

# Electronic Waste: A Critical Non-Renewable Pollutant

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## Abstract

*E-waste is an indirect and unexpected waste that affects people, animals and the environment through contamination of air, soil and water. The distribution and long-term storage of electronic waste can have serious impacts on environmental resources. India is the largest energy consumers and are also responsible for the increase in energy and energy waste. Therefore, this article focuses on a detailed description of e-waste management in India, including the recycling process and its consequences. What makes this review article unique is the discussion of legal documents and information from various periods of India. It also provides readers with adequate information about various aspects of the increase in e-waste and methods to manage it. Therefore, it provides sufficient information to reduce consumers' energy consumption and manage factories. In addition, it will also help policymakers involved in shaping India's future e-waste policy. Electronic products/devices that have reached the end of their useful life are considered electronic waste (e-waste). Electronic products can be dangerous or toxic that many people are unaware of; therefore, it should be disposed of carefully when not needed. All of the products are harmful to the environment. E-waste contains rich materials that can be used and recycled, such as copper, gold, silver and platinum. However, the loss of these resources results from improper disposal and accelerates the decline of natural resources. Burial and incineration of e-waste causes many types of pollution and has a significant impact on human health. New technologies are used to manage these wastes efficiently and effectively. However, the management of various types of waste still faces many problems and challenges. The purpose of this section is to describe different types of waste and their impact on the environment. It also explores new technologies for waste management and the challenges faced during waste management.*

**Keywords:** E-waste, Environmental impacts, Policy, Legal instruments, Health impacts, Pollution

## INTRODUCTION

The rapid growth and decline in costs of electronic products has led to a major change in the way consumers are exposed to new electronic products and digital technologies. Mobile phone and internet usage has increased dramatically in the last decade. According to the Digital 2020 report [106], there are 5.15 billion mobile phone users and 4.57 billion internet users worldwide as of July 2020. Approximately 60% of people in the world use mobile phones and the internet. It is clear from the report

that the number of mobile phone and internet users increased by 2.4% and 8%, respectively, compared to the previous year's data [106]. Today's machines have many uses and make life easier. The rapid proliferation of electronic devices worldwide will have an impact on the environment due to the large amount of e-waste. With the development of e-commerce, the proliferation and availability of electronic products has led to global pollution.

Electronic waste (E-waste) is the fastest growing waste in the world [107]. E-waste can be collected

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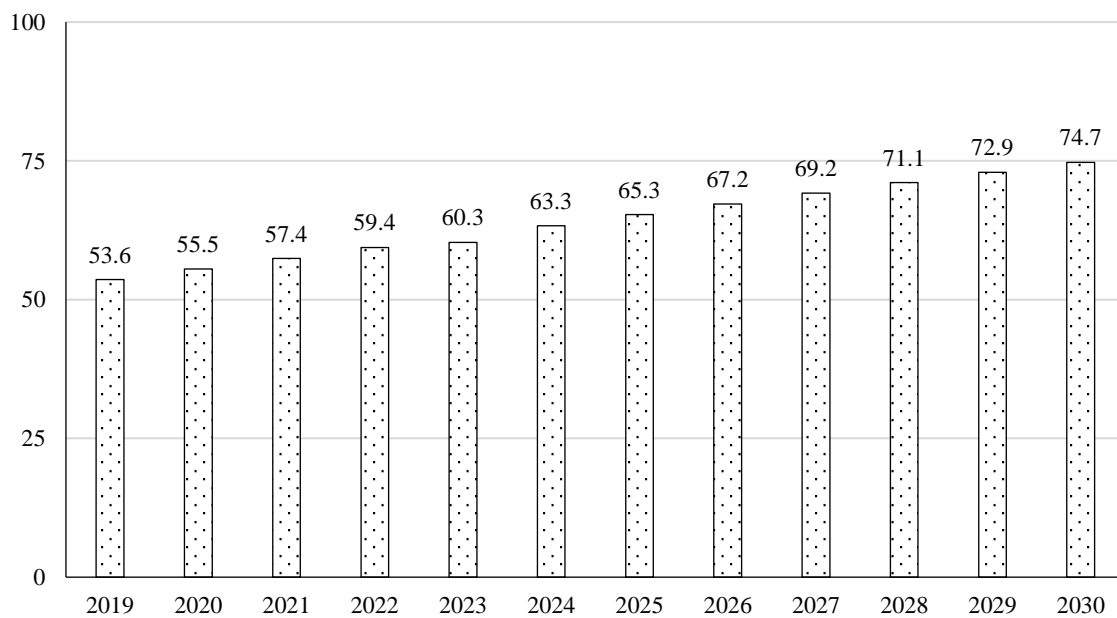
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from simple household appliances, [105], phones, batteries, small electronic devices used in transportation, medical devices and security. In today's life, people need these devices to make their work easier and more efficient. The above restrictions not only increase e-waste, but also increase something else, as shown in Figure 2. According to the 2020 Global E-Waste [3] Monitoring Report [1], e-waste was estimated at 53.6 million tonnes in 2019, of which 17.4% was effectively collected and recycled, the remaining 82%. The global amount of e-waste is expected to reach 74.7 million tons by 2030. Global e-waste [9] forecasts for the next few years are shown from the collected literature as shown in Figure 3 [1]. Approximately 50 million tonnes of e-waste are produced worldwide each year; Developed countries in Europe and the United States produce more e-waste per capita. Asia currently produces the most waste, at approximately 24.9 million tonnes, followed by the US and Europe. However, when looking at per capita consumption, Europeans produce 16.2 kg per capita, Americans 13.3 kg, and Asians 5.6 kg per capita. China regulates e-waste and divides e-waste into 14 categories. In addition, China has reduced its WEEE [2,7,11] imports in recent years [108]. Japan and South Korea have established e-waste regulations; Japan became the first country to implement a renewable energy (EPR) policy. India has its own e-waste policy but produces approximately 2.4 kg of waste per capita [1].



**Figure 2.** Major reasons for increasing the e-waste.



**Figure 3.** Global forecasting of e-waste.

E-waste contains many small and complex components such as CFCs, arsenic, barium, cadmium, cobalt, copper [15], lead, lithium, mercury, nickel, PCBs, selenium, silver, zinc and other chemicals. From e waste [5] metals [4] can be recovered [16-42] such as iron, lead, gold and copper [15] etc. [1,109]. In many developing countries, there are problems in the distribution of e-waste due to its complexity, and the recycling of e-waste [13] has become more difficult due to the increased use of electricity from electronic and fire products. Although many countries have implemented various measures to properly manage e-waste, most e-waste remains in landfills, incinerated, exported to developing countries, or discarded by illegal workers [110]. E-waste [5] contains hazardous substances that can harm human health and the environment [8] unless authorized by personnel through appropriate procedures. Workers engaging in unauthorized activities due to mismanagement of e-waste will be affected as workers will not have proper protective clothing. It also affects people living near the landfill and burning area [111].

Countries like India are experiencing great difficulties due to their large populations and high energy consumption. There are already some articles on e-commerce management in the literature [10]. But there is not a single review article focusing on India's new legal documents and knowledge base. Therefore, this article focuses on a detailed description of e-waste<sup>12</sup> management in India, including the recycling process and its consequences. The main purpose of this article is to discuss legal documents and information that appeared at different times in India. It is very difficult to accurately predict the cost of e-waste in the next few years because it depends on many factors. However, the annual consumption of electrical and electronic devices can be considered as an estimate.

In the second section, the situation of stakeholders regarding various dimensions of e-waste is explained in detail. E-waste does not directly harm humans and animals. E-waste [5] will have serious impacts on the environment due to its large accumulation and long-term pollution. Changes in biogeochemical cycles and their effects on all living things on Earth. Biogeochemical cycles in ecosystems are mainly affected by improper burial and incineration of e-waste. Therefore, various methods are used to treat e-waste [5]. India is one of the top five countries in the world in terms of e-product production. Therefore, a serious action plan is needed to be discussed regarding the e-waste situation and management [14] in India.

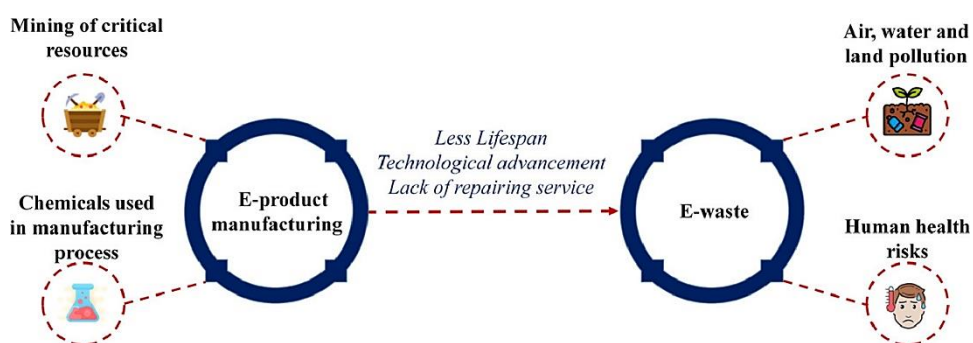
### Contributors of E-waste

E-equipment mainly includes small and large electronic equipment, monitors and displays, heat transfer equipment, lamps and IT and communications equipment. Table 1 shows examples of each group of programs for e-waste [1].

**Table 1.** Contribution of e-waste based on the different categories.

Category	Examples	Contribution of e-waste(million metric tons)year 2019
Small equipment	Irons, Toasters, Luminaires, Radio sets, Microwave oven, Ventilation equipment, Vacuum cleaners, Clocks and Watches, Digital cameras, Electric kettles, Video cameras	17.4
Large equipment	Large medical devices, Large monitoring and control instruments, Photovoltaic panels, Cookers, Electric stoves, Large computer mainframes, Large printing machines, Washing machines, Clothes dryers, Dish washing machines	13.1
Monitors and screen	Televisions, LED/LCD, Monitors, Tablets, E-Book readers, Laptops	6.7
Temperature exchange equipment	Heat pumps, Freezers, Air-conditioners, Refrigerators	10.8
Lamps	CFL, Fluorescent lamps, Pressure sodium lamps, Metal halide lamps, LED lamps	0.9
Small IT and telecom equipment	Mobile phones, Printers, Routers, Personal computers, Telephones, GPS and navigation equipment	4.7

According to the 2020 Global E-Waste Research Report, the percentage of e-waste in the screens and monitors category in 2014 decreased by only 1% according to available data, while the percentage of other groups increased. Contribution of e-waste [1]. From a design perspective, the emergence of new energy products pollutes the environment. Figure 1 shows the recontamination of the environment from electronic products to e-waste. First, energy production from specialty metals such as gold, cobalt, and palladium that can be harvested through mining requires more land, water, and energy [111]. Additionally, the operation of electronic equipment requires a large number of chemicals that can release harmful gases and cause pollution. For example, the LCD panel must be fluorinated greenhouse gases with an atmospheric lifetime of 3000 years. Surprisingly, this oil has the potential to warm the earth 1000 times more than natural gas.



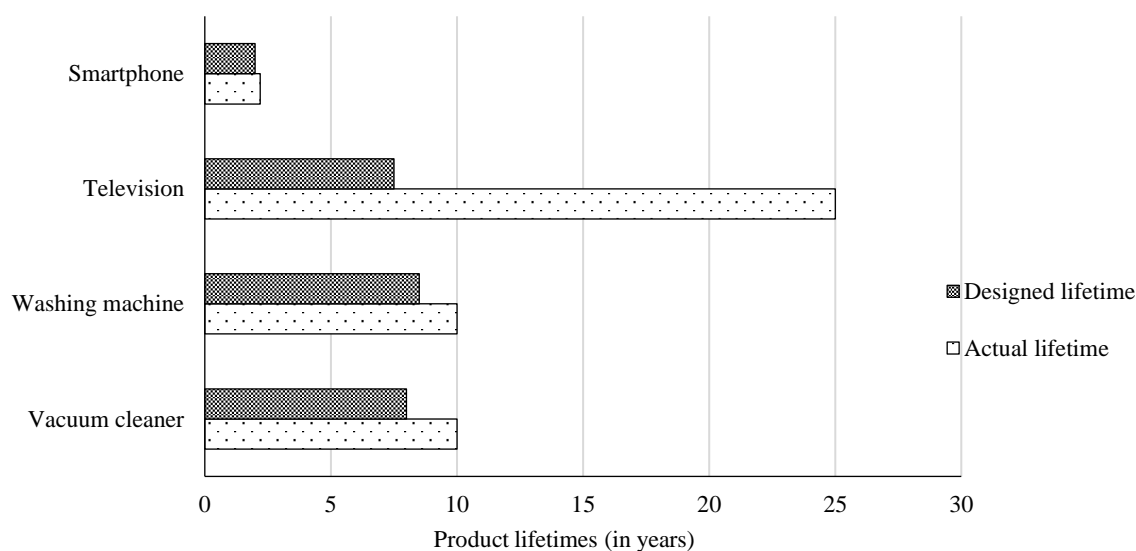
**Figure 1.** Graphical Representation of E- waste.

Secondly, the shortening of the lifespan of electrical equipment due to the advancement of technology causes the existing electrical equipment to change [1]. Failure to take necessary precautions for special electronic products directly affects the consumer's purchase of new products, causing an increase in the demand for the production of special electronic products. From the above discussion, it is clear that e-waste can be generated by producing more energy and consumers using more energy. Therefore, it will affect the environment and harm human health. Technological advances are also necessary for today's world, but they also need to take environmental issues into consideration to make people rethink [112].

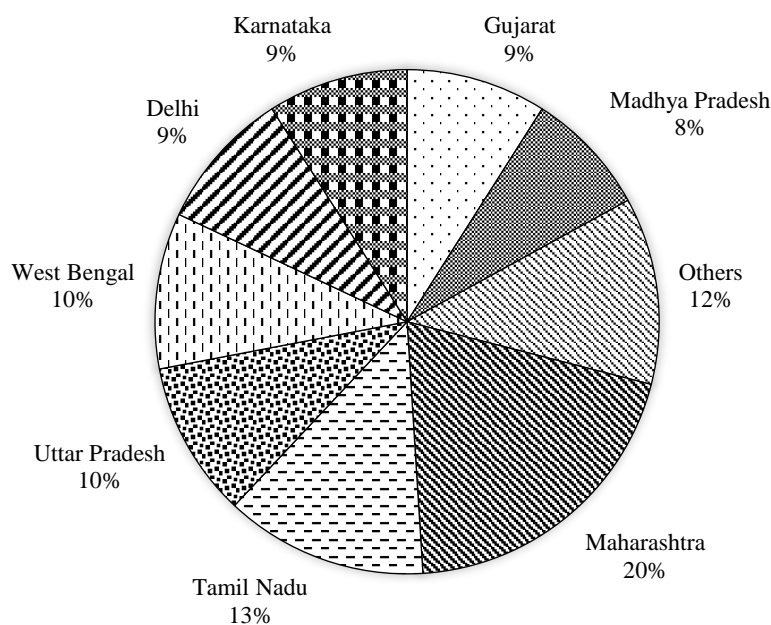
According to the European Environment Agency report [1], the actual life and design life of four major electronic products, including smartphones, TVs, washing machines and vacuum cleaners, are compared with that shown in Figure 4. It is worth noting that real life is always less than the conceived life. Figure 4 clearly shows that the actual lifespan of LCD TVs is far from the designed lifespan due to backward technology. Technological obsolescence is when a product appears obsolete to consumers due to the introduction of new products with improved features or the use of materials (such as mixing together) that make the product incompatible with recently developed software. LCD TV design should include approximately 30% plastic, 34% metal, 22% glass, 6% electricity, 5% aluminum, 2% copper and 1% other materials. Due to the large volume of the LCD, it feels heavy around. Additionally, the LCD accounts for half of the 300kg weight. Emissions per year, which is an estimate of greenhouse gas emissions over the entire life cycle of the same product [1]. The increased use of new products due to technological developments and the lack of indirect treatment [6] services have led to increased consumer awareness (lack of knowledge about e-waste) and the impact of e-waste on air, water and soil during disposal has increased and recycling.

Considering the e-waste recycling process in India Figure 5, only 5% of e-waste is collected and recycled, 95% is done by the unorganized sector. Many children and young people are involved in the collection and processing of e-waste, including 450,000 child workers aged between 10 and 14. Without safety precautions, prolonged exposure of waste products during recycling can cause serious damage to the nervous system, skin diseases, cancer, heart disease, liver disease, respiratory disease and brain disease. In 2018, the percentage of e-waste in India was 4.56 times the country's annual e-waste capacity. The cost of e-waste continues to increase due to lack of information on disposal and recycling

methods. The major electronic devices driving the rise of e-commerce in India are desktop computers, smartphones, laptops and televisions. According to the Economic Times e-magazine, India is one of the world's leading users of smartphones in terms of sales, usage and network usage [115]. More than 70 of the 83 solid metals in the content period are required to create today's smartphones [111]. Processing these metals directly affects the environment. Considering urban areas, it is seen that 4 out of every 20 mobile phone users have 4G, 11 have 3G and the remaining users have basic phones. This allows the country's telecommunications industry to continue to develop, but will face social problems in the [116].



**Figure 4.** Actual lifetime of electronic appliances.



**Figure 5.** Contribution of E-waste at different states in India.

#### Contribution of E-waste at PCMC Area

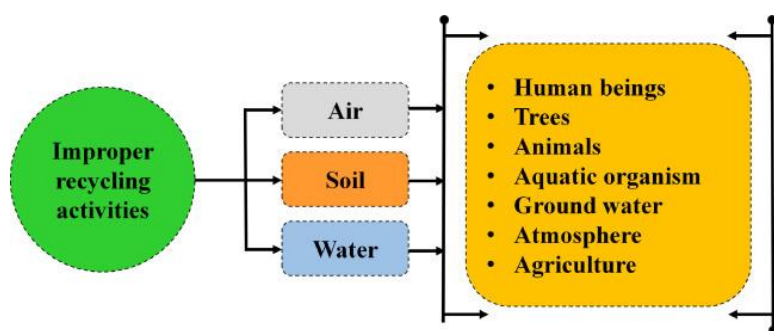
In 10 hours of work, 900 kilograms of mobile phones and USB cables, nearly 1,000 mobile phones (including the latest iPhone models), 17 LCD TVs, a total of 50 CPUs and UPSs, and garbage were collected, in the jurisdiction of the Pimpri-Chinchwad Municipal Corporation (PCMC) on Sunday. At the end of the day, the volunteers weighed in with more than 2.5 tonnes of collected waste.

### Environment Concerns and Health Hazard

Approximately six million workers are employed in the e-waste and recycling process in sweatshops and non-participating factories in India. Improper disposal of e-waste will affect the environment and harm people. There are many types of e-waste and the emissions from e-waste are numerous. E-waste can be classified into hazardous and non-hazardous categories [117]. Generally speaking, e-materials include glass, wood, printed circuit boards, batteries, ferrous (steel, iron) and non-ferrous metals (aluminium, copper and lead), concrete, rubber, ceramics, rare earths and other precious metals (gold) is found. More than 1 million poor people are involved in the recycling process. Most of them live in cities and do not know the dangers of e-waste [118]. 90% of e-waste in India is generated from three categories of WEEE [2,7,11], which include electrical appliances, household appliances, and information and communication equipment [119]. Chemicals are also part of e-waste and affect human health [120]. The main toxic substances and their effects on human health are shown in Table 2. Figure 6 shows all the reasons for the use of bad energy sources. The impact of imported energy sources was explained in the previous section. As seen in Figure 6, air and water are the main pollutants. Therefore, the potential of e-waste to cause air and water pollution is explained below. Environmental impact assessment (EIA) and life cycle assessment were used to assess the environmental impact of e-waste [114]. examines the importance of EIA in reducing environmental pollution caused by e-products from the perspective of researchers. Additionally, needs for improving EIA stages processes and procedures and suggestions for the future are discussed. On the other hand, life cycle assessment and product flow assessment were taken into account to estimate the environmental impact of printed circuit board e-products in Malaysia [113]. According [113], direct incineration with energy recovery is considered the best e-waste technology.

**Table 2.** Causes of chemical substances due to e-waste.

Chemical substances	Availability	Causes
Lead	Computer monitors, PCB, Glass panels	Central and peripheral nervous systems, kidney, blood systems, children's brain development, reproductive systems
Mercury	Thermostats, relays, sensors, PCB and measuring equipment, flat panel displays	Kidney, brain
Cadmium	Infra-red detectors, semiconductor chips, batteries, toys and plastics	Kidney, respiratory systems
Chromium IV	Corrosion resistant used for coating electro-galvanized steels and individual components (Screws, rivets, switches, plugs, antenna and other accessories)	Damage to DNA
PVC	Cables, computer housings	When incinerated, it will emit toxic fumes which damage the immune system & pulmonary dysfunction
Beryllium and non-sparking tools, gears and cogs in aviation industry	Used with copper and nickel to produce electrical contacts, gyroscopes, spot-welding electrodes, springs,	Chronic beryllium disease, skin disease
Antimony	Batteries, semiconductors	Irritation of eye and skin, stomach pain, diarrhea
Arsenic	Integrated circuit and semiconductors	Affects digestive tract, lung cancer, skin cancer.
Phthalates	Plastic enclosures, cables, wires, and connectors	Damage to liver and kidney
Barium	Ceramics, automobile, electronic tubes and glass	Short term exposure to barium can cause liver, cardiac or spleen damage
Dioxins & Furans	Older transformers, capacitors, fluorescent lighting fixtures, electrical devices	Damage immune and hormone system



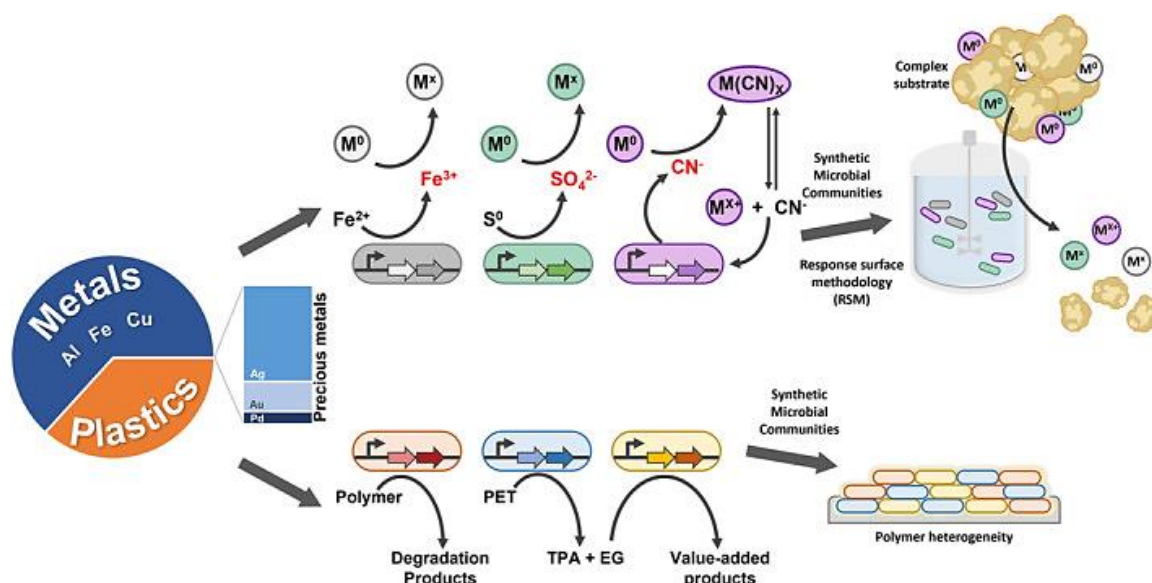
**Figure 6.** Effect of pollution due to informal activities of e-waste.

### E-waste Disposal Methodologies

Most electronic waste is disposed of in landfills and incinerators. E-waste is also exported from developing countries to developing countries. In recent years, many countries have banned e-waste exports and established e-waste separation laws. E-waste disposal methods such as disposal, acid baths, incineration, leaching, recycling and reuse are widely followed.

### Future Suggestions for e-waste Management in India

Due to mismanagement of e-waste and recycling of e-waste, major problems arise in terms of environmental impact and health. It pollutes Figure 6 soil, agriculture, groundwater, marine life and air. To reduce the above impacts, all countries should establish laws and regulations to address e-waste and proper e-recycling. It is recommended to pay more for recycled materials to reduce illegal recycling. However, India has enacted various laws to regulate the use of hazardous substances in the manufacturing of electrical and electronic equipment. It is recommended that electrical and electronic products in shops or factories be strictly inspected regularly to check the content of defective products. India should reduce its imports of electronic products because imported products will not be able to cope with the impact of e-waste in the future.

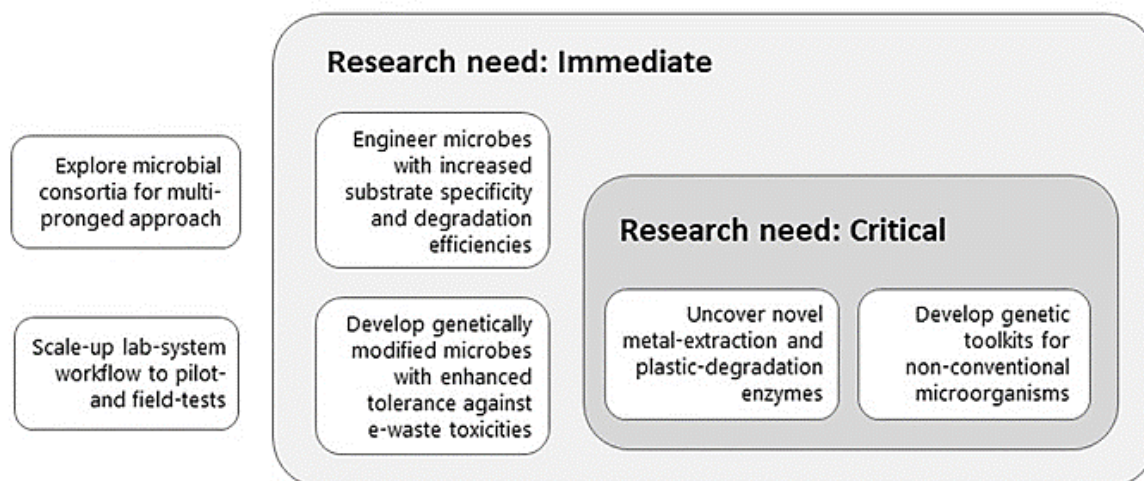


**Figure 7.** Biologically engineered microbes for E-Waste Disposals.

Manufacturers must provide the names of collection centers or companies dealing with the collection and recycling of e-waste, including contact information such as address, phone number and email. Cashiers and retailers should be monitored for compliance with current regulations. If the agency violates the law and is fined, this must be done. Most recycling in India is done manually in small shops, homes and often with bare hands. The existence of low-cost labor and unregulated business and

environment have enabled illegal activities to flourish in society. For this reason, it is necessary to monitor the disposal of e-waste from illegal activities and make recommendations after legal activities. In addition, awareness in the unregistered sector needs to be increased in order to reduce the unregistered sector.

### Research need: Near Future



**Figure 8.** Roadmap to addressing the research needs to overcome technological gaps in the advancement of bioremediation of e-waste using biologically modified microorganisms.

Biological methods [43-105] to obtain valuable products from e-waste appear to be safe and effective compared to traditional methods such as mechanical and chemical methods. Bacteria such as *Acidithiobacillus* spp., *Sulfobacillus* spp., *Pseudomonas* spp. can recover alkalis (copper, iron, nickel, lead, zinc) and precious metals (silver, gold, cobalt, palladium, platinum) from e-waste (Figure 7). In particular, the acidophilic group of bacteria plays a prominent role in bioleaching [28-31] in e-waste due to their lenience towards heavy metals. Implementation of bio laws in developing countries will take longer, but this appears to be associated with environmental pollution. The informal sector plays a significant role in processing large amounts of e-waste and most of the workers employed in this informal sector are below the poverty line. Therefore, it is important to establish waste management policies that take into account economic conditions and health measures that will minimize illegal activities in the future.

## CONCLUSION

There is no doubt that e-waste is the biggest waste in the world. In this review article, the sources of e-waste, the importance of e-waste management, and the dangers and benefits of metals in e-waste are discussed. This article also examines the annual increase in e-waste and the environmental and health impacts associated with illegal e-waste and recycling. Different e-waste disposal methods and their advantages are discussed. Detailed information on dismantler/recycler in various states is provided. This article focuses on the rules, guidelines and regulations in India. The main points of each rule are discussed separately. Based on the analysis of various factors, future recommendations have been made to improve the situation of e-waste in India and increase consumer awareness about electronic waste and products. The municipal waste collection law was enacted in 2000. Separation of waste cannot be done only by workers. This is an equal responsibility to the customer. Because they need to be disposed of as waste in an appropriate place. Therefore, home consumers need to raise awareness about electronic waste disposal. In addition, local e-waste collection points should be increased and always open so that consumers can easily dispose of their e-waste. Despite the progress, bioremediation of e-waste using bioengineered microorganisms is still in its infancy and there is still a lot of research Figure 8 and development to be done before the technology can be commercialized. Progress has been made in

increasing cellular tolerance to e-waste toxicity, meeting the need to recycle more metals in a single process, and improving the efficiency of biofiltration. Therefore, streamlined processes from production to the end user should be created accordingly.

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