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Original Article

Assessment of knowledge, attitude, perceptions and risk assessment among workers in e-waste recycling shops, Thailand

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Abstract

To study the knowledge, attitudes and perceptions, to study the health effects, and to investigate the concentration of Pb and Cd in indoor dust samples, drinking water samples, and personal air samples and to assess the health risk among workers who worked at e-waste recycling shops in the southern region, Thailand. This cross-sectional descriptive study was conducted among workers from 136 electronic waste recycling stores in Southern Thailand, between January and July 2021. The study questionnaire was given to the 272 e-waste workers participating. Indoor dust, drinking water, and personal air samples were collected 27 e-waste shops and the concentrations of Pb and Cd in all samples were determined by graphite furnace atomic absorption spectrometry. Descriptive statistics and the simple linear regression were used to analyze. Overall, 176 employees (64.7%) suffered nasal irritation, 181 employees (66.5%) reported coughing/sneezing, and 163 employees (59.9%) had inconvenient breathing/jamming symptoms. Also, 158 employees (58.1%) had skin peeling symptoms, and 188 employees (69.1%) had muscle aches. The results indicate the positive influence of increasing knowledge and attitudes on the average practice score. The hazardous index (HI)-values of indoor dust samples, drinking water samples, and personal air samples were less than 1, was considered health-protective. The results will provide the direct evidence needed by e-waste managers to warn learners. Thus, there is a need for education programme to increase knowledge among the workers. In addition, information dissemination, involvement with organizations and associations is a necessity for workers in this study.

Keywords: knowledge, attitude, perception, risk assessment, recycling shops

Introduction

At present, e-waste management is a major global problem. It is estimated that the amount of e-waste in Europe will reach 12.3 million tons. In Thailand, the Bank of Thailand (2017) [1] published its second quarter electricity and electronics industry report which showed an increase in production compared to the same period in 2016. In 2020, the volume and type of e-waste is likely to increase every year. These e-wastes contain many materials [2]. Most of them are heavy metals such as lead, mercury, cadmium, chromium and beryllium, as well as other dangerous substances found in large quantities as well, brominated flame retardants, le vinyl chloride (polyvinyl chloride, PVC) polychlorinated biphenyl polychlorinated biphenyls, PCBs, triphenyl phosphate (TPP), nonylphenol (nonylphenol, NP), and polychlorinated naphthalene. Polychlorinated naphthalene, PCNs, dioxins and furans can contaminate the environment [3]. The health effects of chemical exposure from electronic waste include effects on the central nervous system and brain causing symptoms of irritability, anxiety, lethargy, dizziness, staggered walking, easy falling, insomnia, personality changes, and amnesia in severe cases. There may be tremors when moving, seizures, unconsciousness and death [4,5]. Effects on the peripheral nervous system and muscles are known [6], starting with weakness in the muscles of the arms and legs. Sometimes there is pain in the muscles and joints. If the body is exposed to large amounts of lead for a long time [7-9] it can cause muscle paralysis. Effects on the digestive system can start with anorexia, nausea, vomiting, and constipation or diarrhea [10]. Severe stomach pain may be found with lead; it can also present as a blue-black line along the edge of the gums next to the teeth. It is often found in the front teeth and molar teeth. Effects on the blood system can occur, including anaemia, and fatigue. In addition, effects of lead accumulation in children under 6 years of age can include altered brain development, causing children to have a low IQ, developmental delay and affected growth [11].

A study on the risk assessment of health and environmental impacts from the sorting and recycling of e-waste found that e-waste recycling areas are contaminated with heavy metals such as cadmium, chromium, lead, zinc, and copper, alongside the contamination of PAHs, PBDDs, PBDEs, dioxins and furans. It is a cancer-causing substance found in the soil, rice, sediment, dust and fish samples [12-14]. This is consistent with a study by Arabi et al. [15] that found contamination of PAHs, PCBs, PBDEs, and heavy metals in plant and soil samples in China and Nigeria. DNA abnormalities can be found in e-waste recycling workers. The DNA damage of workers was found to be associated with chemical exposure in the e-waste recycling process, compared to the control group who were not exposed to hazards in the e-waste recycling process (result was statistically significant at 0.05). A study in Ghana by Wittsiepe et al. [16] found that the concentrations of polychlorinated dibenzo-p-dioxins, ibenzofurans (PCDD/Fs) and biphenyls (PCBs) were higher in the blood of e-waste recycling workers than in the control group who did not work on e-waste recycling plants. Matsukami et al. [17] reported heavy metal contamination in soils from segregation sites in Vietnam. Recycling of e-waste and e-waste disposal areas use open burning methods. A study of the concentrations of heavy metals in human biological samples revealed that the levels of lead and cadmium in the blood of children in the e-waste recycling areas in Guiyu Town and Taizhou City, Zhejiang Province, China were above the standard and higher than the urban control group. Chendian also found that the contamination of lead and cadmium in the placenta, hair, urine, blood of the samples living in the Guiyu, Taizhou and Longtang areas exceeded the standard levels and those of other areas which were not control areas [14]. However, workers in e-waste recycling shops were informal workers; they had limited information on health effects from exposure to toxicants during work and there had been poor behavioral hygiene. Thus, research into the knowledge, attitudes, perceptions, and practices are important as they can influence evidence-based interventions. In addition, there is inadequacy of data on the knowledge, attitudes, perceptions, and practices of e-waste management in e-waste recycling shops and the associated negative effects in Thailand. The objective of this research was to study the knowledge, attitudes and perceptions of e-waste practice recycling shop workers, to study the health effects on workers, and to investigate the concentration of Pb and Cd in indoor dust samples, drinking water samples, and personal air samples and to assess the health risk from exposure of Pb and Cd indoor dust samples, drinking water samples, and personal air samples among workers who worked at e-waste recycling shops in the southern region, Thailand.

Materials and Methods

Study population and samples

The Ethics Committee of the Institute of Research and Development, Thaksin University, approved this research (COA No. TSU 2021-037 REC No.0019).

This cross-sectional descriptive study was conducted among workers from 136 electronic waste recycling stores in Southern Thailand, between January and July 2021. The sample groups of electronic waste recycling shops were calculated with Crazy and Morgan's formula at a 95% confidence level. One hundred and thirty-six factories are located in Southern, Thailand. The subject workers were also recruited by purposive selection. All workers (272 persons) at these 136 electronic waste recycling stores in southern agreed to participate in the study. Inclusion criteria for the subjects were as follows: 20-60 years old and in occupational contact with electronic waste recycling stores for at least one year. Cooperative letters and informed verbal consent were obtained from all study participants.

From observed in e-waste recycling shops, the most of e-waste recycling shops in this study present to solders, lead-acid batteries, cathode ray tubes, cabling, printed circuit boards, fluorescent tubes, semiconductor chips, and infrared detectors which the above-mentioned types of e-waste contain high amounts of lead and cadmium. Thus, the dust sampling, drinking water sampling, and personal air sampling was selected by purposive selection. The electronic waste recycling stores in Southern Thailand were 136 sites to determine the sample size by using the 20% of the electronic waste recycling stores.

Sample collection, preparation, sample digestion, and analysis

The study questionnaire was given to the 272 e-waste workers participating in this study, and all 272 completed and returned it, giving a response rate of 100%. The data collected were checked by researchers. The questionnaire was tested for internal consistency and had a very high Cronbach's α value of 0.980. The questionnaire had questions on knowledge, attitudes, and perception for 40, 10, and 10 items, respectively.

If the knowledge of respondents on hazardous waste scores was equal to or greater than 27 of a total score of 40, it was high, if it was between 14 and 27 it was moderate, and if the score was 13 or less, this was low.

For the attitude of respondents toward hazardous waste variables, cumulative scores were negative, neutral, and positive measured on a 3-point Likert scale, scoring 1, 2 and 3, respectively.

For the perception of respondents toward hazardous waste variables, cumulative scores were high, moderate, and low measured on a 3-point Likert scale, scoring 1, 2 and 3, respectively.

Indoor dust can be defined as fine (≤100 μm) settled airborne particles in indoor environments, whereas the pollutants in indoor dust may originate from interior and exterior sources. Indoor dust samples were randomly collected between April-May 2021 during the dry season in 27 electronic waste recycling stores. The samples of settled surface dust were collected in 1 m^2 area by using a polyethylene brush and placed in the dustpan by sweeping the living room floor most accessible to the occupants such as office desk, window, and other internal components of e-waste [18]. Dust samples was then transferred into a resealable plastic bag, brought to the laboratory and placed in a desiccator for 24 h, then sieved through a 100 μm screen, and oven dried at 105 °C for 24 h, respectively. The dried samples (0.5 g) were weighed and mixed with 6 mL of a mixture solution consisting of (HNO3-H2SO4) in a ratio of 3:1, then digested using microwave digester. The samples were then made up to a volume of 50 mL in the volumetric flask with distilled water. Drinking water samples were stored by 50 polyethylene bottles previously which washed in nitric acid. The water samples were acidified with 50% (v/v) nitric acid (E. Merck, Darmstadt, Germany) to brink the pH to less than 2 and analyzed within two days. All samples were filtered prior to analysis using Whatman® Ashless Filters, Grade 541, (Whatman, London, UK) to reduce the suspended solids associated with the risk of obstructing the capillary tubing in the instrument were measured by graphite furnace atomic absorption spectrometry (GFAAS, PerkinElmer, Analyst 800) [19]. The lead and cadmium in workplace can be defined as lead and cadmium concentration of an airborne contaminant that may affect people while performing their job. Such workplace pollutants may affect workers' health, especially if exposure continues over longer periods of time even at low levels. Airborne lead and cadmium specimens were collected from April 10 to 30, 2021, using personal sampling. Airborne lead and cadmium specimens were gathered using a 37 mm diameter 0.8 μm pore mixed cellulose ester membrane filter and a three-piece filter holder cassette and personal sampling pumps (model 224-PCXR8; SKC Inc.; Eighty-Four, Pa) calibrated at a flow rate of approximately 2.0 l/min at a height of 1.5 m, corresponding approximately to face height of a standing worker. Airborne lead levels and cadmium levels were measured by graphite furnace atomic absorption spectrometry, according to NIOSH method 7082/1994 [20] and NIOSH method 7048/1994 [21], respectively. All samples were analyzed for lead (Pb) and cadmium (cd) content by using graphite furnace atomic absorption spectrometry (GFAAS, Perkin Elmer, Analyst 800). The blank experiment was carried out by repeating the procedure for sample preparation without the sample and using compared with the sample solution to identify the elemental composition of heavy metals in the dusts. Detection limits of GFAAS were 0.0020 mg/L for Pb and 0.0001 mg/L for Cd.

Risk assessment

Risk assessment due to exposure to metal polluted in dust, drinking water, and airborne was carried out to estimate the chronic risk of workers exposed to the dust, drinking water, and airborne occupational hazards exposed at the electronic waste recycling stores.

Estimation of risk was calculated using USEPA exposure factors handbook [22].

Average daily dose (ADD) of dust ingested was determined using the equation below.

$$ADD = C \times IngR \times EF \times ED/ Bw \times AT \quad (1)$$

Average daily dose (ADD) of drinking water was determined using the equation as follows:

$$ADD = C \times IR \times EF \times ED/BW \times AT \quad (2)$$

Average daily dose (ADD) of airborne was determined using the equation below.

$$ADD = CxInhRxEFxED/BWxATxPEF \quad (3)$$

Where C is the concentration of Pb and Cd in dust (mg/L), drinking water (mg/L), and personal air samples (data from laboratory analysis), IR is the ingestion rate (2 L/day for age over 6 years old, U.S. EPA 1989) [23], EF is the exposure frequency (360 days/year) [24], ED is the exposure duration (average of exposure duration of workers 13 years) [24], BW is the body weight (average of body weight of workers 62 kg, from questionnaires), AT is the average time of exposure (ED×365 days/year) , PEF is the particle emission factor in m^3 kg-1 [25]. When hazardous quotients (HQ) and hazard index (HI) values are less than one, there is no risk to the population, but if these values exceed one, there may be concern for potential non-carcinogenic effects [23].

Statistical analysis

Data were collected by questionnaire and analyzed using a software programme. For descriptive statistics, percentages and frequency values were computed for the variables. The simple linear regression was used to analyze the univariate and interaction effects of average knowledge and attitude scores to the average practice score.

Results and Discussion

Results

General information of e-waste workers

The results of general information interviews of 272 employees working in 136 electronic waste recycling shops found that most of the sample employees were male, accounting for 262 people (96.3%). Overall, 64.3% were married and

36.4% had high school education level/vocational certificate. Half of the employees (136; 50.0%) cigarette smoked and 108 (39.7%) drank alcohol. Overall, 125 employees had been injured or suffered an accident at work (46.0%).

The work patterns of the employees in the sample group showed that 200 employees worked 8 hours per day (73.5%) and 72 (26.5%) worked for more than 8 hours per day. There were 179 employees (65.8%) in the sample group who worked 6 days per a week, and 93 employees (34.2%) who worked more than 6 days per a week. For the period of work (years), it was found that there were 172 employees (63.2%) in the sample group with a working period of less than or equal to 23 years, and 100 employees (36.8%) who had worked for more than 13 years (Table 1).

Table 1. Socio-demographic characteristics of the employees (n = 272).

Information	Number	Percent
Sex		
Male	262	96.3
Female	10	3.7
Education levels		
High school education level / Vocational certificate	210	77.21
More than high school education level / Vocational certificate	62	22.79
Injured or accidents from work		
Yes	147	54.0
No	125	46.0
Cigarette smoked		
Yes	136	50.0
No	136	50.0
Drank alcohol		
Yes	108	39.7
No	164	60.3
Occupational lifestyle		
Hours worked per day		
8 hrs.	200	73.5
≥8 hrs.	72	26.5
Days worked per week		
6 day/week	179	65.8
≥6 day/week	93	34.2
Years of worked		
≤13 years	172	63.2
>13 years	100	36.8
Mean±SD; 13±3.52 years		
Personal hygiene behavior		
Always personal protection equipment used		
Mask		
Yes	174	63.97
No	98	36.03
Gloves		
Yes	198	72.79
No	74	27.21
Boot safety		
Yes	157	57.72
No	115	42.28
Glasses safety		
Yes	87	31.99

Table 1. (continued)

No	185	68.01
Always washed hands before lunch		
Yes	127	46.69
No	145	53.31
Washing hands with detergents		
Yes	134	49.26
No	138	50.74
Change cloth after worked		
Yes	53	19.49
No	219	80.51
Take a shower after worked		
Yes	45	16.54
No	227	83.46

The employees who always used personal protection equipment used masks (63.97%), gloves (72.79%), safety boots (57.72%), and safety glasses (31.99%). In addition, 46.69% of employees always washed their hands before lunch, 49.26% washed their hands with detergents, 19.49% changed their clothes after work, and 16.54% took a shower after work.

Table 2. Socio-demographic characteristics of employees who respondents (n=272).

Items		Knowledge				Attitude				Perception			
		Low	Moderate	High	p-value	Negative	Neutral	Positive	p-value	Low	Moderate	High	p-value
Sex													
Male	262	149 (56.87)	101 (38.55)	12 (4.58)	0.001*	53(20.23)	142(54.20)	67(25.57)	0.003*	132(50.38)	65(24.81)	65(24.81)	0.001*
Female	10	5 (50.00)	2 (20.00)	3 (30.00)		4(40.00)	4(40.00)	2(20.00)		2(20.00)	4(40.00)	4(40.00)	
Education levels													
High school education level / Vocational certificate	210	128 (60.95)	77 (36.67)	5(2.38)	0.001*	99(47.14)	25(11.90)	86(40.96)	0.004*	137(65.24)	42(20.00)	31(14.76)	0.001*
More than high school education level / Vocational certificate	62	15(24.19)	37(59.68)	10(16.13)		20(32.26)	24(38.71)	18(29.03)		12(19.35)	14(22.58)	36(58.06)	
Injured or accidents from work													
Yes	147	68(46.26)	59(40.14)	20(13.60)	0.061	19(12.93)	53(36.05)	75(51.02)	0.001*	79(53.74)	21(14.29)	47(31.97)	0.001*
No	125	25(20.00)	67(53.60)	33(26.40)		74(59.20)	28(22.40)	23(18.40)		26(20.80)	28(22.40)	71(56.80)	
Cigarette smoked													
Yes	136	57(41.91)	48(35.29)	31(22.80)	0.073	62(45.59)	41(30.15)	33(24.26)	0.001*	68(50.00)	18(13.24)	50(36.76)	0.001*
No	136	49(36.03)	55(40.44)	32(23.53)		37(27.21)	25(18.38)	74(54.41)		33(24.26)	25(18.38)	78(57.35)	

Table 2. (continued)

Drank alcohol													
Yes	108	42(38.89)	43(39.81)	23(21.30)	0.092	50(46.30)	33(30.56)	25(23.14)	0.001*	68(62.96)	5(4.63)	35(32.41)	0.001*
No	164	58(35.37)	57(34.76)	49(29.87)		31(18.90)	75(45.73)	58(35.37)		46(28.05)	29(17.68)	89(54.27)	
Occupational lifestyle													
Hours worked per day													
8 hrs.	200	121(60.50)	58(29.00)	21(10.50)	0.001*	51(25.50)	68(34.00)	81(40.50)	0.001*	34(17.00)	72(36.00)	94(47.00)	0.001*
≥8 hrs.	72	63(87.50)	3 (4.17)	6(8.33)		57(79.17)	5(6.94)	10(13.89)		60(83.33)	4(5.56)	8(11.11)	
Days worked per week													
6 day/week	179	85(47.49)	67(37.43)	27(15.08)	0.024*	81(45.25)	69(38.55)	29(16.20)	0.001*	46(25.70)	34(18.99)	99(55.31)	0.001*
≥6 day/week	93	51(54.84)	35(37.63)	7(7.53)		67(72.04)	17(18.28)	9(9.68)		78(83.87)	5(5.38)	10(10.75)	
Years of worked													
≤13 years	172	108(62.79)	52(30.23)	12(6.78)	0.013*	73(42.44)	65(37.79)	34(19.77)	0.001*	74(43.02)	40(23.26)	58(33.72)	0.001*
>13 years	100	71(71.00)	19(19.00)	10(10.00)		87(87.00)	9(9.00)	4(4.00)		72(72.00)	14(14.00)	12(12.00)	

Table 2 shows a significant association between knowledge, attitudes and perception, and the socio-demographic characteristics of employees who responded.

A recent study found that many factors influence difference knowledge, attitudes, and practice at a 0.05 level, including sex (p=0.001), education levels (p=0.001), hours worked per day (p=0.001), days worked per week (p=0.024), and years worked (p=0.013) with electronic waste recycling shops showing statistically significant differences between the two groups.

In addition, sex (p=0.003), education levels (p=0.004), injured or suffering accidents at work (p=0.001), cigarette smoked (p=0.001), drank alcohol (p=0.001), hours worked per day (p=0.001), days worked per week (p=0.001), and years of worked (p=0.001) showed statistically significantly differences in the attitudes of employees toward electronic waste recycling shop management. The socio-demographic variables and perception of respondents of household hazardous waste management was statistically significantly different at the 0.05 level, including sex (p=0.001), education levels (p=0.001), injured or accidents from work (p=0.001), cigarette smoked (p=0.001), drank alcohol (p=0.001), hours worked per day (p=0.001), days worked per week (p=0.001), and years of worked (p=0.001), respectively.

In that study, females had a significantly higher knowledge and perception level than males, with the education levels of high school/vocational certificate having significantly lower knowledge, attitude, and perception levels than those with an education level of more than high school/vocational certificate. With regard to the employees who were injured or suffered accidents at work, they had significantly lower knowledge, attitudes, and perception levels than employees who were not injured at work. The non-smokers and non-alcohol drinkers had significantly higher attitudes, and perception levels than smokers and drank alcohol. With regard to occupational lifestyle, it was found that knowledge, attitude, and perception levels differed significantly; employees who had worked ≥8hr per day had significantly lower knowledge, attitude, and perception levels compared to those who had worked <8hr per day. Employees who had worked ≥6 days/week had significantly lower knowledge, attitude, and perception levels compared to those who had worked <6 days/week. Employees who had worked >13 years had significantly lower knowledge, attitude, and perception levels compared to those who had worked ≤13 years, respectively.

Health effects of e-waste workers

The results of interviews with employees about the health effects of working in waste recycling shops in the past 6 months showed that a total of 188 employees (69.1%) had accidents, such as the sharpening of spikes, etc. and 84 employees (30.9%) had never been in an accident while working. Also, 170 employees (62.5%) had eye irritation, and 174 employees (64.0%) experienced skin rashes/inflammation. Overall, 176 employees (64.7%) suffered nasal irritation, 181 employees (66.5%) reported coughing/sneezing, and 163 employees (59.9%) had inconvenient breathing/jamming symptoms. Also, 158 employees (58.1%) had skin peeling symptoms, and 188 employees (69.1%) had muscle aches (Table 3).

Table 3. Health impacts of working in electronic waste recycling shops in the past 6 months (n = 272).

Health Effects	Symptoms	
	Yes (Number, %)	**No (Number, %)**
1 . Accidental illness, injury/pricking with sharp objects	188 (69.1)	84 (30.9)
2.Eye irritation	170 (62.5)	102 (37.5)
3.Skin rash/inflammation	174 (64.0)	97 (35.7)
4. Nasal irritation/nasal sting	176 (64.7)	96 (35.3)
5. Cough/sneeze	181 (66.5)	91 (33.5)
6.Inconvenient breathing/jamming	163 (59.9)	109 (40.1)
7. Peeling skin	158 (58.1)	114 (41.9)
8. Muscle aches	188 (69.1)	84 (30.9)

The employees who worked in the process of weighing, recording and sorting products had accidental illness, injury/pricking with sharp objects (p<0.001), cough/sneeze (<0.001), and muscle aches (p<0.001), which were significantly different health effects to those who did not work in this process. In the disassembly process, workers had accidental illness, injury/pricking with sharp objects (p<0.001), skin rash/inflammation (p<0.001), and muscle aches (p<0.001), which were significantly different health effects between who did not work in this area. Workers in the smash-grinding process reported accidental illness, injury/pricking with sharp objects (p<0.001), skin rash/inflammation (p<0.001), and muscle aches (p<0.001), which were significantly different compared to those who did not work in this process. Those in the component sorting process had skin rash/inflammation (p=0.018), inconvenient breathing/jamming (p<0.001), and peeling skin (p<0.001) compared to those who did not work in this area. In the subprojects, workers had eye irritation (p<0.001), skin rash/inflammation (p<0.001), nasal irritation (p<0.001), cough/sneeze (p<0.001), inconvenient breathing/jamming (p<0.001), peeling skin (p<0.001), and muscle aches (p=0.015). In the process of the extraction/fragmentation of precious metals, workers had eye irritation (p=0.012), nasal irritation (p=0.011), cough/sneeze (p=0.049), inconvenient breathing/jamming (p=0.042), and peeling skin (p=0.009) (Table 4).

Table 4. Health effects divided by procedures of electronic waste recycling shop (n = 272).

Work processes	Symptoms							
	Accidental illness, injury/pricking with sharp objects (n=188)	**Eye irritation (n=170)**	**Skin rash/inflammation (n=174)**	**Nasal irritation/nasal sting (n=176)**	**Cough/sneeze (n=181)**	**Inconvenient breathing/jamming (n=163)**	**Peeling skin (n=158)**	**Muscle aches (n=188)**
Weighing, recording and sorting products	62 (32.98)	17 (10.00)	7 (4.02)	19 (10.80)	58 (32.04)	18 (11.04)	5 (3.16)	71 (37.77)
P-value	<0.001*	0.552	0.821	0.601	<0.001*	0.611	0.752	<0.001*
Disassembly Process	32 (17.02)	10 (5.88)	38 (21.84)	15 (8.52)	3 (1.66)	12 (7.36)	5 (3.16)	45 (23.94)
P-value	<0.001*	0.784	<0.001*	0.684	0.987	0.810	0.891	<0.001*
Smash-grinding process	40 (21.27)	23 (13.53)	24 (13.79)	25 (14.20)	16 (8.84)	18 (11.04)	8 (5.06)	28 (14.89)
P-value	<0.001*	0.621	<0.001*	0.683	0.741	0.684	0.811	<0.001*
Component sorting process	30 (15.96)	25 (14.71)	34 (19.54)	18 (10.23)	15 (8.29)	39 (23.93)	50 (31.65)	5 (2.66)
P-value	0.384	0.289	0.018*	0.389	0.425	<0.001*	<0.001*	0.884
Subprojects	14 (7.45)	57 (33.53)	40 (22.99)	57 (32.39)	51 (28.18)	41 (25.15)	52 (32.91)	36 (19.15)
P-value	0.429	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.015*
Extraction/fragmentation of precious metals	10 (5.32)	38 (22.35)	31 (17.82)	42 (23.86)	38 (20.99)	35 (21.48)	38 (24.06)	3 (1.59)
P-value	0.458	0.012*	0.075	0.011*	0.049*	0.042*	0.009*	0.889

* Pair t-test; compare symptoms with no symptoms.

The simple linear regression was used to analyze the univariate and interaction effects of average knowledge and attitude scores to the average practice score of employees in the electronic waste recycling shop (Table 5). The univariate models suggested knowledge and attitude as the significant predictor variables ($p<0.005$); these contributed to the total variability of the average score. Therefore, significant interaction was shown when these variables were entered simultaneously into the linear regression model ($p<0.005$). Both knowledge and attitude were confirmed as unique predictors of practice, and their interaction contributed to the practice average score. The results indicate the positive influence of increasing knowledge and attitudes on the average practice score. Thus, compared to employees with lower average knowledge and attitude scores, those with higher averages showed better average practice scores.

Table 5. Association between the average knowledge and attitude ratings of employees and their average practice rating in electronic waste recycling shop.

Assessment	Pearson's R	Adjusted R^2	B	`95% CI for B	P- value
Knowledge	0.465	0.054	35.908	29.008 – 39.799	<0.005
Attitudes	0.597	0.064	34.759	24.276 – 38.662	<0.005
Knowledge*Attitude Knowledge Attitude	0.471	0.059	0.470 0.435	0.314 – 0.428 0.353 – 0.419	<0.005

*Sig. <0.05.

Concentration of lead and cadmium in samples, and risk assessment

The concentration of Pb and Cd ranged from 12.05-25.30 mg/kg and 11.00-18.90 mg/kg in indoor dust samples, respectively, from ND–0.0191 mg/L and ND–0.0045 mg/L in drinking water samples, respectively, from 23.20-68.50 μg/m^3 and 0.57-3.14 μg/m^3 in personal air samples, respectively. The average daily dose of Pb and Cd were 1.03195E-05 mg/kg-day and 5.84439E-05 mg/kg-day in indoor dust samples, respectively. The average daily dose of Pb and Cd were 0.0007 mg/kg-day and 4.67644E-05 mg/kg-day in drinking water samples, and 8.4655 mg/kg-day and 0.5085 mg/kg-day in personal air samples, respectively. The hazard quotients of Pb and Cd were 0.0003 and 0.0584 in indoor dust samples, respectively. The hazard quotients of Pb and Cd were 0.0491 and 0.0094 in drinking water samples, and 0.1693 and 0.2034 in personal air samples, respectively (Table 6).

Table 6. Concentrations of lead and cadmium, average daily dose, and hazard quotient from exposure pathways (collected from 27 recycling shops).

Heavy Metals	Indoor Dust (n=54); Mean± Standard deviation (min, max) (mg/kg)	ADD adults (mg/day)	HQ for ingestion pathway	Drinking water(n=54); Mean± Standard deviation (min, max) (mg/L)	ADD adults (mg/day)	HQ for ingestion pathway	Air (n=54); Mean± Standard deviation (min, max) (μg/m^3)	ADD adults (mg/day)	HQ for Inhalation pathway
Lead (mg/Kg)	17.49±3.66 (12.05, 25.30)	1.03195E-05	0.0003	0.0299±0.0581 (ND, 0.0191)	0.0007	0.0491	36.64± 15.17 (23.20-68.50)	8.4655	0.1693
Cadmium (mg/Kg)	14.13±2.24 (11.00, 18.90)	5.84439E-05	0.0584	0.0019±0.0013 (ND, 0.0045)	4.67644E-05	0.0094	2.18±0.80 (0.57-3.14)	0.5085	0.2034

Control of Pb= 2.50, Cd=Not Detected, respectively.
Dust standards for lead=85mg/Kg and cadmium = 0.8 mg/Kg [26].
Drinking water standards for lead=0.01 mg/L, and cadmium=0.003 mg/L [27].
Air in workplace standards for lead=50 μg/m^3 [20], and cadmium=10 μg/m^3[21].

Discussion

Half of the employees in this study used PPE (mask, gloves, and boot safety). However, The International Labour Organisation (ILO) [28] reported that a huge percentage of e-waste workers globally are engaged in high-risk practices without the use of any PPE. The results of health effects among employees in electronic waste recycling shops included reports of accidents such as the sharpening of spikes while working. These results are supported by Burns et al. (2019) [8], who reported that the majority of injuries were lacerations and the most common injury location was the hand. In addition, Ohajinwa et al. [29] reported that cuts on the hands/fingers of e-waste workers were the most common injuries. The results in this study showed symptoms related to eye irritation, skin rashes/inflammation, skin peeling symptoms, nasal irritation/nasal stings, coughing/sneezing, inconvenient breathing/jamming symptoms [30] and muscle aches [31-33].

The results of health effects were compared among employees stratified by each process. The process of weighing, recording and sorting products is the first step of electronic waste recycling. These processes were associated with accidental illness, injury/pricking with sharp objects, cough/sneeze, and muscle aches, respectively. Many researchers have reported [34,35], that recycling e-waste generally uses technology such as physical disassembly using simple equipment such as hammers, screwdrivers, and chisels. The results supported by Bleck and Wettberg (2012) [36] observed that waste management procedures in developing countries are characterized by a dominance of manual handling tasks. Thus, this process can affect the health of employees as they are in contact with e-waste products and exposed to many toxics. In work sites, electronic waste is typically placed on the ground directly, so it needs to be shoveled by hand, or is left in containers to be picked up by hand. Manual collection and lifting of the electronic waste containers are of serious concern due to the associated occupational risks. Employees can be exposed to the residues of toxic chemicals from electronic waste that may lead to the spread of various diseases as a result of their daily exposure to work-related hazards.

In the disassembly and smash-grinding process, accidental illness, injury/pricking with sharp objects, skin rash/inflammation, and muscle aches were reported. These processes can be done manually, mechanically or *via* a combination of both. Manual dismantling involves tools such as screwdrivers, hammers and labelled containers, while mechanical dismantling may involve conveyor belts, giant shredders and magnets [37].

Those involved in the component sorting process had skin rash/inflammation, inconvenient breathing/jamming, and peeling skin; in this process, employees may be in contact with many forms of electronic waste, for example by dismantling compressors, air conditioners and refrigerators, separating CFC agents in refrigerants in older air conditioners, causing the spread of chemicals and evaporation which damages the ozone layer in the atmosphere [38].

Those in the subprojects process had eye irritation, skin rash/inflammation, nasal irritation/nasal sting, cough/sneeze, inconvenient breathing/jamming, peeling skin, and muscle aches. In any case, e-wastes are often manually sorted, while compounds such as fluorescent lights, batteries, UPS batteries, and toner cartridges should not be crushed or shredded by hand because the hazardous compounds found in e-waste that can cause toxicity to human health, such as polybrominated diphenyl ethers, polychlorinated biphenyls, and heavy metals including lead, mercury, cadmium, aluminum etc. This was reported significant associations between e-waste and adverse outcomes in exposed populations [39-42].

The extraction/fragmentation of precious metals led to eye irritation, nasal irritation/nasal sting, cough/sneeze, inconvenient breathing/jamming, and peeling skin. These routes are based on traditional processes of metal extraction from their primary ores. Similar steps of acid or caustic leaching are employed for the selective dissolution of metals from e-waste such as removal of components from circuit boards by heating methods [43], or the release of metals by using acidic solutions to retrieve gold or other precious metals [44]. Safarzadeh SM et al. (2007) [45] reported that heavy metals are recovered from solutions through electro-refining or chemical reduction processes that show metal concentrations in primary ores and consume significant energy during extraction.

A result of a survey of around 272 employees in electronic waste recycling shops also showed that the employee's knowledge of e-waste practices in recycling shops is still relatively moderate. This differed to the results presented by Islam et al. [46] whose studies obtained information showing that total respondents had no knowledge of e-waste. The employee's knowledge of e-waste practice in recycling shops was different, showing a significant association with sex, education levels, and occupational lifestyle. This result was supported by Nuwematsiko et al. [47] who reported a lack of knowledge on e-waste management; people blindly expose their lives to the damaging effects of e-waste. In addition, for some economic reasons, negative health effects which would have been prevented among the risk groups are prevalent. The same result was reported by Shamanna M et al. [48], Kwatra S et al. [49] who stated that the factors which could be associated with poor knowledge towards adverse health risks were education and type of work.

The employee's attitude and perceptions of e-waste practice in recycling shops were significantly different and associated with sex, education levels, injury or accidents at work, cigarette smoking, alcohol drinking and occupational lifestyle. This result was different to that of Tatlonghari R and Jamias S [50], who also reported that KAP level did not vary between male and female respondents. In addition, Ohajinwa CM et al. [51], presented workers' knowledge, attitude, and practice levels, and noted that it is dependent on the interaction effects between job designation and the other explanatory variables (location/ethnicity, position in business and use of personal protective equipment (PPE)) showing that these factors are very much intertwined. The results indicate the positive influence of increasing knowledge and attitude on the average practice score. This opposes with the study by Asampong et al. [33], who reported that the lack of formal education of e-waste workers in Ghana influenced their attitudes and practices.

The processes in electronic recycling shops mean that employees are exposed to dangerous chemicals because these unsafe recycling techniques are used to recover valuable materials with no or very little technology. Thus, most workers in this study of an informal sector have limited education and may therefore make concessions in their knowledge and exposure to information on e-waste practice in electronic waste recycling shops which consequently affects their perceptions. The result is supported by that of Shamanna M et al. [48] which stated that the majority of centre owners felt that informal e-waste handling does not pose any health risks and reported the need for an awareness campaign on this topic.

The concentrations of Pb and Cd in indoor dust samples were all below the New Dutch List optimum value (85 mg/Kg) [26]. In addition, the concentrations of Pb and Cd in drinking water samples were 24.07% (12/54 samples) and 12.96% (7/54 samples), respectively, which exceeded the permissible values in guidelines for drinking water quality [27]. For the concentrations of Pb and Cd in air personal samples were 25.93% (14/54 samples) and 16.67% (9/54 samples), respectively, which exceeded the permissible values in guidelines for air personal samples [20,21]. The average daily dose of lead and cadmium is calculated by using the RAIS reference doses in mg/day and heavy metal concentrations shown in Table 6. It has been established that $HQ<1$ is an indication that adverse effects are not likely to occur, and thus can be considered to have negligible hazard [22]. Although the results of the risk assessment were less than 1, the results of the employee's health impact survey showed injuries and illnesses from worked, such as inconvenient breathing/jamming symptoms etc. The effect may be due to restrictions on environmental data, including dust samples, drinking water samples, and personal air samples with only 20 percent (27 stores) of the total 136 stores which may be due to random stores, perhaps not those found to be health-affected because most of the samples did not exceed the permissible values in guidelines.

Limitations of cross-sectional studies are difficult to determine whether the exposure or outcome came first, not suitable for studying rare diseases or diseases with a short duration, and susceptible to biases. Thus, in the next study, it should be designed a research model that can find factors that correlate and affect the health of workers. In addition, this study determined concentrations of lead and cadmium in environmental media. However, the results showed that certain health effects, such as nose irritation, were reported by employees working in subproject procedures and the extraction/fragmentation of precious metals. The symptom was different than for employees who did not work in such a procedure (p-value at 0.001 and 0.011, respectively). Therefore, the symptoms may be related to other types of heavy metals such as nickel or chromium. Thus, in the next study, the study of the quantity of other kinds of heavy metals, such as nickel or chromium, is an interesting issue. The findings of this study have reported work-related illnesses and reports of work-related injuries and injuries in recycling shops. Injuries to workers are reported overall and separated by recycling plant procedures. There is a weakness in this research. Thus, in the next study, the evaluation of specific health effects of exposed chemicals is an interesting issue. Similarly, biological measurements for workers exposed to chemicals are also interesting issues.

Conclusions

The amount of e-waste generated continues to increase, along with the number of informal e-waste workers employed in e-waste recycling shops. E-waste workers put their health at risk with direct exposures to e-waste due to the infrequent usage of PPE. Informal workers often underestimate the health risks associated with their occupation. It is important to make workers in these informal settings aware of potential health-risks.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

CRediT author statement

SD: Conceptualization, Methodology, Investigation, Writing-Original draft Preparation, Writing-Review & Editing, Supervision, Project administration, Funding acquisition, Data curation and Formal analysis; PD: Validation, co-investigation.

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