



## Occupational Health Risks Among E-waste Recyclers in Chattogram, Bangladesh: A Cross-Sectional Study

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### Abstract

Technological advancements have rapidly expanded electronic waste (e-waste), which has exposed informal recyclers in Bangladesh to hazardous substances and health risks. This study investigates safety measures, occupational health risks, and associated health problems among e-waste workers in Chittagong City Corporation (CCC). A cross-sectional study was conducted in urban areas of Chittagong City Corporation and some portions of Sitakunda. Data were collected from urban recycling shops where household-based e-waste is gathered for recycling, with 84 e-waste workers selected through snowball sampling. Data were collected via face-to-face surveys using the Kobo Toolbox, covering socio-demographic information, workplace hazards, safety practices, and self-reported health conditions. Statistical analysis, including chi-square tests, was performed using SPSS v.26 to examine relationships between occupational exposure and health outcomes. The majority were engaged in waste collection (95.2%), burning (66.7%), and dismantling (72.6%), primarily handling e-waste from households (98.8%). Workers frequently encountered heavy metals, with aluminium (98.8%), copper (96.4%), and lead (79.8%) being the most common. Health issues included cuts and burns (86.9%), skin problems (77.4%), and respiratory symptoms, while 64.3% lacked PPE. A significant correlation was found between burning/dismantling activities and acute health conditions ( $p = 0.00$ ), but no association was observed between heavy metal exposure and chronic diseases. The study underscores the urgent need for occupational safety measures, PPE enforcement, and healthcare access for e-waste workers. Strengthening regulations, promoting formalised recycling practices, and increasing awareness can reduce health risks, improve worker safety, and enhance environmental sustainability in Bangladesh's e-waste sector.

**Keywords:** E-waste, occupational health, heavy metal exposure, chronic diseases, informal sector

### Introduction

The rapid advancement of technology has led to a significant increase in the production and consumption of electronic devices worldwide. The number of electronic products per capita has grown substantially, with mobile phones, computers, televisions, and household appliances becoming integral to modern living (Forti *et al.*, 2020). In 2022, 62 million tonnes

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of e-waste were produced worldwide, and it is predicted to reach the production of 82 million tonnes by 2030 (Forti *et al.*, 2024). E-waste consists of discarded electronic devices such as computers, televisions, mobile phones, refrigerators, and batteries, many of which contain hazardous heavy metals including lead, cadmium, mercury, arsenic, and chromium (Liu *et al.*, 2023; Singh *et al.*, 2018). Improper management of these substances can pose severe environmental and health risks. Despite the increasing volume of e-waste, only 20% is formally recycled, while the majority is either improperly discarded or processed through informal recycling activities like pen burning, manual dismantling, acid leaching, etc. (Parvez *et al.*, 2022).

In Asia, urbanisation and economic growth have intensified the demand for consumer electronics, which has consequently led to a surge in electronic waste generation (Parvez *et al.*, 2022). The region contributes the largest share to global e-waste production, with estimates suggesting an increase from 53.6 million tonnes in 2019 to 74.7 million tonnes by 2030 (Forti *et al.*, 2020), and the United Nations University (2015) reported that within Asia, Hong Kong is the top producer of e-waste, generating 21.7 kilograms of e-waste per individual. Limited access to formal recycling infrastructure in developing countries such as China, India, and the Philippines has led to significant informal sectors engaged in e-waste recycling. Informal recycling practices, including the extraction of valuable metals using unsafe methods such as open burning and acid leaching, expose workers to hazardous substances (Manomaivibool & Wichienchot, 2021). In Bangladesh, the informal recycling of e-waste is widespread, often occurring in unregulated scrapyards and dismantling centres, where workers manually extract valuable materials without proper protective equipment (Alam & Qiao, 2020). Such unsafe dismantling practices in urban areas of Bangladesh expose workers to toxic substances through inhalation, ingestion, or direct skin contact, increasing their risk of neurological disorders, respiratory diseases, skin conditions, and organ damage (Ma *et al.*, 2018; Xu *et al.*, 2018).

Bangladesh has become a major hub for e-waste disposal, with a significant proportion of waste originating from illegal imports, domestic consumption, and discarded appliances (Roy *et al.*, 2022). The weak enforcement of environmental regulations and low labour costs have contributed to the rapid expansion of informal e-waste recycling, particularly in Chittagong City Corporation (CCC), which it considered a key hub for e-waste management due to having the country's largest seaport, the emergence of ship-breaking industries, and proximity to global markets (Roy *et al.*, 2022). Informal workers engaged in e-waste collection, dismantling, and burning often rely on rudimentary techniques such as open burning and acid leaching to extract valuable metals (Fischer *et al.*, 2020). These practices release highly toxic fumes and heavy metal residues, leading to acute and chronic health effects among workers. Additionally, exposure to hazardous chemicals has been linked to cancer, reproductive issues, and respiratory complications (Ma *et al.*, 2018; Xu *et al.*, 2018). Although extensive research has been conducted on e-waste management, environmental pollution, and toxic exposure, there remains a critical gap in understanding the occupational health hazards faced by informal e-waste workers in Bangladesh. Existing studies have largely overlooked workplace safety measures, health risks, and chronic illnesses among recyclers, particularly in Chittagong City, due to a lack of focus on the occupational health risks faced by these workers. Given the growing informal e-waste sector and the lack of regulatory oversight, a

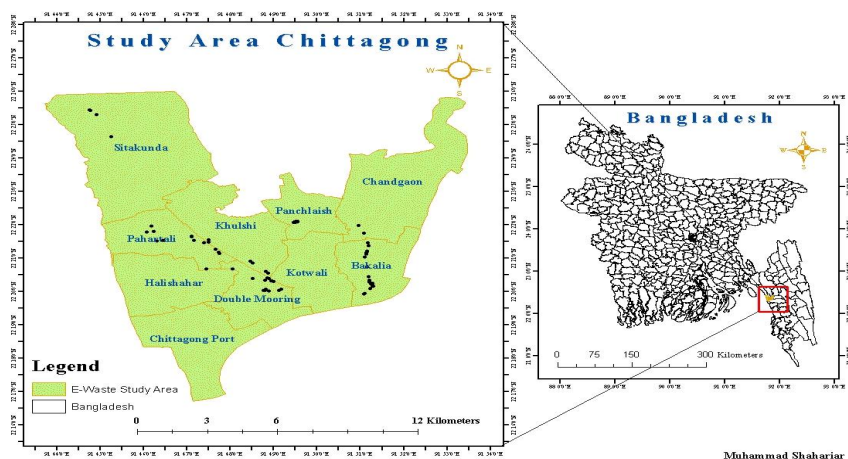
comprehensive assessment of healthcare and safety practices among workers is urgently needed. This study aims to evaluate workplace safety conditions and assess the health risks associated with informal e-waste recycling in Bangladesh. Specifically, it seeks to analyse the correlation between heavy metal exposure and chronic illnesses among e-waste workers. By addressing these issues, the study will provide evidence-based recommendations for improving occupational health and safety regulations within the e-waste recycling sector.

This research contributes to a more profound understanding of workplace health hazards in the informal e-waste sector in Bangladesh. The findings will be valuable for policymakers, environmental agencies, and labour rights organizations, enabling them to develop targeted interventions aimed at improving workplace safety, enforcing regulatory policies, and promoting sustainable e-waste management practices. Furthermore, this study will raise public awareness about the occupational risks associated with informal e-waste recycling and advocate for better working conditions and access to healthcare for affected workers.

## **Materials and Methods**

### ***Study Design***

This study employed a cross-sectional design conducted over three months, from January to March 2024, to assess the health impacts of e-waste processing among workers engaged in collection, burning, and dismantling within Chittagong City Corporation (CCC). The study covered major e-waste processing locations, including Pahartoli, Khulsi, Panchlaish, Chandgaon, Halishahar, Kotwali, Bakalia, Double Mooring, and Chittagong Port (Figure 1). It considered sociodemographic characteristics, working conditions, types of e-waste exposure, workplace safety measures, associated health risks, and injuries to provide a comprehensive understanding of occupational health in informal e-waste recycling.



**Figure 1:** Map depicting the study area of informal e-waste recycling scrapyards within Chittagong City Corporation (CCC), Bangladesh.

### ***Study Population***

We applied the snowball sampling technique to recruit 84 participants from e-waste processing sites in CCC. The informal nature of the sector and absence of a database of workers meant that snowball sampling, where initial respondents were used to identify otherwise eligible e-waste collectors, burners, or dismantlers, was used to engage workers collecting, burning, and dismantling e-waste. The sample size of eighty-four is not a random statistical calculation but the result of pragmatic factors and limited resources, and it is in line with previous studies. Due to the lack of a comprehensive registry of e-waste workers, however, workers were sampled such that the overall population could be represented meaningfully from a statistical perspective. Similar studies on occupational health in the informal sector have justified the approach with a sample size of 55 (Ronald, 2023).

The male-only nature of the study population reflects the gender balance in the informal e-waste sector in Chittagong. Through both field observations and interviews, we learnt that dismantling and burning are labour-intensive and dangerous jobs and therefore are male-dominant roles. Because this research focused on more physically dangerous operations (dismantling and burning), children did not participate in studies. Although children frequently participate in e-waste processing by carrying out less hazardous roles such as collection or light processing, they were not the focus of this study. We excluded children because they were not directly involved in the examined activities. Similarly, women typically engage in e-waste tasks such as sorting and light processing, which fall outside the purview of this study. We categorised participants into three main e-waste handling roles: dismantlers (n = 61), burners (n = 56), and collectors (n = 80).

### ***Data Collection Tools***

Data were collected using digital questionnaires, covering essential aspects of the study. The questionnaire included socio-demographic details such as age, education, income, and involvement in e-waste activities. It also examined workplace hazards, including poor ventilation, exposure to open electricity lines, and PPE usage. Additionally, it assessed health conditions and chronic diseases associated with heavy metal exposure, documenting self-reported symptoms such as burns, respiratory issues, skin conditions, and musculoskeletal pain. Participants also provided information on chronic illnesses, including hypertension, diabetes, kidney disease, anaemia, and mental health disorders. The structured survey enabled a systematic assessment of occupational health risks among e-waste workers.

### ***Data Collection Procedure***

Data collection was conducted through face-to-face surveys by the researchers over three months (January to March 2024) using the Kobo Toolbox. Before participation, respondents were fully informed about the study's objectives, potential risks, expected benefits, and their right to withdraw at any time without penalty. After obtaining informed consent, participants completed a structured survey covering socio-demographic factors, workplace hazards, healthcare and safety practices, self-reported health conditions, and chronic disease assessments. Participants were acknowledged for their time and contributions upon completion of the survey.

### **Data Analysis Procedure**

The collected data were exported from Kobo Toolbox to Microsoft Excel for sorting and cleaning before analysis using SPSS Version 26. To visualise the study area, ArcGIS 10.8 was used for mapping survey locations based on recorded latitude and longitude coordinates. Descriptive statistics were used to summarise socio-demographic characteristics, e-waste collection patterns, frequency of contact with metals, healthcare and safety practices, and reported health issues. To assess statistical relationships, a chi-square test was conducted to evaluate the association between e-waste worker categories (collectors, burners, and dismantlers) and injury types. Additionally, a chi-square test was applied to analyse the relationship between heavy metal exposure and chronic diseases among participants.

### **Ethical Considerations**

The study adhered to strict ethical guidelines to protect participants' rights and confidentiality. Informed consent was obtained from all participants, ensuring they were aware of the study's purpose, methods, potential risks, and their right to withdraw at any stage without negative consequences. Anonymity and confidentiality were maintained by securely storing all data and ensuring individual responses remained unidentifiable.

## **Results**

### **Socio-demographic Profile of the Respondents**

The findings indicate that 44% of the respondents were above the age of 35, while 42.9% fell within the 26–35 age range. All participants in the study were male, with 58.3% having only completed primary education and 30.9% being illiterate. A majority of respondents were married (65.5%). Every participant in this study was involved in e-waste handling; some were involved in one particular work, and some were in multiple activities. 95.2% engaged in collection, 66.7% in burning, and 72.6% in dismantling. The majority of the workers (40.5%) earn 3000-6000 taka per month as a monthly wage. Regarding working hours, 54.7% of individuals worked more than 10 hours per day, while 44.1% worked exactly 10 hours. Most workers (73.8%) collected less than 100 kg of e-waste daily. Participants gathered e-waste from multiple locations, with 98.8% collecting from households, 75% from industries, and 82.1% from office institutions (Table 1).

**Table 1:** Socio-demographic Profile of Respondents

<b>Facts</b>	<b>Categories</b>	<b>Frequency</b>	<b>Percentage</b>
<b>Age</b>	18 - 25	11	13.1%
	26 - 35	36	42.9%
	Above 35	37	44.0%
<b>Sex</b>	Male	84	100%
<b>Education</b>	Illiterate	26	30.9%
	Primary	49	58.3%
	Secondary	9	10.8%
<b>Marital status</b>	Single	29	34.5%
	Married	55	65.5%
<b>Involvement with e-waste</b>	Collecting	80	95.2%
	Burning	56	66.7%

Facts	Categories	Frequency	Percentage
<b>Working hours</b>	Dismantling	61	72.6%
	5 - < 10 hrs	1	1.2%
	10 hrs	37	44.1%
	Above 10 hrs	46	54.7%
<b>Income</b>	3000-6000 taka per month	34	40.5%
	7000-10000 taka per month	21	25%
	8000-11000 taka per month	29	34.5%
<b>Amount of collected e-waste (Kg)</b>	100 - 500	22	26.2%
	0 - <100	62	73.8%
	100 - 500	22	26.2%
<b>E-waste collection area</b>	Household	83	98.8%
	Industry	63	75%
	Office institution	69	82.1%

**Types of E-waste Collected**

Workers in the study reported collecting various types of electronic waste. The most frequently collected item was televisions (98.8%), followed by mobile phones (97.6%) and desktop computers (96.4%). Additionally, over 90% of participants reported collecting refrigerators (91.7%), CPUs (90.5%), and laptops (94.0%). Other commonly gathered e-waste items included washing machines (79.8%), air conditioners (88.1%), and wiring boards (88.1%) (Table 2).

**Table 2:** Types of E-waste Collected by Respondents

Type of waste	Frequency	Percentage
Television	83	98.8%
Computer Desktop	81	96.4%
Mobile phone	82	97.6%
Refrigerator	77	91.7%
Air conditioner	74	88.1%
Laptop	79	94.0%
Washing machine	67	79.8%
Wiring board	74	88.1%
CPU	76	90.5%

**Exposure to Heavy Metals**

Participants frequently encountered toxic heavy metals during their work. Aluminium (98.8%) was the most common, followed by copper (96.4%), silver (88.1%), and lead (79.8%). Gold exposure was reported by 73.8% of participants, while zinc exposure was 25.0%. Mercury was the least encountered heavy metal, with only 8.3% exposure (Table 3).

**Table 3:** Frequency of Respondents Exposed to Heavy Metals

Type of metals	Frequency of respondent's encounter	Percentage (%)
Aluminum	83	98.8%
Zinc	21	25.0%
Copper	81	96.4%
Gold	62	73.8%
Silver	74	88.1%
Lead	67	79.8%
Mercury	7	8.3%

### ***Healthcare and Safety Practices Among Workers***

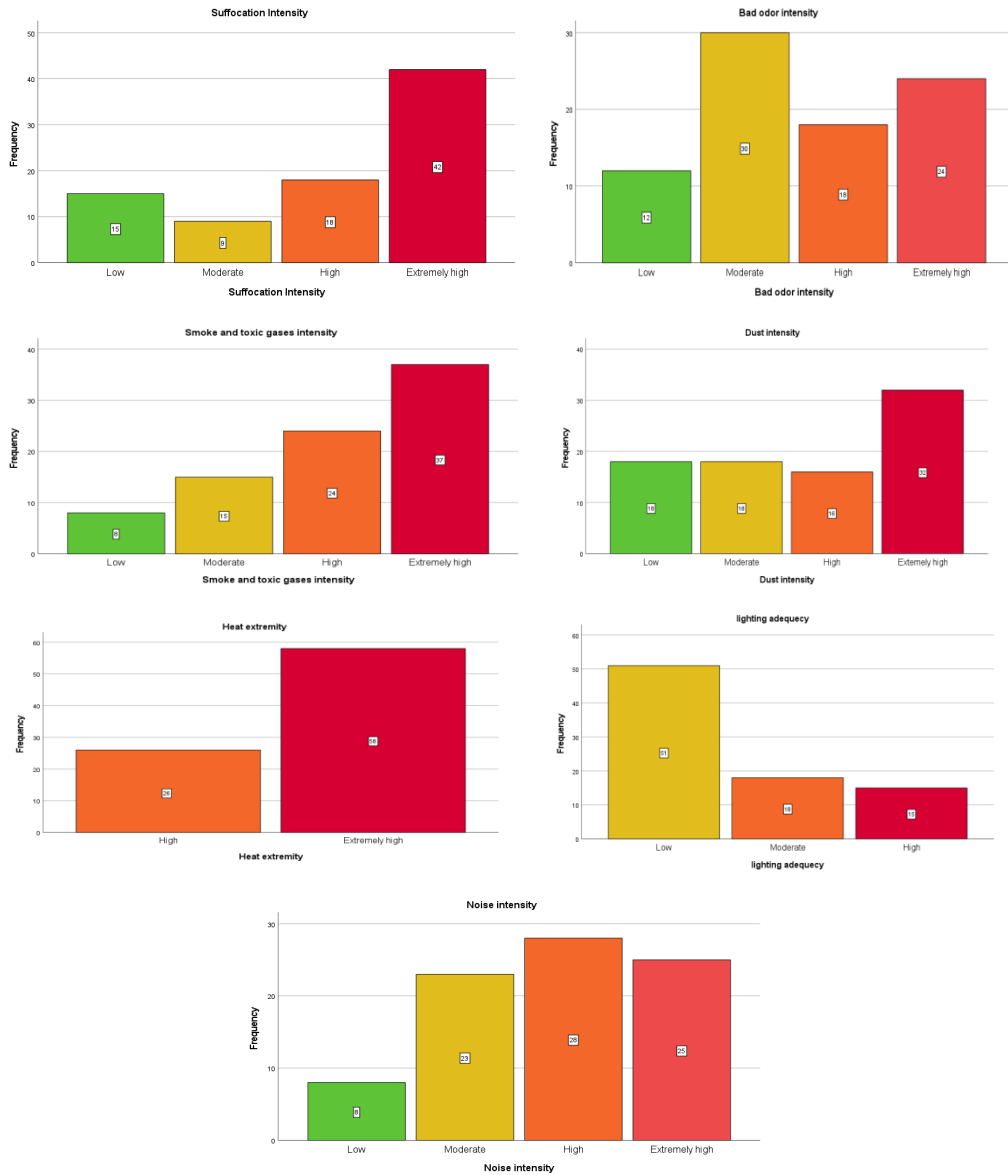
Most workers lacked access to proper safety measures. Only 35.7% of respondents used PPE, and 84.3% had not undergone a health check-up in the last month. Regarding medical care, 33.3% of the workers depend on first aid for any accidental injuries and pains and are totally untouched by formal treatment, and 31% of them choose medical pharmacies, as these are easily accessible and the chemists suggest medicines to them. Very few workers sought medical treatment in government hospitals (21.45%), and a smaller portion (14.3%) chose local clinics because the fees are usually too high for them to be affordable. (Table 4).

**Table 4:** Healthcare and Safety Practices Among Workers

Facts	Categories	Frequency	Percentage (%)
Use of PPE	Yes	30	35.7%
	No	54	64.3%
Health check-up (in last 1 month)	Yes	13	15.7%
	No	70	84.3%
Usually go for medical care	First aid only	28	33.3%
	Local clinics	12	14.3%
	Government Hospitals	18	21.4%
	Pharmacy	26	31%

### ***Occupational Environmental Condition***

The e-waste workers are experiencing extremely deplorable workplace environmental conditions that contribute significantly to health risks. A majority reported extremely high exposure to suffocation (50%), bad odour (28.6%), and dust (38.1%). Furthermore, 37% of workers are exposed to extremely high levels of smoke and toxic gases that can cause respiratory and other chronic diseases. Moreover, lighting is inadequate for 60.7% of workers, which is more likely to increase the risk of accidents. These findings highlight a hazardous, unsafe and unhealthy work environment in the e-waste sector, underscoring the urgent need for improvement (Figure 2).



**Figure 2:** Occupational Environmental hazards faced by the e-waste workers

***Perceived Work-induced Health Problems of Workers***

The results indicate that cuts and burns were the most frequently reported (self-reported) health issues (86.9%), followed by itching and skin problems (77.4%), and back and neck pain (71.4%). Additionally, 40.5% of workers reported red and itchy eyes, while 39.3%

experienced shortness of breath. Hearing loss was the least reported health problem (2.4%). These findings suggest that workers engaged in e-waste processing are highly vulnerable to occupational injuries and skin-related issues, likely due to direct contact with hazardous materials, open burning, and inadequate protective measures (Table 5).

**Table 5:** Work-induced Health Problems Among E-waste Workers

<b>Health Problems</b>	<b>Frequency of respondents affected (%)</b>	<b>Percentage (%)</b>
<b>Cuts and burns</b>	73	86.9%
<b>Itching and skin problems</b>	65	77.4%
<b>Shortness of breath</b>	46	54.76%
<b>Red and itchy eye</b>	34	40.5%
<b>Back pain and neck pain</b>	60	71.4%
<b>Hearing loss</b>	2	2.4%

### ***Long-term Chronic Health issues of the workers***

The finding indicates a high prevalence of long-term chronic health issues among informal e-waste workers. Hypertension affects the largest portion, with 40.5% of respondents reporting symptoms, followed closely by diabetes (39.3%) and anemia (38.3%). Cardiac symptoms are impacting 29.8% of the workers. These health issues reflect prolonged exposure to toxic substances and physically demanding work conditions highlighting the serious health risks faced by workers in the informal e-waste sector (Table 6).

**Table 6:** Long-term Chronic Health issues of the workers

<b>Health Problems</b>	<b>Frequency of respondents affected (%)</b>	<b>Percentage (%)</b>
<b>Diabetes</b>	33	39.3%
<b>Cardiac symptoms</b>	25	29.8%
<b>Anemia</b>	32	38.1%
<b>Hypertension</b>	34	40.5%

### ***Mental Health Disorders***

The numbers show that a lot of people who work with electronic waste have mental health problems. The most common ones are depression and anxiety (40.5%). These high rates are probably caused by long-term exposure to dangerous chemicals like lead and mercury, which can make it harder for the brain to work and keep moods stable. Working situations that aren't safe, like long hours, low pay, and not knowing if you'll have a job tomorrow, make emotional distress even worse. Sleep disorders are also common (25%), which could be because of the physical stress of work, stressors in the surroundings, or changing living or working schedules. 39% of people with cognitive disorders may have them because heavy metals are neurotoxic and long-term mental stress can damage neurons. Also, 36.9% of workers have substance use disorders, which suggests that many of them may use drugs or alcohol as a way to deal with the mental stress they face every day. Overall, the mental health of people who work with e-waste is very bad because of the dangers they face on the job, the problems they face in their communities, and the fact that they don't have a support system (Table 7).

**Table 7:** Mental Health Disorders

<b>Mental Health Disorders</b>	<b>Frequency</b>	<b>Percentage</b>
<b>Depression and Anxiety</b>	34	40.5
<b>Substance Use Disorder (SUD)</b>	31	36.9
<b>Sleep disorder</b>	21	25
<b>Cognitive disorder</b>	33	39.3

***Correlation Among Variables: Age and Work-induced health issues***

The data on the association between age and health problems caused by work shows that red, itchy eyes ( $p = 0.001$ ) and itching and skin problems ( $p = 0.001$ ) are statistically significantly linked to age. This means that these conditions are different in a meaningful way between age groups. More people in both age groups are having problems, especially those over 35. Other health problems, like cuts and burns ( $p = 0.10$ ), shortness of breath ( $p = 0.130$ ), and neck and back pain ( $p = 0.392$  and  $0.857$ ), do not change significantly with age. It was very rare for people in all three groups to lose their hearing, so there was no p-value given. There wasn't a strong link between age and most work-related health problems, but there was a link between age and red, itchy eyes and skin problems. This shows that older workers need extra safety steps in these areas (Table 8).

**Table 8:** Cross-tabulation of Age and Work-induced health issues

<b>Work-induced health issues</b>	<b>Age</b>	<b>Yes</b>	<b>No</b>	<b>P-value</b>
<b>Cuts and Burns</b>	18-25	7	4	0.10
	25-35	30	6	
	above_35	36	1	
<b>Shortness of breath</b>	18-25	3	8	.130
	25-35	25	11	
	above_35	18	19	
<b>Red and itchy eye</b>	18-25	2	9	<b>.001</b>
	25-35	9	27	
	above_35	23	24	
<b>Neck and back pain</b>	18-25	6	5	.392
	25-35	26	10	
	above_35	28	9	
<b>Hearing loss</b>	18-25	0	11	.857
	25-35	1	35	
	above_35	1	36	
<b>Itching and skin problems</b>	18-25	3	8	<b>.001</b>
	25-35	29	7	
	above_35	33	4	

**Correlation Among Variables: Work-induced Health Issues and Work Involvement**

The study assessed the association between workers' involvement in different e-waste activities (collection, burning, and dismantling) and the occurrence of injuries and other health issues. No statistical correlation was observed between injuries and workers involved in collection. However, a significant correlation was found between burning activities and injuries, such as cuts and burns, itching and skin problems, and red and itchy eyes ( $p < 0.05$ ). Similarly, workers involved in dismantling showed a significant correlation with cuts, burns, and skin-related problems, but no relationship was found with breathing issues, back pain, or hearing loss (Table 9).

**Table 9:** Cross-tabulation of Work Involvement and Injuries

Health issues		Working categories								
		Collecting			Burning			Dismantling		
		Do	Don't	p-value	Do	Don't	p-value	Do	Don't	p-value
<b>Cuts and burns</b>	Yes	69	4	1.00	55	18	<b>0.00</b>	59	14	<b>0.00</b>
	No	11	0		1	10		2	9	
<b>Itching and skin problems</b>	Yes	61	4	0.57	52	13	<b>0.00</b>	56	9	<b>0.00</b>
	No	19	0		4	15		5	14	
<b>Shortness of breath</b>	Yes	31	2	0.64	25	8	0.23	26	7	0.33
	No	49	2		31	20		35	16	
<b>Red and itchy eye</b>	Yes	32	2	1.00	31	3	<b>0.00</b>	32	2	<b>0.00</b>
	No	48	2		25	25		29	21	
<b>Back pain and neck pain</b>	Yes	57	3	1.00	45	15	<b>0.02</b>	47	13	0.10
	No	23	1		11	13		14	10	
<b>Hearing loss</b>	Yes	2	4	1.00	2	0	0.55	2	0	1.00
	No	78	4		54	28		59	23	

**Correlation Between Heavy Metal Exposure and Chronic Conditions**

This study also examined the association between exposure to heavy metals (aluminium, zinc, copper, gold, silver, lead, and mercury) and chronic illnesses such as diabetes, cardiac issues, depression, hypertension, and anaemia. The results show no significant correlation ( $p > 0.05$ ) between heavy metal exposure and any chronic diseases, indicating that while workers are exposed to hazardous substances, long-term effects may require extended monitoring to establish definitive health impacts (Table 10).

**Table 10:** Cross-tabulation of Heavy Metal Exposure and Chronic Conditions

Heavy Metals Exposure	Diabetes			Cardiac symptoms			Hypertension			Anemia			
	Yes	No	P value	Yes	No	P value	Yes	No	P value	Yes	No	P value	
<b>Aluminium</b>	Yes	32	51	0.39	24	59	0.29	34	49	1.00	32	51	1.00
	No	1	0		1	0		0	1		0	1	
<b>Zinc</b>	Yes	9	12	0.79	3	18	0.10	7	14	0.60	7	14	0.79
	No	24	39		22	41		27	36		25	38	
<b>Copper</b>	Yes	32	49	1.00	24	57	1.00	33	48	1.00	32	49	0.28
	No	1	2		1	2		1	2		0	3	
<b>Gold</b>	Yes	25	37	0.80	17	45	0.43	25	37	1.00	21	41	0.20
	No	8	14		8	14		9	13		11	11	
<b>Silver</b>	Yes	30	44	0.73	20	54	0.15	31	43	0.73	27	47	0.49
	No	3	7		5	5		3	7		5	5	
<b>Lead</b>	Yes	26	41	1.00	17	50	0.13	27	40	1.00	25	42	0.78
	No	7	10		8	9		7	10		7	10	
<b>Mercury</b>	Yes	3	4	1.00	2	5	1.00	2	5	0.69	2	5	0.70
	No	30	47		23	54		32	45		30	47	

**Usage of personal protection tools and Health issues**

The data shows that there is a strong link between using personal safety tools and having some health problems. In particular, people who don't use personal protective equipment are much more likely to get cuts and burns ( $p = 0.008$ ) and anaemia ( $p = 0.003$ ). This shows that not having protection is strongly linked to these health problems. However, the link between using safety tools and hypertension is not statistically significant ( $p = 0.17$ ), which means that other things may be more to blame for this condition. Overall, the results show how important it is to use personal safety equipment (PPE) to lower the risk of getting certain illnesses and injuries at work (Table 11).

**Table 11:** Cross-tabulation of Personal protection usage and Injuries and diseases

Use Personal Protection tools		Cuts and Burns		Injuries and diseases			Hypertension			
Do	Don'ts	Yes	No	P-value	Yes	No	P-value	Yes	No	P-value
30	54	73	11	.008	32	52	.003	34	50	0.17

## Discussion

This study aimed to assess the e-waste handling process in Chittagong City, from collection to dismantling, and analyse its impact on workers' health while identifying the relationship between occupational exposure and health outcomes. Participants in the study were involved in various stages of e-waste processing, with most initially working in waste collection, followed by burning and dismantling. Armughan & Zafar (2022) identified several basic dismantling techniques, including open burning, acid leaching, melting, and incineration, which generate hazardous gases and heavy metals, posing significant health risks. Although this study did not quantify total e-waste generation in Chittagong, respondents reported collecting less than 100 kg of e-waste daily. In contrast, Roy *et al.* (2022) estimated that Bangladesh generates 3 million metric tons (MMT) of e-waste annually, while BEMMA reported an annual consumption of 3.2 million electronic devices (Islam & Chisty, 2014).

The shipbreaking industry is a major contributor to Chittagong's e-waste, responsible for over 95% of the city's e-waste production (Iqbal, Ahmed *et al.*, 2020). However, this study found that households, businesses, and commercial buildings were the primary sources of disposed e-waste. These findings align with Roy *et al.* (2022), who noted that small scrap dealers (SCDs) play a vital role in collecting e-waste from residential and commercial sectors. Nearly all major e-waste collection sites in Chittagong City were included in this study, where collected materials were subsequently sold to retail scrap shops. Chittagong has several key locations for e-waste collection and processing. Islam & Chisty (2014) identified major hubs, including CDA Market, Coxy Market, Ice Factory Road, Vatiary, and Kadamtali. Additionally, this study covered Fauzdarhat, Pahartali, A.K. Khan, Halishahar, Bohoddarhat, Shah Amanat Bridge, Dewanhat, Agrabad Chawmuhuni, and Kattali, illustrating the widespread nature of informal e-waste recycling in the city. This study found that televisions were the most frequently discarded electronic items, followed by cell phones, desktop computers, laptops, refrigerators, and CPUs. Roy *et al.* (2022) estimated that 296,302 television sets contribute to 1.7 lakh tonnes of e-waste, while mobile devices account for 10.5 kt. In Bangladesh, five major categories dominate e-waste, including air conditioners, computers, televisions, refrigerators, and mobile phones. The increased accessibility of mobile devices has contributed significantly to the growing stream of abandoned electronics (Roy *et al.*, 2022). In contrast to the findings of Iqbal *et al.* (2020), who reported that obsolete desktop computers account for most discarded e-waste, this study found that newer electronic items were increasingly being disposed of. Participants frequently handled metals found in e-waste, with aluminium having the highest exposure rate, followed by copper, silver, lead, and gold, while zinc and mercury exposure was minimal. Armughan & Zafar (2022) also

identified cadmium, nickel, zinc, chromium, mercury, lead, and beryllium as common e-waste components, along with precious metals such as silver, copper, and gold. Roy *et al.* (2022) highlighted the significance of e-waste recycling in recovering materials such as gold, copper, glass, aluminium, lithium, and plastics. The World Health Organisation (WHO, 2021) has classified lead, mercury, cadmium, and PM<sub>2.5</sub> particles as among the top 10 toxic substances in e-waste, which pose severe health risks to workers. Findings indicate that skin irritations, cuts and burns, and post-burn back and neck pain were the most common health issues among e-waste workers. Armughan & Zafar (2022) found that crude e-waste recycling leads to respiratory disorders, asthma, eye infections, and skin allergies. The burning of e-waste releases toxic chemicals, increasing the risk of asthma, skin rashes, and eye irritation.

This study revealed a strong correlation between burning and dismantling activities and higher occurrences of cuts, burns, itching, and eye irritation. However, only a small percentage of workers reported hearing issues and odour problems, as many had become accustomed to these conditions. Decharat & Kiddee (2020) linked e-waste exposure to skin diseases, while Taher (2017) reported that 64% of workers experienced hearing or vision impairments. Moreover, a significant association is found between the usage of personal protection status (whether the workers use personal protection or not) and injuries like cuts and burns and chronic diseases like anaemia and hypertension. A related study in Ghana highlights that e-waste workers suffered significantly from work-related injuries, back pain, and red itchy eyes, which is attributed to specific recycling tasks like burning and dismantling, which are often performed informally without using personal protection tools like PPE (Feldt *et al.*, 2020). Not using personal protection equipment can result in increased exposure to toxic substances, potentially leading to long-term chronic health conditions like anaemia among e-waste workers (Li *et al.*, 2024). Another significant finding of the present study is the association between age and work-induced health issues, which claims that age is correlated to injuries, skin problems, and back pain. A study by Singh and Wani (2019) also investigates that age is an influencing factor in work-related health issues among e-waste workers. Similarly, Hossain *et al.* (2010) found that 83% of individuals exposed to toxic substances suffer from chronic illnesses such as cancer, asthma, and neurological disorders. Additional health risks include renal failure, infant mortality, and congenital disabilities due to exposure to toxic elements such as beryllium, lead, mercury, and copper (Islam & Chisty, 2014). Despite these risks, this study found no significant correlation between heavy metal exposure and chronic illnesses, including diabetes, hypertension, heart disease, depression, and anaemia. This contrasts with Hossain *et al.* (2010), who reported long-term illnesses among those exposed to hazardous substances. Findings indicate that e-waste workers in Chittagong City lack access to protective measures and safety regulations, consistent with Iqbal, Ahmed *et al.* (2020), who reported that no inventory exists to assess the extent of the e-waste problem and safety protocols are not enforced during informal disassembly. Most study participants did not wear personal protective equipment (PPE) and did not visit healthcare facilities for regular checkups. Although workers expressed concerns about toxic fumes, electrical hazards, and inadequate ventilation, they were unable to implement safety measures due to financial and logistical constraints. The daily accumulation of e-waste in Chittagong continues to rise. Iqbal *et al.* (2020) attributed this increase to the declining lifespan of electronic products and the increasing penetration of electronic devices. Given the hazardous

consequences of e-waste exposure, workers remain at risk of serious health complications from toxic metal exposure and unsafe working conditions.

## **Conclusion**

This study highlights the occupational health risks faced by informal e-waste workers in Chittagong, Bangladesh, emphasising their exposure to hazardous substances, inadequate workplace safety measures, and lack of healthcare access. Findings indicate that workers frequently handle toxic heavy metals such as aluminium, copper, and lead, leading to skin irritations, burns, respiratory issues, and eye infections. A significant correlation was found between burning and dismantling activities and acute health conditions, while no association was observed between heavy metal exposure and chronic diseases such as diabetes, hypertension, and anaemia. Despite these occupational risks, most workers lacked proper protective equipment (PPE) and access to medical care, exacerbating their health vulnerabilities. However, the small sample size (n=84) limits the generalisation of the findings to a broader population of e-waste workers in Bangladesh. The association between socio-economic status (income, education, healthcare access) and health issues (injuries, pains, chronic diseases, mental health problems) was examined, but no significant outcome was found. The exposure level of the hazardous substances cannot be quantified for time and budget limitations, and the study was questionnaire and observation based. The study objective was focused on work-related health issues only, which is the reason why lifestyle, nutrition status, physical activities, etc., were not included. Future research should consider larger sample sizes, long-term health monitoring, lifestyle investigation, and in-depth biochemical assessments to evaluate cumulative heavy metal toxicity and chronic disease progression. Additionally, studies should explore the effectiveness of policy interventions and alternative e-waste recycling methods to improve worker safety and environmental sustainability. To mitigate health risks in the informal e-waste sector, urgent policy reforms are needed to enforce occupational safety standards, formalise e-waste management, and increase awareness about safer recycling practices. Strengthening regulatory frameworks, promoting PPE usage, and expanding healthcare access will be crucial steps toward ensuring worker well-being and sustainable e-waste recycling practices in Bangladesh.

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