higher toxic composition.

The grey products industry has also had significant development over the past ten years, and India is anticipated to reach a PC penetration rate of 65 per 1,000 by the year 2008 [**MAIT (2004)**].

The PC sales figure in India has been very impressive, showing a huge growth from a mere 14,05,290 in 1999-2000 to 46,14,724 in 2005-2006 and is conservatively projected to touch 56,00,000 by 2006-2007. The expected annual average growth rate of the PC is likely to be 21%, while consumption of PC in the top four cities (Delhi, Mumbai, Kolkata, Chennai) grew by 25% as of 2006 [**Ghosh S (2007)**]. For the laptop segment, the growth is more impressive; the sales figure has jumped from 50,954 in 2002-2003 to 4,31,834 in 2005-2006 having registered an astonishing growth rate of 143% in 2005-2006 **[MAIT (2004), Ghosh S (2007)**]. The overall PC sales in 2012-2013 considerably slowed down and the sales figure are well below expectations. The overall sales figures touched 11.31 million in 2012-2013, registering a growth of 5% over the last fiscal. Desktop PCs continued to dominate the sales proceedings contributing around 60% of the sales although it is somewhat lesser than last year's contribution of 63%. Notebook sales posted a muted growth rate of 10% in 2012-2013 compared to the 22% rate in the previous year. Tablet PCs witnessed a massive growth rate of 424%. The sales for 2012-2013 stood at 1.9 million units as against 0.36 million units in 2011-2012 [**MAIT (2013)].** Sixty-five cities in India generate more than 60% of the total E-waste generated in India. Ten states generate 70% of the total E-waste in India [**Sanjay J (2008)**]. Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh, and Punjab in the list of E-waste-generating states in India. According to the forecast, based on a logistic model and material flow analysis [**Yu J. (2010)**], the volume of obsolete PCs generated in developing regions will exceed that of developed regions by 2016-2018. By 2030, there would be two obsolete PCs in the developing world for every obsolete PC in the developed world. Similar forecasts have arrived at independently [**Dwivedy M (2012)**]. The advent of LCD, plasma, and bigger displays altered how Indians perceive television, which led to a remarkable increase in sales and a significant increase in the rate of disposal as well **[Ari V. (2016)].**

There are over 75 million mobile users and the number has increased to 200 million as of




*Source: Fig -Growth of E- waste in India: Past and forecasts for the future [Ari, V. (2016)]*

2008 **[Sinha S. (2006)].** An estimated 30,000 computers become obsolete every year in the IT industry in Bengaluru alone **[Tiwari M (2008)]**. India has about 15 million computers and the base is expected to grow to 75 million computers by 2010 since the life cycle of a PC has come down to 3-4 years from 7 to 8 years a few years back, and the segment is suffering from an extremely high obsolescence rate of 30% per year [**Tiwari M (2008)**]. Massive amounts of garbage are being produced as a result of industrialization's quick rise. According to several recent kinds of research on the development of E-waste, this tendency is expected to spread to smaller towns and cities and increase at an incredible rate **[Ari V. (2016)].**

The high rate of obsolescence of these items and the incapacity of technology to facilitate upgrades from the standpoint of commercial feasibility are also significant contributors to incremental waste creation. This pattern of consumption and planned obsolescence is a component of business management strategy in developing product designs with short lifespans that encourage a high-waste economy and are marketed to those with more disposable money. A new computer model is released into the market every two years, making the old one outdated. The Indian mentality has thus far been able to extend the use of such things by coming up with creative solutions; but, after contracting the new consumerism bug, this approach is gradually changing **[Ari V. (2016)].**

**Sources and categories of E-waste:**

Electrical tools, portable electronic devices like portable digital assistants (PDAs), video and audio equipment, including MP3 players and peripherals, and large and small household appliances are all categorized as electrical and electronic equipment. IT equipment also includes computers, computer games, and peripherals.

Table 1 Major categories of electric and electronic equipments

| **Equipment** | **Units (million)** | **Weight (tonnes × 103)** | **% of total** |
|---|---|---|---|
| Large household appliances | 10 | 392 | 43 |
| Small household appliances | 15 | 30 | 3 |
| IT equipment | 22 | 357 | 39 |
| Telecommunications | 7 | 8 | 1 |
| Radio, TV, audio | 12 | 72 | 8 |
| Lamps | 77 | 12 | 1 |
| Monitoring and control | 8 | 8 | 1 |
| Toys | 8 | 8 | 1 |
| Electrical and electronic tool | 6 | 28 | 3 |
| **Total** | 165 | 915 | 100 |

*Source: [Hilty (2005), Oertel (2005)]*

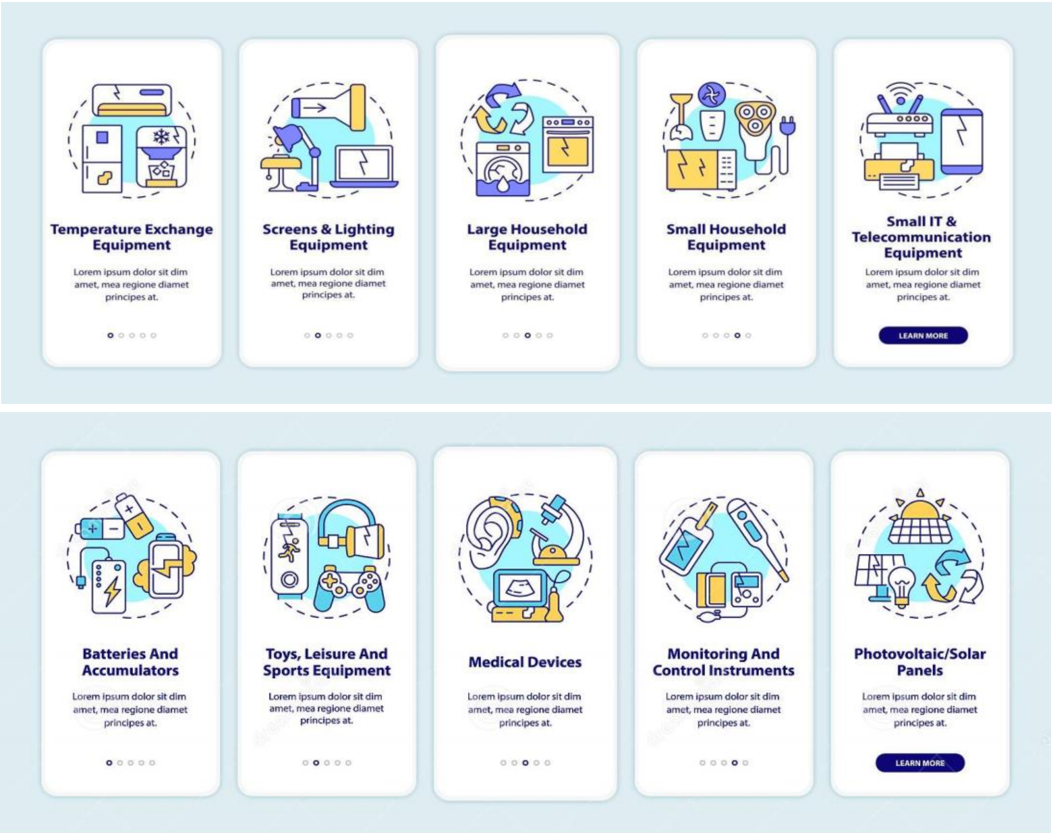
More and more everyday items that were once classified as electrical equipment, like refrigerators, are now being classified as "electronic" items thanks to the addition of programmable microprocessors; more than 98% of these components are found in products other than computers, like toys and household appliances **[Hilty (2005), Oertel (2005)]**.

When these goods have served their purpose, they turn into WEEE or E-waste. Equipment that requires electric currents or electromagnetic fields to function properly is referred to as WEEE. This includes devices for the generation, transfer, and measurement of current. **[Schafer (2003)]**. In response to the increasing volumes of WEEE and their potential environmental impacts through various disposal routes, the European Commission published a proposal in 2002 **[EU (2002a)]** for Directives on Waste from Electrical and Electronic, Equipment **[WEEE (2001)]**. The Directive of the Parliament and European Union Council on waste electrical and electronic equipment subdivides WEEE into ten different categories **[EU (2002b)].**

- Large household appliances (refrigerators/freezers, washing machines, dishwashers).
- Small household appliances (toasters, coffee makers, irons, hairdryers).
- Information technology and telecommunications equipment (personal computers, telephones, mobile phones, laptops, printers, scanners, photocopiers).

- Consumer equipment (televisions, stereo equipment, electric toothbrushes, transistor radios).
- Lighting equipment (fluorescent lamps).
- Electrical and electronic tools (handheld drills, saws, screwdrivers).
- Toys (Play station, Gameboy, etc.).
- Medical equipment systems (except for all implanted and infected products).
- Monitoring and control instruments.
- Automatic dispensers **[Babu, B. R (2007)]**

For effective management of E-waste, it is difficult to identify and classify the items that makmake upwaste **[Birloaga I (2018)].** the electronic device for producing, exchanging, and estimating electric circuits for use with a power supply range not exceeding 1000 Volts for alternating current and 1500 Volts for direct current. E-waste is defined as hardware that depends on electrical streams or electromagnetic systems to function properly. According to the definition provided, electronic trash includes items like computers, televisions, telephones, iPods, fluorescent lights, printers, toys, etc. **[Zeng X (2015) Akram, R (2019), Wang Y (2011)].** This also includes all components and large appliances used in both households and commercially.




*Source: Different type of E-waste categories [www.alamy.com]*

The main sources of E-waste in India comprise the government, public, and private (industrial) sector discards, which account for almost 70% of the total E-waste generation. The growth in the government sector alone has been a staggering 126% as of 2006 [**Agarwal R (2003)**]. It has been projected that significant government agencies including Railways, Defense, and Healthcare produce significant amounts of E-waste. In India, the majority of businesses change their hardware infrastructure every three to five years, sometimes considerably sooner depending on the advantages of the permissible depreciation rate. Due to their high cost, electronic products are not abandoned in public spaces like streets or landfills. These are often kept for a long time in homes or warehouses before being either sold to or transferred to scrap merchants for monetization; however, this practice is expected to alter with time. About 15% of the total comes from individual families, with the remaining 85% coming from the commercial or corporate sector. Even while individual houses do not generate a lot of garbage related to computers, this market sector is undoubtedly responsible for the widespread purchase of consumer durables like televisions, refrigerators, air conditioners, etc. Rapid technological improvements and falling product prices are both changing the pattern of longer usage, which is fueling an increase in the production of domestic E-waste.

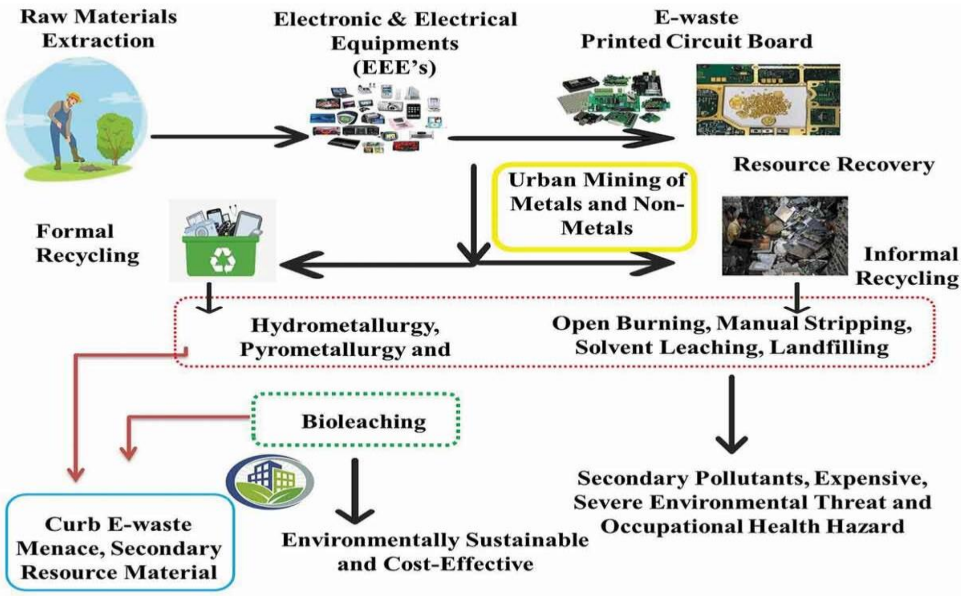
Unreliable imports are a significant source of E-waste and are increasing the amount of garbage produced in


*Source: why E-waste is a growing problem [gradesofgreen.org]*

the nation. However, precise data on these imports is not readily available due in large part to the nature of the trade. E-waste is no exception; hazardous trash from the industrialized world has historically been sent to developing nations, including India. Due to the enormous volumes of E-waste that industrialized countries are producing and the rigorous environmental regulations that are being implemented, notably in European countries, the cost of disposal is rising. [**Mahesh P (2007)**]. As per available data, the cost of recycling a single computer in the US is US$20 while the same could be recycled in India for only US$2, a gross saving of US$18 if the computer is exported to India [**Mahesh P (2007)**]. Most developed countries stand to benefit economically by dumping E-waste in developing countries. E-waste imports to India are rising as a result of lax environmental legislation, ineffective enforcement measures, inexpensive labor, and raw materials, an uneducated populace, and the unorganized character of the industry. Even though it is illegal to import electronic garbage into India, there have been several cases of this waste arriving in Indian ports disguised as commodities intended for charitable organizations or mixed metal waste [**Mahesh P (2007)**]. However, estimates indicate that unethical imports of E-waste are at least as great as what is produced domestically.

## MAJOR POLLUTANTS IN E-WASTES

As per the Association of Plastics Manufacturers in Europe (APME), E-waste is a diverse mixture made out of ferrous, non-ferrous, ceramic, and plastic materials. E-waste is classified according to the manufacturing material and contains > 1000 different constituents, which fall into two categories, (I) toxic and (ii) non-toxic substances. Extensively, it incorporates ferrous/non-ferrous metals, plastics, glass, printed circuit boards (PCB), cement, ceramic, rubber, etc. [**Wang R (2014), Yamane LH (2011)**] After plastics (21%), non-ferrous metals (13%), and other elements, steel and iron make up around 50% of electronic garbage. Non-ferrous metals include rich metals like silver, platinum, gold, and palladium as well as trace metals like Cu and Al. Toxic waste includes substances like As, Cd, Cr, Hg, Pb, and Se as well as fire-resistant E-waste, which is divided into four different classes based on the amount of each substance in the electrical devices: (I) heavy metals, (II) halogens, (III) radioactive substances, and (IV) various substances. [**Hurst C (2010)**] Trace earth metals are metals that are not generally known because they are less used in the production section and are basic to high-tech appliances [**Hurst C (2010)**]. Because they are less common in manufacturing and are essential to high-tech products, trace earth metals are less well-known metals **[Hurst C (2010)]**. A few applications would be impossible without the availability of both trace and precious metals, which are seen as essential components of the present invention. Trace earth metals are essential in




*Source: E-waste as a challenge as public and ecosystem health [Arya S. (2020)]*

the manufacturing of computers, cell phones, and weapons (cruise missiles, reactive armor, and detecting systems), according to the US Department of Energy (2011).

There is value in these metals in green techniques, for example, in windmills, hybrid motor automobiles, and as a catalytic agent in the oil processing plant. The wide utilization of these metals in recent innovation has therefore produced an increased demand and wide generation of all such toxic metals. The main part of mining in the supply of electronic and modern gadgets cannot be ignored. **[Rademaker JH (2013)]** reported that despite the influence of mining in the stream of basic crude elements, the impression of the mining cannot be overlooked for these metals. Moreover, **[Schluep Mc (2009)]** demonstrated that mining needs an extensive land space with activities that have a negative impact and contaminate the water, air, and land.

Besides, the exploitation of resources is related to the introduction of radioactive components to the environment and also has adverse impacts on humans [**Rademaker JH (2013)**]. According to **[Schluep Mc (2009)]**, the extraction of trace and valuable metals enhances $CO_2$ emission. The researchers reveal that the Environmental Science Pollution Reproduction of a tonne of gold, platinum, or palladium produces $CO_2$ emissions of almost 10,000 tonnes. With the depletion of outrace and valuable metals, increasing land destruction, and contamination of water and air because of mining, considerations have been made to overcome the situation by the administration of WEEE. With present-day electrical and electronic gadgets, containing up to 60 distinct elements of which some are important and some are lethal, this material should be taken under priority [**Jinhui (2013)**]. **[Rademaker JH (2013)]** revealed that various countries have set up procedures to maintain the particular and worldwide supplies of these metals by the country to diminish their reliance on China, taken as a leading provider of trace metals [**Rademaker JH (2013), Jinhui L (2013)**]. In the USA, more than 0.5 billion PCs are discarded in 1997, and 0.13 billion mobile sets were disposed of bringing about around 65,000 tonnes of waste in 2007 [**UNEP (2009)**]. In 2010, mobiles are discarded around 0.61 billion in Japan, which contain 40 toxic and non-toxic substances. An estimate by **[Schluep Mc (2009)]** demonstrates that from a huge amount of cell phones without batteries, effective recycling can recoup Au (0.34 kg), Ag (3.5 kg), and Pb (0.14 kg) [**Schluep Mc (2009)**]. The stream of this E-waste generation could be highly toxic to human health in not considered appropriate [**Schluep Mc (2009)**] concurs that E-waste might be a major root of rare and valuable metals. This gives a contrasting option to mining as well as guarantees among others a consistent supply of metals and effective, reasonable, and low-cost management of E-waste materials. During the recovery of E-waste in both developing and developed states, the basic raw ingredients are recovered during recycling but are not analyzed yet [**Bengtsson M (2011)**]. Generally, WEEE is the combined assembling of many metals, some of which are exceptionally toxic, i.e., the creation of semiconductors, circuit boards, disk drives, and monitors is highly chemically toxic [**Bengtsson M (2011), Tsydenova O (2011)**]. The CPU comprises heavy metals like Cd, Pb, and Hg and PCBs have substantial metals, like Sb, Ag, Cr, Zn, Pb, Sn, and Cu. In WEEE, Pb is predominantly utilized in CRTs in screens, Sn-Pb binds, PCB, cabling, and luminous tubes. E-waste additionally has brominated fire retardants (BFRs), for example, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDEs) which are utilized in PCB, connectors, covers, and cables. Many studies recommended that BFRs have negative impacts on humans, and thus be constrained or exchanged together [**Ghosh B (2015)**]. Interaction with PBDEs by the individuals employed in E-waste reprocessing industries has been considered by many researchers across the world [**Tue N M (2010), Zhang M (2019)**]. Additionally, PBDEs are found in nature around some E-waste recycling areas. An investigation of the occurrence of PBDEs in the air, ash, dust, soil, drinking water, and residue in E-waste recovering as in China and India discovered a high amount of PBDEs beyond the levels in an urban or industrial area. Toxins in E-waste materials are commonly packed in plastics, PCBs, batteries, and LCDs [**Kumar R (2014)**]

**IMPACTS OF E-WASTE AND HEAVY METALS ON THE ENVIRONMENT**

Lethal substances have been found in E-waste materials during the past twenty years. E-waste management is not adequately regulated by regulations everywhere around the globe. E-waste has grown significantly, and inadequate laws and administrative frameworks in both wealthy and developing nations have had significant negative effects on the environment. Reusing and disposing of E-waste in landfills appeared to cause a significant loss of environmental viability [**Akram, R (2019)**]

Table 2 Different types of e-waste pollutants, occurrence, and their impacts on human health

| POLLUTANTS | OCCURRENCE | IMPACT ON HUMAN HEALTH |
|---|---|---|
| Arsenic (As) | Semiconductors, diodes, microwaves, LEDS (light-emitting diodes), solar cells | Soluble inorganic arsenic is acutely toxic and intake of inorganic arsenic over a long period can lead to chronic arsenic poisoning. Effects, which can take years to peripheral neuropathy, diabetes, renal system effects, cardiovascular disease, and cancer [**WHO (2010a)**] |
| Barium (Ba) | Electron tubes, filler for plastic and rubber, lubricant additives | Short-term exposure causes muscle weakness and damage to the heart, liver, and spleen. It also produces brain swelling after short exposure [**Osuagwu OE, (2010)**] |
| Cadmium (Cd) | Batteries, pigments, solder, alloys, circuit boards, computer batteries, monitor cathode ray tubes (CRTs) | Has toxic, irreversible effects on human health and accumulates in the kidney and liver. Has toxic effects on the kidney, the skeletal system, and the respiratory system, and is classified as a human carcinogen [**WHO (2010b)**]. |
| Chromium (Cr) | Dyes/pigments, switches, solar | Respiratory tract irritants can cause pulmonary sensitization. Increase the risk of lung, nasal, and sinus cancer. Severe dermatitis and usually painless skin ulcers. Severe liver abnormalities. DNA damage, gene mutation, sister chromatid exchange, chromosomal aberrations. |
| Cobalt (Co) | Insulators | Hazardous in case of inhalation and ingestion, and is an irritant of the skin. Has carcinogenic effects and is toxic to the lungs. Repeated or prolonged exposure can produce target organ damage [**MSDS(2005)**] |
| Copper (Cu) | Conducted in cables, copper, ribbons, coils, circuitry, pigments | Very hazardous in case of ingestion, in contact with the eyes, and when inhaled. An irritant of the skin and toxic to the lungs and mucous membranes Repeated or prolonged exposure can produce target organ damage [**MSDS(2005)**]. |

| | | |
|---|---|---|
| Lead (Pb) | Lead rechargeable batteries, solar, transistors lithium batteries, PVC (polyvinyl chloride) stabilizers, lasers LEDs, thermoelectric elements, circuit boards | Causes damage to the central and peripheral nervous system, blood system, and kidneys and affects the brain development of children [**Osuagwu OE (2010)**]. A cumulative toxicant that affects multiple body systems, including the neurological, hematological, cardiovascular, and renal systems [**WHO (2010c)**]. |
| Lithium (Li) | Mobile telephones photographic equipment, video equipment (batteries) | Extremely hazardous in case of ingestion as it passes through the placenta. It is a hazardous and an irritant of the skin and eye, and when inhaled. Lithium can be excreted in maternal milk [**MSDS(2005)**] |
| Mercury (Hg) | Components in copy machines and steam irons; batteries in clocks and pockets calculators, switches, LCDs | Harmful effect on the nervous, immune, and digestive systems, lungs, and kidneys and may be fatal corrosive to the skin, and eye, and may induce kidney toxicity. Neurological and behavioral disorders, Kidney effects have been reported, ranging from increased protein in the urine to kidney failure. |
| Nickel (Ni) | Alloys batteries relay semiconductors pigments | Allergic reactions (skin rash, etc.), stomach aches, and adverse effects in their blood (increased red blood cells) and kidneys (increased protein in the urine). Chronic bronchitis, reduce lung function, and cancer of the lung and nasal sinus. |
| Polychlorinated biphenyls (PCBs) | Transformers, capacitors, softening agents for paints, glue, plastic | Possible cancer, affects the immune system, nervous system, and endocrine system. It accumulates in the fat-rich tissues of almost all organisms. |
| Phthalates | Used to soften plastics | Disrupts the endocrine system, reproduction, fertility, and birth and has developmental effects. Also has organ system toxicity and is linked to liver cancer and affects the brain, nervous system, and immune system. |
| Silver (Ag) | Capacitors, switches (contacts), batteries, resistors | Very hazardous in case of eye contact, ingestion exposure can result in death. Repeated exposure can deteriorate health by an accumulation in one or many human organs [**MSDS(2005)**]. |
| Zinc (Zn) | Steel, brass, alloys, disposable and rechargeable batteries, luminous substances | Contact with the eyes can irritate, inhale, and causes cough, and if ingested, abdominal pain, diarrhea, and vomiting are common [**Akram R (2019)**]. |
| Antimony (Sb) | CRTs, printed circuit boards, etc. | Very hazardous in the event of ingestion, hazardous in the event of skin and eye contact, and inhalation. Causes damage to the |

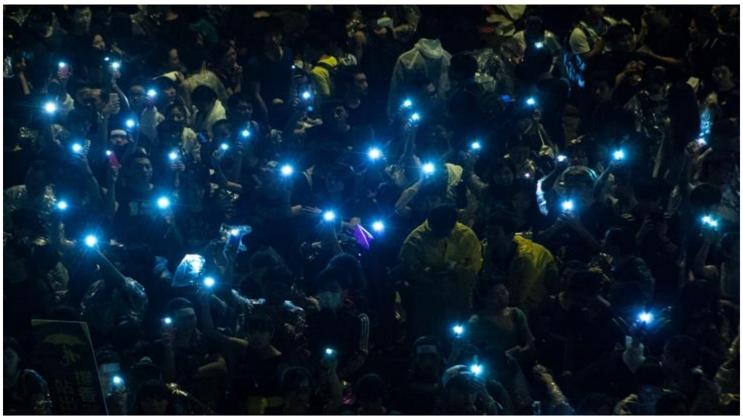
| | | |
|---|---|---|
| | | blood, lungs, nervous system, liver, and mucous membranes [**MSDS(2005)**] |
| Beryllium (Be) | Motherboards of computers | Carcinogenic (causing lung cancer), and inhalation of fumes and dust can cause chronic beryllium disease or berylliosis and skin diseases such as warts [**Osuagwu OE (2010)**]. |
| Dioxins | Created when electronics are burnt in the open air | Highly toxic and can cause chloracne, reproductive and developmental problems, interfere with hormones, and cause cancer [**Ghosh B (2015)**] |
| Gallium. | Integrated circuits, optical electronics, etc. | Hazardous in case of skin (may produce burns) and eye contact, ingestion, and inhalation. Severe overexposure can result in death. Toxic to lungs and mucous membranes. Repeated or prolonged exposure can produce target organs damage [**WHO (2010a)**]. |
| Indium | LCD screens | Can be absorbed in the body by inhalation or ingestion. Is irritating to the eyes and respiratory tract may have long-term effects on the kidneys. Environment effects have not been investigated and information on its effects on human health is lacking; therefore, utmost care must be taken [**Akram R (2019)**]. |
| Chlorofluorocarbons (CFCs) | In older fridge and coolers | Found to destroy the ozone layer and is a potent greenhouse gas. Direct exposure can cause unconsciousness, shortness of breath, and irregular heartbeat. Can also cause confusion, coughing, sore throat, difficulty in breathing, and eye redness and pain. Direct skin contact with some types of CFCs can cause frostbite or dry skin [**Dekant (1996)**]. |
| Polyvinyl chloride (PVC) | Cabling and computer housing plastics contain PVC for its fire-retardant properties | Produces dioxins when burnt; causes reproductive and developmental problems, immune system damage, and interferes with regulatory hormones [**Ghosh B (2015)**]. |
| Tin | Lead-free solder | Irritates in case of skin and eye contact, ingestion, and inhalation. Can cause gastrointestinal tract disturbances, which may be from irritant or astringent actin on the stomach [**WHO (2010a)**]. |

| | | |
|---|---|---|
| Polybrominated diphenyl ethers (PBDEs) | The plastic housing of electronic equipment and circuit boards reduces flammability | High lipophilicity, and high resistance to the degradation processes. Hepatotoxicity and behavioral effects have been demonstrated. BFRs in general have been shown to disrupt endocrine system function sand may have an effect on the levels of thyroid-stimulating hormone and cause genotoxic damage, causing high cancer risk [**Tsydenova O (2011)**]. |

According to **[Arwidsson Z. (2009), Aston J. (2010), Baba A. (2010), Babu R. (2007), and Culver J. (2005)]**, the lifespan of central processing units (CPUs) has decreased from 4-6 years in 1997 to 2 years in 2005. The largest and fastest-growing industrial sector in the world is the electronics sector **[Secretariat, R. S. (2011)].** The fastest-growing waste stream in the industrialized world is now the result of rapid expansion, quick product obsolescence, and discarded electronics. After the initial phase of economic liberalization, the issues related to E-waste in India began to emerge around 1990 **[Sinha S (2007)].** While the lifespan of these items is shorter and shorter, the worldwide market for EEE has been growing tremendously over the past 20 years. Predictably, the usage of microprocessors in everyday items would rise together with the number of electrical devices on a worldwide scale. One of the fastest-growing worldwide industrial activities is the manufacture of EEE. The use and production of EEE have expanded as a result of rapid economic expansion, urbanization, and rising consumer demand [**Balabanic D (2011), Bandyopadhyay A. (2008), CPCB (2007)**]. Young people and children frequently purchase and use the majority of technological gadgets. As a result, these age groups are the primary target market for most technological products. Some of these tools are essential in the field of education, improving students' abilities and knowledge. Additionally, it helps learners in developing their educational techniques. The gadgets do, however, have significant disadvantages, especially if their usage is not restricted, just like many previous innovations [**Edgearticles (2018)**]. **[Manikkampatti Palanisamy, M., (2022)]** There have been published studies on the hydrometallurgical procedures used to extract heavy metals from discarded printed circuit board material. It was discovered that the process's sluggishness and longer processing times were limits, which led to less effective recovery and a significant impact on the recycling industry. To develop more affordable techniques for hydrometallurgical leaching followed by selective metal extraction, many types of studies have been carried out. When compared to two-step leaching, older chemical leaching methods needed substantial outlays on leaching agents, high temperatures, pressure, and procedures to be practical for serious environmental issues. Bioleaching is still in its infancy as a technique for use in industry. The bioleaching method, which is restricted by longer intervals and low yields, has many areas for further development. **[Michael C. and Sugumar RW. (2013)**] According to [Michael C. and Sugumar RW. (2013)] research, the harmful impacts that the rising amount of e-waste is having on natural resources including air, soil, and water are what is causing the world's issues today. In the current study, leachate from discarded electronic parts that had been allowed to dissolve in water samples taken from several rivers was examined for the presence of heavy metals. The findings show that even when there is a small amount of time, hazardous chemicals still have a strong tendency to leak. According to our research, as has been released to a level of 0.053 ppm, along with Cd, Cr, Pb, Hg, and 0.010 ppm. The findings show that a lot of metals have a tendency to leach, and the degree of leaching is dependent on the water's quality. The physicochemical characteristics of the water samples, such as pH, hardness, conductance, and TDS, altered as a result of leaching. Physical characteristics like viscosity and density, on the other hand, were not significantly impacted. These studies emphasize the risk of disposing of electronic waste in riverbeds, particularly when there is no or little water flow. **[Gupta M (2022)]** examined how WEEE is becoming to be a significant problem for the environment and society. The presence of dangerous metals in WEEE can harm both human and animal health. This article highlights the many E-waste recycling methods that are available, as well as the potential risks involved with recycling. In this study, we also emphasize the present and future trends that should be taken into account for recycling E-waste. Leaching of lead into groundwater may result from lead disposal. CRT may release toxic fumes into the air when it is crushed and burned, endangering the health of everyone breathing that air. If not properly managed, cadmium removed from a battery of normal size can contaminate a sizable volume of water. E-waste, if not recycled properly can leave a high impact on society and the environment, giving rise to bigger problems in the future. **[Kishore, J. (2010)]** shows that one of the world's most urgent environmental issues is the dangerous nature of E-waste. The issue is getting worse due to the rising volume of E-waste produced in conjunction with a lack of knowledge and the necessary skills. A preventative approach to the health risks of handling E-waste among these employees in India is urgently needed since a large number of workers in India are involved in the crude dismantling of these electronic products for their livelihood and their health is in danger. These employees should get the necessary training on personal safety and the proper management of E-waste. Although there are various technical options for managing E-waste, they must first meet certain requirements, such as legal requirements, collecting systems, logistics, and manpower should be prepared. This may require operational research and evaluation studies. **[Nnorom, I. C., and Osibanjo, O. (2009)]** collected waste plastic housing units (N = 60) of mobile phones (of different models, and brands), and analyzed them for Pb, Cd, and Ni, using AAS after acid digestion using a 1:1 mixture of $H_2SO_4$ and $HNO_3$. The mean (±S.D.) and range of the results are 58.3 ± 50.4 mg/kg (5.0–340 mg/kg) for Pb, 69.9 ± 145 mg/kg (4.6–1005 mg/kg) for Cd, 432 ± 1905 mg/kg (5.0–11,000 mg/kg) for Ni, and 403 ± 1888 mg/kg (5.0–12,500 mg/kg) for Ag. Approximately 90% of the results for the various metals were ≤100 mg/kg. Results greater than 300 mg/kg were generally less than 7% for each metal and could be attributed to exogenous contamination of the samples. These results suggest that there may not be any immediate danger from EOL mobile phone plastic housing if appropriately treated/managed. However, considering the large quantities generated and the present low-end management practices in most developing countries, such as open burning, there appears a genuine concern over the potential for environmental pollution and toxicity to man and the ecology. [**Olubanjo, K., Osibanjo, O., and Chidi, N. I. (2015)]** collected thirty-five (35) units of waste computer CPUs and 24 units of waste computer monitors of different brands, manufacturers, years of manufacture, and models collected from different electronic repairers' shops in Ibadan, South-western Nigeria and investigated for the lead and copper contents. The devices were disassembled and the PWB of the CPUs and monitors; and the cathode ray tube CRT of the monitor were milled and representative samples were digested with a mixture of $HNO_3$-$H_2O_2$-HCl and analyzed using AAS. The results showed very high levels of Cu and Pb in the samples with Cu concentrations ranging from 83100-705300 mg/kg for PWB of CPUs, 39150-630300 mg/kg for PWB of monitors, and 73.2-468 mg/kg for CRT. The Pb contents varied from 18060-400650 mg/kg for PWB of CPU, 8460-80850 mg/kg for PWB of monitor, and 429-9900 mg/kg for CRT. The outcomes went over the TTLC threshold that was used to classify wastes as hazardous. Adopting ineffective management techniques for these wastes might cause environmental damage and expose people to poisons. To handle these wastes as hazardous wastes, the proper steps need to be taken **[Olubanjo K (2015)**].

Electronic garbage, or "E-waste," is disposed of improperly and processed in ways that can harm both people and the environment. Today, there are more mobile phones than people in the entire planet. Our propensity to just discard items and keep buying new ones contributes to the problem of worldwide E-waste.

The environmental hazards caused by improper disposal of E-waste can be briefly described as follows:



*Source: Pro-democracy protesters hold up their mobile phones after heavy rain in Hong Kong[www.independent.co.uk]*

1. **Air Pollution:** The burning of wires releases hydrocarbons into the atmosphere.
2. **Water Pollution:** When incorrectly disposed of, harmful elements from electronic equipment, such as mercury, lead, and lithium, combine with ponds, lakes, and groundwater. The water is then inadvertently consumed by the communities that depend on those sources of water. All forms of life are at risk from these heavy metals. These heavy metals are hazardous for all forms of living beings.
3. **Soil Pollution:** As they are ingested by plants from the soil, these heavy metals make their way into the food chain. These metals not only kill plants but also other living things who eat them, creating a deadly food chain [**get-green-now**].

**10 Shocking Facts from The Global E-waste Monitor**

The Global E-waste Monitor is a yearly report on the global impact of E-waste and seeks to educate the wider public on the challenges they can help combat. We have collected 10 of the most interesting, shocking, and thought-provoking facts from the report we believe everyone should know.

1. **In 2019, 53.6 million tonnes of E-waste was produced.**

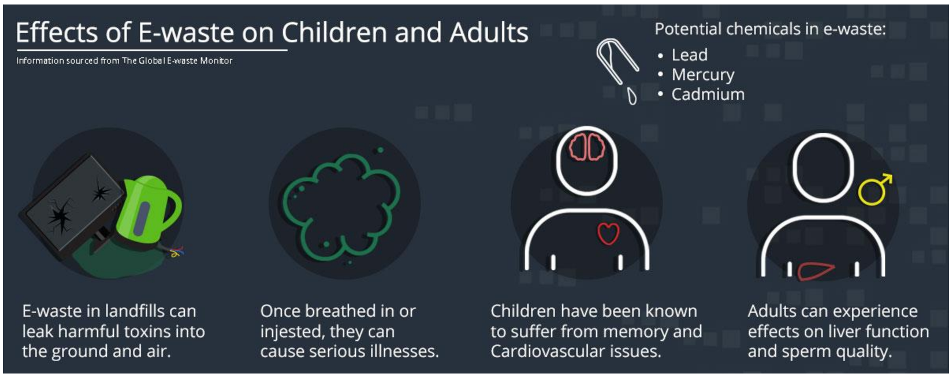
Throughout a single year, the world produced more tonnes of E-waste than the entire population of Kenya (53 million). This waste is an increase of almost 2 million tons from the previous year, the weight of 200 Eiffel Towers.

2. **Only 17% of E-waste was recycled sustainably.**

   Of the 53.6 million tons produced last year, only 17% was recycled. This means 83% of the electronic waste generated in 2019 was discarded through improper means and has the potential to be thrown into landfills where it can leak harmful toxins into the earth.

3. **Adults and children can be significantly harmed by landfills.**

   Once we dispose of an asset, we may not want to think about where it will end up next. But in reality, electronics thrown into landfills can be harmful to nearby residents. Through inhalation, skin exposure, and ingestion, toxins can cause illness which can cause brain damage and even kill those exposed to it.




*Source: Effects of E-waste on children and Adult[**Emily Graham (2020)**]*

4. **Most of our E-waste comes from everyday items.**

   Our most used items are the ones that make up a large proportion of the E-waste problem. Small equipment, such as cameras and vacuum cleaners, was one of the worst offenders, with 17.4 million tons becoming waste in 2019. This is over 10 million tons more than screens and monitors, which we usually expected to be the main culprits in E-waste.

5. **An estimated 50 tonnes of mercury is lost annually**

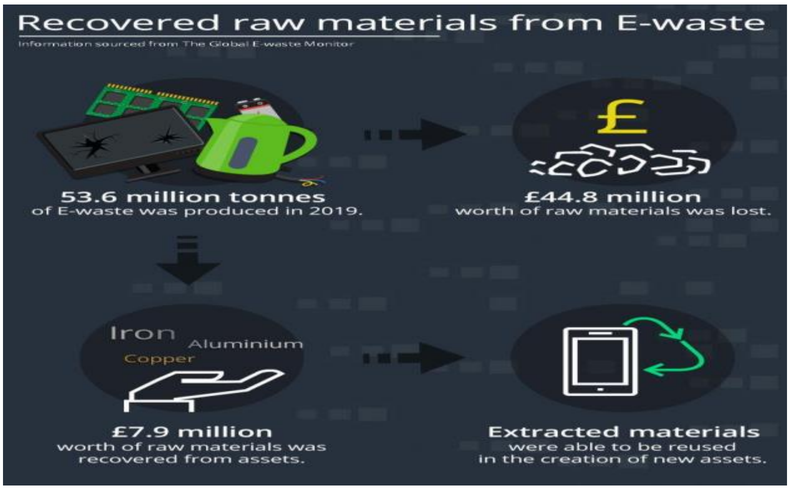
   As we mine and search the planet for resources to create new electronics, we deplete the planet's reserve. This is why reusing devices and their components are so important to preserving the world's resources and preventing the loss of valuable metals.

6. **The value of the raw materials in the 2019 E-waste stream amounts to £44.8 million**

   We may not realize it, but important metals like iron, copper, and gold reside in our devices. These are valuable assets and are recoverable through proper recycling processes at WEEE Recycling centers, where specialists extract metals from redundant elements to be reused in new equipment.

7. **£7.9 million worth of raw materials were recovered.**

Although £44.8 million was lost, £7.9 million was saved through the extraction of metals by professional recycling centers. This means that almost £8 million has been saved from landfills and lost waste flows, but this is still only less than a quarter of what was lost.




*Source: Recovered raw materials from E-waste* **[***Emily Graham (2020)]*

The current estimated amount of raw materials needed each year for the production of electronics is 39 million tonnes. Too much of this comes from mining virgin ores from our Earth, rather than extraction from E-waste.

8. **71% of the world's population is covered by a national E-waste policy, legislation, or regulation.**

   Since 2014, 17 more countries have become covered by some sort of policy, legislation, or regulation. This is a great leap forward to educating the mass public on the E-waste crisis. However, there is always more to be done, with 117 countries still without these important policies.

9. **It is estimated that the annual amount of E-waste will exceed 74 million tonnes in 2030.**

   As the increase in annual E-waste is rising steadily by 2 million tonnes per year, it is expected that in just 10 years our yearly electronic waste will surpass the weight of 203 Empire State buildings.

10. **The amount of E-waste is rising at an alarming rate.**

    The information gained from The Global E-waste Monitor each year displays the effect we have on the planet just by producing E-waste. The rate at which the world is producing electronic waste is faster than a human can count. The counter below from The World Counts displays the estimated amount of E-waste thrown out this year.

    It is important now more than ever to contribute to E-waste solutions such as recycling, reuse, and refurbishment [**Emily Graham (2020**), **Forti V. (2020)**].

**THE GLOBAL COST OF E-WASTE:**

A global ecological problem is an E-waste. It brings up issues with information security, human exploitation, and contamination of the soil, water, and air. Scavengers who burn electronic garbage to obtain copper risk polluting the air. Toxins from electronic trash can get into the ground and water systems if it is not properly disposed of. And unlike light bulbs, which were designed to fail, many pieces of E-waste are still functional and may retain data that might be used after disposal. Consumers now see functioning electronics as being inadequate or useless due to the shorter lifespans of electronic equipment, which manufacturers have promoted or engineered **[Kaya, M. (2019)].**

E-waste recycling is regulated in nations like the United States, however many products still end up in landfills. Only 29% of the E-waste produced by the $206 billion in consumer electronics purchases made in the United States in 2012 was recycled. remainderders were just thrown away [**Theatlantic (2019)**].

**COLLECTION, TREATMENT, AND DISPOSAL SYSTEMS:**

Collection, treatment, and disposal systems are critical elements of E-waste management. Most developed countries have framed conventions, directives, and laws aimed at fostering proper collection, treatment, and recycling of E-waste, as well as safe disposal of the non-recyclable components **[Gullett BK (2007)**]. These include the EPR, product stewardship, advance recycling fund (ARF), the 3Rs or Reduce, Reuse, Recycle initiative, etc. For the EU, two directives have been promulgated to place an obligation on the producers of E-goods to take back EOL or waste products free of charge to reduce the amount of waste going to landfills **[Bo B (2010)]**. However, in developing and transition countries, E-waste is treated in backyard operations, using open sky incineration, cyanide leaching, and simple smelters to recover precious metals mainly copper, gold, and silver with comparatively low yields and discarding the rest with municipal solid waste at open dumps, into surface water bodies and at unlined and unmonitored landfills **[Lepawsky J (2015)]**, thereby causing adverse environmental and health effects.

Table 3 Comparison of typical E-waste treatment processes in developed and developing countries

| **Developing countries** | **Developed countries** |
|---|---|
| Informal sector | Formal sector |
| Manual dismantling | Manual dismantling |
| Manual separation | Semi-automation separation |
| Recovery of metals by heating, burning, and acid leaching of E-waste scrap in small workshops | 0Recovery of metals by state-of-the-art methods in smelters and refineries |

*Table Source -Comparison of typical E-waste treatment processes in developed and developing countries [Nnorom IC (2005)].*

According to **[Ari, V. (2016)]**, E-waste is a growing issue in both developed and developing countries. The issue is somewhat more severe in poorer countries because of a lack of effective collection and disposal methods, awareness, and legislation. On one hand, these wastes are harmful to the environment, but on the other, they have value. They are rich in precious metals and other metals of worth. The largest sources of E-waste are personal computers, closely followed by televisions and cell phones. They need to pay quick attention to the management of E-waste in general, and their recycling and reuse in particular, as the expansion in their consumption pattern predicts a greatly increased amount. Their 3R is now required. There are several technical possibilities as a result of the research and development on their recycling. However, a thorough examination of the choices indicates that there is currently no widely recognized paradigm for the treatment of E-waste. The technique for recycling is influenced by several different elements, including the region's economic situation. There is a severe paucity of R&D activities in India for managing and recycling E-waste. E-waste is mostly made up of three different materials: glass, plastics, and metals. The glass can be remelted to make more glass or to recover lead. Plastics that thermosets are challenging to recycle. The recycling of other plastic kinds can be done to create chemicals or use them as fuel. Metals can be treated to recover specific metals after being removed from polymers. The optimum plan for recovering metals, according to some, is to use physical separation techniques followed by metallurgical processing. For the recycling of E-waste to best serve the region's interests, careful technological development must be pursued.

**Disposal system:**

E-waste is primarily disposed of through landfilling. The majority of the time, abandoned electrical products either burn publicly or wind up in landfills alongside other municipal rubbish, where they release harmful and cancer-causing gases into the atmosphere. When it comes to the safe methods used and practices, the informal sector's disposal of E-waste in developing and transitional nations is relatively primitive, leading to low material recovery. **[Yu J, (2010a)]**.

Table 4 Comparison of typical disposal systems in developed and developing countries

| **Developed countries** | **Developing countries** |
|---|---|
| Incineration with MSW | Opening burning |
| Landfill disposal | Open dumping |

*Table Source- Comparison of typical E-waste disposal systems in developed and developing countries [Puckett J (2002)]*

Developed countries manage E-waste differently than developing and transitional nations. Guidelines and education campaigns on the destiny of E-waste are lacking in developing and transitional nations. Particularly, less advanced disposal methods are employed, such as open burning, dumping, and unregulated landfill sites, which pose serious environmental contamination and workplace exposure to toxins created from E-waste. [**Babu BR ( 2007)]**. In developing nations like Brazil **[Oliveira CRD (2012)]**, China **[He W (2006)]**, and India **[Dwivedy M (2012)]**, significant obstacles to the disposal of E-waste have been analyzed. These analyses highlight the difficulty in implementing/enforcing current regulations and clean technologies, which is backed by a lack of capacity building and awareness. In contrast, wealthy nations have created expensive procedures and complex disposal plans that make handling garbage less dangerous. The lack of data prevents a complete analysis of the problem, nevertheless. This indicates that the typical socioeconomic and legal circumstances of emerging and developed nations constrain the handling of E-waste in developing and transitional countries. The regulations that guide the disposition of E-waste in developing countries are mostly fragmented and lack monitoring, while in developed countries the regulations are stringent and there is effective monitoring **[Gullett BK (2007)]**.

Both developed and developing nations are facing significant challenges in disposing of and recycling this new type of garbage. India's recycling industry may be characterized as medieval despite having some of the most cutting-edge high-tech software and hardware development capabilities in the world **[CUI J (2008)]**. E-waste management has become a matter of environmental and health concern as a result of the dumping of E-waste, particularly computer garbage, into India from industrialized nations. Certain electronic product components, as compared to normal municipal garbage, include harmful materials that pose a risk to both the environment and human health [**Culver J (2005), Bhutta KS (2011), Puckett J (2002), Puckett J (2002), Sinha-Khetriwal D. (2002)**]. For instance, toxic substances like lead, mercury, and cadmium are frequently discovered in television and computer displays, while nickel, beryllium, and zinc are frequently found in circuit boards. These compounds make recycling and proper disposal of E-waste crucial problems. E-waste recycling has become a hotly debated global issue. In this study, using China as a case study, **Zhang, K., Schnoor, J. L., and Zeng, E. Y. (2012)** analyze the environmental, economic, and social implications of E-waste recycling in the developing world. More practical approaches, taking into account local economic and social conditions and the principles of Extended Producer Responsibility, are recommended to alleviate the increasing environmental disruption from improper E-waste disposal.

Most people are unaware of the potential negative impact of the rapidly increasing use of computers, monitors, and televisions. When these products are placed in landfills or incinerated, they pose health risks due to the hazardous materials they contain. The improper disposal of electronic products leads to the possibility of damaging the environment. As more E-waste is placed in landfills, exposure to environmental toxins is likely to increase, resulting in elevated risks of cancer and developmental and neurological disorders. A major driver of the growing E-waste problem is the short life span of most electronic products- less than two years for computers and cell phones [**Widmer R (2005), Davis C. (2006)**], that has been disposed of by the users. Materials of international cycles require the 3R principle (reduce, reuse, recycle) to control the secondary resource transboundary movement which is increasing in Asian countries that have rapid economic growth [**Chao Y (2016)**]. The challenge is to effectively reduce environmental contamination at its origins, such as industrial raw materials and other relevant resources **[Cucchiella F (2014)].** According to a report from 2006, the International Association of Electronics Recyclers predicted that by 2010, somewhere in the neighborhood of 3 billion units, or an average of about 400 million units per year, would be discarded due to the growth and obsolescence rates of the various categories of consumer electronics **[Akram R (2019)]**.

## E-WASTE PROCESSING FACILITIES

Reselling is another choice. Although companies like eBay and OLX provide the means, obsolescence still makes it difficult to use used goods. Older devices wind up in landfills if makers and developers do not maintain them. Markets for the reuse of such gadgets seem promising in emerging nations with poor purchasing power. Outdated phones are already in high demand in many countries like older Nokia phones with the monochrome snake game are still in widespread **[Theatlantic (2019)].**

E-waste processing facilities are in terrible circumstances. Devices must first be painstakingly hand sorted before being dismantled. Additionally, toxic substances including mercury, lead, silver, and flame retardants are present in old electronic equipment. They also include trace amounts of precious raw materials including gold, copper, titanium, and platinum; 200 grams of gold may be found in a tonne of electrical waste. This occasionally renders the E-waste recycling industry unprofitable. Manufacturers may help create E-waste reuse facilities in underdeveloped nations rather than utilizing them as dumps, for example, to play a part in this. In 2017, it is expected that up to 50 million tonnes of electronic waste, primarily computers, and cell phones, would be discarded, according to a United Nations Environment Programme research titled "Waste Crimes." This is an increase of 20% over 2015, when roughly 41 million tonnes of electronic garbage were dumped globally, primarily in third-world nations acting as landfills**[Theatlantic (2019)]**.

To decrease electronic waste, everyone must contribute. Consumers can hold off on buying new products until they actually need them, or preferably delay doing so. When feasible, they can fix the equipment rather than throw it away. Additionally, they can discard or sell their old equipment after making a new purchase. However, consumer activism can only be so effective. Governments must control electronic waste as well as the manufacturers of the consumer devices that they profitably resell to the same customers over and over again. [**E-waste (2006)**].

## CHALLENGES AND OPPORTUNITIES

Under the scenario, the E-waste management strategy for India has the following challenges, which need to be studied and addressed more systematically and scientifically:

### Scientific challenges:

- Eco-friendly recovery solutions
  - Precious metals
  - Base metals
- Value addition to recyclables for reuse
  - Plastics
  - Glass and other recyclables
- Disposal of process waste and residues
  - Size reduction
  - Toxic reduction

### Engineering challenges

- Scientific collection, transport, handling, segregation, and disposal of E-waste
- Integrated/distributed processing facilities

◦ Unorganized to organize
◦ Involvement of SMEs and NGOs
• Feasible techno-economical solutions
◦ Processing
◦ Recycling
◦ Recovery

**Organizational challenges:**

• Appropriate definition for E-waste in the Indian context
• Inventorization of E-waste generation, import, and its characterization
• Organization and structuring of the E-waste management system
• Training and awareness on safety, health, and environment

In addition, the government's role and responsibilities are crucial for creating India's E-waste Management Strategy in terms of the flow of transboundary hazardous waste and the impact of government policies on employment in both recycling and importing nations for E-waste as well as in countries that export and import it. Furthermore, because hazardous garbage from around the world invariably ends up in places with lax environmental laws or developing economies, the unsavory aspects of recycling it would never receive the attention it deserves. The goal of the strategy should be to create and identify practical means of enhancing employment quality in India's recycling sector, where labor with little training is in abundant supply and people are starving for any source of money. Any strategy should maintain a balance between economic development, occupational and environmental health, and both **[Wath (2011)]**.

**E-WASTE ECONOMY IN THE UNORGANIZED SECTOR:**

India is ranked as Asia's second-largest producer of electronic garbage. A MAIT-GTZ **[Purushothaman M. (2020), Imported E-waste (2010)],** estimate states that India produced 110 million laptops' worth of electronic garbage in 2007, or 330,000 lakh tonnes. More than 90% of the nation's produced E-waste is recycled and disposed of on the unorganized market. The urban slums of metros and mini-metros make up the majority of the unorganized sector, where recycling activities are carried out by untrained workers utilizing the most basic techniques to cut costs. E-waste is received and handled in India similarly to how it is in China, according to a search conducted by the BAN in collaboration with the Toxic Link, or the situation might be even worse.

The unorganized sector is made up of a variety of tiny, informal companies that are not subject to strict environmental or safety regulations. Workers encounter risky working circumstances since they could not be using safety gear like gloves or masks. Some of the most hazardous dangers to both the environment and the employees have released gases, acid solutions, poisonous smoke, and polluted ashes **[MAIT (1982)]**.

To further expose themselves, their families, and the environment to harmful pollutants, many workers reprocess garbage from the comfort of their homes. For instance, to extract metals from circuit boards, gas torches are used to heat the boards just long enough to melt the solder, which then separates the metal components from the boards. Another method of obtaining metals is to manually scrape circuit boards after soaking them in an open acid bath to obtain copper and other valuable elements close to open drains. The dismantlers in this industry, who make around Rs. 100 per day, either extracting metals on their own or collaborating with a large merchant,. It cost, Rs. 230 to purchase two motherboards, each weighing one kg. After selling the metals, a 10% profit is generated. **[Secretariat, R. S. (2011), Purushothaman M. (2020), Down to Earth, (2010)]**.

Either open burning of the circuit boards or acid stripping are steps are steppedrcuit board recycling process. The chips, condensers, and capacitors must first be taken from the circuit board for both operations. Wire cutters and pliers are frequently used by children to detach the pieces from the circuit boards. Some of the Integrated Circuits (IC) chips and components are marketed for reuse after some pin straightening. The goods that are unfit for reuse are burned over open flames until they are reduced to metals. The boards themselves are burnt in an open pit to recover the remaining copper and metal solder after the chip extraction and burning. The lighter ash is removed from the ashes after burning by floating them in water. Nitric acid is used in another procedure to remove gold and platinum from circuit boards. Both approaches open burning and acid baths involve dangers to both the workers' health and the residents of the neighborhoods.

Computer displays, CPUs, keyboards, televisions, remote controls, radios, mobile phones, and other electrical appliances are sources for the circuit boards. According to estimates, Moradabad (Uttar Pradesh), commonly known as Peetal Nagri or the brass city, receives around half of the circuit boards used in Indian appliances [**Secretariat, R. S. (2011), Purushothaman M. (2020)]**

**E-WASTE ECONOMY IN THE ORGANIZED SECTOR:**

Although organized recyclers established the E-waste recycler's association in July 2009, they have only been able to take home 10% of the market share due to fierce competition from unorganized industries. In light of a sizable informal sector, one issue the organized sector is experiencing is the absence of acceptable collection and disposal systems and appropriate technology. Households and organizations can find themselves holding outdated goods in their warehouses or storerooms as a result of improper collecting systems. Even when things are exchanged or provided, they are reconditioned and then put back on the market. Electronics goods that are no longer in use make up a very minor fraction of the E-waste processing stream [**Secretariat, R. S. (2011)]**. This is the dilemma facing the 10,000 sq. ft. formal E-waste dismantling unit in Noida (Uttar Pradesh) belonging to the TIC Group India Pvt. Ltd which can process up to 500 tonnes of E-waste annually. But since June 2008, when it was launched, the unit has processed only 200 tonnes. Similarly, the Attero recycling unit in Roorkee (Uttarakhand) is a 35-crore plant that can process 36,000 tonnes of waste in a year although it is getting only 600 tonnes currently. The formal sector also lacks refineries for precious metals recovery. Therefore, according to the E-waste Recyclers' Association formed by organized recyclers in July 2009, the only way to sustain formal business in the current scenario is the license to import [**Jeyaraj P (2021)**]. The only recognized E-waste recycling plant in India that is authorized to import E-waste from wealthy nations is the Attero recycling unit. The Ministry of

Environment and Forests, Government of India, is now processing applications from other official organizations.

Thoughts on the matter of importing licenses as the only means of maintaining official business in the present situation vary. According to The Toxics Link, managing E-waste should prioritize protecting the environment over preserving commercial interests. If imports are permitted, a lot of dangerous, non-recyclable goods would be dumped in our landfills, which is not acceptable. The country produces enormous amounts of trash, thus it was essential to set up a reliable collecting system and forbid waste imports to maintain plant capacity **[Secretariat, R. S. (2011)]**.

Legal recyclers utilize ecologically friendly methods and don't use chemicals or the process of cremation in contrast to informal recyclers. International corporations that must maintain a green image and those that do not want their products to reach the grey market and compete with their new items are among the clients of formal recyclers. Contrary to the organized industry, informal traders would restore and sell a computer even if some of its components are still functional and it qualifies as E-waste. Selling any working computer component would be more profitable than selling it in its component metal form. E-waste is produced annually, and only about 10% of it is recycled; the rest is reconditioned.

Comparison of the E-waste economy between the informal and formal sectors in the table given below provides a comprehensive insight into the methods, safeguards, capital investments, and earnings involved in the E-waste business [**Diana Ceballos (2016)**.

Table 5 Comparison of the E-waste economy between the informal and formal sectors

| Informal | Formal |
|---|---|
| 1. Cathode Ray Tubes' (CRTs) are broken manually to separate their components – glass, metal, and copper. The glass, comprising lead, is sold to bakeries or bangle makers. Since it retains heat, the glass goes into the base of ovens. Phosphors, if inhaled, can be toxic. The CRTs are sold to nonbranded television makers | The components of the CRTs are separated by heating in a closed chamber, which sucks out phosphors from the components. They are then crushed in shredder machines. Glass containing lead is sold to the companies that manufacture the CRTs. |
| 2. Circuit boards have gold-plated brass pins, microchips, and condensers which are separated by heating. Fumes released during heating are toxic. Gold-plated brass pins are soaked in acid to recover the gold and brass separately. Microchips and condensers are heated in big containers filled with acid to extract metallic parts. | Circuit boards are crushed in shredder machines. They are sent to approved smelters abroad, where after smelting at 1200°C, the metals in the circuit board collect together. Since smelting is carried out in closed chambers at high temperatures, it is not hazardous. The metals-lead, copper, nickel, tin, gold, silver, and palladium-are then separated by electro-refining |
| 3. No safety precautions followed. Informal recyclers paid Rs.200-300 | Protective equipment- gloves, masks, shoes, caps- are provided to employees. |

| | |
|---|---|
| daily in Seelampur; Rs. 100-150 in Moradabad | Rs. 5,000 per month paid to unskilled workers |
| 4. Minimal capital investment is required. Cost includes the price of e-scrap, bribes to transfer it across state borders and set up and run shops, and rent for the workspace. | Investment for a dismantler is about Rs. 30 lakh and for a recycling plant, about Rs. 25 crore. |

Some support recycling E-waste while underscoring the necessity for safe recycling and the establishment of new facilities since it is an inexpensive source of raw materials and employs numerous people. At the opening of the Attero Recycling Plant in Roorkee in Delhi in January 2010, **Dr. A.P.J. Abul Kalam**, a former president of India, also commented on the advantages of safe recycling. He said: "With metal prices rising, recycling will help in sustaining our economy as it is much cheaper than extracting metals from its ore." [**E-waste (2010)**] In this regard, the UNEP study from July 2009 named "Recycling From E-waste to Resources" has examined issues linked to E-waste, including market potential for recycling of E-waste and transfer of cutting-edge technology for a chosen 11 countries, including India[**E-waste, Lok Sabha (2010)**].

**Suggestion-**

How to Reduce E-Waste and Hazardous on the Environment

The following are ten suggestions to curb these environmental hazards, reduce electronic waste, and save our planet:

**1. Sell old electronics**

- One of the best and easiest methods of reducing the electronic waste footprint is to sell or donate your electronic gadgets to those in need.
- If you are planning on selling, you should be able to easily find a buyer as they will have the opportunity to purchase the same product at a much lower price than if it were new. You get easy money while the buyer gets a nice gadget; a win-win for both.
- A good place to sell old electronics (without any fees) is Craigslist. You can sell unwanted devices by posting a local ad and meeting up with potential buyers.
- Another website you can use to sell old devices is Kijiji, which works similarly to Craigslist. Kijiji is the Canadian version of Craigslist [ **get-green-now**].

**2. Donate old Electronics:**

- Donating electronics to the needy is also a practice followed by many. It not only gives the gadget a new life but also makes you feel good about yourself.
- If you decide to donate your old electronic devices when you don’t need them anymore, make sure to clear any information (like data in your laptop hard drive) before you donate it.
- To learn more about donating gadgets safely and correctly, check out this EPA guide on donating and recycling electronics.

**3. Recycle and Dispose of E-Waste Properly:**

- Improperly disposed of E-waste is becoming more and more hazardous, especially as the sheer volume of our E-waste increases.
- For this reason, large brands like Apple, Samsung, and other companies have started giving options to their customers to recycle old electronics. Sometimes, you may even get financial compensation for recycling your old devices!
- Recycling old electronics allows the expensive electronic parts inside to be reused. This can save a lot of energy and reduce the need for mining of new raw resources, or manufacturing new parts.
- You can find electronic recycling programs in your local area by doing a Google search for "recycle electronics" and your city or area name.

**4. Maintain your Electronics**

One of the best ways to save your money and reduce E-waste is to keep your electronics well-maintained, to increase its life. Here are some tips to get you started.

***Maintaining a Laptop or Computer:***

- Make sure your PC's hard drive or SSD doesn't get full. This allows it to keep running smoothly and quickly for a long time.
- Clean your computer often so that it doesn't get dirty.
- Whenever possible, try not to overcharge your battery. This means unplugging your charger before your laptop hits 100%, which will improve your battery's overall lifespan.

***Maintaining a Mobile Phone:***

- Use a phone case and screen protector so that your phone doesn't break when you drop it.
- Similarly to laptops, keep your device clean and don't always fully charge your battery if you don't need to (This improves overall battery lifespan).

By maintaining your electronics, you save money on having to buy new gadgets when your old ones break down. You're also keeping electronics out of landfills by increasing the total lifespan of your electronic devices.

**5. Repurpose or Re-evaluate:**

Always think twice before upgrading or buying a new electronic device:

1. **Do you need this new device?**
2. **Is it a *need*, or more of a *want*?**
3. **Will it add value to your personal or professional life in any way?**

- If you answered "no" to any of the above questions, then it might be best to re-evaluate your thoughts and avoid buying them.
- To add to this, you can **repurpose old electronics that aren't useful anymore for their intended use**.
- **For example,** An old mobile phone can work as an mp3 player or even as a GPS device. Don't throw it away, think wisely![ **get-green-now**].

**6. Store Data Online:**

- Cloud services are much better than you would think in reducing your environmental impact.
- By storing data online, you get to access your data from anywhere around the world, without the need to carry a storage device at all times. Cloud storage also gives you a large amount of storage, for free or for very cheap.
- This not only offers convenience to you but **reduces the need for manufacturing new storage devices**.
- This indirectly **reduces your carbon footprint and curbs the amount of generated E-waste**.

**7. Buy Energy Star Rated Electronics**

Investing in environmentally friendly electronics has interdependent benefits.

A high Energy Star-rated device **consumes less energy, reducing your electricity bill significantly.** In addition, because less energy is required, **it keeps a check on resource (energy) depletion by avoiding over-utilization**. It indirectly saves the environment by reducing the load on resources' (energy) extraction and depletion.

When purchasing, look for electronics and appliances with the Energy Star logo.

**8. Learn to Repair Broken Electronics at Home**

- Some brands of modern electronic devices are only meant to last for a few years under regular use before failing.
- However, along with maintaining your electronic devices by cleaning them regularly to help them last for longer, you could also learn how to fix hardware problems on your device.
- Online sites such as iFixit provide free, step-by-step guides for fixing common issues across hundreds of different device models, along with pictures of the device and of the required tools for each repair job.
- Nowadays, there are also many Youtube videos teaching you how to fix a broken laptop or do a phone screen replacement yourself. Many times, all it takes is a bit of time and patience before your gadget is good as new!
- By learning to repair your electronics at home, you will gain more detailed knowledge and understanding of the hardware of your device.
- You'll also learn useful repair skills, and avoid having to travel to a professional repair shop and pay expensive fees for other people to fix your device.
- Best of all, you will be able to continue using your device for longer and won't have to throw it away [**get-green-now**].

**9. Rent Electronic Equipment instead of Buying**

- If you are planning to use a specific piece of electronic equipment for a limited period, it would be a better idea to rent it instead of buying it.
- For example, if you sparingly use industrial weighing scales for measuring, say, the weight of electronic waste, rent the scales instead of buying them.

- Renting equipment is both a cost-effective and environmentally friendly option, as you only have to pay for the duration you rent rather than buying the equipment outright and then letting it rot away after one or two uses.

**10. Spread the Word!**

- Let's say you've been faithful in your quest to reduce electronic waste. You're buying fewer unnecessary electronics and donating your outdated ones, among other things.
- You are doing your part, and that's great! Now, it's time to share your knowledge with other folks who may be less aware of the hazards of E-waste.
- Next time you see a family member improperly disposing of an old computer or buying a new smartphone for no reason, take the time and share your knowledge on the detrimental effect of their actions.
- Most importantly, give those people a reason to act on your advice. For example, if you know of a good place nearby to donate old electronics, make sure to let them know!
- One honest discussion about responsible ways to reduce E-waste has the potential to make a measurable difference both in your community and on a global scale [ **get-green-now**].

**Directions for Future Research**

Electronic waste is an emerging field and offers many directions for further research. An important, and necessary, area of research is the gathering of empirical data on the quantity of E-waste generated worldwide and the economic and environmental costs of the waste. From a business perspective, it would be interesting to study the potential of the E-waste recycling market, and the opportunities it presents. On a governmental level, further research into the applicability and effectiveness of various instruments for managing E-waste would be very useful. One of the most interesting directions for such research would be to develop a systems dynamics model of the stocks and flows that take place, and how policy interventions might affect them. Systems Dynamics lends itself well to such a study because managing E-waste requires a holistic approach keeping in mind business, social and environmental issues, and systems dynamics as a field is fundamentally multidisciplinary [**Sterman (2001)**]. Systems dynamics models make it easy to identify the stocks, flows, causal loops, and leverage points in the system [**Sterman (2001)**], which could be especially useful to design and evaluate new policies before the implementation of an E-waste management system.

## CONCLUSION

Electronic gadgets are meant to make our lives happier and simpler, but they contain toxic substances, and their disposal and recycling become a health nightmare. It has penetrated every aspect of our lives and most of us do not think about what happens to these gadgets when we discard or upgrade. The use of electronic devices has proliferated in recent decades and proportionality, the quantity of electronic devices that are disposed of is growing rapidly throughout the world **[ Needhidasan S. (2014)].**

The conditions at E-waste processing facilities are dire. Devices have to be laboriously manually sorted and then disassembled. Furthermore, used electronic devices contain hazardous materials like mercury, lead, silver, and flame-retardants. They also contain small amounts of valuable raw materials, such as gold, copper, titanium, and platinum; one tonne of electronic waste might yield 200 grams of gold. This sometimes makes the business of E-waste recycling unviable. Manufacturers have a role to play here, too: for example, by assisting in the creation of E-waste recycling centers in developing countries rather than using them as dumping sites. According to a United Nations Environment Program report titled "Waste Crimes," up to 50 million tons of electronic waste mainly, computers and smartphones are expected to be dumped in 2017. That's up 20% from 2015, when about 41 million tons of electronic waste was discarded, mostly into third-world countries serving as global landfills. E-waste-generated metals like as- As, Ba, Cd, Cr, Co, Cu, Pb, Li, Hg, Ni, PCBs, Ag, Zn, Sb, Be, In, CFCs, Sn, and PVC affect the environment and human health.

The hazardous nature of E-waste is one of the rapidly growing environmental problems of the world. The ever-increasing amount of E-waste associated with the lack of awareness and appropriate skill is deepening the problem. A large number of workers are involved in the crude dismantling of these electronic items for their livelihood and their health is at risk; therefore, there is an urgent need to plan a preventive strategy for health hazards of E-waste handling among these workers in India. Required information should be provided to these workers regarding the safe handling of E-waste and personal protection. For E-waste management many technical solutions are available, but to be adopted in the management system, prerequisite conditions such as legislation, collection system, logistics, and manpower should be prepared. This may require operational research and evaluation studies. E-waste is an emerging issue, driven by the rapidly increasing quantities of complex end-of-life electronic equipment. The global level of production, consumption, and recycling induces large flows of both toxic and valuable substances. E-waste can be toxic, is not biodegradable, and accumulates in the environment, in the soil, air, water, and living things.

This review provides a concise overview of India's current E-waste scenario, namely the magnitude of the problem, environmental and health hazards, current disposal and recycling operations, and some important suggestions.

International E-waste Day has been observed on $14^{th}$ October 2018.

- The day aims to raise awareness about the millions of tonnes of E-waste generated worldwide each year, which harms the environment and natural resources.
- Earlier this year, the Principal Bench of the National Green Tribunal (NGT) issued directions for the implementation of.

**ABBREVIATIONS:**

| | |
|---|---|
| 3R | Reduce, Reuse, Recycle |
| AAS | Atomic Absorption Spectrophotometry |
| APME | Association Of Plastics Manufacturers In Europe |
| ARF | Advance Recycling Fund |
| BAN | Basel Action Network |
| BFRs | Brominated Fire Retardants |
| BFRs | Brominated Flame Retardants |
| CRTs | Cathode Ray Tubes |
| CRTs | Cathode Ray Tubes |
| EEE | Electronic And Electrical Equipment |
| EOL | End-Of-Life |
| EPA | Environmental Protection Agency |
| EPR | Extended Producer Responsibility |
| EU | European Union |
| E-waste | Electronic Waste |
| IT | Information And Technology |
| IT | Information Technology |
| LCD | Liquid Crystal Display |
| LEDs | Light-Emitting Diodes |
| MSW | Municipal Solid Waste |
| Mt | Metric Tons |
| PAHs | Polycyclic Aromatic Hydrocarbons |
| PBB | Polybrominated Biphenyls |
| PBDEs | Polybrominated Diphenyl Ethers |
| PCB | Printed Circuit Board |
| PWB | Printed Wiring Boards |
| PCs | Personal Computers |
| PDAs | Portable Digital Assistants |
| POPs | Persistent Organic Pollutants |
| PVC | PVC (Polyvinyl Chloride |
| RoHS | Restrictions On Hazardous Substances |
| Step | Solving The E-Waste Problem |
| TEs | Trace Elements |
| TTLC | Toxicity Threshold Limit Concentration |
| UN | United Nations |
| UNEP | United Nations Education Programme |
| US | United States |
| USEPA | United States Environmental Protection Agency |
| WEEE | Waste Electronic And Electrical Equipment |
| WHO | World Health Organization |

**ACKNOWEDGMENTS**

I express my deep sense of gratitude to my Ph.D. supervisor, Prof. Susan Verghese P., Department of Chemistry, St. John's College, Dr. Bhimrao Ambedkar University, Agra for suggesting the problem, valuable guidance, encouragement and constant help during the study period.

**REFERENCES**


[1] Abbas Z (2011) WEEE/E waste management in Pakistan WEEE/E-waste management workshop on the take-back system. United Nations Environment Programme (UNEP)/International Environment Technology Centre (ITEC), Osaka

[2] Agarwal R, Ranjan R, Sarkar P. (2003) Scrapping the hi-tech myth: Computer waste in India.; Toxics Link.

[3] Akram, R., Fahad, S., Hashmi, M. Z., Wahid, A., Adnan, M., Mubeen, M., & Nasim, W. (2019). Trends of electronic waste pollution and its impact on the global environment and ecosystem. Environmental Science and Pollution Research, 26(17), 16923-16938.

[4] Andarani P, Goto N. Potential E-waste generated from households in Indonesia using material flow analysis. Journal of Material Cycles and Waste Management 2014; 16: 306-320.

[5] Ari, V. (2016). A review of the technology of metal recovery from electronic waste. E-waste in transition—From pollution to resource, 121-158.

[6] Arwidsson Z, Allard B. (2009) Remediation of metal-contaminated soil by organic metabolites from fungi II-metal redistribution. Water Air Soil Pollut.;207(4):5–18.

[7] Arya, S., & Kumar, S. (2020). Bioleaching: urban mining option to curb the menace of E-waste challenge. Bioengineered, 11(1), 640-660.

[8] Aston JE, Apel WA, Lee BD, (2010) Peyton BM. Effects of cell condition, pH, and temperature on lead, zinc, and copper sorption to Acidithiobacillus caldus strain BC13. J Hazard Mater.;184:34–41.

[9] Baba A, Adekola F, Ayodele D. (2010) Study of metals dissolution from a brand of mobile phone waste. Metalurgija – J Metallurgy;16(4):269–277.

[10] Babu BR, Parande AK, Basha CA. (2007) Electrical and electronic waste: A global environmental problem. Waste Management & Research, 25: 307-18

[11] Balabanic D, Rupnik M, Klemencic AK. (2011) Negative impact of endo cline disrupting compounds on human reproductive health. Reprod Fertil Dev.; 23(3):403–416.

[12] Balde C P, Forti V, Gray V, Kuehr R, Stegmann P (2017) The global e-waste monitor 2017: quantities, flows and resources. United Nations University, International Telecommunication Union, and International Solid Waste Association pp. 1-116

[13] Bandyopadhyay A. (2008) A regulatory approach for E-waste management: a cross-national review of current practice and policy with an assessment and policy recommendation for the Indian perspective. Int J Environ Waste Manage.; 2:1–2.

[14] Beary H. Bangalore faces E-waste hazards. (2005). Available from: news.bbc.co.UK/2/hi/south Asia/4,222,521.stm

[15] Bengtsson M (2011) Chemical hazards associated with the treatment of waste electrical and electronic equipment. Waste Manag 31:45–58

[16] Bhutta KS, Adnam O, Xia Ozhe Y. (2011) Electronic waste: a growing concern in today's environment. Economics Research International.

**[17]** Birloaga I, Veglio F (2018) WEEE characterization, division, and regulation. In 'Waste electrical and electronic equipment recycling' pp 1–12

**[18]** Bo B, Yamamoto K. (2010) Characteristics of e-waste recycling systems in Japan and China. World Academy of Science, Engineering and Technology; 62.

**[19]** Chakraborty, S. C., Qamruzzaman, M., Zaman, M. W. U., Alam, M. M., Hossain, M. D., Pramanik, B. K., & Moni, M. A. (2022). Metals in E-waste: Occurrence, fate, impacts and remediation technologies. Process Safety and Environmental Protection, 162, 230-252.

**[20]** Chao Y, Liu W, Chen Y, Chen W, Zhao L, Ding Q, Wang S, Tang YT, Zhang T, Qiu RL (2016) Structure, variation, and co-occurrence of soil microbial communities in abandoned sites of a rare earth elements mine. Environ Sci Technol 50:11481–11490

**[21]** CII. E-waste management, Green Business Opportunities. (2006); 12 (1): Confederation of Indian Industry, Delhi.

**[22]** CPCB.(2007) Draft guidelines for environmentally sound management of electronic waste. pp. 10–25

**[23]** Cucchiella F, DAdamo I, Gastaldi M (2014) Sustainable management of waste to energy facilities. Renew Sust Energ Rev 33:719–728

**[24]** Cui J, Zhang L. (2008) Metallurgical recovery of metals from electronic waste: a review. J Hazard Mater.; 158:228–256.

**[25]** Culver J. The life cycle of a CPU. (2005). http://www.cpushack.net/life-cycle-of-cpu.html.

**[26]** Das A, Vidyadhar A, Mehrotra S P. (2009) A novel flowsheet for the recovery of metal values from waste printed circuit boards. Journal of Hazardous Materials.; 53: 464 - 469.

**[27]** Dave, S. R., Shah, M. B., & Tipre, D. R. (2016). E-waste: metal pollution threat or metal resource. J Adv Res Biotech, 1(2), 14.

**[28]** Davis C. (2006) Why is electronic waste a problem? Earthtrends.

**[29]** Dekant, W. (1996). Toxicology of chlorofluorocarbon replacements. Environmental Health Perspectives, 104(suppl 1), 75–83.

**[30]** Department of Environment. The E-waste inventory project Malaysia. Department of Environment, Malaysia 2009.

**[31]** Diana Ceballos, Zhao Dong, and Marcy Franck (2016). Formal E-Recycling: The Complexity of Solving the E-waste Problem Worldwide.

**[32]** Down to Earth, (2010) 'IT's underbelly: E-waste recycling hub: Moradabad; vol.19, no.1, May 16-31, p.24

**[33]** Dwivedy M, Mittal R K (2012). An investigation into E-waste flows in India. Journal of Cleaner Production.; 37: 229–242. DOI: 10.1016/j.jclepro.2012.07.017.

**[34]** Edgearticles (2018) https://edgearticles.com/2018/07/09/essay-on-electronic-gadgets-meaning-advantages-and-disadvantages/

**[35]** Emily Graham (2020) https://s2s.uk.com/news/10-shocking-facts-from-the-global-E-waste-monitor/

**[36]** EU (2002a) EU Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE) joint declaration of the European parliament, the council and the commission relating to article 9, Official Journal L037:0024-39

**[37]** EU (2002b) EU Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE). EEA, (2003) EEA, Waste from electrical and electronic equipment (WEEE), European Environment Agency, Copenhagen

**[38]** EU (2002b). Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS). Official Journal L037, 13/02/2003 p. 19 – 23;

**[39]** E-waste causes concern, The Hindu, 23 January 2010

**[40]** E-waste, Lok Sabha Unstarred Question No. 5449, dated 28.04.2010.

**[41]** E-waste. (2006) Quarterly newsletter of Envis centre, Pondicherry pollution control committee, Pondicherry. 2006; 2 (2).

**[42]** Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). The global e-waste monitor 2020. United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam, 120.

**[43]** Ghosh B, Ghosh MK, Parhi P, Mukherjee PS, Mishra BK (2015) Waste printed circuit boards recycling: an extensive assessment of current status. J Clean Prod 94:5–19

**[44]** Ghosh S, Mahesh P. E-waste: (2007) Flooding the city of joy. Study on E-waste in Kolkata.

**[45]** Greenpeace. Report on Recycling of electronic wastes in China & India: Workplace & environmental contamination. (2005).

**[46]** Greenpeace: The E-waste problem. (2006).

**[47]** Gullett BK, Linak WP, Touati A, Wasson SJ, Gatica S, King CJ. (2007) Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations. Journal of Material Cycles and Waste Management; 9: 69-79.

**[48]** Gupta, M., Ashok, K., Upadhyaya, V., & Nigam, S. (2022). Metal Recovery from E-waste by Recycling Techniques: A Review. In 2022 8th International Conference on Smart Structures and Systems (ICSSS) (pp. 1-5). IEEE.

**[49]** Ha, N. N., Agusa, T., Ramu, K., Tu, N. P. C., Murata, S., Bulbule, K. A., & Tanabe, S. (2009). Contamination by trace elements at E-waste recycling sites in Bangalore, India. Chemosphere, 76(1), 9-15.

**[50]** Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European Union and the world in 2005. Journal of industrial ecology, 19(5), 765-777.

**[51]** Hageluken C. (2006) Recycling of electronic scrap at Umicore's integrated metals smelter and refinery. Erzmetall.; 59: 152–161.

**[52]** He W, Li G, Ma X, Wang H, Huang J, Xu M, Huang C.(2006) WEEE recovery strategies and the WEEE treatment status in China. Journal of Hazardous Materials; B136: 501-512.

**[53]** Hilty, L.M. (2005) Electronic waste – an emerging risk? Environmental Impact Assessment Review, 25, 431–435.

**[54]** https://get-green-now.com/reduce-ewaste-hazards

**[55]** https://gradesofgreen.org/welcome-to-launch/launch-toolkit-e-waste-drive/

**[56]** https://www.geeksforgeeks.org/what-is-E-waste/

**[57]** https://www.independent.co.uk/tech/there-are-officially-more-mobile-devices-than-people-in-the-world-9780518.html

**[58]** https://www.istockphoto.com/photo/computer-scrap-metal-and-iron-dump-gm172201150-3439290

**[59]** Huang K, Guo J, Xu Z. (2009) Recycling of waste printed circuit boards: A review of current technologies and treatment status in China. Journal of Hazardous Materials.; 164: 399–408.

**[60]** Hurst C (2010) China's rare earth elements industry: what can the West learn?. Institute for the Analysis of Global Security Washington DC pp 1–42

**[61]** Imported e-waste seized by customs officials, The Times of India, 20 August, 2010.

**[62]** Iqbal M, Syed JH, Breivik K, Chaudhry MJI, Li J, Zhang G, Malik RN (2017) E-waste driven pollution in Pakistan: the first evidence of environmental and human exposure to flame retardants (FRs) in Karachi City. Environ Sci Technol 51:13895–1390

**[63]** Jeswani, H. K., Smith, R. W., & Azapagic, A. (2013). Energy from waste: carbon footprint of incineration and landfill biogas in the UK. The International Journal of Life Cycle Assessment, 18, 218-229.

**[64]** Jeyaraj, P. (2021). Management of E-waste in India–Challenges and recommendations. World Journal of Advanced Research and Reviews, 11(2), 193-218.

**[65]** Jinhui L, Brenda N L N, LiliL, Nana Z, Keli Y, Lixia Z (2013) Regional or global WEEE recycling. Where to go? Waste Manag 33:923–934

**[66]** Joseph K. (2007) Electronic waste management in India - Issues and strategies. In: Proceedings of Sardinia, Eleventh International Waste Management and Landfill Symposium; S. Margherita di Pula, Cagliari, Italy.

**[67]** Karla V. (2004) An article UNEP recognises the E-waste problem in Asia-Pacific, published on June 26, 2004.

**[68]** Kaya, M. (2019). Electronic waste and printed circuit board recycling technologies. Springer International Publishing.

**[69]** Kimberley M.(2007) An article E-waste in India: A Growing Industry and Environmental Threat, Published on September 10. http://www.treehugger.com/ files/2007 /10/E-waste_in_india.php.

**[70]** Kishore, J. (2010). E-waste management: as a challenge to public health in India. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine, 35(3), 382.

**[71]** Kumar R, Shah DJ (2014) Review: current status of recycling of waste printed circuit boards in India. J Environ Prot 5:1–9

**[72]** Ladou, J., & Lovegrove, S. (2008). Export of electronics equipment waste. International journal of occupational and environmental health, 14(1), 1-10.

**[73]** Lee C-H, Chang S-L, Wang K-M, Wen L-C. (2000) Management of scrap computer recycling in Taiwan. Journal of Hazardous Materials; A73: 209–220.

**[74]** Lee J-C, Song H T, Yoo J-M. (2007) Present status of the recycling of waste electrical and electronic equipment in Korea. Resources, Conservation and Recycling.; 50: 380–397.

**[75]** Lee, S. G., Lye, S. W., & Khoo, M. K. (2001). A multi-objective methodology for evaluating product end-of-life options and disassembly. The International Journal of Advanced Manufacturing Technology, 18(2), 148-156.

**[76]** Lepawsky J.(2015) The changing geography of global trade in electronic discards: Time to rethink the problem. The Geographical Journal; 181: 147-159.

**[77]** Li J, Lu H, Guo J, Xu Z, Zhou Y. (1995) Recycle technology for recovering resources and products from waste printed circuit boards. Environmental Science and Technology. 2007; 41.

**[78]** M. N. Mundada , sunil kumar & a. V. Shekdar (2004) E-waste: a new challenge for waste management in India, International Journal of Environmental Studies, 61:3, 265-279,

**[79]** Maharashtra Pollution Control Board (MPCB). Report on assessment of electronic wastes in Mumbai-Pune area. (2007).

**[80]** Mahesh P. (2007) E-waste: WEEE other side of the digital solution.; Toxics Link Factsheet No: 31.

**[81]** MAIT (1982) was set up in 1982 for purposes of scientific, educational and IT industry promotion in India. Deutsche Gesellschaft Fuer Technische Zusammenarbeit or GTZ has been active in India on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). GTZ cooperates with the Central Government and various State agencies with its priority areas for cooperation being sustainable economic development, energy, environmental policy and conservation and sustainable use of natural resources.

**[82]** MAIT (2013) annual ITOPs study. Indian IT Hardware Industry.

**[83]** MAIT. (2004) Worldwide ICT diffusion trends.; 12.

**[84]** MAIT-GTZ (2007) study. E-waste assessment in India: Specific focus on Delhi. (2007).

**[85]** MAIT-GTZ, (2019) Study Reveals Extent of E-waste Challenge, Press Release.

**[86]** Manikkampatti Palanisamy, M., Myneni, V. R., Gudeta, B., & Komarabathina, S. (2022). Toxic Metal Recovery from Waste Printed Circuit Boards: A Review of Advanced Approaches for Sustainable Treatment Methodology. Advances in Materials Science and Engineering, 2022

**[87]** Material Safety Data Sheet (MSDS)(2005) Material safety data sheet listing.

**[88]** Mehta P (2019) E-waste, chemical toxicity, and legislation in India. In advanced methodologies and technologies in engineering and environmental science. IGI Global pp 144–156

**[89]** Michael, C., & Sugumar, R. W. (2013). Studies on leaching of heavy metals from E-waste. Orient J Chem [Internet], 29(3), 1149-54.

**[90]** Mmereki, D., Li, B., Baldwin, A., & Hong, L. (2016). The generation, composition, collection, treatment and disposal system, and impact of E-waste. E-waste in Transition-from Pollution to Resource, 65-93.

**[91]** Needhidasan, S., Samuel, M., & Chidambaram, R. (2014). Electronic waste–an emerging threat to the environment of urban India. Journal of Environmental Health Science and Engineering, 12, 1-9.

**[92]** Nnorom IC, Osibanjo O. (2008) Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. Resources, Conservation and Recycling; 52: 843-58.

**[93]** Nnorom, I. C., & Osibanjo, O. (2009). Toxicity characterization of waste mobile phone plastics. Journal of hazardous materials, 161(1), 183-188.

**[94]** OECD.(2001) Extended producer responsibility: a guidance manual for governments. Paris7 OECD.

**[95]** Oertel, B., Wölk, M., Hilty, L.M. & Köhler, A. (2005) Risks and opportunities of the use of RFID systems. Bundesamt für Sicherheit in der In., Bonn.

**[96]** Oliveira CRD, Bernardes AM, Gerbase, AE.(2012) Collection and recycling of electronic scrap: A worldwide overview and comparison with the Brazilian situation. Waste Management; 32: 1592-1610.

**[97]** Olubanjo, K., Osibanjo, O., & Chidi, N. I. (2015). Evaluation of Pb and Cu contents of selected parts of waste personal computers. Journal of Applied Sciences and Environmental Management, 19(3), 470-477.

**[98]** Osuagwu OE, Ikerionwu C (2010) E-cycling E-waste: the way forward for Nigeria IT and electro mechanical industry. Int J Acad Res 2: 142–149.

**[99]** Puckett J, Byster L, Westervelt S, Gutierrez R, Davis S, Hussain A, Dutta M. (2002) Exporting harm: The high-tech trashing Asia. Basel Action Network (BAN) and Silicon Valley Toxics Coalition (SVTC).

**[100]** Puckett J, Westervelt S, Gutierrez R, Takamiya Y. (2005). The digital dump: Exporting re-use and abuse to Africa.

**[101]** Purushothaman, M., Inamdar, M. G., & Muthunarayanan, V. (2020). Socio-economic impact of the e-waste pollution in India. Materials Today: Proceedings. doi:10.1016/j.matpr.2020.05.242

**[102]** Rademaker JH, Kleijn R, Yang Y (2013) Recycling as a strategy against rare earth element criticality: a systemic evaluation of the potential yield of NdFeB magnet recycling. Environ Sci Technol 47:10129– 10136

**[103]** Ramesh S, Joseph K. (2006) Electronic waste generation and management in an Indian city. Journal of Indian Association for Environmental Management.; 33 (2): 100–105.

**[104]** Robinson B. (2009) E-waste: An assessment of global production and environmental impacts. Science of Total Environment; 408: 183-191.

**[105]** Robinson WS (2009) Ecological correlations and the behavior of individuals. Int J Epidemiol 38:337–3

**[106]** Sanjay J. Ten states contribute 70% of e-waste generated in India. 2008. The Financial Express. Available from: archive.financialexpress.com/news/ten-states-contribute-70-of-ewaste-generated-in-India/283,644 [Accessed on 2008 March 13].

**[107]** Schafer, T., van Looy, E., Weingart, A. & Pretz T. (2003) Automatic separation devices in mechanical recycling processes. In: Proc. International Electronics Recycling Congress, 13–15 January.

**[108]** Schluep M, Hagelueken C, Kuehr R, et al (2009) Recycling, from E-waste to resources. UNEP DTIE; StEP Initiative

[109] Secretariat, R. S. (2011). E-waste in India. India Research Unit (Larrdis), Rajya Sabha Secretariat, New Delhi, 1-122.

[110] Sinha S, Wankhade K, Siha-Khatriwal D. (2007) Mumbai: Choking on E-waste. A study on the status of E-waste in Mumbai.

[111] Sinha S. (2006) E-waste: Challenges and opportunities in India. Toxics Dispatch No: 29.

[112] Sinha, D. (2004). The management of electronic waste: a comparative study on India and Switzerland. St. Gallen7 University of St. Gallen.

[113] Sinha-Khetriwal D. (2002) The management of electronic waste: A comparative study on India and Switzerland. St. Gallen, Switzerland: M.S. thesis, University of St. Gallen.

[114] Sinha-Khetriwal, D., Kraeuchi, P., & Schwaninger, M. (2005). A comparison of electronic waste recycling in Switzerland and in India. Environmental Impact Assessment Review, 25(5), 492-504.

[115] StEP.(2005) Solving the E-waste problem: a synthetic approach (StEP), Draft Project Document; http:// step.ewaste.ch

[116] STERMAN, J. D. (2001). Systems Dynamics Modeling: Tools for Learning in a Complex World. California Management Review, 43, 4.

[117] Theatlantic (2019) https://www.theatlantic.com/technology/archive/2016/09/the-global-cost-of-electronic-waste/502019/

[118] Theo L. (1999) Integrated recycling of non-ferrous metals at Boliden Ltd. Ronnskar smelter. In: Proceedings of IEEE International Symposium on Electronics and the Environment;. P. 42–47

[119] Tiwari M, Sarkar J. (2008) India may become outsourcing hub for E-waste management.

[120] Tong X, Li J, Tao D, Cai Y. (2015) Re-making spaces of conservation: Deconstructing discourses of E-waste recycling in China. Area.; 47 (1): 31–39.

[121] Tsydenova O, Bengtsson M (2011) Chemical hazards associated with treatment of waste electrical and electronic equipment. Waste Manag 31:45–58 Tsydenova O,

[122] Tue N M, Sudaryanto A, MinhT B, Isobe T, Takahashi S, Viet P H, Tanabe S (2010) Accumulation of polychlorinated biphenyls and brominated flame retardants in breast milk from women living in Vietnamese E-waste recycling sites. Sci Total Environ 408:2155–2162

[123] Umair S, Björklund A, Petersen EE (2015) Social impact assessment of informal ecycling of electronic ICT waste in Pakistan using UNEP SETAC guidelines. Resour Conserv Recycl 95:46–57

[124] UNEP (2009) Basel convention on the control of transboundary movements of hazardous wastes and their disposal. United Nations Environment Programme. http://www.basel.int/

[125] UNEP (2010) A report: Recycling from E-waste to resources, 2010. Released by United Nations Environment Programme (UNEP); 2010. February 22, 2010.

[126] Van Yken, J., Boxall, N. J., Cheng, K. Y., Nikoloski, A. N., Moheimani, N. R., & Kaksonen, A. H. (2021). E-waste recycling and resource recovery: A review on technologies, barriers, and enablers with a focus on Oceania. Metals, 11(8), 1313.

[127] Wang R, Xu Z (2014) Recycling of non-metallic fractions from waste electrical and electronic equipment (WEEE): a review. Waste Manag 34:1455–1469

[128] Wang Y, Luo C, Li J, Yin H, Li X, Zhang G (2011) Characterization of PBDEs in soils and vegetations near an E-waste recycling site in South China. Environ Pollut 159:2443–2448

[129] Wath, S. B., Dutt, P. S., & Chakrabarti, T. (2011). E-waste scenario in India, its management and implications. Environmental monitoring and assessment, 172, 249-262.

[130] WEEE, (2001) Waste Electronic and Electrical Equipment (WEEE) Survey, Ireland

[131] Wei L, Liu Y. (2012) Present status of E-waste disposal and recycling in China. Procedia Environmental Sciences.; 16: 506–514.

[132] Widmer R, Oswald-Krapf H, Sinha-Khetriwal D, Schnellmann M, Böni H. (2005) Global perspectives on E-waste. Environ Impact Assess Rev.; 25(5):436–458.

[133] World Health Organisation (WHO) (2010a) Exposure to arsenic: a major public health concern.

[134] World Health Organisation (WHO) (2010b) Exposure to cadmium: a major public health concern.

[135] World Health Organisation (WHO) (2010c) Exposure to lead: a major public health concern.

[136] www.alamy.com/e-waste-categories-brochure-template-image417854161.html

[137] Yamane LH, Moraes VT, Espinosa DCR, Tenório JAS (2011) Recycling of WEEE: characterization of spent printed circuit boards from mobile phones and computers. Waste Manag 31:2553–2558

[138] Yu J, Williams E, Ju M, Shao C. (2010a) Managing E-waste in China: Polices, pilot projects and alternative approaches. Resources, Conservation and Recycling.; 54: 991– 999.

[139] Zeng X, Song Q, Li J, Yuan W, Duan H, Liu L (2015) Solving E-waste problem using an integrated mobile recycling plant. J Clean Prod 90: 55–59

[140] Zhang K, Schnoor J L, Zeng E Y. (2012) E-waste recycling: Where does it go from here? Environmental Science and Technology.; 46: 10,861–10,867.

[141] Zhang M,ShiJ, MengY, GuoW, LiH, Liu X, Zhang Y, GeH, Yao M, Hu Q (2019) Occupational exposure characteristics and health risk of PBDEs at different domestic E-waste recycling workshops in China. Ecotoxicol Environ Saf 174:532–539.