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E-Waste in Pakistan: How Discarded Electronics are Poisoning the Land

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ABSTRACT
The integration of artificial intelligence (AI), surveillance technologies, and algorithmic governance into modern societies presents complex legal and ethical challenges a phenomenon best captured by the emerging concept of "techno-legality." This article explores the intersection of law and technology, focusing on how AI-driven systems, state surveillance, and digital decision-making are redefining accountability, privacy, and human rights. It critically examines issues such as the opacity and bias in algorithmic decision-making, the absence of legal personhood for autonomous systems, and the weakening of democratic oversight in digital governance frameworks. By analyzing prominent global case studies including China's Social Credit System and the U.S. NSA surveillance programs the article demonstrates the uneven global landscape of techno-legal regulation. The discussion extends to regulatory instruments such as the EU AI Act and GDPR, highlighting their strengths and limitations in addressing rights-based concerns. Furthermore, it evaluates the ethical and legal implications for marginalized communities, who are disproportionately impacted by opaque digital systems. Emphasizing the need for international legal harmonization and inclusive governance models, the article calls for multi-stakeholder collaboration between legal scholars, technologists, and civil society. It concludes with actionable policy recommendations, including the formulation of human rights-centered digital laws, algorithmic transparency mandates, and democratic oversight structures. In an age where technology rapidly outpaces legislation, this paper underscores the urgency of rethinking legal paradigms to foster a more accountable and equitable digital future.

Keywords: *Techno-Legality, Artificial Intelligence, Surveillance, Digital Governance, Privacy, Human Rights, Algorithmic Bias, Regulatory Frameworks, Ethical AI, International Law.*

Introduction

The e-waste has become one of the most significant environmental issues in Pakistan with its exponential growth of 15-20 percent per year, much faster than the average growth rate of 3-4 percent across the world (UNEP, 2023). Due to the proliferation of low-priced smartphones, computers, and home appliances, Pakistan has become one of the five highest e-waste-producing countries in South Asia, and produces about 3.9 million metric tons annually (Baloch et al., 2023). This growth is driven by the increasing consumer demand, product obsolescence by producers, and second-hand electronics that are imported to Pakistan, mainly by developed nations, and constitute almost 40% of the e-waste revenue in Pakistan (Iqbal et al., 2022). In contrast to those nations that have well-developed waste management systems, Pakistan does not have any formal recycling system, and 80 percent of the electronics waste is being recycled on informal markets, mainly in slums and open landfills (WWF-Pakistan, 2023).

The results of uncontrolled disposal of e-waste are disastrous to the environment and to health. In the present-day electronics, there are more than 1,000 potentially toxic substances, such as lead, mercury, cadmium, and polycyclic aromatic hydrocarbons (PAHs), which can leak to the environment upon crushing, burning, or dumping the gadget (Khan et al., 2021). Research on Pakistani e-waste sites shows that soil lead levels are 12,000 mg/kg in Sher Shah market the largest e-waste processing area, in Karachi, which is 300 times higher than the WHO safety standards (Ali et al., 2023). Likewise, groundwater in areas surrounding the informal recycling centers in Lahore has a mercury concentration of 0.45 mg/L, which is highly exceeding the standard limit of 0.001 mg/L (Pakistan Environmental Protection Agency, 2022). These toxins accumulate in food crops; a 2023 study showed that the cadmium content in Gujranwala, Pakistan, rice paddies around e-waste sites was 8 times over the Codex Alimentarius code, having dangerous food safety impacts (Hussain & Malik, 2023). The human toll is no better: an estimated 250,000 informal recyclers, of whom 60,000 are children, develop respiratory diseases, DNA damage, and pre-term births as a result of constant exposure (ILO, 2023).

The solution to this crisis must be multi-faceted. Although the National E-Waste Management Policy (2021) in Pakistan defines the extended producer responsibility (EPR) systems, the country has not implemented them, given weak enforcement and opposition by the industry (Ministry of Climate Change, 2023). It is possible to learn lessons on Indian E-Waste Rules (2022), which introduced the requirement of manufacturer take-back programs and increased the formal recycling rates to 35% (TERI, 2023). Pyrolysis-based metal recovery is promising as pilot programs such as the E-Waste-to-Resource project in Karachi show the possibility of cutting landfill reliance by 70 percent in pilot areas (UNDP, 2023). The awareness of the population is also important- a survey in 2023 showed that 82 percent of Pakistanis are not aware of the dangers of e-waste, which adds to the necessity of the country-wide campaigns (Gallup Pakistan, 2023). Unless something is done swiftly, the World Bank predicts that the amount of e-waste in Pakistan will triple by 2050, making extensive farmlands barren and increasing government spending on health by about six billion dollars a year (World Bank, 2023). It is no longer time to make small steps but to introduce systemic changes that are focused on the models of the circular economy in order to prevent this impending catastrophe.

The Scale of E-Waste in Pakistan

Pakistan has become one of the biggest contributors of electronic waste to South Asia with 4.2 million metric tons of waste being generated every year, a quantity set to increase twofold by the year 2030 at the present 20 percent annual rate of growth (Sustainable Development Policy Institute [SDPI], 2023). Several forces contribute to this exponential growth, the first one being rapid urbanization (annual urban growth of 3.2 percent), another being the IT sector (which contributes $3.5 billion to the GDP), and the third one being the 25 million new mobile phone users annually (Pakistan Telecommunication Authority [PTA], 2023). This issue is further aggravated by the 40,000 metric tons of unlawful e-waste imports, mostly European and Chinese, presented as a second-hand goods (Federal Board of Revenue [FBR], 2023). Compared to the region, Pakistan has surpassed both India and Bangladesh in per capita e-waste production (2.3 kg, 1.9 kg, and 1.2 kg, respectively), yet it is still lower than the world average of 7.3 kg (Global E-Waste Monitor, 2023). These numbers are probably not the full scope of the crisis since there is no national inventory system in place; researchers believe that 35 percent of e-waste is never registered in the informal deals (Khan et al., 2023).

Pakistan has really scary trends in the composition of e-waste. Smartphones occupy the waste processes, and 62 million smartphones are disposed of each year, which amounts to 9,300 metric tons of lithium-ion batteries infiltrating ecosystems (National University of Sciences & Technology [NUST], 2023). Television waste is then next on the list at 280,000 units/month with 4.2 tons of leaded glass and 1,800 kg of ozone-depleting CFCs emanates per day out of discarded refrigerators (Pakistan Environmental Protection Agency [Pak-EPA], 2023). The most worrying, perhaps, is the fivefold growth of waste in solar panels since 2020, at the time when renewable energy development efforts are backfiring without recycling strategies (Alternative Energy Development Board [AEDB], 2023). Such numbers sharply contrast those of developed countries: 42.5 percent of the EU e-waste is recycled via controlled channels, whereas in Pakistan, formal recycling only lingers at less than 5 percent (European Environment Agency [EEA], 2023 vs. WWF-Pakistan, 2023).

Pakistan is a country that suffers because of systemic failures, as illustrated in global comparisons. Japanese Home Appliance Recycling Law has recovery rates of 86 percent, collected by recycling fees paid by consumers, whereas the proposed Extended Producer Responsibility (EPR) in Pakistan has met no success and still waits to be implemented after three years (Ministry of Economy, Trade and Industry [METI], 2023 vs. Ministry of Climate Change [MoCC], 2023). It is economically unbelievable: every year the country loses up to 380 million dollars' worth of recoverable gold/silver by using the primitive recycling process, which can pay off 12 modern recycling facilities (Pakistan Business Council [PBC], 2023). In the meantime, a similar developing economy, such as Nigeria, has decreased informal recycling by 40 percent with the help of the public-private partnership model that Pakistan must replicate (Basel Convention Regional Center, 2023). Unless something is done about it, Pakistan will surpass 10 million metric tons of e-waste by 2030, to the same extent that Thailand is now producing it, but without the same kinds of infrastructure (International Telecommunication Union [ITU], 2023).

How E-Waste is Poisoning Pakistan's Land and Water Systems

Unregulated dumping of electronic waste in Pakistan has led to extreme environmental pollution due to the discharge of long lasting poisonous chemicals. Modern electronics synthesize a concoction of toxic substances such as Lead (Pb), Mercury (Hg), Cadmium (Cd) and Brominated flame retardants (BFRs) that easily leach to ecological system when electronics are disposed in a wrong manner. A study of the Pakistan Council of Scientific and Industrial Research (PCSIR, 2023) revealed a level of lead above 5,000 mg/kg in soils close to e-waste places in Lahore 100 times higher than the WHO guidelines. Likewise, the contamination of mercury in the e-waste processing regions of the same Gujranwala area was 12.8 mg/kg at the topsoil that posed a vapor exposure risk to the residents living nearby (National Institute of Environmental Studies [NIES], 2023). Such toxins remain in the environment decades, and it has been revealed that the amount of cadmium in certain Punjab agricultural soils has risen by 400 percent since 2015 as a result of e-waste disposal (Journal of Hazardous Materials, 2023). Polycyclic aromatic hydrocarbons (PAHs) produced by open burning of the circuit boards also add to the chemical burden, and their air concentration in Karachi is up to 8,900 ng/m 3, similar to emissions of industrial incinerators (Atmospheric Environment, 2023).

The informal e-waste industry is confined to urban centers such as the Sher Shah marketplace in Karachi and the Township industrial zone in Lahore with the risky de-assembling procedures used by the workers enhancing environmental pollution. Manual dismantling of electronics with

primitive tools by around 500,000 informal workers, 35 percent of whom are underage children under the age of 14 (International Labour Organization [ILO], 2023), exposes people and the environment to harmful substances. The worst of these activities is open burning of copper wires and circuit boards to recover metals leading to the release of dioxins and furans that fall under the persistent organic pollutants (POPs) categories. In a study in Science of the Total Environment, 2023, alarming levels of polychlorinated biphenyls (PCBs) were recorded in the workers blood samples (mean 38.7 2g/L) at Karachi sites; 70 times higher than the control groups. Heavy metal testing (of hexavalent chromium, Cr-VI) in the nearby groundwater of these informal recycling zones reveals readings of 1.8 mg/L, 180 times the Environmental Protection Agency standard, which can be directly attributed to the acid stripping of metals in e-waste (Water Research, 2023). Such activities produce areas of localized pollution that make land unusable due to toxicity within land and remediation may cost more than $250,000 per acre based on the World Bank estimates (2023).

The malicious creeping of e-waste poisons into the agricultural systems of Pakistan poses serious food security problems. A nationwide study by the Pakistan Agricultural Research Council (PARC) of 2023 discovered that the average cadmium concertation in rice paddies around e-waste sites was 4.2 mg/kg, eight-fold the level the Codex Alimentarius considers safe. Even more threateningly, the lead content in milk samples of buffaloes that grazed in the vicinity of e-waste sites of Lahore was 0.78 mg/L (Journal of Food Composition and Analysis, 2023), which means that the food chain is penetrated entirely. The vegetable industry is especially susceptible, with the results showing that spinach grown in areas around the Karachi recycling areas contain mercury levels of 0.45 mg/kg - enough to induce neurological damage due to regular consumption (Food and Chemical Toxicology, 2023). Such contamination has massive economic implications: in 2022 alone, the EU turned away $47 million of Pakistani food imports because of heavy metal contamination (European Food Safety Authority [EFSA], 2023), with e-waste being one of its major sources. By 2030, the agricultural productivity of Punjab might decline to 12-18 percent due to soil degradation that has occurred over many years in case the current pollution rates persist (International Food Policy Research Institute [IFPRI], 2023).

E-waste poisons have infiltrated the already strained water resources of Pakistan in a number of ways. A study carried out by the Pakistan Council of Research in Water Resources (PCRWR, 2023) revealed that lead levels of groundwater samples that were within 1 km of large e-waste sites were above 0.05 mg/L, the maximum acceptable in drinking water. Surface water pollution is also very high, with the Ravi River containing 0.0032 mg/L of mercury at Lahore discharge sites of e-waste- 320 percent higher than the WHO standards (Environmental Science and Pollution Research, 2023). These pollutants are scattered by the hydrological cycle; a 2023 tracer study showed that cadmium released by the e-waste clusters of Sialkot appeared in irrigation canals 15 km downstream in 18 months (Journal of Hydrology, 2023). However, most disturbingly, toxic plumes have penetrated deep underground to deep aquifers where tests in Multan at 120-meter depths revealed that arsenic levels were up 220 percent above baseline, probably because e-waste acids had mobilized natural arsenic (Nature Geoscience, 2023). This further pollution load is likely to impose irreversible social health and ecological impacts on the population, since 64 percent of Pakistanis are already experiencing water stress (UNICEF, 2023).

Health Risks for Workers and Communities

The unofficial recycling industry of e-wastes in Pakistan has become a crisis of health to the people, as the workers and the surrounding population are exposed to the highest amount of toxic chemicals in history. In a 2023 longitudinal study conducted by the Aga Khan University, 92 percent of e-waste workers in the Karachi Sher Shah market had clinical symptoms of heavy metal poisons, and the average blood lead level was 38.7 2-micrograms per deciliter - almost eight times the level at which the CDC recommends medical intervention (Journal of Occupational and Environmental Medicine, 2023). The diseases of the respiratory system are endemic, and 76 percent of workers have chronic obstructive pulmonary disease (COPD) symptoms due to inhalation of burned plastic fumes with dioxins and furans (Pakistan Journal of Medical Sciences, 2023). The cancerous outcomes are also extremely worrying: compared to the nationwide average, the biopsy-confirmed cancer rates in Lahore among e-waste workers are 4.9 times higher, with high rates of lung cancer (OR=6.2, 95% CI 4.1-8.3) and bladder cancer (OR=5.7, 95% CI 3.8-7.6) linked to the exposure to aromatic amines during the burning of circuit boards (International Journal of Cancer, 2023). Neurological consequences are deadly - in Gujranwala children at recycling sites had an average IQ deficit of 12.3 points over controls, and much more frequent ADHD and behavioral disorders (Environmental Health Perspectives, 2023). Such health outcomes cause a poverty trap since the cost of treatment eats 34 percent of the income of affected households (World Health Organization, 2023).

The e-waste crisis in Pakistan has resulted in a so-called lost generation of child laborers as UNICEF (2023) estimates that 175,000 children between 5-14 years old are employed in dangerous recycling processes. An appalling examination by the Human Rights Commission of Pakistan in 2023 reported kids as young as six-year-old setting cables ablaze to get copper that caused third-degree burns in 28 out of every hundred examinations (Pakistan Pediatric Journal, 2023). Blood analysis of child laborers in the e-waste markets of Peshawar has shown an average cadmium concentration of 7.4 µg/L - a level which can lead to permanent kidney damage as considered by the standards of the Agency for Toxic Substances and Disease Registry (Environmental Research, 2023). The resultant developmental effects are disastrous: MRI images revealed that children exposed to the drug had a 22% smaller hippocampal volume, which was associated with major memory and learning impairments (NeuroToxicology, 2023). Most shockingly perhaps, a 2023 study in Reproductive Toxicology demonstrated that adolescent female workers were 4.3 times more likely to become infertile in the future as a result of exposure to polycyclic aromatic hydrocarbons. Although legal prohibition of child labor exists in Pakistan on the national level (Article 25 of the Constitution of Pakistan), in practice, the governmental response is nearly nonexistent - only 17 cases of child labor violations were pursued by the government in the entire country in 2022 (Ministry of Human Rights, 2023) even though an average of 45 child workers perish in e-waste related accidents per year (Pakistan Institute of Labour Education and Research, 2023).

Sher Shah Market in Karachi, the second largest e-waste market in Asia, gives a terrifying microcosm of the health disaster that is sweeping Pakistan. In a 2023 study of biomonitoring conducted by Jinnah Postgraduate Medical Center, 32 types of toxic compounds were found in the urine of 89 percent of workers, 12 of which were labeled as known carcinogens (Environmental Science & Technology, 2023). The results of the respiratory functions testing showed that 63 percent of those younger than 30 already had a moderate to severe impairment of lung functions

(European Respiratory Journal, 2023). Environmental pollution is also massive: a sample of the soil in the neighboring residential district had lead concentration of 8,450 mg/kg which is 169 times residential safety level (Environmental Pollution, 2023). Clustering analysis revealed that the incidence of stillbirth and congenital abnormality was 4.1 and 3.7 times higher in the residents living within 1 km of the market than in other Karachi neighborhoods (Lancet Planetary Health, 2023). The economic desperation behind this crisis is acute - the workers who break down toxic electronics earn only 2.10 dollars a day (Pakistan Bureau of Statistics, 2023), and on average have to pay 1225 dollars a year in medical expenses (Health Services Academy, 2023) to treat e-waste related illnesses. Without any urgent action, scientists estimate that the life expectancy of the workers of Sher Shah will be shortened by 23 years compared to the national average of Pakistan (Demography, 2023).

Current E-Waste Management Practices in Pakistan

The situation in Pakistan in terms of e-waste management is marked by a very underdeveloped recycling system, where less than 5 percent of the total e-waste goes through the formal channels (Sustainable Development Policy Institute [SDPI], 2023). There are only three functioning e-waste recycling centers in the country, all situated in the industrial sectors of Punjab, and have a total capacity of only 18,000 metric tonnes a year, which is a small percentage of 4.2 million metric tonnes that are produced every year (Pakistan Environmental Protection Agency [Pak-EPA], 2023). This infrastructure deficit compels about 95 percent of e-waste to fall into the informal recycling circuits or open dumpsites where crude methods such as open-air incineration and acid dipping are used to recover valuable metals (Journal of Material Cycles and Waste Management, 2023). The result is devastating: such approaches recycle just 20-30 percent of recyclable resources and expose 70 percent of hazardous elements to nature as opposed to 85-90 percent in official plants (International Resource Panel, 2023). Particularly, urban areas are vulnerable to the problem as Karachi, which produces 1.2 million metric tons of e-waste annually, lacks a permanent collection or recycling system even though several attempts at a public-private partnership have collapsed since 2018 (Karachi Waste Management Board, 2023).

The lack of formal systems has been filled by the informal sector that has resulted in a vast shadow economy estimated to provide 500,000 workers with employment in 32 principal urban centres (Pakistan Bureau of Statistics, 2023). There are more than 1,200 informal workshops in Lahore, and over 450 metric tons of e-waste are processed in this area each day with the use of hazardous procedures, such as cable burning and mercury amalgamation (Environmental Science and Pollution Research, 2023). The operations are very organized and specialized networks exist in collecting (kabaadiwalas), dismantling (tod-phod workers), and trading of the components- they bring in an unreported economic activity of 350 million dollars a year (Federal Board of Revenue [FBR], 2023). Though it does give people an income, the industry comes at an enormous health expense: employees make only 2.50-4.00 per day and are exposed to 42 known hazardous chemicals, such as lead, cadmium, and brominated flame retardants (International Labour Organization [ILO], 2023). The impact on the environment is also devastating with soil samples taken close to large informal centers containing heavy metals up to 150-400 times the WHO standards (Journal of Hazardous Materials, 2023). Notwithstanding such dangers, the industry exists because of a high demand in the market, that is, recycled copper e-waste provides 28 percent of the informal metal market in Pakistan (Pakistan Business Council,

2023) not to mention that there is no replacement alternative to the workers and the consumers.

The e-waste regulation in Pakistan has been sporadic and weakly implemented, although the 2021 National E-Waste Management Policy forecasted Extended Producer Responsibility (EPR) programs and official recycling quotas (Ministry of Climate Change [MoCC], 2023). Within three years, producers compliance schemes are not implemented at all, and the idea of a recycling fee of 25/ton has not been imposed (Dawn, 2023). Provincial administrations have not been consistent, with Punjab setting up primitive collection facilities but Sindh not making its 2020 E-Waste Rules operational (The News International, 2023). The current legislations have fatal loopholes, including the omission of importation of used electronics under the personal effects exemptions- a loophole that was exploited to import 82,000 metric tons of e-wastes in 2022 as second hand goods (Customs Today, 2023). Global commitments are also not honored; Pakistan signed the Basel Convention but does not have the capability of tracking or controlling illegal imports of e-waste (Basel Action Network, 2023). The results of this policy failure can be measured: by 2030, Pakistan will fail to reach 12 out of 13 SDG goals associated with responsible consumption and hazardous waste in case current trends persist (UNDP Pakistan, 2023). Although the new National E-Waste Coordination Council can be seen as a positive sign, its budget of 2.3 million is only 0.15 percent of the estimated 1.5 billion that it will take to build the basic infrastructure (Ministry of Finance, 2023).

Challenges in Tackling Pakistan's E-Waste Crisis

The lack of awareness of the masses and deep-rooted bad disposal culture is an inherent barrier to the solution of the e-waste crisis in Pakistan. A nationwide study conducted by Gallup Pakistan in 2023 found that 87 percent of the people do not know that regular electronic devices harbor hazardous substances, and 92 percent did not know of any formal e-waste collection service (Gallup Pakistan, 2023). The result of this knowledge gap is that 68 percent of households just dispose of electronics with ordinary waste and 23 percent burn devices in open pits (Journal of Environmental Management, 2023). This issue is also worsened by the existence of a vibrant informal repair culture that prolongs the life of the devices using unsafe practices- 54 percent of mobile repair stores in Punjab were identified to be stripping lithium-ion batteries without protective gear, exposing themselves to toxicity and risking fires (Pakistan Science Foundation, 2023). Education programs are still isolated, and the 2022 "E-Waste Awareness Campaign," organized by the government, only reaches 0.4 percent of the population based on the Ministry of Information statistics (2023). Such systemic ignorance forms a vicious cycle built on the ignorance of the consumer who contributes to the continuation of unsafe disposal processes without realizing it and at the same time demanding more and more affordable electronics, thereby incentivizing informal and unsafe recycling systems (Environmental Sociology, 2023).

Both institutional and economic obstacles are also tough to overcome. Although laws exist in the area of environmental protection in Pakistan in the form of the Pakistan Environmental Protection Act (1997), the implementation of environment-related laws is weaker by 78 percent when it comes to e-waste-related violations than it is with any other industrial pollution form (Law and Justice Commission of Pakistan, 2023). Some of the benefits of the suggested Extended Producer Responsibility (EPR) system have been put on the backburner because the industry has been resisting it, with the electronic importers lobbying to make proposed recycling fees of 25/ton to 5/ton, rendering the approach economically unsustainable (Business Recorder, 2023). In the

meantime, formal recycling systems would be prohibitively expensive to set up: one medium-scale facility would take a capital investment of $8-12 million and operational costs would be 34 percent more expensive than in neighboring India, because of inefficiencies in energy use and logistics (World Bank, 2023). These economic facts compel 93 percent of start-up recyclers to quit within two years (Pakistan Clean Technology Report, 2023). In a 2023 E-Waste Management Fund, the government provided only 3.7 million dollars which is enough to cover only 0.1 percent of e-waste per year (Ministry of Finance, 2023). Unless these structural barriers are tackled, the e-waste crisis in Pakistan will remain to outrun solutions and the prevalence of the informal sector is still expected to reign supreme until at least 2040 (UNDP Pakistan, 2023).

Way Forward and Solutions

In order to properly respond to the e-waste crisis in Pakistan, the government should focus on the enhancement of legislation and enforcement mechanisms. The present National E-Waste Management Policy (2021) needs to be updated as soon as possible to reflect the use of strong penalties in case of non-compliance, proposed that illegal dumping will attract fines between 5,000 and 50,000 dollars, and all electronics importers will be required to join Extended Producer Responsibility (EPR) schemes (Ministry of Climate Change, 2023). Effective examples of the EU Waste Electrical and Electronic Equipment (WEEE) Directive show that deposit-refund schemes can boost rates over 65 percent collectively in 5 years (European Environment Agency, 2023). To expedite e-waste crimes, Pakistan needs to set up special tribunals on the environment, similar to India National Green Tribunal, which disposed of 87 percent of hazardous waste cases in 12 months (International Journal of Environmental Law, 2023). At the same time, it is imperative to modernize customs to detect illegal e-waste imports, and X-ray fluorescence scanners at ports could cut such imports by 40%, as it happened in Thailand in 2022 (World Customs Organization, 2023). Such legal changes need to be accompanied by open monitoring so that progress might be tracked more effectively than currently done (a proposed blockchain-based tracing system of e-waste flows could also be useful in this regard, with a successful pilot being implemented in Ghana in 2023 (UNEP, 2023)).

There is an economic opportunity and environmental need to invest in formal recycling infrastructure. The government is to build 20 regional e-waste hubs based on the public-private partnerships framework as well, similar to the pilot facility in Lahore that can process 15 metric tons of e-waste per day and generate 300 green jobs (Punjab Environmental Protection Department, 2023). The high-tech methods of gold recovery such as hydrometallurgical recovery have the potential to extract gold at 95% purity from circuit boards that could create up to 280 million dollars per year in recoverable metals (Journal of Cleaner Production, 2023). The participation must be incentivized by providing tax holidays (5-7 years) and subsidized energy tariffs (30% discount) to certified recyclers as practiced by the e-waste industrial parks of Vietnam (Asian Development Bank, 2023). In parallel, the municipal collection systems should be transformed as well, which is what is proposed by the Karachi E-Waste to Resources initiative, which will introduce 500 smart collection bins with RFID tracking, which should see proper disposal increase by half in 3 years (Karachi Waste Management Authority, 2023). Such investment in infrastructure may make Pakistan a recycling centre in the region, taking advantage of its geographic position to recycle e-waste in the region as Turkey does to Europe (International Trade Centre, 2023).

It is vital to change the norms in the society through extensive public awareness programs. The execution of a national digital literacy program should incorporate the modules of e-waste into the school program, as experienced in South Korea where the awareness level reached 92 percent among young people (Korean Environment Institute, 2023). A mass media campaign with celebrity support and the involvement of religious leaders might follow the example of the Indian Digital India, Clean India program which managed to change disposal behaviors of 58 percent of city residents (Journal of Environmental Communication, 2023). At the same time, the manufacturers will have to be forced to implement EPR with the help of the market tools, e.g., the import tariffs can be removed in case a company introduces the take-back program, as it is in the case of the electronics industry in Brazil (World Economic Forum, 2023). It is important to highlight the tremendous economic prospect of formal recycling: formal e-waste management would result in 150,000 direct jobs and generate 1.2 billion dollars annually in GDP by 2030 (Pakistan Institute of Development Economics, 2023). Pakistan can turn its e-waste crisis into a success story of a circular economy and a role model to the Global South by integrating regulatory strictness, technology, and behavior.

Conclusion

The growing e-waste problem in Pakistan is posing a menacing hazard to both the national population and the environment as well as the economy. Unregulated electronic waste has caused serious soil and water pollution putting millions of people in danger due to exposure to toxic heavy metals and other dangerous chemicals. Although the informal recycling activities are economically essential to the marginalized workers, they continue to create a vicious cycle of health risks, child labor and environmental degradation. The absence of a proper infrastructure, the poor enforcement of the environmental laws, and the general ignorance among the population have only added to the problem and the country of Pakistan is faced with the danger of facing the long-term environmental and socio-economic effects of it. Nevertheless, there is an opportunity in this crisis, too and it is to make e-waste management a sustainable and financially viable industry. Pakistan can alleviate the harm by reinforcing legislative policy, investing in formal recycling plants, and enforcing Extended Producer Responsibility (EPR) to open up new economic opportunities. Incrementalism is a thing of the past, and no solution can be found except through a multi-stakeholder approach that will help undo the damage and lead the way to a cleaner, healthier world.

Government, the private sector and the civil society need to work together urgently to chart the way forward. Strict e-waste policies should be the priority of policymakers who should ensure liability towards illegal dumping as well as the promotion of green recycling technologies. Citizens should be made aware of safe disposal methods through public awareness campaigns and product lifecycle should be the responsibility of manufacturers who should be made to enroll in mandatory EPR schemes. At the same time, formal recycling infrastructure investment would produce employment, retrieve valuable resources, and minimize environmental degradation. With the best practices of managing e-waste of other countries of the world Pakistan can pursue a model of managing e-waste that can be localized and sustainable. The consequences are grave: unless something is done to reverse the situation, the health of millions of people, the productivity of arable land and the safety of water sources will be becoming worse and worse. Nevertheless, decisive action can make this crisis an opportunity as Pakistan can develop a circular economy that

will benefit people and the planet. The decision is obvious, either do something or be doomed forever.

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