

Public Cognizance of E-waste Effects on Human Health and Environment: Evidence from Punjab, Pakistan

MOHAMMAD ARMUGHAN and SAMEEN ZAFAR

The negative effects of electronic waste (e-waste) on the environment and human health are globally acknowledged. Across the world, developing countries in Asia are the most vulnerable countries in hosting e-waste. Informal recycling and crude processing of e-waste cause environmental degradation and harm human health. Therefore, the study analyzes public awareness about e-waste effects on human health and the environment using a logit model with a mean comparison of variables based on primary data of 312 respondents. Meanwhile, the study notifies the correlation of e-waste generation with gross domestic product (GDP), population, and electrical & electronic equipment (EEE) put in the Pakistani market. Moreover, the study discusses other pollutants putting a burden on human lives and the environment in Pakistan. Lastly, we provide a brief overview of the study's implications on both theory and practical applications while emphasizing key areas for future research work.

Keywords: E-waste, Human Health, Environment, Public awareness.

1. INTRODUCTION

Electrical and electronic equipment (EEE) includes all types of products that are used in business, transportation, household, health, security, and power generation systems. In short, *“any household or business item with circuitry or electrical components with power or battery supply is called EEE”* (Step Initiative, 2014). E-waste is the abbreviation of “electronic waste”. *“E-waste is a term used to cover items of all types of EEE and its parts that have been discarded by the owner as waste without the intention of re-use.”* (Step Initiative, 2014).

Globally, 40,634,930 still counting tons of e-waste thrown out in 2021 (The World Counts, 2021). In 2019, about 53.6 million metric tons (Mt) of e-waste was produced and it is expected to exceed 74Mt in 2030 (Forti et al., 2020). E-waste is slightly different from other wastes. E-waste carries harmful substances (lead, mercury, flame retardants, arsenic, etc.) and valuable metals (silver, copper, gold, etc.) that need special recycling techniques to protect the environment and human health (Sepúlveda et al., 2010). E-waste is composed of 30% organic material (flame retardants, polymers, and glass fiber), 40% inorganic materials (non-ferrous and ferrous), and 30% ceramics material (alumina, mica, and silica) (Rautela et al., 2021). Inorganic metals contain base metals (tin, aluminum, copper, and iron), valuable metals (palladium, gold, and silver), heavy metals (cadmium, nickel, zinc, chromium, mercury, lead, and beryllium), and earth metals (tantalum, gallium, and platinum groups) (Kaya and Martin, 2016).

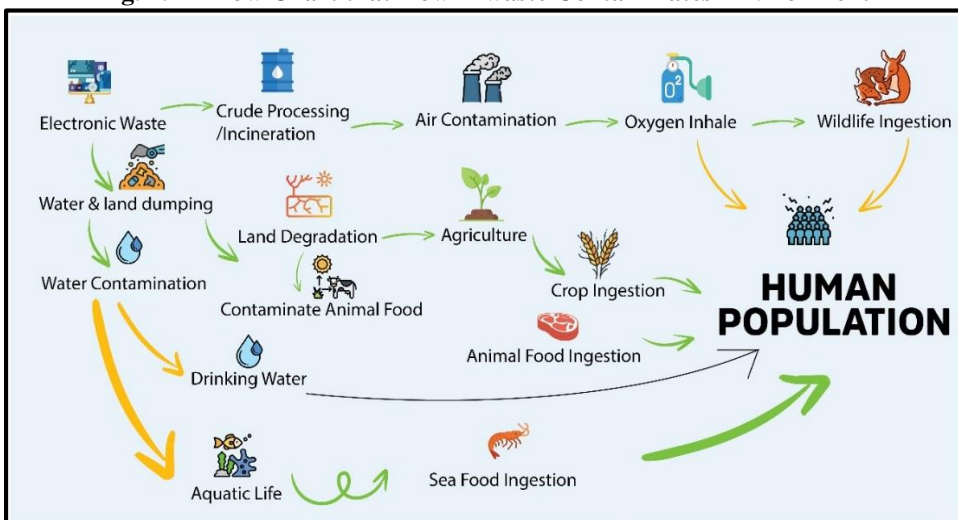
Mohammad Armughan <armughan@pide.org.pk> is Research Fellow, Pakistan Institute of Development Economics (PIDE), Islamabad. Sameen Zafar is affiliated with the Suleman Dawood School of Business (SDSB), Lahore University of Management Sciences (LUMS), Lahore.

Heavy metals contaminate the environment with low concentrations by biomagnification in animals and plants or chemical concentration in the food cycle (Fu et al., 2008; Luo et al., 2011). Plants absorb heavy metals through soil and water, whereas humans and animals intake heavy metals via air, water, and food ingestion (Zhao et al., 2010).

E-waste possesses many hazardous substances like brominated flame retardants, cadmium, polychlorinated biphenyls, lead, and mercury that pollute the environment and jeopardize human health without direct exposure to the environment (Wong et al., 2007). Normally, the processing of e-waste retrieves precious metals (copper, gold, and silver) by using simple techniques like open burning, acid leaching, melting, and incineration. These processes release a vast range of poisonous gases and heavy substances into the environment which pollutes the atmosphere, and terrestrial and aquatic ecosystems (Grant et al., 2013). Improper disposal and crude processing of e-waste, as highlighted by Patil and Ramakrishna, (2020), have been shown to result in chronic and life-threatening health issues, including kidney damage, lung cancer, liver damage, and eye and throat infections, among others. These health issues not only impact workers involved in the crude processing of e-waste (Caravanos et al., 2011) but also affect the general population coming into contact with environments contaminated by e-waste and its toxic components (Huo et al., 2007; Liu et al., 2018).

In developing and poor countries usually the opportunity cost of treating and recycling e-waste is human health and environment (UNEP, 2010). In comparison with other continents, Asia is at the top in generating e-waste with 24.9 Mt (Forti et al., 2020). E-waste recycling, crude processing, and dumping cause serious human health issues. E-waste incineration contaminates the air, e-waste land dumping causes soil pollution, and disposing of e-waste in rivers pollute water leading to overall environmental degradation. Resultantly, people inhale polluted air, drink adulterated water, eat compromised seafood and land grow tainted crops. Considering the process, heavy metals are included in our food chain through crop ingestion and seafood ingestion. A causal loop between e-waste and its effects on human health and the environment is shown in Figure 1.

Fig. 1. A Flow Chart that How E-waste Contaminates Environment



Source: Authors work*

* Flow chart is designed by Ms. Manhal Zainab (graphic designer at PIDE).

Pakistan generated 433 kilotons (Kt) of e-waste in 2019 (Forti et al., 2020). National Environment Policy (NEP) in Pakistan covers air, water, ozone, climate change, agriculture, and import/export of hazardous chemicals or waste products (NEP, 2005). On June 28, 2022, the National Hazardous Waste Management Policy (NHWMP) was approved by Pakistan's federal cabinet which caters to e-waste trade, generation, dumping, and discusses transboundary movement of hazardous wastes. With a great sigh, NHWMP fails to elaborate on e-waste management in the country (NHWMP, 2022). Regretfully, so far, no policy implementations have been observed on private or public levels.

Annually, Pakistan receives an average influx of 95,415 tons of electronic waste (Imran et al., 2017). It has come to light that within the sprawling urban landscape of Karachi, the nation's largest metropolis, informal e-waste recycling has emerged as a significant sources of organic flame retardant emissions (Iqbal et al., 2017). These emissions not only compound environmental degradation but also pose a consequential risk to the health and well-being of the labor force engaged in e-waste recycling activities (Iqbal et al., 2017).

Rapid technological advancement in consumer goods drives the demand for EEE, directly contributing to the escalation of e-waste volumes as consumers play a pivotal role in this process. Various studies have shown that public awareness is an essential element in reducing e-waste. (Borthakur and Govind, 2018; Safa'at et al., 2019; Islam et al., 2020; Zafar and Armughan, 2023). Therefore, based on primary data with a sample size of 312, the study aims to assess public awareness about e-waste effects on human health and the environment in Pakistan. Moreover, the study depicts e-waste generation in Pakistan. For better analysis, the study investigates e-waste correlation with the gross domestic product (GDP), population, and EEE put on the Pakistani market, which are strongly correlated. The study offers insights into the diseases caused by e-waste and its contribution to environmental degradation through an extensive literature review. Lastly, the study incorporates a slight overview of other pollutants that are causing harm to the environment and affecting human health.

2. LITERATURE REVIEW

2.1. E-waste in Global Context

The rapid growth of EEE industry with information technology, aid in generating e-waste globally and poses threat to human health and the environment (Duan et al., 2009; Song et al., 2013). In 2009, Robinson (2009) estimated that global e-waste production range from 20 - 25 million tons annually. The world generated around 44.7 Mt of e-waste in 2016 and it is estimated that it will surpass 53 Mt in 2021 (Baldé et al., 2017). Worldwide e-waste quantity is growing exponentially at the rate of about 2 Mt yearly (Forti et al., 2020).

2.2. E-waste in Asian context

In Asia, 24.9 Mt e-waste was generated of which 2.9 Mt e-waste was properly collected and recycled (Forti et al., 2020). Some of the largest e-waste-generating Asian countries are given in Table 1.

Table 1

Largest e-waste-generating Asian countries in 2019.

Sub Region	E-waste generated
Western Asia	2.6 Mt 6 kg per capita
Turkey	847 Kt
Saudi Arabia	595 Kt
Iraq	278 Kt
Central Asia	0.2 Mt 7.1 kg per capita
Kazakhstan	172 Kt
Turkmenistan	39 Kt
Kyrgyzstan	10 Kt
Eastern Asia	13.7 Mt 8.6 kg per capita
China	10129 Kt
Japan	2569 Kt
South Korea	818 Kt
South-Eastern Asia	3.5 Mt 5.4 kg per capita
Indonesia	1618 Kt
Thailand	621 Kt
Philippines	425 Kt
Southern Asia	4.8 Mt 2.6 kg per capita
India	3230 Kt
Iran	790 Kt
Pakistan	433 Kt

Source: Global E-waste Monitor 2020.

Despite the existence of the Basel Convention, E-waste is exported from the United States (US), Australia, Canada, European Union (EU) countries, Kuwait, Singapore, United Arab Emirates (UAE), Japan, and Korea to India, China and Pakistan (Cobbing, 2008; Li et al., 2013). Where Singapore and UAE play the role of intermediaries for distributing e-waste from US and EU countries to South Asian countries (Cobbing, 2008). Over 9 years (2005 – 2014), the quantity of generating e-waste is doubled in Southeast Asian countries (Iqbal et al., 2015).

Besides the world's largest manufacturing country, China is considered an e-waste dumping hub (Chi et al., 2011). Moreover, China receives e-waste in large quantities from developing countries (Shinkuma and Huong, 2009).

India is considered a highly polluted and populated country. The rapid industrialization in India has caused threats to the environment and human health (Parikh, 2012). India is trying to deal with its e-waste in an eco-friendly manner because e-waste is ruining the ecological system (Maheshwari et al., 2013).

Pakistan imports approximately all major EEE which means the entire EEE sector is dependent on importation (Bashar, 2000). The extensive growth in EEE imports elucidates the increasing trend of e-waste generation in the near future (Iqbal et al., 2015). In 2014, Pakistan's mobile phone subscriptions were 138 million, indicating the threat of increasing e-waste (PTA, 2014). In 2021, Pakistan's total mobile phone subscriptions increased from 138 to 185 million (PTA, 2021). Pakistan is considered one of the prime locations for e-waste dumping where e-waste is treated illegally and informally (Puckett, 2002; Iqbal et al., 2015).

2.3. E-waste and Public Cognizance

Public awareness regarding e-waste is a vital research area, especially among young consumers driving demand for electronic products. In the United States, a study revealed that consumer actions played a pivotal role in managing and reducing e-waste (Arain et al., 2020). A study conducted in Ghana by Edumadze et al. (2013) highlighted the significant challenge posed by low public awareness of e-waste, hindering the adoption of proactive eco-friendly practices. In Asian developing nations such as India and Bangladesh, e-waste recycling procedures prove inefficient due to the widespread lack of awareness among the majority of the population regarding the proper handling and disposal of e-waste (Sivathanu, 2016). Research conducted in northwest China found that young consumers exhibited limited awareness of recycling programs, policies, and e-waste laws, emphasizing the importance of law awareness for effective e-waste management (Ramzan et al., 2019). In a study conducted in India, Sivathanu (2016) found that there was a direct correlation between consumer awareness and the inclination to engage in e-waste recycling.

In essence, it is crucial to take into account consumers' awareness of EEE, as they are the primary generators of e-waste (Kwatra et al., 2014). Increasing e-waste awareness among consumers holds particular significance in areas characterized by larger and urban populations (Safa'at et al., 2019). Across different countries, numerous non-governmental organizations (NGOs) have made efforts to educate the public about the significance of e-waste management. For instance, they utilize social media as a platform to engage and disseminate information about e-waste to consumers (Hutami et al., 2020).

2.4. E-waste Impact on Human Health

E-waste recycling processes contain top 10 chemicals which have adverse effects on human health (WHO, 2021). The chemicals include heavy metals like cadmium, dioxins, mercury, lead, fine particles (particulate matter 2.5), and other air pollutants (WHO, 2021).

The studies have found crude processing, recycling, and disposal of e-waste are related to adverse health effects (Forti et al., 2020). These include effects on children's height (Zheng et al., 2008), thyroid stimulating hormone (TSH) (Yuan et al., 2008), increases oxidative stress biomarkers (Chung et al., 2008), unfavorable birth results (Zhang et al., 2017), affect neurodevelopment (Huo et al., 2019), affect cognitive skills (Soetrisno and Delgado-Saborit, 2020), damage DNA (Alabi et al., 2012), heart diseases (Cong et al., 2018), affect respiratory system (Amoabeng Nti et al., 2020), affect immune system (Huo et al., 2019), affect hormonal system (Maheshwari et al., 2013), skin diseases (Decharat and Kiddee, 2020), hearing loss (Xu et al., 2020), and cancer (Davis and Garb, 2018). For details see Table 2.

2.5. E-waste Impact on Environment

Disposing of e-waste by landfills contains hazardous metals that contaminate land, soil, and other biodegradable waste (Patil and Ramakrishna, 2020). Dumping e-waste fragments in rivers may leach harmful substances into groundwater, drinking water, and irrigation systems through which heavy metals enter the food chain (Patil and Ramakrishna, 2020). Toxic e-waste pollutants may enter the food chain by plant roots through contaminated groundwater and soil (Maheshwari et al., 2013).

Incineration of e-waste fragments like wires and cables containing polyvinyl chloride (PVC) for extracting valuable materials contains harmful chemicals like acid fumes and dioxins (Patil and Ramakrishna, 2020). The remaining fly ashes of burned e-waste in the vicinity are also very dangerous for the environment (Leung et al., 2008).

Table 2

E-waste Impacts on Human Health and the Environment.

Heavy Metals	Electrical and Electronic Equipment	Environment Exposure	Effects on Human Health
Lead (Grant et al., 2013; Huo et al., 2019)	Circuit boards, light bulbs, cathode ray tubes, batteries, televisions.	Soil, water, air	Renal, heart diseases, neurodevelopmental, reproductive system
Chromium (Grant et al., 2013)	Tapes, anticorrosion coatings, floppy disks	Soil, water, air	Allergy, cancer
Cadmium (Grant et al., 2013; Lin et al., 2017)	Switches, batteries, connectors, circuit boards, infrared detectors, semiconductor chip, mobile phones, cathode ray tubes, printer's ink/drum, toners, photocopying machines	Soil, water, air, food (vegetables and rice)	Bone, renal
Mercury (Grant et al., 2013; Lin et al., 2017)	Thermostats, switches, monitor, sensors, cells, circuit boards, LCD, screens, cold cathode, fluorescent lamps	Soil, water, air, food (seafood)	Ingestion, inhalation neurodevelopmental renal, dermal contact
Nickel and lithium (Grant et al., 2013; Lin et al., 2017)	Batteries, cathode ray tubes	Soil, water, air, food (plants)	Liver, allergy, inhalation, ingestion, transplacental, skin contact
Barium (Huang et al., 2014; WHO, 2021)	Vacuum tubes, fluorescent lamps, cathode ray tubes	Soil, water, air, food	Neurodegenerative disease
Beryllium (Grant et al., 2013; WHO, 2021)	ceramic components of electronics, computers, power supply boxes, X-ray machines	Water, air, food	Cancer, lung disease, skin diseases
Brominated flame retardants Polybrominated diphenyl ethers (PBDEs) (Yu et al., 2018; WHO, 2021)	Plastics (thermoplastic components) of computers	Soil, water, air, food	Reproductive system, endocrine disruption, neurodevelopmental
Polychlorinated biphenyls (PCBs) (He et al., 2015; WHO, 2021)	Dielectric fluid in electrical equipment (capacitors and transformers)	Soil, water, air, food (seafood)	Damage DNA, impact neurodevelopment and cognitive function, damage human peripheral lymphocytes

Globally, extensive research has been conducted on the impacts of e-waste on both human health and the environment. However, in the specific context of Pakistan, there is a noticeable dearth of research on this critical subject matter, resulting in a significant literature gap. This research study serves the pivotal purpose of bridging this gap by conducting an initial public awareness assessment of the effects of e-waste on human health and the environment. This assessment draws from a wide range of primary data, thereby establishing a valuable foundation of knowledge for future studies related to this critical topic within the Pakistani context.

3. METHODOLOGY

3.1. Primary Data

For primary data, a questionnaire was designed and distributed among metropolitan cities i.e., Islamabad[†], Lahore, Rawalpindi, Multan, and Faisalabad. Initially, 20 questionnaires were piloted in Lahore. After minor adjustments, the online questionnaire was distributed to the Pakistani public through formal (emails) and informal (social media) channels. We used a convenient sampling technique due to our target audience being the general public. Around 400 questionnaires were circulated, with a response rate of 78% the study included 312 responses for the analysis which were considered to be sufficient for population representation, as mentioned by Sekaran (2002) sample size greater than 30 is appropriate for research. For analysis, we used logistic regression because our predicted variable (public awareness) is dichotomous. Moreover, for further analysis mean comparison of variables was conducted to assess public awareness about e-waste effects on human health and the environment in STATA. All the quantitative data was collected from metropolitan cities of Punjab (a province in Pakistan).

Logit Model Explanation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

Y = public awareness about e-waste's effect on human health and environment

β_0 = constant

χ_1 = household income

χ_2 = education

χ_3 = age

χ_4 = gender

χ_5 = city scaled according to the development

ε = error term

Logistic Regression

Logistic regression is a statistical technique used to explore and quantify the relationship between a binary dependent variable (in this case, public awareness, which can be either aware or not aware) and one or more independent variables. The goal is to understand how changes in the independent variables influence the likelihood of an individual being aware of e-waste issues.

[†]Islamabad is capital territory but for the study it is included in Punjab (province of Pakistan).

Mean Comparison

Mean comparison is an essential statistical technique that allows you to quantify and understand how variables differ or relate to each other. It provides valuable insights for research, decision-making, and hypothesis testing. Thus, we conducted a mean comparison analysis on data from 312 respondents to assess differences in variables and categories.

3.2. Secondary Data

For secondary data, a systematic literature review of e-waste effects on human health and the environment was conducted with a comprehensive search of existing literature from published journal articles, institutional reports, and official websites. Moreover, secondary data comprises time series data of Pakistan from 2015 to 2019. E-waste generated and EEE put on market data were collected from “The Global E-waste Statistics Partnership”, and gross domestic product (GDP) and population-related data were collected from “World Bank”. All secondary data was compiled in MS Excel and exported to STATA. As mentioned by Kusch-Brandt and Hills (2017) and Perkins (2014) GDP and population are associated with e-waste generation. Therefore, based on the data, the Pearson Correlation test was conducted to see the relationship between variables in the context of Pakistan. For the strength of Pearson correlation (refer to Table A1 in the appendix).

Explanation of variables for Pearson correlation

- E-waste generation
 - Overall e-waste produced in Pakistan
 - E-waste generated per capita in Pakistan
- EEE put on the market
 - Overall EEE put on the Pakistani market
 - EEE put on market per capita in Pakistan
- Population
 - Population living in Pakistan
- Gross domestic product (GDP)
 - GDP of Pakistan in terms of purchasing power parity (PPP) in United States dollar (USD)

4. RESULTS AND DISCUSSION

Pakistan is a developing country with weak and pliable laws leading to illegal import, informal recycling, crude processing, and dumping of e-waste (Iqbal et al., 2015; Sajid et al., 2018). E-waste generation in Pakistan is growing exponentially because it imports secondhand EEE and e-waste in large quantities. Over time Pakistan is becoming a prime location for e-waste recycling and dumping. The site areas of metropolitan cities (Karachi, Hyderabad, Peshawar, Lahore, Rawalpindi, Multan, Gujranwala, and Faisalabad) of Pakistan are dumping and recycling points for e-waste.

4.1. Results and discussion on primary data

4.1.1. Demographics

The primary data was collected from five metropolitan cities of Punjab. In the survey most participants were young from the age bracket of 18 to 32. Among participants 56% were male and 44% were female. Respondents were from diverse social classes of education, occupation, income, and residence. For details, please refer to Table 3.

Table 3

Demographic Characteristics of the Respondents

Demographics	Sample Size (N)	Sample Size (%)
Gender		
Male	175	56
Female	137	44
Age		
18 – 22	48	15
23 – 32	232	74
33 – 42	18	6
43 – 52	9	3
53 and above	5	2
Education		
Matriculation	9	3
Intermediate	19	6
Bachelors	130	42
Masters	143	46
Doctorate	11	4
Occupation		
Unemployed	19	6
Employed	112	36
Student	163	52
Entrepreneur	18	6
Household Income (Monthly in PKR)		
50,000 – 70,000	81	26
70,001 – 110,000	90	29
110,001 – 150,000	111	36
150,001 and above	30	10
City		
Islamabad	72	23
Lahore	109	35
Multan	59	19
Faisalabad	48	15
Rawalpindi	24	8

4.1.2. Public Cognizance

According to the survey, about 271 (87%) among 312 were concerned about the environment. Around 237 (76%) participants were aware that “*e-waste typically contains hazardous materials that can harm human health and the environment.*” Among 312

respondents 271 (87%) responded that everyone should contribute to a sustainable environment.

To obtain a clearer picture of the relationship between income and public awareness, it's essential to control potential confounding variables. These are variables that might also affect awareness and could create spurious or misleading results if not taken into account. In this study, education, age, gender, and city were identified as potential confounding variables and were included in the analysis (Table). To see the measure of the fitness of the logit model please (refer to Table A2 in the appendix).

Table 4
*Logistic Regression Results for Public Awareness about E-waste's
Effects on Human Health & Environment.*

Awareness ⁺	(1)	(2)	(3)	(4)	(5)
Income	0.552*** (0.159)	0.478** (0.165)	0.536** (0.172)	0.523** (0.173)	0.518** (0.172)
Education		0.629*** (0.185)	0.584** (0.187)	0.591** (0.188)	0.585** (0.188)
Age			-0.677*** (0.206)	-0.674** (0.205)	-0.657** (0.206)
Gender				-0.187 (0.313)	-0.180 (0.314)
City					-0.0342 (0.0521)
Constant	0.765*** (0.215)	-0.586 (0.445)	0.171 (0.501)	0.277 (0.532)	0.491 (0.624)
N	312	312	312	312	312

t statistics in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

⁺Public awareness about e-waste's effects on human health and the environment.

Income's Positive Significant Impact: In accordance with the findings of (Bhat and Patil, 2014), our study analysis revealed that in Pakistan (Punjab) income has a statistically significant positive impact on public awareness regarding e-waste. This means that as income levels increase, the likelihood of individuals being aware of e-waste issues also increases. Importantly, this positive impact holds true even when we control for education and age, indicating that income's effect is robust and not merely a result of these other variables.

Negative Net Impact of Gender and City: Conversely, gender and city had a negative net impact on public awareness, as suggested by the analysis. This means that, on average, individuals of a certain gender or residing in specific cities of Punjab tended to have lower levels of awareness regarding e-waste, all else being equal.

Continued Significance of Income: Even when we accounted for the influence of gender and city in the analysis, income's impact on awareness remained statistically significant. This reaffirms the importance of income in driving awareness and suggests that it's not solely influenced by gender or geographic location.

Based on the findings, we can conclude that income is positively related to public awareness of e-waste in Punjab. In other words, individuals with higher incomes are more likely to be aware of the negative effects of e-waste on human health and the environment. This could be attributed to various factors, such as greater access to information and resources. Furthermore, the study also observed a positive relationship between education and public awareness, indicating that individuals with higher levels of education tend to be more aware of e-waste issues in Punjab.

Table 5 displays a mean comparison of various variables, such as gender, income group, city of residence, and more. This analysis aims to uncover differences in public awareness levels regarding the effects of e-waste on human health and the environment across different demographic groups.

Gender Differences: Similar to (Fan et al., 2022), our study reveals that females tend to be more aware of the adverse effects of e-waste on human health and the environment compared to males of Punjab. This suggests that there may be gender-specific factors or information sources that contribute to this difference in awareness.

Age and Tech-Savviness: Consistent with the discoveries from (Agyei-Mensah and Oteng-Ababio, 2012), our study shows people in the age bracket of 18 to 32 in Punjab exhibit higher awareness levels regarding e-waste effects. This can be attributed to the fact that the younger generation, often referred to as "digital natives," is more tech-savvy and likely to engage with electronic devices and information about their environmental impact.

Income and Awareness: In Pakistan (Punjab), respondents with monthly incomes below 110,000 PKR are less aware of e-waste effects compared to those earning more than 110,000 PKR per month. This suggests that individuals with higher incomes may have more access to information or resources that enable them to be more aware of e-waste issues. However, likewise (Agyei-Mensah and Oteng-Ababio, 2012) it's interesting to note that in Punjab awareness slightly decreases when income surpasses 150,000 PKR per month, indicating a potential saturation point where income's influence on awareness plateaus.

Education Levels: In line with the findings of (Bhat and Patil, 2014; Liang and Sharp, 2017), our study indicates that public awareness of e-waste effects tends to increase with higher levels of education in Punjab. Respondents with master's and bachelor's degrees are more aware of these issues compared to those with lower educational qualifications. This observation suggests that education plays a crucial role in shaping awareness levels, possibly by enhancing individuals' understanding of environmental concerns.

Occupation Status: When considering occupational status in Punjab, the analysis reveals that employed individuals and students tend to be more aware of e-waste effects compared to the unemployed and entrepreneurs. This may be attributed to the fact that individuals in employment or academic settings are more exposed to information and discussions related to e-waste and its implications.

City-wise Awareness: Lastly, the study ranks metropolitan cities in Punjab based on their levels of awareness about e-waste effects, from least to most aware. In chronological order, the cities are Rawalpindi, Lahore, Multan, Islamabad, and Faisalabad.

Table 5
Mean Comparison of Different Classes.

Mean Comparison	Mean	SD	Freq
Gender			
Female	0.825	0.382	137
Male	0.783	0.413	175
Total	0.801	0.4	312
Age			
18-22	0.75	0.438	48
23-32	0.862	0.346	232
33-42	0.444	0.511	18
43-52	0.444	0.527	9
Above 52	0.4	0.548	5
Total	0.801	0.4	312
Income			
0-70,000	0.679	0.47	81
70,001-110,000	0.778	0.418	90
110001-150,000	0.892	0.312	111
Above 150,000	0.867	0.346	30
Total	0.801	0.4	312
Education			
Matric	0.333	0.5	9
Intermediate	0.474	0.513	19
Bachelor	0.8	0.402	130
Master	0.895	0.307	143
PhD	0.545	0.522	11
Total	0.801	0.4	312
Occupation			
Unemployed	0.421	0.507	19
Employed	0.848	0.36	112
Student	0.834	0.373	163
Entrepreneur	0.611	0.502	18
Total	0.801	0.4	312
City			
Rawalpindi	0.542	0.509	24
Multan	0.814	0.393	59
Faisalabad	0.917	0.279	48
Lahore	0.789	0.41	109
Islamabad	0.819	0.387	72
Total	0.801	0.4	312

This ranking provides valuable insights into geographical variations in awareness levels, which could be influenced by factors such as access to information, environmental initiatives, or local educational resources.

Mean comparison analysis uncovers several important findings regarding the factors influencing public awareness of e-waste effects. These insights can be valuable for designing targeted awareness campaigns, educational programs, and policy interventions to improve awareness and environmental consciousness among different demographic groups.

4.2. Results and Discussion on Secondary Data

4.2.1. Pearson Correlation

According to Kusch-Brandt and Hills (2017), e-waste generation is linked with GDP. Likewise, our study confirms that e-waste generation is strongly correlated with GDP see Table.

Table 6

The Pearson Correlation Test Results of E-waste with Other Variables

Variables	Correlation	
	Coefficient (r)	Interpretation
E-waste generated with GDP	0.9872	Very strong correlation
E-waste generated per capita with GDP per capita	0.8955	Strong correlation
E-waste generated with population	0.9988	Very strong correlation
E-waste generated with EEE put on the market	0.9362	Very strong correlation
E-waste generated per capita with EEE put on the market per capita	0.9224	Very strong correlation

GDP serves as a standard and widely accepted measure of a country's economic development. It provides valuable insights into the overall economic performance of a nation. In the context of Pakistan, like in many countries, GDP plays a pivotal role in assessing the country's economic health.

GDP and Standard of Living: Pakistan's economic growth is intricately linked to the standard of living of its population. As the economy expands, people often experience improvements in their income levels and overall financial well-being. This economic progress often leads to significant lifestyle changes.

Changing Lifestyle and Electronics Preferences: As individuals experience economic growth, their preferences and priorities regarding spending also evolve. People tend to allocate more of their resources towards acquiring advanced EEE. This shift in preferences is driven by a desire for improved quality of life, convenience, and access to modern technology.

Economic Development and E-Waste Generation: The connection between economic development and e-waste generation is notable (Kusch-Brandt and Hills, 2017). Likewise, in Pakistan, an increase in the economic well-being of a population typically translates into a higher demand for electronic devices, contributing to the generation of e-waste. This is because individuals and households with higher incomes tend to invest more in electronic gadgets, from smartphones to computers and other consumer electronics.

Globalization and Tech-Savvy Culture: In the era of globalization, the concept of purchasing power parity comes into play. As individuals' purchasing power increases, they

are more inclined to spend on electronic items (Baldé et al., 2017). This phenomenon is often driven by a desire to stay tech-savvy and keep up with the latest advancements in technology. Hence, there is a strong correlation between e-waste generation per capita and GDP per capita in Pakistan. The more economically empowered a population is, the more they spend on electronic devices.

Changing Trends in Electronic Consumption: Broadly speaking, trends in electronic consumption have shown that people are spending comparatively more on EEE due to a combination of professional and personal requirements (Forti et al., 2020). Similarly, in Pakistan electronic devices have become integral to daily life, facilitating communication, work, entertainment, and education. This growing reliance on electronics further fuels the demand for such products in Pakistan.

Population Growth and E-Waste Generation: As indicated by research, such as the study conducted by Perkins et al (2014), there is a pronounced association between population growth and the generation of e-waste. This relationship is not unique and is echoed in various parts of the world. Our study supports this association, reinforcing the notion that e-waste is strongly correlated with the growth of Pakistan's population.

Demand for Affordable Electronics: In Pakistan, where employment opportunities may be insufficient, and many individuals face low-income levels and affordability challenges, there is a considerable demand for cheap electronic products. People often seek affordable options for acquiring necessary electronic devices, such as smartphones and laptops, which have become integral to modern life.

Importation of Used EEE: To meet this demand for affordable electronics, Pakistan imports electronic waste in the form of used EEE for resale and recycling (Iqbal et al., 2015; Sajid et al., 2018). This practice, while addressing the affordability concern, carries significant implications. Importing e-waste, particularly in an unregulated manner, can result in economic gains for some but comes at a considerable cost to human health and the environment.

Economic Benefit versus Human and Environmental Costs: In developed countries, discarded EEEs are categorized as 'waste' with no salvage value, while in developing countries, such 'waste' is treated as valuable (Borthakur and Govind, 2017). The importation of e-waste in Pakistan for selling and recycling may provide economic benefits in the short term. However, it also entails a high cost in terms of human life and environmental degradation. The improper handling and disposal of e-waste can expose workers and communities to hazardous materials and pollutants, leading to health risks and environmental pollution. This underscores the ethical and environmental dilemmas associated with this practice.

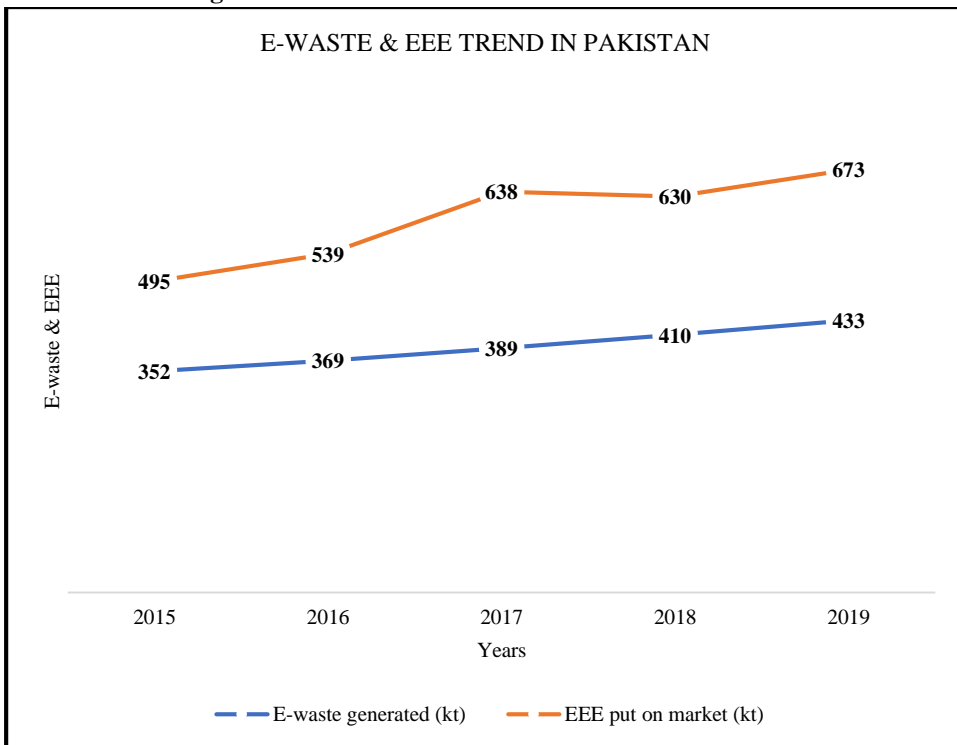
A shift in Consumer Demographics: Additionally, there is a noticeable shift in consumer demographics contributing to the demand for electronic items. In Pakistan, nowadays, even infants, toddlers, and preschool children are increasingly drawn to electronic gadgets, often more so than traditional toys. This evolving trend emphasizes how population growth and changing consumer preferences are generating increased demand for electronic devices from a very early age. Moreover, in recent years, a significant portion of the population, especially the youth, now prefers electronic indoor games over physical activities. This shift has given rise to the e-entertainment industry, driving an increased demand for new electronic gadgets in Pakistan.

Correlation Between E-Waste and Electronics Market: There is a strong and direct correlation between e-waste generation and the electronic products introduced to the Pakistani market. This correlation can be understood in the following ways:

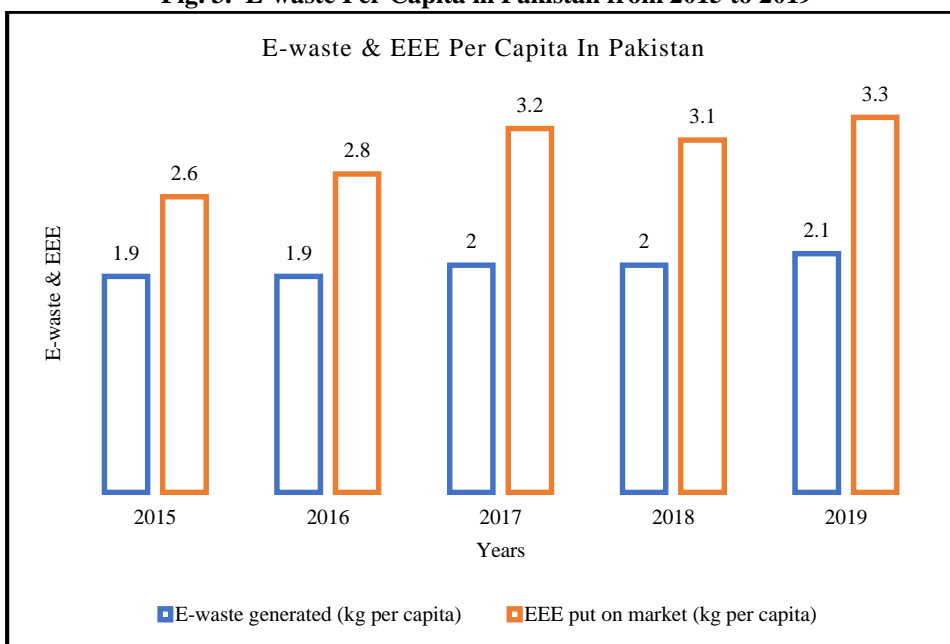
- **Branded Products:** Branded electronic products, when introduced into the Pakistani market, are often perceived as new. This perception leads consumers to treat them as fresh and reliable purchases.
- **Secondhand Electronics:** Secondhand electronic items, upon import, are typically repaired and refurbished. These refurbished devices are then placed back into the market for resale. They provide a more affordable alternative for consumers but may have a shorter lifespan compared to new electronics.
- **Wasted EEE:** Wasted EEE, on the other hand, serves a different purpose. Instead of being used as functional devices, they are primarily sought after for their valuable materials, such as copper, silver, and gold. The extraction process, often carried out under the guise of recycling, involves methods like incineration and crude processing these extraction methods release harmful toxins and pollutants into the environment, endangering the health of workers involved and contaminating local ecosystems.

To understand the scale of e-waste generation in Pakistan, Fig. 2. and Fig. 3. provide visual representations of e-waste trends over time.

Fig. 2. E-waste Trend in Pakistan from 2015 to 2019



Source: The Global E-waste Statistics Partnership.

Fig. 3. E-waste Per Capita in Pakistan from 2015 to 2019

Source: The Global E-waste Statistics Partnership.

4.3. Other Contributing Factors

Along with e-waste, industrial waste, plastic waste, solid waste, and household waste are other contributing factors to environmental degradation and human health hazards. Globally, air pollution is one of the biggest health hazards to human life. According to the World Air Quality Report air pollution causes 7 million premature deaths yearly (IQAir, 2020). Nowadays, one of the most prevailing issues is Smog (smoke fog). In industrialized countries and cities, smog is a type of intense air pollution; it consists of nitrogen oxides and other air pollutants to form ground-level ozone (not the ozone which protects the earth from ultraviolet radiation) when in contact with sunlight. The major sources of smog are emissions from vehicles, power plants, factories, construction, wood burning, burning fossil fuels, chemical solvents, plastic products, and charcoal starter fluid (GoC, 2020; West, 2021). Smog causes serious human health issues like eye, nose, and throat irritation, heart diseases, emphysema, asthma, lung infection, chronic bronchitis, and other respiratory infections. Moreover, it impacts the environment by inhibiting plant growth and causing damage to forests and crops (GoC, 2020; West, 2021).

Globally, Asian countries are the most polluted countries in the world, especially China, India, Pakistan, and Bangladesh (IQAir, 2020). As discussed above, all types of wastes emit harmful gases either in their production, usage, or recycling. E-waste seems to have a small portion of other wastes, but it has significant effects on human health and the environment.

Pakistan is the second highest country with particulate matter (PM) 2.5 concentration in its air (IQAir, 2020). In 2020, Lahore (a city in Punjab) was ranked as the 18th most polluted city in the world (IQAir, 2020). During the winter season Lahore

experiences the highest level of air pollution due to temperature/thermal inversion (a reversal of the normal behavior of temperature in the troposphere), biomass burning, and agriculture burning in Pakistan and India.

4.4. Limitations and Future Work

Punjab a province of Pakistan is a highly populated province among other provinces (PES, 2018). Therefore, the study includes the respondents (survey) from metropolitan cities of Punjab. The primary results are specific to Punjab and there is a broad scope of similar research to be conducted in other provinces of Pakistan.

5. POLICY IMPLICATIONS

Our study has yielded several significant policy recommendations for Punjab (Pakistan).

1. Awareness Programs:

Policy: Develop and implement awareness campaigns targeted at individuals with lower-incomes and education levels.

Rationale: Recognizing that education positively influences e-waste awareness, efforts should focus on reaching out to less-educated populations to bridge the awareness gap.

2. Information Dissemination:

Policy: Promote the widespread dissemination of information related to e-waste management and its environmental impact through accessible channels.

Rationale: Individuals with higher incomes tend to have better access to information. Ensuring that comprehensive e-waste information is available through various mediums, including digital platforms and community initiatives, can help raise awareness among all income groups.

3. Affordable Recycling Programs:

Policy: Under the E-waste Management Plan (GOP, 2021), establish and implement affordable and accessible e-waste recycling programs and facilities for the disposal of electronic devices

Rationale: Affordable recycling options can encourage responsible e-waste disposal, particularly among lower-income groups, while also creating job opportunities in the recycling and waste management sectors.

4. E-Waste Legislation and Enforcement:

Policy: The NEP and NHWMP should be revised to incorporate comprehensive e-waste laws that encompass responsible disposal, recycling, and EEE management measures. Furthermore, enforcement agencies should prioritize rigorous enforcement and compliance.

Rationale: Effective e-waste legislation can provide a framework for the safe handling of e-waste and promote sustainable practices, benefiting both public health and the environment.

5. Public-Private Partnerships:

Policy: Encourage partnerships between the government, private sector, and civil society organizations to jointly address e-waste challenges. Moreover, develop an Extended Producer Responsibility (EPR) model for EEE manufacturers and encourage producers to comply with EPR policies.

Rationale: Collaboration among different stakeholders can leverage resources, knowledge, and expertise to create effective e-waste management programs and awareness campaigns.

6. Environmental Considerations in Economic Growth:

Policy: Integrate environmental considerations into economic growth policies and plans, ensuring that development efforts account for e-waste challenges.

Rationale: With 87% of respondents concerned about the environment, embracing a balanced approach to economic development, one that prioritizes environmental sustainability, can mitigate e-waste's adverse effects.

7. Regulating E-Waste Imports:

Policy: Strengthen regulations on the importation of electronic items, especially secondhand and wasted electronics, to ensure safe disposal and responsible recycling.

Rationale: Strict controls on imports can minimize health and environmental hazards associated with improper e-waste processing.

8. Holistic Approach:

Policy: Adopt a holistic approach that addresses the complex interplay between economic development, population growth, and e-waste generation.

Rationale: Considering economic, social, and environmental dimensions is crucial for developing effective policies that mitigate the negative impacts of e-waste while promoting sustainable development.

6. CONCLUSION

The study attempts to investigate public cognizance of e-waste effects on human health and the environment, which is significant, and the public is willing to contribute towards sustainable practices to protect the environment. There is a relationship between GDP, economic development, lifestyle changes, and e-waste generation. Economic growth and improved living standards drive higher demand for electronic devices, resulting in increased e-waste.

Additionally, the interplay between population growth, e-waste generation, and the associated socioeconomic and environmental challenges is complex. While population growth is a natural phenomenon, its consequences on employment, income levels, and affordability can drive the demand for cheap electronic products. Importing and managing e-waste, although economically appealing, raises critical concerns about human well-being and environmental sustainability. Furthermore, the evolving consumer landscape, where youngsters are captivated by electronic gadgets, adds another layer to the multifaceted relationship between population dynamics and electronic waste

generation. Lastly, e-waste is not only a factor contributing to environmental degradation, but there are other influencing factors like solid waste, industrial waste, organic waste, plastic waste, and so on.

Addressing the challenges related to e-waste requires a comprehensive approach, including efforts to regulate imports, promote responsible recycling, strict e-waste policy implementation, and increase awareness about the environmental and health risks associated with improper e-waste disposal. This, in turn, contributes to the development of a circular economy.

APPENDIX

Table A1

Strength of Pearson Correlation

Correlation coefficient (r)	Interpretation
0.00 – 0.29	No/little correlation
0.30 – 0.49	Weak correlation
0.50 – 0.69	Moderate correlation
0.70 – 0.89	Strong correlation
0.90 – 1.00	Very strong correlation

Source: (Zady., 2000; Garcia Asuero et al., 2006).

Table A2

Logit Model Measures of Fitness

Log-Lik Intercept Only	-155.569	Log-Lik Full Model:	-137.321
D(306):	274.641	LR(5):	36.497
		Prob > LR:	0
McFadden's R ² :	0.117	McFadden's Adj R ² :	0.079
Maximum Likelihood R ² :	0.11	Cragg & Uhler's R ² :	0.175
McKelvey and Zavoina's R ² :	0.186	Efron's R ² :	0.125
Variance of y*:	4.042	Variance of error:	3.29
Count R ² :	0.814	Adj Count R ² :	0.065
AIC:	0.919	AIC*n:	286.641
BIC:	-1482.717	BIC':	-7.782

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