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Impact of E-waste on Human Health and Environment

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ABSTRACT

Electronic waste, or e-waste, is a rapidly growing global issue, with 62 million tons generated in 2022 and an expected increase to 82 million tons by 2030. The improper disposal of e-waste poses significant environmental and health risks due to the presence of toxic substances like lead, mercury, and cadmium. These pollutants can contaminate soil, water, and air, causing severe health problems, including neurological damage, kidney issues, and cancer. Informal recycling practices in developing countries exacerbate these issues. Responsible e-waste management is crucial to mitigate these risks and promote sustainable practices. This review investigated the impact of es-waste on human health and environment. Findings from this study reveals that E-waste exposure has severe environmental and health consequences. When electronic devices are disposed of in landfills, they release toxic chemicals like lead, mercury, and cadmium, contaminating soil, water, and air. These pollutants pose significant risks to humans and wildlife, causing reproductive and neurological disorders, cardiac problems, and cancer. Workers in e-waste recycling facilities are particularly vulnerable, suffering from respiratory problems, skin burns, and toxic poisoning. Informal recycling practices exacerbate these issues, highlighting the need for responsible e-waste management. Communities near disposal sites are also at risk, experiencing increased health problems due to contaminated water, soil, and air. The environmental impact is equally alarming, with e-waste contributing to soil pollution, groundwater contamination, and air pollution. Sustainable e-waste recycling practices can mitigate these risks, promoting environmental protection and public health. Proper disposal and recycling of e-waste are crucial to preventing these adverse effects. The impact of e-waste on the environment and human health is a pressing concern. Toxic substances from discarded electronics contaminate soil, water, and air, causing severe health problems. Responsible e-waste management, including proper disposal and recycling, is crucial to mitigate these risks. Sustainable practices can reduce environmental pollution and protect public health, emphasizing the need for global cooperation and awareness to address the growing e-waste problem effectively. Proper action is essential now

Keywords: *E-waste, Human health, Environment, Electronic waste management, and hazardous materials.*

Introduction

Electronic garbage is rapidly becoming one of the world's most rapidly expanding solid waste streams [1, 2]. The global production of electronic garbage in 2022 was over 62 million tons. Only 22.3% of the material was formally collected and recycled, as reported by [3].

Economic and technological progress ensures a steady stream of new devices, rendering older ones obsolete and contributing to the trash cycle. In 2019, there was a 21% rise from 2015 to an estimated 53.6 million metric tons of e-waste generated globally. This exemplifies the rate of technological development. Particularly noteworthy are regional disparities in the generation of e-waste; 46.4% of the world's e-waste is produced in Asia, with the Americas coming in second with 24.4% [4, 5]. People sometimes assume that huge industrial equipment is the main source of e-waste, but in reality, the majority of it originates from quickly broken consumer and business devices. As an example, the rise in popularity of digital currencies like Bitcoin has led to a rise in the use of specialized computers called "miners" to verify transactions. The gadgets' hardware needs frequent replacement due to wear and technological advancements [6]. The discarded parts become cumbersome and hefty once they have passed their expiration date. There are potentially harmful and valuable materials in these discarded electronics, including computers, cellphones, appliances, and more. All countries are affected, even though it's disproportionately produced in high-income regions; for instance, India generates millions of tons per year at the moment [7].

The issue of e-waste management is growing in importance due to the exponential growth of e-waste on a global scale. Prospects for material recovery and the problems in handling e-waste are crucial to sustainable manufacturing [8]. According to [9], there are precious metals like copper, silver, and gold that can be found in e-waste and used in new industrial methods. While several countries have adopted different approaches to managing electronic trash, Switzerland was an early pioneer in creating novel methods for doing so. Recycling in Switzerland is overseen by organizations such as the Swiss Foundation for Waste Management and the Swiss Association for Information, Communication, and Organization Technology through the Producer Responsibility Organization [10, 11]. Developed countries, like the US, have stricter regulations for controlling e-waste than poorer nations. Stronger legislation is still necessary for developing nations to adequately address the increasing problem of e-waste. Recycling in an eco-friendly manner has not been widely used, even though it is a potential solution to the problem of electronic waste [12].

What makes e-waste so important is the danger it poses. According to [13], e-waste poses a significant risk to both human and environmental health. When you throw out old electronics, you're likely to find elements like lead, mercury, cadmium, chromium, arsenic, and persistent organic compounds like PCBs and flame retardants. When these pollutants permeate the ground, water, and air, they endanger ecosystems and people's health. For example, according to [14], there is evidence linking open burning and polluted runoff to respiratory illnesses, cancer, and environmental damage in exposed communities. Because there aren't many rules in place to protect workers and the environment, e-waste contaminants end up in local water, soil, air, and dust [15, 16]. Some chemicals are known or suspected to cause developmental neurotoxicity. There is serious concern about neurodevelopmental impairments in children residing in e-waste recycling communities, as they may have been exposed to high-level toxicant combinations for their entire lifetimes [17].

Mutations in the reproductive system brought on by these chemicals' exposure through the digestive, respiratory, or cutaneous systems can lead to long-term health problems or even birth abnormalities [18]. Particularly at risk are pregnant women, infants, and young children due to the link between e-waste pollution and illnesses like obesity, asthma, and neurodevelopmental abnormalities [19]. Among the well-documented health consequences include reduced lung capacity, stunted growth, lower cognitive development, and adverse pregnancy outcomes (stillbirth, preterm birth, and low birth weight) [20]. Nickel, a known carcinogen, is a persistently harmful element in the human body [21]. Furthermore, there is mounting evidence that a higher risk of cancer is associated with increasing levels of thallium, nickel, and mitochondrial DNA damage. It is now well acknowledged that e-waste poses significant threats to both the environment and human health, necessitating prompt action.

An in-depth examination of how e-waste impacts ecosystems and human health is the objective of this article. Examining worldwide generation trends and management strategies, it will identify the primary barriers to e-waste control, including infrastructure, policy, and awareness. We will go over the hazards of e-waste toxicants like lead, mercury, cadmium, arsenic, and flame retardants in detail, including how they cause harm and what effects they could have on human health. The evaluation will look at environmental impacts including water and soil contamination and biodiversity loss as well as documented health impacts like children's neurological impairments and respiratory difficulties in recycling communities. We will discuss the risks associated with informal recycling procedures. Finally, solutions to reduce the impact will be evaluated, including public education campaigns, improved formal recycling technology, and encouraging regulatory actions. Ultimately, this analysis aims to inform public health, environmental policy, and waste management stakeholders on the primary dangers posed by e-waste, as well as to pinpoint areas where further research is needed and provide workable solutions to lessen the impact of this trash on people and the planet.

E-waste Generation and Management

The amount of electronic trash generated on a global scale has been rising due to the quick pace of technological advancement. Annual global e-waste production is estimated to be 50 million tonnes, according to research [22]. A report from the Basel Convention states that 66 percent of the global population is safeguarded by laws regarding electronic trash [23]. Recovering resources from e-waste involves burning or illegally selling 40 million tonnes of it annually, with only 20% of that material really being recycled. The e-waste laws and the Basel Convention have not prevented this. Around 62 Mt, or 7.8 kg per person, was produced in 2022, as reported by [24]. The US, Europe, Japan, China, and India are the top five contributors. For example, in 2019, the majority of the world's electronic trash (46.4% of total) came from Asia, with only roughly 24.4% coming from the Americas [25]. A research found that India generates 146,000 metric tons of electronic garbage annually, which is equivalent to 5-10% of the global total [26]. Common examples of such items are medical equipment, home appliances, office supplies, and consumer electronics. Consumption habits impact these numbers; developed countries tend to throw away electronics more often, while developing nations see a rise in waste due to increased availability. The typical yearly growth rate of e-waste is 3 to 5% [27, 28], due to reasons including shorter product lifespans and increasing gadget proliferation.

The management of electronic trash is now a combination of formal and informal processes. Formal recycling facilities are those that are regulated and have the required equipment to deconstruct and recover materials. Many industrialized nations have instituted systems to collect and recycle e-waste; for example, manufacturers in the European Union are obligated to do so by the WEEE law [29]. The two directives that the European Union passed to address the growing concerns about e-waste were the Waste Electrical and Electronic Equipment (WEEE) directive and the Restriction on the Use of Hazardous Substances (RoHS) directive. All new electrical devices must comply with the RoHS rule, which forbids the use of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers. As per the WEEE requirement, producers must organize the collection and recycling of electronic trash, often known as "take-back"[30]. [31] reported that worldwide collection rates for e-waste are still poor, with only approximately 17-22% of it being technically recycled. Incorrect management of the remaining trash occurs frequently. While some countries in the developed world choose to bury or burn their trash, recycling rates in 2007 were just 18% in the US [32]. Unlawfully exported or traded goods make up a significant amount. Worldwide, between 60% and 90% of electronic waste is either illegally traded or discarded every year [33]. This illicit flow frequently reaches low-income nations, taking advantage of their lax regulations and cheap labor [34].

Key challenges hampering effective e-waste management:

I. Inadequate infrastructure: Treatment facilities, transportation networks, and collecting centers are lacking in many areas. Inadequate collection infrastructures and a lack of consumer awareness regarding the possibilities for recycling electronics make it difficult to recycle WEEE efficiently, which poses a big problem to the recycling business as well [35]. Hazardous materials and heavy metals are the main reasons why many systems find it difficult to handle e-waste effectively. Since WEEE is frequently seen as a production expense, many systems choose the least expensive disposal techniques. More sustainable practices are being mandated by governments, yet many businesses still struggle to meet these standards [36]. Electronics are frequently thrown into the regular trash by consumers in the absence of specialized e-waste programs.

ii. Regulatory Gaps: Significant volumes of e-waste have been transferred to poor nations and recycled in nearby cities and villages using antiquated methods, notwithstanding the Basel Convention's regulations governing the transboundary transportation of hazardous waste [37, 38]. Many countries lack a comprehensive e-waste strategy, whereas some (such as the EU and parts of Asia) have legislation regulating recycling and restricting dangerous compounds [39].

iii. Low level of public awareness: Customers frequently don't understand why or how to discard devices. E-waste risks and recycling choices are widely unknown, according to studies.

iv. Economic Factors: Because of the complicated disassembly and environmental controls, recycling e-waste is expensive. Many systems choose less expensive disposal techniques as a result of this financial burden [40]. On the other hand, illicit recycling can make money off of precious metals, providing financial incentives to keep up risky behaviors.

Together, these elements make managing e-waste a significant task. Because of this, the majority of discarded electronics are not handled securely, which increases the danger of environmental contamination and health issues.

Toxic Substances in E-waste

Numerous chemical components found in electronic equipment can be dangerous if released. For instance, according to [41], a single cell phone may contain more than 40 distinct elements, such as rare earths and heavy metals. Among the most common toxicants found in e-waste are:

I. Lead (Pb): One of the most extensively researched developmental neurotoxins is lead (Pb), which is also regrettably one of the main toxicants found in e-waste. Lead causes oxidative stress and disrupts neurotransmitter pathways in cells. Children that are exposed to even low levels of lead have behavioral issues, concentration impairments, and a lower IQ [42, 43]. Cathode-Ray Tube (CRT) glass, batteries, and solder all use it. According to [44] and [45], an old CRT television may contain between 1.5 and 2 kg of lead.

ii. Mercury (HG): Due to its use in cell phones, laptop monitors, cold cathode fluorescent lamps, and printed circuit boards (such as switches and relays), mercury (Hg) can be released into the environment in its elemental vapor form when e-waste is not properly recycled [5]. Even though there are only trace amounts (less than 1-2 g) in each device, informal recycling can leak elemental mercury vapor or change it into methylmercury in water bodies. Methylmercury bioaccumulates in fish and is extremely poisonous. The development of the fetal brain is seriously endangered by mercury's easy passage across the placenta [6].

iii. Cadmium (Cd): A component of semiconductor chips and Ni-Cd batteries. Chronic exposure to cadmium causes bone demineralization and renal failure as it builds up in the kidneys and bones. According to [7], children who are exposed to high levels of cadmium during pregnancy have lower cognitive function. excessive cord blood Cd in babies may indicate excessive maternal exposure, although during the first trimester, the placenta reduces the amount of Cd transferred from mother to fetus. According to [8], these babies might also have postnatal exposure to cadmium in the same mother's home.

iv. Arsenic (As): Certain alloys and semiconductors contain arsenic (As). In addition to causing vascular and skin damage, arsenic is a well-known carcinogen that can cause skin, lung, and bladder cancers. Neurological impairments and delayed development have been associated with arsenic pollution in e-waste recycling regions [9].

v. Chromium (Cr): Metal coatings are protected against corrosion by chromium (hexavalent, Cr^6+). Cr^6+ is a respiratory carcinogen that, at high exposure levels, can induce liver and kidney damage as well as lung cancer [10]. Living close to recycling facilities has been linked to elevated chromium levels.

vi. Brominated Flame Retardants (e.g. PBDEs): Circuit boards and polymers are treated with brominated flame retardants (PBDEs, for example) to lessen their flammability. Fat bioaccumulates these persistent organics. Research on animals indicates that PBDEs affect learning and memory and interfere with thyroid hormone signaling [11]. High levels of PBDE have been linked to endocrine disruption and developmental abnormalities in humans.

Each of these chemicals affects living things in its own unique way. Lead and methylmercury are only two of many heavy metals that can induce oxidative stress; studies have shown that these metals can increase levels of reactive oxygen species in the brain, which can harm neurons [12]. Because lead mimics calcium in neurons, it can disrupt synaptic processes. Besides being an oxidative stressor, cadmium has the ability to substitute zinc and impede several processes. Since brominated retardants are structurally similar to thyroid hormones, they can attach to hormone receptors and alter endocrine function [13]. Taken together, these mechanisms clarify how e-waste's minute chemical concentrations can inflict harmful effects on living organisms. Electronic trash poses a significant danger to ecosystems. Incorrect disposal, such as illegally depositing trash in open landfills or water bodies, can significantly degrade soil and water quality. According to [14], when electronic waste breaks down or is burned, it releases harmful chemicals into the environment. These compounds contaminate our water, soil, and air, making them unsafe to drink or be around.

In addition, the release of harmful particulate matter into the air from burning e-waste raises the danger of cancer, chronic diseases, and environmental damage. When e-waste breaks down, it can release harmful elements into the soil, including lead, mercury, and cadmium. This can harm local ecosystems and populations as well as the land plants rely on for growth. Incorrect disposal techniques, such as illegally dumping e-waste on open ground or sending it to landfills, put public health and food safety at danger by allowing toxic metals and flame retardants to seep into soil and groundwater. Soil contamination weakens crops, making them more susceptible to pollution absorption, which in turn reduces agricultural output and puts consumers' health at risk [15]. Large particles are often released into the environment when e-waste is burned, shredded, or disassembled; these particles settle quickly and worsen contamination. Soil contamination is conditional on several factors, including soil type, temperature, pH, and composition.

Impact of E-waste on Human Health

Toxicity from e-waste has been connected to a number of health issues. Key effects are discussed below.

I. Neurological damage: E-waste contains heavy metals, which are strong neurotoxins. According to [16], children's brain development may be hampered by exposure to lead and mercury from polluted dust, soil, or food. Numerous studies have demonstrated that a 2–3 IQ point drop is linked to every 10-μg/dL increase in blood lead content [17]. According to [18], e-waste pollution increases the risk of neurodevelopmental abnormalities and cognitive impairment in babies and fetuses [19]. Additionally, neuronal signaling and memory can be affected by toxic chemical substances (PCBs, PBDEs, etc.). Chronic exposure to e-waste emissions can cause headaches, mood swings, and memory loss in adult workers.

ii. Respiratory problems: Air pollution is a result of informal e-waste processing. Merely 18% of e-waste is gathered for recycling in the US; the other 80% is dumped in landfills, and 2% is burned. According to [21], metal may leak from e-waste in landfills. Fine particulate particles and harmful chemicals (furans, dioxins, and brominated substances) are released when plastics or wiring burn [22]. Inhaling these contaminants impairs respiratory function and promotes inflammation in the lungs. Asthma and lung capacity are lower in areas near e-waste operations, according to [23]. Acid-leaching and open fire fumes can irritate airways and over time may lead to cancer or chronic bronchitis.

iii. Reproductive and developmental effects: Pregnant women who are exposed to chemicals from e-waste run the chance of having a bad baby. Research has connected maternal exposure at recycling facilities to increased incidence of low birth weight, preterm delivery, and stillbirth [24]. Lead and mercury, for example, can build up in fetal tissue since many e-waste compounds pass the placenta. This exposure during crucial developmental windows can result in learning, motor, and behavioral impairments that last a lifetime. Continued exposure in young children (by contaminated dust, dirt, or breastmilk) puts their immunological and neurological development at much greater risk [25].

In conclusion, e-waste contains harmful materials that pose actual health risks. According to epidemiological research, children who live in informal recycling communities have higher blood levels of lead and cadmium as well as more neurobehavioral problems [26, 27]. Chronic exposure patterns in these areas highlight how crucial it is to reduce e-waste contaminants in order to safeguard public health.

Table 1. Health Impact in e-Waste exposed populations

Location/Population	Pollutants Measured	Exposure Levels / Findings	Health Outcome
Children near informal sites	Blood Pb ≥ 5 μg/dL	High prevalence of lead exposure	↓Cortisol; behavioral & IQ deficits [28]
Informal e-waste workers	Musculoskeletal & CNS complaints	Headache (29 %), numbness (20 %), skin disorders (31 %)	Neurological, skin, and musculoskeletal issues [29]
General e-waste communities (review)	Multiple heavy metals and organics	Elevated pollutant levels in dust, soil, air	Respiratory and cardiovascular risk elevated [29]

Environmental Impact of E-waste

E-waste contaminants harm ecosystem health and environmental quality in a number of ways:

I. Soil and Water Pollution: Toxic chemicals seep from abandoned devices into soils and waterways. Rainfall or dumping causes metals and organics to leach into ground and surface water [30]. Alarmingly high levels of lead, mercury, cadmium, arsenic, PCBs, and other contaminants have been discovered in soils and sediments close to e-waste sites by empirical investigations conducted in China and India. POPs produced or subsequently released during recycling are released into the atmosphere because of their semi-volatile nature. In Antarctica, researchers have reported a variety of POPs [31]. The study found that harmful substances emitted in the early phases of recycling e-waste can have permanent and long-lasting effects. Crops and aquatic life may absorb these pollutants, allowing them to enter the food chain. For instance, crops cultivated in polluted soil may accumulate heavy metals, which could endanger people and wildlife indirectly. Groundwater close to disposal sites frequently contains more hazardous metals than is safe, demonstrating how long-term leaching can contaminate freshwater sources.

ii. Air pollution: Toxins are released into the atmosphere when e-waste is burned and melted outdoors. Dioxins, furans, brominated chemicals, and small particles are released when plastics and wires burn [32]. The air quality in nearby towns may be impacted by these persistent pollutants since they can travel great distances from the site. Combustible persistent organic pollutants (POPs) have the ability to spread far and contaminate far-flung ecosystems. As previously mentioned, breathing in this contaminated air can lead to respiratory ailments in both humans and animals, as well as the deposition of poisons on soil and vegetation downstream.

iii. Biodiversity Loss: E-waste contamination can change environments and decrease biodiversity over time. For plants, insects, and animals, toxic runoff and polluted air produce unfavorable conditions. For example, when water bodies are overloaded with PCBs and heavy metals, fish are killed and crustaceans and amphibians have a lower chance of reproducing. Toxins can accumulate in terrestrial wildlife by ingestion of contaminated soil or prey. Ecosystem degradation around major e-waste hubs has been observed in recent research. According to one analysis conducted in India, e-waste contaminants in soil and water are "aggravating environmental pollution and ecosystem degradation" [33]. Significant contamination was found in nine out of 10 cities, according to recent research by [34], highlighting the alarming levels of e-waste pollution in India. The study demonstrated how e-waste affects individuals thousands of miles away in both rural and urban regions, having a profound effect on air quality. Such contamination has the potential to reduce biodiversity and change the species composition over time, favoring organisms that can withstand pollutants.

To put it briefly, improper e-waste disposal pollutes the ecosystem. Persistent pollutants and heavy metals build up in soil and water, harming biological populations and decreasing ecosystem resilience.

Informal Recycling Practices

Many developing countries dispose of their electronic garbage in unregulated and informal methods. Acid baths are used to leach metals from circuit boards, insulated wires are burned to recover copper, and gadgets are disassembled by hand with screwdrivers and hammers. In informal recycling operations like as disassembly, cutting, heating, acid leaching, and burning, workers and residents in small town and village workplaces are exposed to dangerous metal combinations and other pollutants [35]. Examples include acid leaching, which can directly release heavy metals into water and soil, and burning wires, which can create dense clouds of black smoke containing dioxins and lead [36, 37]. Many times, workers don't wear protective gear while handling dangerous dust and fumes.

Environmental and human health are under grave danger. [38] and [39] note that rapid urbanization and economic expansion in Lagos, Nigeria, have led to an increase in electronic use, which in turn has caused substantial e-waste problems. These concerns impact human health as well as the environment. Pollutant hotspots are often found in the areas immediately surrounding informal recycling workshops due to the high amounts of toxicants in the dust and dirt [40, 41]. Lead, mercury, and cadmium levels in the blood of pregnant women and children who work or scavenge in these areas are greater than those of local controls. Worldwide, millions of women and children could be exposed to harmful materials if they recycle in this manner, according to the World Health Organization [42, 43].

Accidental injuries are also common, particularly those involving explosives and sharp objects. A study conducted by [44] found that unregulated, crude recycling practices pose a risk of "serious contaminations of local air, dust, soil, and water" and result in "dire environmental consequences." However, facilities that are specifically built to minimize pollutants and ensure the safety of employees are utilized in formal recycling. Competent personnel run filters, shredders, and chemical treatments in controlled environments. There are a lot of risks connected with informal handling, thus many experts say that safe, formal techniques should be implemented gradually.

Establishing regulated e-waste facilities with occupational safety regulations (such as masks, gloves, and ventilation) is one way to greatly reduce exposures. Enhancing training and supervision of employees is equally crucial [45]. Eliminating the risky outdoor pursuits practiced by the unorganized sector is, ultimately, a crucial step toward protecting the environment and public health.

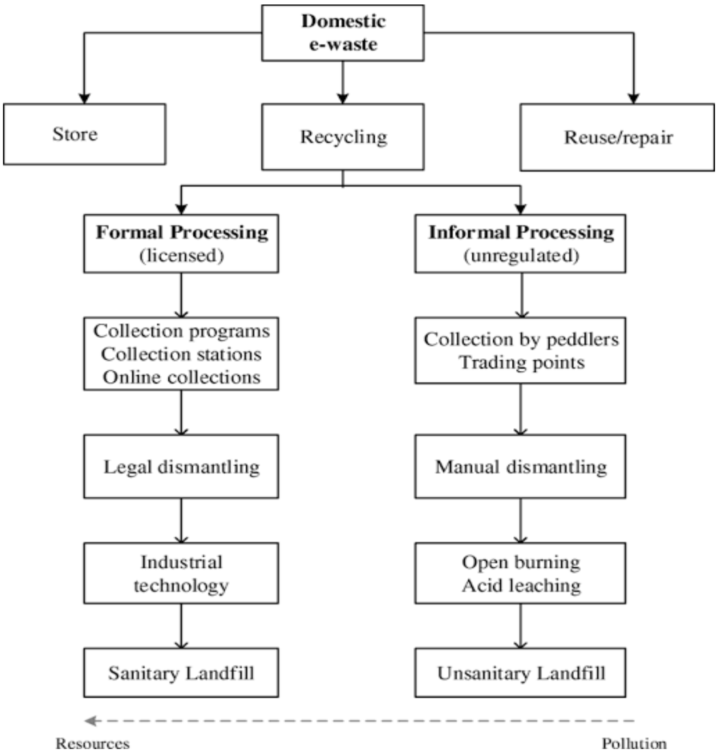

Figure 1. Informal vs. Formal Recycling Comparison
Source: [3]

Mitigation Strategies

A comprehensive strategy combining technology, education, and policy is needed to address the e-waste crisis:

I. Improved Recycling Infrastructure: Both industry and governments need to make investments in material recovery technology and official recycling facilities. Metals can be securely recovered while contaminants are captured by mechanized processes (e.g., hydrometallurgical metal recovery, closed-system shredding). Manufacturers are encouraged by Extending Producer Responsibility (EPR) programs to create products that are easy to recycle. For example, by requiring manufacturers to pay for recycling and take-back, the EU's WEEE Directive has increased the collection of e-waste [4]. Formal recycling rates can also be raised by implementing EPR in other areas, which requires businesses to meet recycling goals.

ii. Education and Public Awareness: Increasing consumer knowledge is crucial to promoting appropriate disposal of e-waste. The public can be informed about risks and collecting choices through media outreach, school programs, and educational initiatives. According to studies, e-waste recycling rates were considerably raised in nations like India when awareness campaigns and laws were combined [5]. Convenient drop-off locations, neighborhood collection campaigns, and unambiguous device labeling of potentially dangerous parts are examples of practical measures. Providing consumers (and employees) with information reduces the production of e-waste and avoids improper handling.

iii. Policy and Regulation: Robust legal structures are essential. This includes passing legislation against open dumping and burning of e-waste and enforcing it. The Waste Electrical and Electronic Equipment (WEEE) directive and the EU's RoHS rule, which limits the use of hazardous materials in new devices (LaDou and Lovegrove, 2008), are two examples that could be imitated [6]. To stop illicit transboundary exports of e-waste, the Basel and Stockholm Conventions must be enforced more strictly on a global scale. Smuggling penalties and domestic recycling incentives can change the economics of dumping. In order to gradually eradicate the most dangerous behaviors, authorities should also address the informal sector (for example, by licensing informal collectors and offering safe alternatives) [7].

The greatest opportunity to reduce the harm caused by e-waste is to combine these strategies: enhanced recycling, education, and strong policy. Governments, businesses, and communities must work together to end the electronics loop and stop harmful exposures.

Table 2. E-Waste policies and regulations

Region/Policy Instrument	Key Features	Strengths	Limitations
EU – WEEE & RoHS Directives	Mandatory recycling, limits on hazardous content (Chen *et al.,* 2011)	High collection rates (42.8 %); safer devices	Implementation complexity across member states
Global E-Waste Policy Uptake	81 countries with policies; 67 using EPR, 46 with targets	Growing legal awareness	Far below ITU target of 97 by 2023 (50 %)
Developing Nations	Often lack formal regulation, rely on informal sector	Low-cost resource recovery	High environmental/health risks due to unsafe practices

Conclusion

An urgent issue is the effect of e-waste on both people's and the planet's health. The disposal of old electronics poses serious health risks due to the toxic compounds that leach into the ground, water, and air. The only way to reduce these dangers is to manage electronic trash responsibly, which includes recycling and disposing of it correctly. Improving public health and reducing pollution are two important goals of sustainable practices, which highlight the importance of international collaboration and education in combating the ever-increasing e-waste crisis. The time for correct action is now

These ideas suggest that immediate action is necessary. Policies and procedures that work include producer responsibility programs, strict regulations for waste management, and expanded opportunities for formal recycling. As an example, the RoHS/WEEE restrictions implemented by the EU have effectively raised collection rates while reducing the quantity of harmful materials found in gadgets.

An increase in recycling can be achieved by the expansion of public education campaigns in conjunction with reasonable policies (Chen et al., 2011; Bhardwaj et al., 2025). In order to discourage illegal dumping and promote global recycling networks, governments should respect international accords like Basel.

Improving these strategies will necessitate additional research. Studying the health impacts of mixed e-waste over the long term, developing safer electronics materials and circular designs, and establishing social and economic mechanisms to retrain informal workers for safer jobs should be the primary goals of this field's researchers. Biomonitoring and low-cost sensors are examples of monitoring technologies that can better pinpoint polluted and exposed locations. The long-term goal is to replace the current electronics life cycle, which involves disposing of harmful equipment, with one that more sustainably reuses materials, protecting both the environment and human health.

Table 3. Summary of Key Findings on the Impact of E-Waste on Human Health and the Environment

Areas	Key Findings	Supporting Evidence (recent studies)
E-waste generation	Global e-waste reached 62 million metric tons in 2022, with recycling rates below 25%. Asia generates the highest volume, Africa has the lowest formal recycling capacity.	[14, 15]
Toxic Substances	Lead, mercury, cadmium, arsenic, and brominated flame retardants are prevalent; they persist in the environment and bioaccumulate.	[16]
Human Health Impact	Chronic exposure linked to neurological damage, respiratory problems, immune dysfunction, and developmental delays in children; high prevalence in informal recycling hubs.	[17]
Environmental Impacts	Soil and groundwater contamination, air pollution from burning plastics, and biodiversity decline in polluted areas.	[18, 19]
Informal Recycling Practices	Open burning and acid leaching cause high airborne toxin levels and contaminate local food chains.	[20, 21]
Mitigation Strategy	Successful interventions include extended producer responsibility (EPR), formal recycling centers, community awareness campaigns, and stricter enforcement of e-waste laws.	[22]

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Conflict of Interest

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