Sociology & Cultural Research Review (SCRR)
Available Online: https://scrrjournal.com
Print ISSN: 3007-3103 Online ISSN: 3007-3111
Platform & Workflow by: Open Journal Systems
https://doi.org/10.5281/zenodo.17150956

E-Waste Governance and Environmental Diplomacy: Advancing SDG 13, 14, and 15 through Formal E-Waste Management in Pakistan

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ABSTRACT

Pakistan's growing electronic consumption, driven by rapid urbanization and digitalization, has led to a parallel rise in e-waste, much of which is processed through informal and unsafe methods. This research examines how formalizing e-waste management in Pakistan can mitigate environmental degradation and help the country meet its international commitments under Sustainable Development Goals (SDG) 13 (Climate Action), 14 (Life Below Water), and 15 (Life on Land). Using a mixed-methods approach, the study evaluates the environmental impacts of informal e-waste handling—such as air and water pollution, soil degradation, and public health risks—and contrasts these with the benefits of formal recycling practices seen in countries like China, Japan, and the European Union. The paper also explores the structural and institutional barriers hindering formalization, including weak enforcement of environmental laws, lack of infrastructure, and the dominance of informal recyclers. It argues for a strategic, inclusive, and sustainable transition framework that combines environmental governance with social protection for informal workers. The study proposes practical interventions such as Extended Producer Responsibility (EPR), licensed collection centers, public awareness campaigns, international cooperation, and the integration of bioleaching and closed-loop recycling systems. By adopting these measures, Pakistan can not only reduce ecological harm but also contribute to global environmental diplomacy, position itself as a responsible regional actor, and support the creation of a circular economy.

Keywords: *E-Waste, Environmental Diplomacy, SDGs, Informal Recycling, Sustainable Development, Climate Action, Circular Economy, Bioleaching, Environmental Governance, Public Health.*

1. Introduction:

The exponential increase in electronic consumption has reshaped the way societies operate worldwide. In the initial phase of digital evolution, electronic products were costly, durable, and manufactured in small volumes. With advancing technology and increased production, electronics became affordable and global. The past decades have seen a gigantic explosion in electronic consumption owing to advances in information technology, domestic appliances, and mobile communication equipment. This world phenomenon did not spare developing countries like Pakistan, in whose economy affordability and accessibility of electrical items has swiftly gone up. Consequently, there has been explosive demand for brand-new

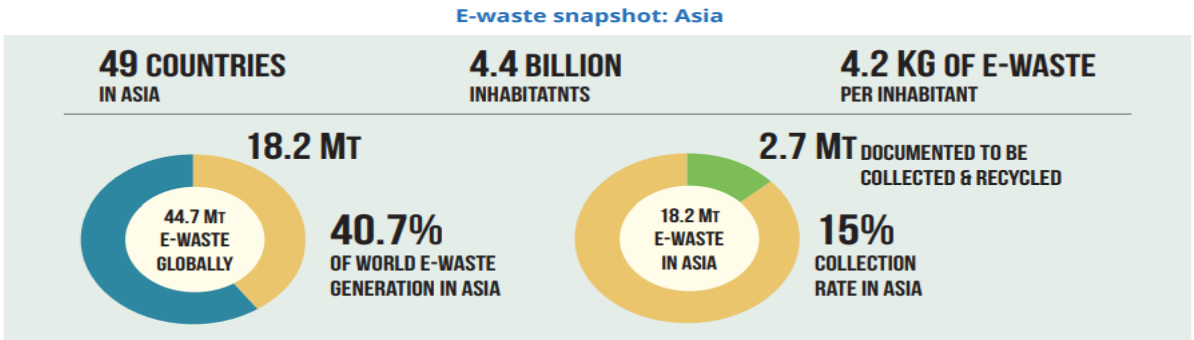
electronic appliances in Pakistan owing to urbanization, economic progress, and global interconnectedness. Nonetheless, such explosive growth of demand did not match this progress in e-waste handling capacity, hence much of e-waste in quantities piled up on a mass level.

Parallel to the increasing use of electronics is the product uselessness phenomenon. The lifespan of electronic equipment has declined precipitously due to both technological and market-oriented reasons like planned obsolescence. There is always a call to switch to newer versions, leading to early disposal of useful equipment. The amount of electronic waste thus has increased many fold. Internationally, e-waste is increasingly regarded as the fastest-growing waste stream, presenting intricate challenges due to its toxic constituents and precious contents. The toxicity of some constituents—lead, cadmium, and mercury—renders inappropriate disposal a critical environmental and public health threat, while the loss of valuable materials such as gold and copper is an indication of tremendous economic inefficiencies.

As a response to this impending crisis, different countries have devised formal and structured ways of dealing with e-waste. To illustrate, the European Union has developed the Waste Electrical and Electronic Equipment (WEEE) directive, which implements Extended Producer Responsibility (EPR), where producers are required to take back end-of-life products and ensure their environmentally responsible recycling. Similarly, Japan possesses a strict home appliance recycling law that makes both the producer and the consumer accountable for secure e-waste disposal and supported by an advanced collection and dismantling system. South Korea has also developed an integrated management system in the form of laws, consumer behavior, and a centralized collection system. All these models are characterized by regulation by government, participation of private enterprise, and public participation, which collectively provide effective material recovery and protection of the environment (Rizwan Rasheed, 2022).

Formalization of management of electronic waste (e-waste) in South Asia differs widely from one country to another, with India being at the forefront in formulating organized mechanisms. India has formalized complete e-waste management laws, such as the E-Waste (Management) Rules of 2011 and their subsequent amendments, which prescribe obligations for producers, consumers, and recyclers, and institute the principle of Extended Producer Responsibility (EPR). Despite all these regulations, challenges still exist in the form of enforcement problems and the prevalence of informal recycling industries, which deal with a significant majority of e-waste.

Figure 1.1: E-Waste Snapshot of Asia



to the widespread prevalence of informal recycling. This is environmentally and health wise very risky, as informal recycling in most cases applies harmful techniques without adequate safety precautions (Sidra Shakil K. N., 2023).

The unevenness in the management of e-waste in South Asia highlights the imperative for regional coordination and the institutionalization of mechanisms in nations where they do not exist. Developing legal frameworks, investing in recycling facilities, and raising public awareness are key interventions to reducing the environmental and health effects of e-waste in the region.

Table 1.1: Countries and their Compliance to Basel convention and SDGs:

Country	National regulation in force*	EPR System	Compliance to Basel Convention	Compliance to SDG's
China	Yes	Yes	Partially	Partially
India	Yes	Yes	Partially	Partially
Pakistan	No	No	Partially	Partially
Japan	Yes	Yes	Partially	Partially
Qatar	No	No	Partially	Partially
Republic of Korea	Yes	Yes	Partially	Partially
Saudi Arabia	No	No	Partially	Partially
United Arab Emirates	No	No	Partially	Partially
Bhutan	Yes	Yes	Partially	Partially
Cambodia	Yes	Yes	Partially	Partially
Bahrain	No	No	Partially	Partially
Bangladesh	No	No	Partially	Partially
Indonesia	No	No	Partially	Partially
Iran	No	No	Partially	Partially
Oman	No	No	Partially	Partially

Source: Compiled by Researcher

Success in such formal systems has lessons for Pakistan. The underlying principle of EPR is the key to these models, and this can be made functional in the Pakistani context through step-by-step legislation and institutional support. Moreover, establishing licensed collection centers, public-private recycling facilities, and giving incentives to consumers for returning end-of-life electronics are measures that could ultimately replace the current informal mechanisms. However, duplicating these systems in Pakistan will involve addressing the unique structural problems that perpetuate informality in its e-waste sector (Muhammad Imran, 2017).

In Pakistan, informality prevails not out of ignorance but also due to systemic issues well entrenched. A major reason for this is that there are no enforceable policy guidelines and no specialized regulatory body to oversee e-waste. While there are some environmental policies, they lack implementation due to bureaucratic red tape and corruption. This lack of governance results in informal recycling widespread without any control. In addition, the country's economy greatly relies on uncontrolled labor markets in which millions of workers, mostly coming from vulnerable groups, look for jobs in insecure and risky situations. E-waste

recycling without formal control gives survival to several individuals who have no access to education or formal employment.

Institutional and technological limitations are also at play. Pakistan is devoid of infrastructure to install and sustain formal recycling facilities, including sophisticated dismantling and material retrieval technologies. Upgrading the sector has been hampered by financial and technical barriers to the government's attempt to act in a more aggressive manner. Compounding these problems are broader socioeconomic forces such as poverty, significant levels of unemployment, and uncontrolled urbanization. These drivers push poorer populations into the informal economy, there engaged in risky e-waste recycling in a bid to economically survive. As consumption patterns and urbanization evolve, the volume of waste electronics rises, yet ways of getting rid of them in safety remain behind.

In response to these structural impediments, the shift to a formalized e-waste management system in Pakistan needs to be planned strategically and inclusively. This not only involves policy change and the development of infrastructure but also social interventions that can tackle poverty and employment, enabling informal workers to shift into cleaner, more sustainable livelihoods. By learning from both global successes and local limitations, Pakistan can start to establish a framework that balances environmental stewardship with economic inclusion. (Haikal Ismail, 2020)

Furthermore, enforcement of environmental and labor laws in Pakistan is extremely lacking. While a few regulations do exist under wider environmental protection laws, there is little to no direct legislation specific to e-waste. When laws do exist, they are applied unevenly and are essentially ineffective. The lack of such laws creates the environment for unofficial recycling facilities to go unchecked, usually in populous urban centers where the health and environmental impacts are worst. Labor protections, especially for workers handling toxic waste, are extremely limited, and there are no effective mechanisms for enforcing workplace safety standards within this industry. Thus, vulnerable workers—children among them—continue to suffer without legal recourse or institutional protection.

Adding to the problem is the splintered character of institutional accountability for managing e-waste. Various government agencies—like environmental protection agencies, customs, ministries of trade, and municipal authorities—work in silos with overlapping or confusing mandates. The absence of coordination results in policy paralysis, wherein no one organization claims responsibility for the issue. In the absence of an overall plan or inter-agency coordination, efforts to legalize e-waste management typically get stuck in the planning phase or lack funding. Institutional fragmentation has hindered the establishment of a clear national plan and discouraged private investment in formal recycling facilities (Rajarathinam Nithya, 2021).

With these governance and infrastructure gaps, reform is both imperative and inevitable. Pakistan is facing increasing pressure to meet international environmental standards as well as its own commitments under the Sustainable Development Goals, specifically SDG 13 (Decent Work and Economic Growth) and SDG 14 (Climate Action), and SDG 15. Apart from international requirements, the magnitude of health and environmental harm resulting from informal e-waste methods has become a critical issue. Neighboring communities are exposed to toxic chemicals in the long run, and economic loss due to unrecovered resources keeps adding up. At the same time, the international focus on resource efficiency and circular

economy concepts necessitates that Pakistan must upgrade its waste management infrastructure.

Still, moving to a formal e-waste management model will require more than just technical upgrades or legal amendments—it will need an inclusive, multi-stakeholder strategy attuned to the social realities behind informal recycling. Reform must prioritize protecting and progressively integrating the informal sector workers into formal frameworks, providing them with secure working conditions, training, and legal protection. This inclusive approach is essential not only for ethical reasons but also to ensure that the transition can be practically achieved and socially sustainable.

2. Hypothesis Statement:

Formalizing Pakistan's e-waste management system will significantly reduce environmental degradation across climate, aquatic, and terrestrial ecosystems, while strengthening Pakistan's capacity to fulfill its international environmental commitments under SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land).

3. Literature Review:

As the electronic consumption rate continues to increase globally, the phenomenon of electronic waste (e-waste) has also dramatically grown as it presents severe environmental and human health risks because of its harmful chemical components. According to scholars like Rizwan Rasheed (Rizwan Rasheed, 2022) and (Haikal Ismail, 2020), even though most European countries, such as the EU, Japan, and South Korea, have established effective legislations to manage proper e-wastes management, such as Extended Producer Responsibility (EPR), South Asia is still far behind, particularly, Pakistan that has no proper institutional legal framework to address this concern.

The health and environmental risks of informal recycling of e-wastes are not a secret. Indicatively, acid leaching and open burning contributes to high rates of air pollution and soil contamination in the major cities of Pakistan (Mureed Kazim J. H.-K., 2024). According to (Sidra Shakil K. N., 2023), contamination of heavy metals in groundwater appears similar, and it is a significant danger to aquatic ecosystems.

In other parts of the world (internationally), formalized e-waste recycling have been shown to play huge environmental advantages. According to Ikhlayel (2017) and Forti et al. (2020), there is a comparison of informal and formal recycling schemes, and the former leads to 85 percent less CO 2 emission and up to 90 percent of more metal recovery. The alternative called bioleaching, a novel metal recovery technology based on microbe cultivation, has also become a sustainable option to traditional metal extraction with low emissions (Adetunji et al., 2023).

Although there has been progress in India by the E-Waste (Management) Rules (2011), there remains the enforcement issue. But on the contrary, the e-waste industry of Pakistan is not regulated and depends on the informal labor force which is extremely harmful to people. Research, such as the one by Muhammad Imran (2017) and Rajarathinam Nithya (2021), emphasizes such issues as the institutional fragmentation and policy gaps and lack of enforcement mechanisms as significant obstacles to development.

Moreover, as the literature also demonstrates, the transition to formalized systems corresponds to various Sustainable Development Goals (SDGs). There is direct stewardship of the SDG 13 (Climate Action) by GHG reductions, SDG 14 (Life Below Water) by less water

contamination, SDG 15 (Life on Land) by less land degradation, and land biodiversity preservation (Md. Kaviul Islam, 2024; Chakraborty, 2025).

4. Research Gap:

Existing research on e-waste in Pakistan primarily focuses on the economic aspects and immediate environmental hazards, with limited attention to its broader implications for international environmental diplomacy and governance. There is a lack of integrated analysis exploring how formalizing e-waste management could help Pakistan simultaneously advance multiple SDGs (13, 14, and 15). Moreover, the intersection of e-waste policy with Pakistan's commitments under global environmental agreements remains underexplored, highlighting the need for an interdisciplinary IR-focused study.

5. Research Problem:

Pakistan's growing e-waste is largely processed through informal, unsafe methods, leading to severe air pollution, water contamination, and soil degradation. Despite its commitments under SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land), Pakistan lacks an effective formal governance framework to manage e-waste sustainably. This study examines how formalizing e-waste management can help Pakistan reduce environmental harm and fulfill its international environmental obligations.

6. Research Questions:

1. How can formal e-waste governance in Pakistan contribute to reducing greenhouse gas emissions, protecting water bodies, and conserving terrestrial biodiversity in line with SDG 13, 14, and 15?
2. In what ways can Pakistan leverage environmental diplomacy and international cooperation to support the transition from informal to formal e-waste management and achieve sustainable environmental governance?

7. Research Objectives:

1. To explore that formal e-waste governance in Pakistan contribute to reducing greenhouse gas emissions, protecting water bodies, and conserving terrestrial biodiversity in line with SDG 13, 14, and 15
2. To propose suitable ways by which Pakistan can leverage environmental diplomacy and international cooperation to support the transition from informal to formal e-waste management and achieve sustainable environmental governance

8. Research Methodology:

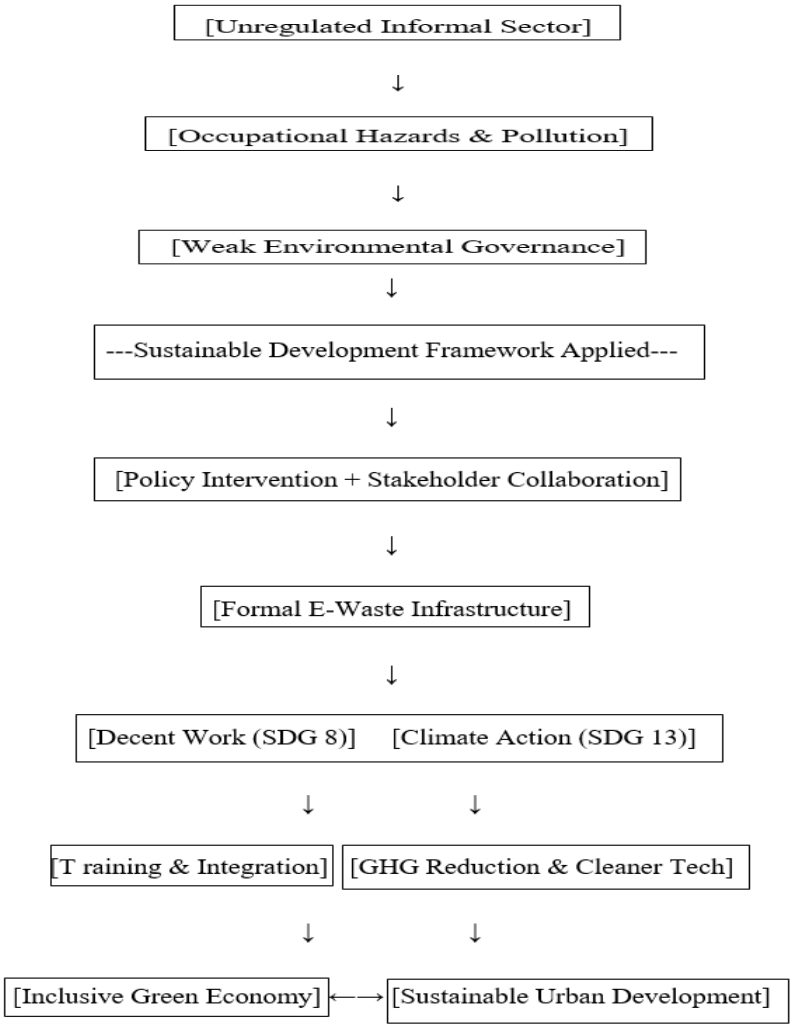
It utilizes a mixed-methods approach combining qualitative and quantitative research methods in this study. Secondary data on the environmental impacts of formal e-waste management shall be drawn from academic literature, government reports, and industry publications. The information will be acquired through primary surveys and interviews among key stakeholders; these shall involve policymakers, industry experts, informal recyclers, and environmental organizations. A comparative analysis of international best practices will also be conducted to identify suitable models for Pakistan. The study will utilize suitable ways by which Pakistan can leverage environmental diplomacy and international cooperation to support the transition from informal to formal e-waste management and achieve sustainable environmental governance.

9. Theoretical Framework

This study is guided by theoretical perspectives of Sustainable Development Theory.

The Sustainable Development Theory focuses on attaining a better balance between growth in the economic, environmental and social spheres of development. Informal to Formal E-Waste Management Transition: This theory therefore applies to e-waste transitions from informal systems to formal operations because it fulfills SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). Formalizing recycling practices are sustainable employment opportunity, occupational health conditions, and environmental conservation.

Flow chart 1.3. Sustainable Development Theory Flow Chart



Source: Compiled by Researcher

By applying these theories, this research will provide a strategic framework for Pakistan's e-waste management transition, ensuring long-term economic and environmental sustainability.

10. Environmental Impacts of Informal E-Waste Management in Pakistan

More people in Pakistan are buying electronic equipment, which leads to more electronic waste. A lot of this waste is not processed properly and is mostly handled by informal recyclers. Informal recycling is economical, but because it's uncontrolled, it causes damage to the environment. In most urban areas near Lahore, Karachi and Rawalpindi, electronic waste is handled by burning it, submerging parts in acid and manually taking the parts apart using no protective equipment (Alviti Kankanamalage Hasith Priyashantha, 2022). The impact involves sending toxic chemicals into the environment, contaminating the nearby water and

worsening soil conditions, all of which threaten both the environment and people's health. This section looks closely at air pollution, water pollution and land degradation as the most important environmental concerns arising from Pakistan's informal e-waste handling, based on real observations and case studies (Hill, 2023).

10.1. Air Pollution

Informal recycling in Pakistan is mainly based on open burning electronic materials such as printed circuit boards and wires to gather copper. As a result of this, different toxic chemicals are sent into the air, for instance, dioxins, furans, PAHs and heavy metals like lead and mercury (Mureed Kazim J. H.-K., 2024)Exposure to these toxins, some experts claim, can result in breathing problems, skin rashes and even cancer for people. Since there are no strict rules on emissions from such unofficial operations, the air within cities like Lahore and Karachi gets worse. Reports indicate that burning e-waste allows many chemicals to be released into the air, water, nearby land and the environment (Mureed Kazim J. H.-K., 2024).

10.2. Water Contamination

Using acid to remove metals from e-waste is a widespread activity in Pakistan's recycling units. Waste from an acid bath leaks toxic materials such as mercury, cadmium and lead into both surface water and groundwater. (Sidra Shakil A. A., 2023)Toxic metals have been found at high concentrations in nearby water bodies in Lahore and Karachi, where informal recycling is most common. This leads to great harm in the marine environment and can be especially dangerous for people in communities that depend on the sea for both water and food. (Muhammad Sajid, 2019)As can be observed in China's Guiyu, where lots of disorganized e-waste is recycled, the environment can be greatly polluted as a good lesson for Pakistan.

10.3. Soil Degradation

In Pakistan, no regulations govern informal e-waste recycling, which leads to a lot of soil pollution. When heavy metals such as lead, cadmium and mercury from electronic parts are deposited, they start to gather in the soil. Soil fertility is lowered by pollution, it destroys beneficial microorganisms, and it adversely affects cultivation. Organic pollutants called polychlorinated biphenyls (PCBs) and brominated flame retardants also destroy soil. (Mureed Kazim Z. S.-K., 2025) Because these chemicals don't easily break down, they remain in the soil for long periods, causing ongoing problems to the environment. According to studies, the soil in places like Guiyu, China, holds much higher amounts of heavy metals than what is allowed internationally.

In Lahore and Karachi, Pakistan, people mostly use open burning and acids to separate metals from the waste they gather. Among the gases discharged are lead (Pb), cadmium (Cd), mercury (Hg) and persistent organic pollutants (POPs) (Times, n.d.). Plants and animals found naturally in an area can pick up these pollutants within time because of these pollutants. The literature revealed a high risk to the environment based on the presence of lead, copper, nickel, and cadmium during e-waste recycling in locations across Karachi and Lahore.

Pollution in both the soil and water not only damage the environment but also poses risks for human food. The toxins from heavy metals in the soil can spread to plants. Additionally, fish can take in harmful chemicals through the water they are inhabit. Consumption of food with contaminants can cause problems like brain diseases and organ damage. The influence of chemicals is even greater still when illicit recyclers disregard environmental standards.

10.4. Public Health Issues:

Hazardous waste from informal e-waste recycling impacts Pakistan's health system either directly or indirectly. Those living close to informal recycling places are breathing polluted air, drinking polluted water and standing on soil tainted with toxins. Having exposure can be linked to many health risks (Tzoraki, 2018). Workers handling e-waste experienced more cases of respiratory diseases, skin diseases, and eye infections (Damian Fischer, 2020). Additionally, those living nearby the recycling plants faced similar health issues.

E-waste chemicals can be especially dangerous to both children and unborn babies. Exposure to lead and mercury during childhood may cause mental difficulties, slower growth, and changes in hormonal function. Studies reviewed in a meta-analysis showed that people living in areas with e-waste are often exposed to high concentrations of heavy metals and persistent organic chemicals and their the women of childbearing age and children in those areas are at particular risk" for improved clarity (Khan, 2022).

11. Environmental Risks to Aquatic Ecosystems (SDG 14)

Informal e-waste recycling in Pakistan heavily relies on crude methods such as acid leaching and open dumping, which have direct and severe impacts on aquatic ecosystems. During acid leaching, concentrated nitric or hydrochloric acids are used to dissolve precious metals from printed circuit boards, producing wastewater rich in heavy metals like lead, cadmium, and mercury (Sidra Shakil A. A., 2023). In the absence of wastewater treatment infrastructure, these toxic effluents are discharged untreated into rivers, streams, and drainage systems, contaminating freshwater sources used for irrigation and drinking (Muhammad Sajid, 2019).

Such contamination disrupts aquatic biodiversity by accumulating in the tissues of fish and other aquatic organisms, posing risks to human health through bioaccumulation in the food chain (Paromita Chakraborty, 2025). Similar trends have been observed in other developing countries where informal e-waste recycling correlates with increased heavy metal concentration in nearby water bodies, threatening SDG 14 targets of reducing marine pollution and protecting aquatic ecosystems (Rajarathinam Nithya, 2021).

By contrast, formal recycling systems in countries like China employ closed-loop hydrometallurgical processes and wastewater treatment facilities, significantly reducing heavy metal discharge into water bodies (Md. Kaviul Islam, 2024). Adopting similar practices in Pakistan would help protect river ecosystems, secure drinking water quality, and align national policies with SDG 14 targets.

11.1. Threats to Terrestrial Biodiversity and Land Resources (SDG 15)

Informal e-waste disposal in Pakistan leads to widespread soil contamination, undermining SDG 15 targets related to combating land degradation and preserving biodiversity. The manual dismantling of devices and subsequent open burning of cables release persistent organic pollutants (POPs) such as dioxins and furans, which settle into surrounding soils (Rizwan Rasheed, 2022). Furthermore, acid leaching residues containing heavy metals like lead, cadmium, and arsenic are often dumped directly onto land, where they penetrate soil layers and accumulate over time (Shakil et al., 2023).

These practices degrade soil fertility, damage crops, and disrupt terrestrial food webs by contaminating plants consumed by livestock and humans (Muhammad Imran, 2017). Studies from Lahore have demonstrated significantly elevated concentrations of lead and cadmium in agricultural fields located near informal e-waste recycling sites, leading to reduced crop productivity and posing chronic health risks to local communities (Sidra Shakil A. A., 2023).

By contrast, countries with formal e-waste recycling systems use controlled dismantling, mechanical separation, and proper landfilling of residues, which mitigate soil contamination and protect terrestrial ecosystems (Md. Kaviul Islam, 2024). Adopting similar systems in Pakistan would contribute directly to achieving SDG 15 goals of halting biodiversity loss and restoring degraded land.

11.2. Comparison between Unregulated Acid Leaching in Pakistan and Closed-Loop Leaching Systems in China and the EU

Most recycling of electronics in Pakistan is run by illegal companies that manage acids without suitable disposal. Ordinary caution isn't taken when handling waste from strong acids, as metals can be placed directly in them safe. For this reason, harmful fluids contaminate nearby soil, water and may harm those living or working close by (Walker, 2025).

In response, the European Union and China have now made using closed-loop leaching a regular approach to recycling. They keep and recyclize the leaching agents before releasing them into nature. Advanced plants deal with waste ahead of disposal to make sure it is neutral. In addition to helping with pollution, they also allow metal to be recovered more safely and ease (Joan Morell, 2025).

12. Environmental Benefits of Formal E waste Management:

Both closed-loop recycling and bioleaching done with traditional technology are both good for the environment. In the first place, these methods produce fewer greenhouse gases than the conventional ones. Since bioleaching is done at room temperature, it uses less energy than smelting (Ikhlayel, 2017). After studying the impact, swapping e-waste recycling for new methods could lead to a 42% increase in greenhouse gas savings.

Sprayers and fertilizers help stop toxins from seeping into the world around us. When waste streams are returned to the beginning and receive treatment, closed-loop systems stop them from polluting the soil and water (Tingting Tian, 2022).

The use of official recycling schemes leads to higher results in metal recovery. Higher recovery means fewer natural resources must be mined—with a circular economy being the result. In addition to saving the environment, using sustainable recycling also helps the economy.

12.1. Bioleaching and New Sustainable Technologies for Recycling E-Waste

As more waste electronics (e-waste) keeps accumulating, we should rely on sustainable techniques in recycling. In Pakistan and other nations, usually, traditional extraction takes place in a dangerous manner that can cause major harm to the environment and people. At the same time, by contrast, modern green technologies involving bioleaching and enclosed leaching systems provide more environmental safety and improved resource recovery (Kumar, 2020).

12.2. Bioleaching: Microbial Extraction with Minimal Chemical Discharge

Instead of relying on expensive equipment, bioleaching uses small creatures to divide metals from e-waste. Through bacteria and fungi metabolism, this process dissolves metals so they are able to be extracted without the need for tough chemicals (Hait, 2017).It is less expensive and much more resourceful to recover copper, gold and nickel from printed circuit boards and electronic items compared to recycling them (Benjamin Monneron-Enaud, 2020).

Bioleaching is very important in protecting the environment. Bioleaching is done in mild conditions which results in fewer contaminating substances than is produced during traditional acid digestion. Moreover, it consumes less energy which means less greenhouse

gas is emitted. Experiments suggest that bioleaching is as efficient at recovering metals as usual methods, but it is also easier on the environment (Adegoke Isiaka Adetunji, 2023).

12.3. Care for Existing Resources

Many electronic devices use limited and important resources such as gold, copper, cobalt and rare earth elements (REEs). Making sure you recycle these items in the right way helps save resources. The International Energy Agency found that bringing back copper and cobalt waste through recycling could achieve up to 30% savings by the year 2040 and 15% savings for lithium and nickel (Buisson, Dhir, & Hegarty, 2024). Recycling REEs found in electronic waste helps to obtain important metals, keep the environment safe from pollution and reuse abandoned landfill sites.

12.4. Refuse of Landfilling: Landfills Last Longer and Lower Methane Releases

Proper recycling of e-waste means it's sent somewhere else, which benefits the material consumption and the environment. Landfills release a massive amount of methane, a gas that has a strong effect on the environment. Out of all methane emissions, landfills release each year 30–35 teragrams of methane to the air. Official e-waste recycling keeps more waste from landfills and helps to reduce methane emissions that are bad for the climate (Akeeb Adepoju Fawole, 2023).

12.5. Comparing informal with formal waste recycling using data and statistics.

Methods of recycling e-waste have a major impact on what happens to the environment. Across many developing countries, people often engage in informal recycling which is harmful both to the environment and to health. In order to address these problems, controlled and advanced technology are used in formal recycling facilities. Here, we compare the emissions, toxin releases and rates of recovery in both formal and informal e-waste recycling based on trusted sources such as Forti et al. (2020), Zeng et al. (2016) and UNEP reports (Vanessa Forti C. P., 2020) (Li, 2016) (Vanessa Forti K. B., 2018).

4.4.6. Comparative Analysis of Emissions and Recovery Rates

The following table delineates key environmental metrics associated with informal and formal e-waste recycling per metric ton of processed waste:

Table 1.2: Environmental Metrics associated with Informal and Formal Methods

Parameter	Informal Recycling	Formal Recycling
CO_2 Emissions (kg/ton)	2,000	300
Metal Recovery Rate (%)	30	90
Soil/Water Contamination Risk	High	Low
Toxic Discharge (e.g., dioxins)	Significant	Minimal

Sources: (Vanessa, 2020)

Standard processes for recycling old electronics, burning and acid leaching, can release hazardous substances into our natural environment. Lead, cadmium and mercury were all found in higher concentrations than usual in the soil and water from recycling yards. According to Zeng and colleagues, some informal e-waste yards had lead levels in the soil that were 100 times too high. When looking at recycling plants, they are required to use proper systems to control waste and emissions which lowers the dangers from contamination.

The findings show that e-waste recycling overseen by officials is kinder to the environment. When greenhouse gases are cut down, metal is recovered more and pollution is lessened,

formal recycling helps keep the environment safe for everyone. E-waste is dealt with more effectively using formal recycling centers, tough rules and educating the public.

13. Support for SDGs: Climate Action is given by running official e-waste recycling projects in Pakistan

Pakistan is facing increasing amounts of electronic waste (e-waste) that are bad for the environment yet present a positive climate opportunity. Portugal's work on climate change, guided by SDG 13, centers mainly on recycling electronic waste correctly. Switching from outdated recycling systems to environmental-friendly methods will allow Pakistan to save important resources, reduce its carbon output and deal with changes brought by climate change (Rizwan Rasheed, 2022).

13.1. Cutting down Pakistan's overall greenhouse gas emissions by encouraging good e-waste management:

Generally, due to people misusing their trash and burning recyclables, Pakistan frequently has both high GHG emissions and a polluted environment. Even so, recycling today is made possible by specialized equipment that helps manage air emissions and gather valuable items (Rizwan Rasheed, 2022). For instance, complying with recycling norms can reduce CO_2 emissions by two-thirds, from 2,000 kg to 300 kg and help hold onto more than twice the metal than previously by gradually rising from 30% to 90% (Repaci, 2023).

When We Use Formal Recycling fuel is saved and emissions are reduced since waste is recycled near where it is generated. Making the switch to formal recycling eliminates the need for much traditional mining that takes a lot of energy and causes the production of lots of GHGs.

When Open Burning and Primitive Recycling are practiced, poisons called dioxins and furans sometimes enter the atmosphere. Recycling in the right way cuts emissions and benefits the environment and air.

Strong hazardous waste treatment and disposal are vital for climate protection. Properly getting rid of chemicals in e-waste helps to keep dangerous GHGs and chemicals out of the environment. Dioxins from the burning of plastics and chemicals are a good example, because they have a bigger overall warming effect than CO2. This way of reusing chemicals ensures they won't harm the climate.

13.2. Studying China's Green Industry Park Model Can Guide Us in Developing Low-Carbon E-Waste Management

What happened in Guiyu, China—changing it from an illegal hub for e-waste to a well-managed industrial park—illustrates how e-waste management can be achieved. In planning the National Circular Economy Pilot Industry Park, facilities for recycling were gathered, environmental rules were issued and waste treatment was updated. The case study shows that strict rules lead to fewer emissions, more recovered resources and safer health for all (John A. Mathews, 2018).

13.3. Importance to Pakistan's agreements and goals for action on climate change

The NDCs of Pakistan under Paris Agreement call for both cutting emissions and improving resistance to climate change (Riaz Ahmad, 2025). By recycling e-waste, institutions follow these values by lowering emissions, saving resources and protecting the environment. By adding e-waste management to its climate development plan, Pakistan can support both its plan for sustainability and care for the environment.

To successfully integrate e-waste recycling into its climate action plan, Pakistan needs to give importance to well-structured policy making and infrastructural up gradation. To begin with, well-defined national recycling standards should be developed, complemented by public awareness that fosters household responsible disposal practices. Fixing faults in existing informal recycling processes is necessary to promote safety and environmental compliance. Also important is investment in new e-waste treatment plants that employ sophisticated technology to safely disassemble, recover, and recycle electronic materials. Not only will these treatment plants curtail toxic emissions, but they will also help facilitate a circular economy model consistent with Pakistan's general sustainability objectives.

Public information campaigns should highlight the fact that degrading electronic trash does not just harm personal health but also threatens to destabilize the environment. Citizens need to be taught how essential proper disposal and recycling are. Also, international cooperation—like learning from China's eco-industrial parks—can offer important lessons for improving Pakistan's own waste management practices (Mehreen Iqbal, 2015). Proper recycling and sorting of old electronics play an important role in climate mitigation by conserving precious resources, saving emissions, and protecting public health. Integrating holistic e-waste policy in national climate action will not only contribute to saving the environment but also further enhance Pakistan's position as a responsible leader towards realizing Sustainable Development Goal 13 (Muhammad Sajid, 2019).

14. Barriers to Formalization and Environmental Governance Challenges in Pakistan's E-Waste Management

Institutional barriers are making it tough for Pakistan to go from loosely managed e-waste collection to a formal recycling process. Problems include not following environmental rules, unclear job assignments, not having the needed technology or resources and opposition from small players.

14.1. Poor Handling of Enforcement in Environmental Law

PEPA 1997 establishes a complete environmental legal system including rules for e-waste management. But enforcing the rules is a big difficulty. Many times, the EPAs established by the federal and provincial governments have too few resources, as well as missing the independence and specialist’s help required to enforce existing environmental laws. So, e-waste recycling without rules which involves techniques like open burning and acid leaching, continues unhindered, and causing serious harm to people and the environment. Institutions Have Separate Roles

How waste is managed in Pakistan is not organized and coordinated by the country’s government bodies. It is the local government who handles waste collection and disposal, whereas formulating rules and policies about the environment is the job of the federal and provincial governments. When services are not organized, essential functions are repeated and some people do not receive them. Since there is not one group in charge of e-waste, practices and rules differ from region to region and no overall policy can be created.

14.2. There Are Limits That Unite Technology and Finance

Setting up e-waste recycling operations that operate smoothly takes a lot of support from technology and required infrastructure. Money problems are blocking Pakistan from making use of advanced technology. The available teaching materials are not suitable for people

working on advanced recycling equipment. Since the reasons mentioned lead to slow progress, informal recycling is a main solution for Afghanistan.

14.3. Matter regarding the Informal Sector

Most of the e-waste in Pakistan is handled by people working in the unorganized sector. People are swayed to avoid formal business steps because it may risk their jobs and incomes. As informal businesses are not closely supervised, formal businesses can't get certain cheap advantages. Problems with the organization of support services cause informal recyclers to avoid formal methods, meaning their dirty practices persist.

There needs to be more cooperation to address what's stopping formalization and improve how Pakistan handles e-waste. Taming environmental laws, creating responsible rules, adding advanced technology and assisting informal people supports greener management of e-waste. Handling these matters will ensure Pakistan is able to defend its people and environment from e-waste and start recycling the proper way.

15. Recommendations

- Develop and pass specific national legislation focused solely on e-waste, separate from general environmental laws, with enforcement mechanisms and penalties for non-compliance.
- Establish government-accredited E-Waste Collection Points in major cities (e.g., Lahore, Karachi, and Islamabad) where citizens can drop off electronic waste safely.
- Launch public incentive programs offering mobile recharge cards, shopping vouchers, or tax credits to individuals who return used electronics to authorized centers.
- Create a mobile app (e.g., "E-Waste Pakistan") to guide the public on where and how to responsibly dispose of e-waste, report illegal dumping, and track collection statistics.
- Partner with universities and technical institutes to conduct training workshops for informal recyclers to upgrade their skills and become part of formal recycling facilities.
- Provide micro-loans or conditional cash grants to informal workers who shift to formal e-waste collection or dismantling centers, especially in urban slums.
- Establish public-private recycling zones equipped with modern dismantling and bioleaching technology to process e-waste efficiently and reduce toxic emissions.
- Incorporate recycling education into school and college curricula, highlighting the environmental and health risks of informal e-waste disposal.
- Implement "EPR compliance labeling" on electronics sold in Pakistan, requiring brands to register with recycling programs and track returns.
- Seek technical support from international agencies (e.g., UNDP, UNEP, GIZ) to design and co-fund pilot eco-parks for safe e-waste recycling in Lahore and Karachi.
- Require all electronics importers and large retailers to file annual e-waste collection reports and contribute financially to waste treatment infrastructure.
- Design TV and social media campaigns to promote the health hazards of informal e-waste burning and the benefits of formal recycling.
- Mandate municipal authorities to collaborate with EPAs and allocate funds for local enforcement against illegal recycling hubs.

- Create a national e-waste registry to monitor producers, recyclers, and recycling volumes in real time through digital reporting platforms.

15. Conclusion

The informal nature of e-waste management in Pakistan poses serious environmental, public health, and economic risks. The lack of a national policy framework, weak institutional coordination, and widespread informal labor practices have hindered sustainable progress. Nonetheless, this crisis presents an opportunity for Pakistan to transition toward a circular economy by learning from international best practices and integrating formalized systems.

Formal e-waste governance—rooted in Extended Producer Responsibility, public-private partnerships, and community engagement—can help Pakistan address critical SDG targets (13, 14, and 15), reduce GHG emissions, and protect land and water ecosystems. Moreover, aligning national environmental strategies with global environmental diplomacy will strengthen Pakistan's international standing and enhance its climate commitments under the Paris Agreement.A coordinated, inclusive, and technologically progressive approach—supported by environmental diplomacy will be crucial to ensuring this transition is effective, equitable, and environmentally just.

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