HEAVY METALS IN HAIR AND NAILS OF ELECTRONIC WASTE DISMANTLING WORKERS IN BURIRAM, THAILAND.

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Hazardous Substance and
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โลหะหนักในเส้นผมและเล็บของผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ในจังหวัดบุรีรัมย์ ประเทศไทย

น.ส.จารุวรรณ สิลาจันทร์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Thesis Title	HEAVY METALS IN HAIR AND NAILS OF ELECTRONIC WASTE DISMANTLING WORKERS IN BURIRAM, THAILAND.
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จารุวรรณ สิลาจันทร์ : โลหะหนักในเส้นผมและเล็บของผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ในจังหวัดบุรีรัมย์ ประเทศไทย. (HEAVY METALS IN HAIR AND NAILS OF ELECTRONIC WASTE DISMANTLING WORKERS IN BURIRAM, THAILAND.) อ.ที่ปรึกษาหลัก : ผศ. ดร.ทรรศนีย์ พฤกษาสิทธิ์, อ.ที่ปรึกษาร่วม : ดร.ปกเกศ วงศาสุลักษณ์

งานวิจัยนี้มุ่งเน้นศึกษาและเปรียบเทียบระดับความเข้มข้นของโลหะหนัก 8 ชนิด (สารหนู แคดเมียม โครเมียม ทองแดง แมงกานีส นิกเกิล ตะกั่ว และ สังกะสี) ในเส้นผมและเล็บของกลุ่มผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์และกลุ่มผู้ที่ไม่ได้ประกอบอาชีพคัดแยะขยะอิเล็กทรอนิกส์ในเขตพื้นที่ตำบลแดงใหญ่ อำเภอบ้านใหม่ไชยพจน์ และตำบลบ้านเป้า อำเภอพุทไธสง จังหวัดบุรีรัมย์ ระหว่างเดือนธันวาคม 2561 ถึง มกราคม 2562 ทำการย่อยตัวอย่างเส้นผมและเล็บด้วยกรดไนตริกโดยเครื่องย่อยไมโครเวฟและวิเคราะห์ปริมาณโลหะหนักโดยใช้เครื่อง Inductively Coupled Plasma Mass Spectrometry (ICP-MS) ผลการวิจัยพบว่าระดับความเข้มข้นของ สารหนูและแคดเมียมในเส้นผมและเล็บของกลุ่มตัวอย่างทั้งสองกลุ่มมีค่าต่ำกว่าค่า LOD (0.75 และ 0.5 µg/g ตามลำดับ) ระดับความเข้มข้นของ โครเมียม ทองแดง แมงกานีส ตะกั่ว และสังกะสี ในเส้นผมของกลุ่มผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์สูงกว่ากลุ่มผู้ที่ไม่ได้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์อย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95% ระดับความเข้มข้นเฉลี่ยของโครเมียม ทองแดง แมงกานีส ตะกั่ว และสังกะสี ในเส้นผมของกลุ่มผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์เท่ากับ 6.44, 18.38, 2.85, 6.64 และ 185.51 µg/g ตามลำดับ ในขณะที่กลุ่มผู้ที่ไม่ได้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์มีค่า 1.24, 6.68, 1.35, 1.28 และ 121.56 µg/g ตามลำดับ สำหรับระดับความเข้มข้นโลหะหนักในเล็บพบว่า ระดับความเข้มข้นของ โครเมียม ทองแดง แมงกานีส และตะกั่ว ในเล็บของกลุ่มผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์นั้นสูงกว่ากลุ่มผู้ที่ไม่ได้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์อย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95% ระดับความเข้มข้นเฉลี่ยของโครเมียม ทองแดง แมงกานีส และตะกั่ว ในเล็บของกลุ่มผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์เท่ากับ 15.91, 39.71, 3.78 และ 4.92 µg/g ตามลำดับในขณะที่กลุ่มผู้ไม่ได้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์มีค่า 9.73, 18.33, 1.78 และ 1.76 µg/g ตามลำดับ ผลการวิเคราะห์แสดงให้เห็นว่าอาชีพคัดแยกขยะอิเล็กทรอนิกส์เป็นปัจจัยเสี่ยงที่เพิ่มระดับความเข้มข้นของโลหะหนักบางชนิดในเส้นผมและเล็บอย่างมีนัยสำคัญ ส่วนปัจจัยอื่นที่เกี่ยวข้องได้แก่ ระยะเวลาทำงาน การใช้อุปกรณ์ป้องกันส่วนบุคคล (PPE) เพศ การทานอาหารทะเล การสูบบุหรี่ การเดินเท้าเปล่าบนพื้นดิน

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Jaruwan Silachan : HEAVY METALS IN HAIR AND NAILS OF ELECTRONIC WASTE DISMANTLING WORKERS IN BURIRAM, THAILAND. . Advisor: Asst. Prof. TASSANEE CHETWITTAYACHAN, Ph.D. Co-advisor: Pokkate Wongsasuluk, Ph.D.

This study aimed to investigate and compare the concentration of eight heavy metals (As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn) in hair and nails of e-waste workers and non-e-waste workers. Hair and nails samples were collected from participants in Daeng Yai sub-district, Ban Mai Chaiyapot district, and Ban Pao sub-district, Puttatisong district, Buriram, Thailand from December 2018 to January 2019. All sampled were digested with nitric acid by microwave digester and the concentration of heavy metals was analyzed by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The results showed that the concentration of As and Cd in both hair and nails of both groups was lower than the LOD (0.75 µg/g and 0.5 µg/g, respectively). The concentrations of Cr, Cu, Mn, Pb, and Zn in the hair of e-waste workers group were significantly greater than those of non-e-waste worker group at significance level of 0.05. The average concentrations of Cr, Cu, Mn, Pb and Zn in the hair of e-waste workers group were 6.44, 18.38, 2.85, 6.64 and 185.5 µg/g-Hair, respectively, while non-e-waste workers groups were 1.24, 6.68, 1.35, 1.28 and 121.56 µg/g-Hair, respectively. For nails, the concentrations of Cr, Cu, Mn, and Pb of the e-waste workers group were significantly greater than non-e-waste worker group at significance level of 0.05. The average concentrations of Cr, Cu, Mn, and Pb in nails of e-waste workers group were 15.91, 39.71, 3.78, and 4.92 µg/g-Nail, respectively, while those of non-e-waste workers groups were 9.73, 18.33, 1.78, and 1.76 µg/g-Nail, respectively. Some associated factors including, e-waste dismantling occupation, working time, PPE using, gender, living time, and the behavior of participants include smoking habits, second-hand smoking habits, seafood consumption, bare feet direct walking expose to soil were probably increase the level of heavy metals in hair and nails.

Field of Study:	Hazardous Substance and Environmental Management	Student's Signature ....
Academic Year:	2019	Advisor's Signature ....
		Co-advisor's Signature ....

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CHAPTER 1

INTRODUCTION

1.1 Background and problem addressed

At present, new electronic appliances with advanced technology such as televisions, computers, and mobile phones have been rapidly grown and expanded worldwide. This causes the market of electronic equipment and electronic industries growing at a higher rate. Consequently, the consumers trend to replace the old appliances before they will not work and will finally become electronic waste or e-waste. The global electronic waste would be more than 40 million tons per year, and the rate of electronic waste has increased rapidly to 4 percentages per year (Prompak.C, 2012; Vasssanadumrongdee.S, 2015). In Thailand, Pollution Control Department reported that there are approximately 600,000 tons of hazardous wastes from the community, and electrical and electronic products were approximately accounted for 400,000 tons in 2017. This reflects the electronic waste has been increasing every year and become an important environmental problem in many areas.

In Thailand, numerous electronic wastes have been disposed improperly since there is no regulation of handling and disposal them. This problem led to informal separating electronic waste in the local community as household business such as cutting, scattering, splitting, and removing parts of electronic products for sale. According to the report of Department of Disease Control, Northeastern, Thailand is one of a large area having electronic waste dismantling and improper disposal in the community, for example, Khongchai district, Kalasin province, and Ban Mai Chaiyapot district and Putthisong district, Buriram province (Vasssanadumrongdee.S, 2015). Buriram province has been found to be the second largest of electronic waste dismantling community of Thailand, most of the workers live in Daeng Yai Sub-district, Ban Mai Chaiyapot district and Ban Pao Sub-district, Putthisong district, and they have worked for a long time, longer than ten years. Theirs dismantling method is primitive, without advanced technology, and inappropriate management system. Moreover, workers do not use personal protective equipment or PPE for preventing harm from exposure to some hazardous substances in particular heavy metals in e-waste. Therefore, heavy metals can be transported and reach to the human body through dermal exposure, inhalation exposure, and oral exposure. Then, heavy metals can be accumulated in some parts of the human body such as blood system, bones, myocardium, parenchymal organs, and also be excreted through skin, sweat, urine, feces, breast milk, hair, and nails. Moreover, long term exposure to heavy metals in e-waste is considered to have human health effect including cancer, neurological effects, and respiratory effects (Michalak et al., 2012).

In addition to detecting environmental pollutants, human bio-monitoring is one of the scientific methods of measuring human exposure to environmental chemicals. Moreover, it can provide information to support the possible adverse health effect. There are various bio-monitoring to investigate the human exposure to environmental contaminants, determination of the metals level by using metabolites in human tissue and body such as blood, feces, urine, hairs, and nails had been done (Haines & Murray, 2012; Król, Zabiegała, & Namieśnik, 2013). Typically, the concentration of heavy metals in blood and urine decreases rapidly after exposure; on the other hand, the concentrations of heavy metals in hairs and nails appeared in greater value for evaluated the concentrations in the past or continues exposure to high levels of heavy metals (Gellein et al., 2008). Interestingly, hairs and nails were then often used as human bio-monitoring or biomarkers for measuring human chemical exposure for a long time. Earlier studies have found the concentration of heavy metals in hairs and nails of workers in electronic waste sites; for example, the study found that lead (Pb), cadmium (Cd), and copper (Cu) were at high concentration in hair of electronic waste workers who worked in electronic waste site in India (Ha et al., 2009). Similarly, there is the study found that lead (Pb), cadmium (Cd), and copper (Cu) in the hair of electronic waste workers in China who worked in electronic waste site for 20 years were significant high concentration (Zheng et al., 2011).

According to the evidence of heavy metals accumulated in hair and nail of workers in electronic waste area from previous studies, it is possible that workers in electronic waste site in Thailand including Dang Yai Sub-district, Ban Mai Chaiyapot district, and Ban Pao Sub-district, Putthisong district, Buriram province, would be found the concentration of heavy metals in their hairs and nails, and found higher than those of non - electronic waste workers. Associated factors of high heavy metals level in hairs and nails of electronic waste workers should be verified. Therefore, this study focuses on heavy metals concentration in hair and nails of electronic waste workers in Dang Yai sub-district, Ban Mai Chaiyapot district and Ban Pao sub-district, Putthisong district, Buriram province. The result of this study especially the relationship between associated factors and accumulation of heavy metals in hair and nails would be beneficial for better planning and guidance for workers in the future.

1.2 Research Objective

The main objective of this study is to investigate heavy metals in hairs and nails of the workers corresponding to e-waste dismantling. Moreover, there are three sub-objectives in this study as follows;

1) To determine the concentration of heavy metals in hair and nails of e-waste workers.

2) To compare the concentration of heavy metals in hairs and nails e-waste workers and non-e-waste workers.

3) To determine associated factors with the concentration of heavy metals in hairs and nails of e-waste workers.

1.3 Research Hypothesis

1. The concentration of heavy metals would be found in both hair and nails in e-waste workers corresponding with the working period.

2. The concentration of heavy metals in both hairs and nails of e-waste workers would be found higher than that of non-e-waste workers.

3. There are socio-demographic factors, including e-waste occupation, gender, age, weight, height, BMI and living time, exposure factors including working time and PPE using, and behavior factors, including smoking habits, second smoking habits, seafood consumption, alcohol consumption, bare feet direct to soil, drinking water, washing and bathing that would be related with the concentration of heavy metals in hairs and nails of e-waste workers.

1.4 Scope of the study

1. Study area.

The study was performed at the e-waste dismantling area and the control area, approximately 5 kilometers away from the e-waste dismantling area, in Dang Yai sub-district, Ban Mai Chaiyapot district and Ban Pao sub-district, Putthisong district, Buriram province, Thailand.

2. Population and target sample.

The populations in this study were the local people in Dang Yai Sub-district and Ban Pao Sub-district in Buriram province. In this study, total target samples of at least 130 people from both villages were randomly selected and divided into at least 100 of e-waste dismantling workers who had worked on dismantling e-waste at least 6 months and at least 30 of non-e-waste workers who live in non-e-waste dismantling area.

3. Sampling Technique.

3.1 Hairs samples were collected from scalp hair by using stainless steel hair scissors and nails samples were collected by using stainless steel nail clippers from participants.

3.2 Personal information of participants was collected by using a questionnaire with a face-to-face interview technique.

4. Analytical Technique.

4.1 Hair and nails samples were prepared following the guidelines of The International Atomic Energy Agency (IAEA)

4.2 Hair and nails samples were digested with nitric acid 65% by microwave digester MARS5 and evaporated the solution

4.3 The concentration of heavy metals (As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn) in hairs and nails were analyzed by Inductively Coupled Plasma Spectrometry Mass Spectrometry (ICP-MS).

5. Data Analysis

The SPSS was used for statistical analysis of the data as follow:

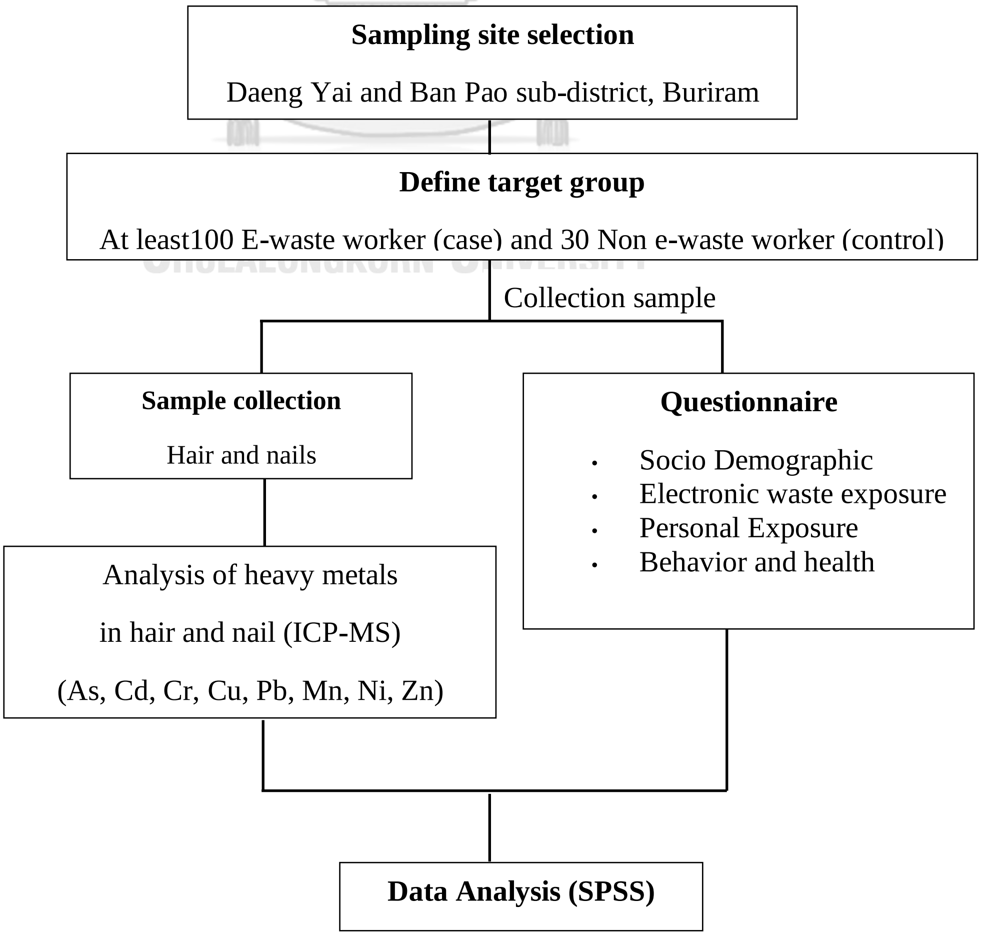
- The Kolmogrov - Smirnov test (K-S test) was used to investigate the normal distribution of heavy metal concentrations in hair and nails.
- Mann-Whitney U-test (2-tailed) was used to investigate the mean difference in heavy metal concentrations in hair and nails between two groups.
- Chi-squared ($\chi2$) was used to analyze associated risk factors.

1.5 Research Expected Outcomes

1. To obtain the baseline data of heavy metals in hairs and nails of e-waste dismantling workers and their possible associated factors of heavy metals accumulation in the study area.

2. The data from this study would be introduced for planning and guiding for workers in this area for future study.

1.6 Research flowchart



1.7 Conceptual Framework

Independent Variables | Dependent Variables

Socio Demographic

- Gender
- Age
- Weight
- Height
- BMI
- Occupation

Behavior factors

- Smoking
- Secondhand smoking
- Alcohol consumption
- Seafood consumption
- Bare feet walking direct expose to soil
- Cleaning kitchenware before cooking
- Washing
- Drinking water

Exposure factors

- Living time
- Working time
- PPE using

→

Heavy metals concentrations

in hair and nails

(As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn)

1.8 Operational Definition

Electronic waste (E-waste)

E-waste in this study is the end-of-life of various electronic products that have become unwanted, non-working or obsolete.

Heavy metals

The heavy metals in this study are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), Nickel (Ni), lead (Pb), and zinc (Zn)

Biomarkers

The biomarkers in this study are heavy metals in hairs and nails. Using for estimate concentration of heavy metals (As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn)

Associate factors

Associate factors in this study are independent variables include 4 groups: socio-demographic, exposure factors, behavior and health factors, and environmental factors.

Independent Variables

Independent variables in this study are identified as 5 groups: socio-demographic; occupation, gender, body weight, age, height, and living time. Exposure factors; working time (working period, working hour, working day), and PPE using. Behavior factors; smoking habits, secondhand smoking habits, seafood consumption, alcohol consumption and bare feet walking directly on the soil.

Dependent Variables

Dependent Variables in this study are heavy metals concentrations in hair and nails.

Exposure group

The exposure group in this study is people who separate electronic waste as workers in Dang Yai Sub-district, Ban Mai Chaiyapot district and Ban Pao Sub-district, Putthisong district, Buriram province.

Non - exposure group

Non - exposure group in this study is people who do not separate electronic waste as workers or who have other jobs except separate electronic waste and live away from electronic waste area 5000 meters (5 kilometers) in Dang Yai Sub-district, Ban Mai Chaiyapot district and Ban Pao Sub-district, Putthisong district, Buriram province.

PPE

The using personal protective equipment to protect the body and reduce exposure route from electronic waste include gloves, mask, and shoes.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition and characteristic of electronic waste.

Electronic waste (e-waste) is the end-of-life electronic products or electronic products that are unwanted, non-working and have reached the end of their useful life (Oguri et al., 2018; Vasssanadumrongdee.S, 2015). Electronic waste can be classified into ten groups by European Commission 2003 as shown in Table 1.

Table 1 Classification of electronic waste by European Commission.

Classification	Example of product waste
1. Large household appliances	Refrigerator, Washing machine, Microwave oven
2. Small household appliances	Vacuum Cleaner, Iron, Toaster, Coffee Maker
3. IT and telecommunications equipment	Computer, Printer, Mobile phone, Radio
4. Consumer equipment	Television, Audio set, Video recorders
5. Lighting equipment	Kinds of lamps
6. Electrical and electronic tools	Electric Saw
7. Toys, leisure and sports equipment	Game player, Electric trains or car-racing sets
8. Medical devices	X-ray machine, Radiotherapy equipment
9. Monitoring and control instruments	Smoke detector, Thermostat, control instruments
10. Automatic dispensers	ATMs machine, Automatic dispensers for beverages

Source: (Rao, Sultana, & Kota, 2017; Vasssanadumrongdee.S, 2015)

2.2 Situation of electronic waste amount in Thailand

Recently, the e-waste problems have been growing every year in Thailand due to the production and consumption of electric appliances are increasing rapidly and made the amount of e-waste increased. However, there is not appropriate regulation for e-waste management directly, and the Pollution Control Department, Thailand reported that the amount of electronic waste in 2007 reached 308,845 tons and they had a tendency to increase to 12 percentages per year (Prompak, 2012). The situation of hazardous waste include e-waste from the community was published by Pollution Control Department, Thailand reported as follow

In 2012, the pollution situations in Thailand were reported that hazardous waste from the community was approximately 700,000 tons include electronic waste 357,000 tons (51 percentages), and other hazardous waste such as battery, bulb, container of chemical 343,000 tons (49 percentages). Moreover, the report of the Pollution Control Department found that the trend of household appliances has increased such as televisions, air conditioners, refrigerators, and computers (Buranasingha, 2016).

In 2013, pollution situation in Thailand were reported that hazardous waste from the community was approximately 562,834 tons include electronic waste 368,314 tons (65.4 percentages) and other hazardous waste such as battery, bulb, container of chemical 194,520 tons (34.6 percentages) (Buranasingha, 2016).

In 2014, pollution situation the Thailand were reported hazardous waste from the community were increased 13,482 tons (2.4 percentages) from 2013. The hazardous waste from the community was approximately 576,316 tons include electronic waste 376,801 tons (65 percentages), and they are mostly refrigerator, computer washing machine, VCD and DVD player, mobile phone and digital cameras. Other hazardous waste such as battery, bulb, and container of chemical was approximately 199,515 tons (35 percentages) (Buranasingha, 2016).

In 2015, pollution situation the Thailand were reported hazardous waste from the community were increased 14,811 tons (2.6 percentages) from 2014. The hazardous waste from the community was approximately 591,127 tons include electronic waste 384,233 tons (65 percentages), and other hazardous waste such as battery, bulb, and container of chemical was approximately 206,894 tons (35 percentages) (Pollution Control Department, 2015).

In 2016, pollution situation the Thailand were reported hazardous waste from the community was approximately 606,319 tons include electronic waste 393,070 tons (65 percentages), and other hazardous waste such as battery, bulb, and container of chemical was approximately 213,249 tons (35 percentages) (Pollution Control Department, 2016).

In 2017, pollution situation the Thailand were reported hazardous waste from the community were increased 2 percentages from 2015. The hazardous waste from the community was approximately 618,749 tons include electronic waste 401,387 tons (65 percentages), and other hazardous waste such as battery, bulb, and container of chemical was approximately 216,639 tons (35 percentages) (Pollution Control Department, 2017). The situation of electronic waste in Thailand as shown in Figure1.

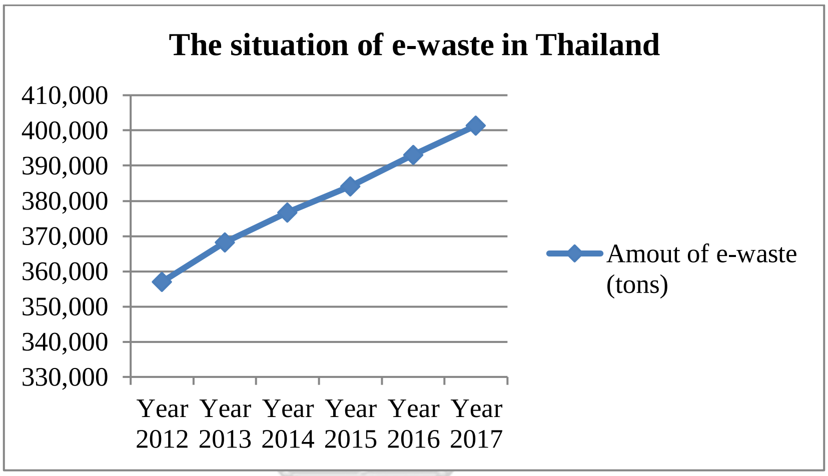


Figure 1 Graph of the situation of e-waste in Thailand

Due to the situation of electronic waste in Thailand has increased every year, and there is not appropriate regulation for e-waste management, so electronic waste were sold to merchants for cutting, scattering, splitting, and removing parts of electronic products at e-waste dismantling sites for sale (Buranasingha, 2016).

The Department of Disease Control has estimated the number of e-waste dismantling sites in Thailand that have found almost 100 sites include Krabi, Karasin, Chonburi, Chiang Rai, Chiang Mai, Lamphun, Nakhon Pathom, Nonthaburi, Pathum Thani, Buriram, Prachin Buri, Phra Nakhon Si Ayutthaya, Ratchaburi, Samut Prakan, Samut Sakhon, Sa Kaew, and Amnaj Charoen Province. Moreover, the well-known e-waste dismantling sites in Thailand are located in 1.) Khong Chai district, Karasin Province 2.) Daeng Yai Sub-district, Ban Mai Chaiyapot district, Buriram Province 3.) Ban Pao Sub-district, Ban Mai Chaiyapot district, Buriram Province and 4.) Sue Yai, Bangkok (Buranasingha, 2016; Vassanadumrongdee et. al. 2015).

2.3 Environmental and health problem from an informal e-waste dismantling

Electronic waste contains hazardous substances and heavy metals, so inappropriate management reach to environmental problems and health effects (Awasthi et. al, 2016). The biggest electronic waste dismantling sites are Guiyu, and Longtang, Guangdong, and Taizhou, Zhejiang in China. There are previous studies in electronic waste dismantling sites in China. They have assessed heavy metals such as Cadmium, Chromium, Lead, Zinc, and Copper in soil samples, and they found that heavy metals in soil samples were higher than standard control area as shown in Table2. Moreover, they have assessed heavy metals in human tissues such as blood, urine and hair, and they found that Cadmium and Lead in the blood of workers also were higher than standard and control area (Vassanadamrongdee et. al, 2015; Song and Li, 2015).

Table 2 Heavy metals in soil samples in e-waste dismantling in China (mg/kg).

Area	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
Guiya, Guangdong	52	10	320	12,700	500	1,100	480	3,500	Li et al. (2011)
Guiya, Guangdong	-	31.96	153.6	788	374	114	1,431	-	Alabi et al. (2012)
Taizhou, Zhejiang	-	7.7	77.4	742	-	64	956	392	Tang et al. (2010)
Taizhou, Zhejiang	36.6	42.3	771.5	2,364	-	-	6.083	5,996	Zhang et al. (2014)
Longtang, Guangdong	-	39.3	-	6.372	-	-	1,635	3,040	Lou et al. (2008)
Longtang, Guangdong	-	0.14	22.5	513	-	-	198	179	Wu et al. (2015)
Standard (China)	**30**	**0.3**	**200**	**50**	**-**	**40**	**250**	**200**	**MEP, 1996**

In addition to China, there are previous studies have assessed heavy metals in environmental samples such as soil in other countries; for examples, India, Nigeria, and Thailand were shown in Table 3.

Table3 Heavy metals in soil samples in e-waste dismantling in other countries (mg/kg).

Area	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
Bangalore, India	-	2.33	73	592	449	-	297	326	Ha et al. (2009)
Lagos, Nigeria	-	7.69	13.86	4,308	270.9	31.99	1,535	-	Alabi et al. (2012)
Klongchai, Kalasin	6	3.3	18	9,267	-	27	1,388	580	Regional Environment Office 10
Sua Yai, Chatuchak, Bangkok	-	< 2	88	4,828	511	74	1,058	1,847	Damrongsiri (2005)
Standard (China)	**30**	**0.3**	**200**	**50**	**-**	**40**	**250**	**200**	**MEP, 1996**
Standard (Thailand)	**3.9**	**37**	**300**	**-**	**1,800**	**1,600**	**400**	**-**	**PCD, 2004**

Source: Vassanadumrongdee (2015)

2.4 Heavy metals in electronic waste and their effects on human health.

The heavy metals are compositions in various electronic products. Robinson (2009) gives lists of heavy metals that are contained in electronic waste as presented in Table 4.

Table 4 Heavy metals in electronic waste.

Heavy metal	Electronic Waste
Antimony (Sb)	Computer parts, CRT screens, Mobile phones, LCD screens, Televisions, Flame retardants, and Plastics.
Arsenic (As)	Computer parts, CRT screens, LCD screens, Plasma screens, Circuit boards, and Doping material for silicon.
Barium (Ba)	Computer parts, CRT screens, LCD screens, Plasma screens, and Getters in cathode ray tubes.
Cadmium (Cd)	Computer parts, Mobile phones, Batteries, Toners, cathode ray tubes (CRTs), and Plastics.
Chromium (Cr)	Computer parts, CRT screens, LCD screens, Plasma screens, Data tapes, Floppy disks, Mobile phones, and Circuit boards.
Copper (Cu)	Computer parts, CRT screens, Plasma screens, LCD screens, Wiring, and Circuit boards.
Lead (Pb)	Computer parts, CRT screens, Plasma screens, LCD screens, Batteries, Circuit boards, Mobile phones, Hard disks, Floppy disks, light bulbs, monitors, and Solders.
Mercury (Hg)	Batteries, Computer parts, Fluorescent lamps, LCD screens, and Switches.
Manganese (Mn)	Batteries.
Nickel (Ni)	Batteries, CD player, Computer parts, Floppy disks, Hard disks, LCD screens, Plasma screens, and Circuit boards.
Zinc	CD Players, Computer parts, CRT screens, Plasma screens, Floppy disks, Hard disk, and Circuit boards.

Source: (Robinson, 2009; Townsend, 2011; Vasssanadumrongdee.S, 2015).

Electronic waste contains various heavy metals, and mostly heavy metals which typically found in electronic waste and easily accumulate in human body were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn), and the major sources of heavy metals are televisions, cathode ray tubes (CRTs) computer parts and LCD displays (Rao et al., 2017; Robinson, 2009; Townsend, 2011; Vasssanadumrongdee.S, 2015). The effects on human health from mostly heavy metals which typically found in electronic waste were shown in Table 5.

Table 5 Heavy metals and their effects.

Heavy Metals	**Acute effects (short-term)**	**Chronic effect (long-term)**
Arsenic (As)	- Gastrointestinal effects. - Central and peripheral nervous system effects.	- Skin lesions. - Brain and nervous systems. - Gastrointestinal effects. - Anemia. - Liver and kidney damage. - Cancer (Lung, skin, and liver).
Cadmium (Cd)	- Lung effects.	- Kidney disease. - Fetal effects. - Increased risk of lung cancer.
Chromium (Cr)	- Shortness of breath. - Coughing and wheezing.	- Perforations and ulcerations of the septum. - Bronchitis, Pneumonia.
Copper (Cu)	- Abdominal pain, nausea, vomiting, and diarrhea. - Respiratory system effects. - Irritation of Dermal and eye. - Gastrointestinal effects. - Hepatocellular toxicity.	- Liver and kidney damage.
Manganese (Mn)	- Lung function effects.	- Central nervous system effects. - Visual reaction time. - Hand steadiness. - Weakness and lethargy. - Respiratory effects.

Nickel (Ni)	- Lungs and kidney effects. - Nausea, vomiting, diarrhea.	- Respiratory effects. - Increased risk of lung and nasal cancers.
Lead (Pb)	- Hypertension. - Malaise, Drowsiness - Abdominal pain, nausea, vomiting, and diarrhea.	- Haematological effects. - Neurological effect. - Muscle weakness. - Tremors and paralysis. - Increase cancer risk.
Zinc (Zn)	- Chest pain, Cough. - Muscle soreness. - Irritation of the throat. - Vomiting and nausea. - Gastric irritation. - Lethargy. - Dizziness.	- Anemia. - Pancreas damage.

2.5 Evaluation of human exposure to heavy metals using biomarkers.

Due to most of the workers live in Daeng Yai Sub-district, Ban Mai Chaiyapot district and Ban Pao Sub-district, Putthisong district, and they have worked for a long time, longer than ten years. The evaluation of human exposure to heavy metals using biomarkers is the one method that can be used.

The biomarker is the method for measuring human exposure to toxic substances or environmental chemicals by measuring the substances or metabolites in human tissues and fluids such as blood, urine, feces, hair and nails which are the most frequently analyzed biological materials to assess the levels of metals. There are three exposure routes that can be transported heavy metals and reach to the human body; dermal exposure, inhalation exposure, and oral exposure, which can cause human health effects. After exposure to heavy metals, heavy metals are accumulated and excreted by pharmacokinetics. Approximate 90% - 95% of heavy metals that are intaken via route exposure were accumulated in the blood, and some were excreted via urine about 75% - 80%, while some were excreted via hair, nails, sweat, breast milk, and feces about 15%. In addition, the approximate 5% - 10% of intaken heavy metals were collected in three parts of the human body including bone and teeth about

90% - 95%, soft tissue such as kidneys and liver about 4%, and about 1% attach with red blood cell (RBCs).

Hair is highly mineralized tissue and can be sampled in relatively high mass when compared to blood and urine. Moreover, hair and nails appear to be of greater value in evaluating past and ongoing exposure to high levels of metals; meanwhile, the concentrations of metal in blood and urine decrease rapidly after exposure. So, hair and nails are mostly used to assess toxic and non-toxic metals of chronic human exposure, and it provides information to support health protection. In addition, the biomarker is used to the application in environmental bio-monitoring due to it is the indicator that is easily accessible and reflects environment pollutants in long term effects. Due to the difficulties in sampling of invasive matrices (blood or tissues of internal organs) and non-invasive markers of exposure (urine, saliva, hair, nails), the biomarker is a good indicator to determine the potentially toxic doses of metals, and assess health effects from occupational and environmental exposure to chemicals or metabolites (Dongarra, Varrica, Tamburo, & D'Andrea, 2012; Michalak et al., 2012; Mikulewicz, Chojnacka, Zielinska, & Michalak, 2011; Schramm, 2008).

2.5.1 Heavy metals in hair.

Hair is a human biological material that is derived from ectoderm that can monitor occupational and environmental exposure to toxic elements. There are two types of keratins include alpha-keratins and beta-keratin. Alpha-keratins contain abundant cysteine residues and amino acids. Hair is rich in fibrous proteins, Alpha keratins. So, the main composition in hair is cysteine that makes up approximately 10 -14 percentages.

Moreover, hair has an affinity for metals at high affinity due to cysteine in the hair (Mandal, Ogra, & Suzuki, 2003). Metals in the hair are bound to sulphur atoms in cysteine or sulphydryl groups (SH groups) in other amino acids. Hair is a cross-linked, part of crystalline, oriented, polymeric network that carries functional groups such as acids, basic and peptide bonds which can cap to binding small molecules. Metals can bind to the hair structure through melanin. Organic amines and metal ions have a high melanin affinity due to melanin are polyanionic polymers that contain negatively charged carboxyl groups and semiquinones at physiological PH;

meanwhile, organic amines and metal ions contain positively charged at physiological PH. So, positively charged inorganic amines interact with negative charges in the melanin polymer by electrostatic forces.

Moreover, the ionic binding can be enhanced by other forces such as Vander Waal’s attraction. In addition, uncharged metals such as Mercury (Hg) can bind to the hydrophobic core of the melanin polymer in hair (Srogi, 2006) Hair can provide a more permanent record of trace elements associated with normal and abnormal metabolism and assimilation from the environment. Heavy metals that are intaken via route exposure were accumulated in hair for one month and excreted via hair after exposure. So, using hair analysis of scalp hair as bio-monitoring is a valuable method used to assess the concentration of heavy metals of different populations (Jursa, Stein, & Smith, 2018; Santos Serrao de Castro & de Oliveira Lima, 2018).

The determination of heavy metal concentrations in hair was used to evaluate heavy metal exposures for occupational and environment. Due to hair samples are easily to collect, transport, store, and analyze. Moreover, they can be used to screen and monitor individuals and populations for exposure to heavy metals systemic poisoning in the occupational environment (Srogi, 2006). There are many studies have assessed heavy metals in hair as a biomarker or bio monitoring as follow.

The present study shows that using hair as an indicator is a noninvasive and cost-effective method. Moreover, it provides preliminary information on the exposure of heavy metals to workers in the area. Therefore, Wang et al. (2009) study used scalp hair samples for indicated heavy metals in an electronic waste recycling area in Taizhou, Zhejiang province in southeastern China. This study elevated nine elements include As, Ba, Cd, Cr, Cu, Mn, Ni, Pb, and V. The samples were analyzed with an inductively coupled plasma mass spectrometer (ICP–MS). The result found that the levels of all heavy metal in this study were found in the rank order Pb > Cu >> Mn > Ba > Cr > Ni > Cd > As > V. In addition, the concentrations of Cu and Pb were very high concentrations in hair of workers in electronic waste recycling areas. On the other hand, the concentrations of Cu and Pb in non-electronic waste workers in the control area were lower than workers in electronic waste recycling areas. Moreover, a multivariate analysis found Cd, Pb and Cu were highly correlated and electronic waste activities are likely to be the source of contamination for Cd, Pb and Cu in human scalp hair.

The study of Zheng et al. (2011) measured heavy metals in hairs between electronic waste workers and non-electronic waste workers in an electronic waste recycling area and control area in Longtang town, Qingyuan City, South China. This study elevated five elements including Cd, Cu, Ni, Pb, and Zn. The hair samples were analyzed with a flame atomic absorption spectrophotometer (FLAAS). The result found that the levels of all elements in this study were found in the rank order Zn > Pb, Cu > Cd > Ni. In addition, the concentrations of Cd, Pb, and Cu were significantly higher in electronic waste workers in the electronic waste recycling area than in the control area. Moreover, a multivariate analysis found Cd, Pb, and Cu were highly correlated, so electronic waste activities suggested the source of contamination for Cd, Pb and Cu in the hair of electronic waste workers.

Ha et. al (2009) study measured trace elements in soil, air dust, and human hair in electronic waste recycling facility sites in Bangalore, India. This study elevated fifteen elements include Ag, Bi, Cd, Cr, Co, Cu, In, Mn, Mo, Pb, Sb, Sn, Tl, V, and Zn. The samples were analyzed with an inductively coupled plasma mass spectrometer (ICP–MS). The result found that the concentrations of Cu, Mo, Ag, Cd, In, Sb, Tl, Pb, and Zn were observed at high levels in hair of electronic waste workers in electronic waste recycling facility sites. Moreover, this study is interesting that found high concentrations of some rare elements such as In, Sb, and Bi in the hair of workers.

In addition to the electronic waste site, there are other areas where the researcher measured and found the heavy metals in human hair. The study of Samanta et. al (2004) analyzed trace elements in biological tissues including hair, nails, and skin-scales of arsenic victims from groundwater area in West Bengal, India by using plasma-mass spectrometry (ICP-MS). This study elevated ten elements include As, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, and Zn. The result found that the concentration of As, Mn, Pb, and Ni are high level than values in the literature for this study in all biological tissues. Maybe because of the exposure of elements through drinking water and diet. Moreover, Mn and Ni are the correlations with other elements such as Fe, Cu, and Zn in hair.

Chojnacka et al. (2012) study the concentration of metal in hair include Al, As, Cd, Hg, Ni, and Pb from 110 individuals in 12 sectors pollutant source in the city of Wrocław, Poland where located a high-density road network, a large number of industrial and energy facilities, plus heat and power plants. All hair samples were analyzed by using plasma-mass spectrometry (ICP-MS). The results found that sector 5 was the most contaminated region for all contents of metals, and Hg and Ni were the highest content in this region. On the other hand, As was the lowest content in this region. However, the content metals in the hair of subjects were significant differences depending on the specific place of residence. Moreover, this result showed that hair mineral content reflected exposure to elements from the environment.

The study of Isabel Molina-Villalba et al. (2015) used the bio monitoring for assessing exposure to five metals include As, Cd, Mn and Pb by conducted in urine and scalp hair samples of children in mining and industrial area in Huelva, Spain. Moreover, they studied the potential contribution of gender, water consumption, and residence area and body mass index on urinary and hair metal concentrations. The results found that only arsenic (As) in the hair of children living near agriculture areas was higher. Moreover, the concentration of metals in the hair of girls exhibited significantly higher than boys.

The study of Drobyshev et al. (2017) using hair as bio monitoring for 18 trace elements include Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Ni, Pb, Se, V, Zn, Ca, Na and P in children who are residing in a proximity to the toxic waste disposal grounds as case area in Leningradskaya Oblast', and control area. The hair samples were analyzed with an inductively coupled plasma mass spectrometer (ICP–MS). The result showed that the concentrations of all metals were relatively high when compared to the previous data. However, there are some differences for As, Ca, Hg, Mn, Na, Pb, and Zn between case area and control area.

The study of Wongsasuluk et al. (2018) used hair as bio monitoring to investigate heavy metals that include As, Cd, Pb, and Hg in the agricultural area in

Ubonratchathani province, Thailand. Hair samples were using an inductively coupled plasma mass spectrometer (ICP–MS) for estimating the concentration of heavy metals. This area consists of the shallow acidic groundwater that is contaminated with heavy metals, so all hair samples were collected for investigating the concentration of heavy metals between the shallow groundwater drinking residents and tap water drinking residents. The result found that the concentrations of all heavy metals in shallow groundwater drinking residents were significantly higher than tap water drinking residents in the hair samples. These studies are examples of the previous study about concentrations of heavy metals in hair samples in different areas. The concentration of the heavy metals from the case of the study shown in Table 6.

Table 6 Concentrations of heavy metal in hair from previous studies (µg/g).

Area	**As**	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Reference**
West Bengal, India (Ground water site)	0.73	0.17	-	1.11	2.25	0.18	1.56	7.21	Samanta et. al (2004)
Taizhou, China (E - waste site)	0.33	0.52	1.32	39.80	5.32	1.09	49.50	-	Wang et al. (2009)
Bangalore, India (E - waste site)	-	0.05	0.40	22.80	1.86	-	16.10	141.00	Ha et. al (2009)
Qingyuan, China (E - waste site)	-	1.15	-	29.81	-	0.74	40.07	138.95	Zheng et.al (2011)
Wrocław, Poland (Industrial site)	0.73	0.08	-	-	-	0.99	2.29	-	Chojnacka et al. (2012)
Huelva, Spain (Mining site)	0.02	0.003	-	-	0.20	-	0.09	-	Molina-Villalba et al. (2015)
Leningradskaya Oblast’ (Disposal site)	0.02	0.11	0.28	10.40	1.60	0.43	2.48	107	Drobyshev et al. (2017)

2.5.2 Heavy metals in the nail.

Nail is one of human biological material that is derived from ectoderm that can monitor occupational and environmental exposure to toxic elements. Nails contain hard keratins up to 22 percentages cysteine Mandal et al. (2003). Nail plate consists of hard, translucent keratins that contain metals, and most of the keratin is derived from the lunular and nail matrix. Keratins formed fingernails and toenails since the root to reach the free edge of the fingertip at the slow process, approximately 0.5 up to 1 mm per week or 2-3 months. Normally, a fingernail grows faster than toenails. Average growth of fingernails is 0.1 mm per day, so fingernail takes about six months to grow out completely. On the other hand, the average growth of toenails is 0.03–0.05 mm/day. There are many factors may affect nail growth such as medical conditions (underlying disease), age (growth rate of the nail in younger are faster than older), gender (growth rate of the nail in men are faster than women), and other individual characteristics. Moreover, the different rates of growth between fingernails and toenails affect cross-comparison of concentrations of metal and exposure assessment. Normally, heavy metals that are intake via route exposure were accumulated in the nail for six months and excreted via hair after exposure (Favaro, 2013; Slotnick & Nriagu, 2006).

The determination of concentrations of heavy metals in nails is also used to evaluate heavy metal exposures for occupational and the environment because nails samples are also easy to collect, transport, store, and analyze. There are many studies have assessed heavy metals in nails as a biomarker or bio monitoring as follow

The study of Samanta et. al (2004) analyzed trace elements in biological tissues including hair, nails, and skin-scales of arsenic victims from the groundwater area in West Bengal, India by using plasma-mass spectrometry (ICP-MS). This study elevated ten elements include As, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, and Zn. The result found that the concentration of As, Mn, Pb, and Ni are high level than values in the literature for this study for all biological tissues. Maybe because of the exposure of elements through drinking water and diet. Moreover, Mn and Ni are the correlations with other elements such as Fe, Cu, and Zn in nails.

Gault et al. (2008) studied the concentration of arsenic (As) in nails samples in the groundwater area in Kandal province, Cambodia by using plasma-mass spectrometry (ICP-MS). The result found that the concentration of As was significant higher in nail samples of the resident who use high arsenic, so it is strongly indicated that consumption of the shallow subsurface waters can be an exposure source of arsenic intake.

The study of Wongsasuluk et al. (2018) used fingernails as bio monitoring to investigate heavy metals that include As, Cd, Pb, and Hg in the agricultural area in Ubon- Ratchathani province, Thailand. Fingernails samples were using an inductively coupled plasma mass spectrometer (ICP–MS) for estimate concentration of heavy metals. This area consists of the shallow acidic groundwater that is contaminated with heavy metals, so all nail samples were collected for investigating the concentration of heavy metals between the shallow groundwater drinking residents and tap water drinking residents. The result found that the concentrations of all heavy metals in the nails samples of shallow groundwater drinking residents were significantly higher than tap water drinking residents.

These studies are examples of the previous study about concentrations of heavy metals in nails samples in different areas. The concentration of the heavy metals from the case of the study shown in Table 7.

Table 7 Concentrations of heavy metal in nails from previous studies.

Area	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
West Bengal, India (Ground water site)	7.24	0.32	-	11.10	28.26	3.89	10.99	97.71	Samanta et. al (2004)
Kandal, Cambodia (Groundwater site)	1.96	-	-	-	-	-	-	-	Gault et al. (2008)
Ubonratchathani, Thailand (Ground water site)	0.29	0.07	-	-	-	-	70.98	-	Wongsasuluk et al. (2018)

2.6 Possible factors association with heavy metals in hair and nails

The socio-demographic and other factors such as exposure factors, behavior and health factors, and environmental factors of subjects may be associated with the concentration of heavy metals in hair and nails. There are examples of previous studies that found the different concentration of heavy metals in difference factors groups shown in Table 8.

Table 8 The associated factors to heavy metals in hair and nails.

Factor	Biomarker	Heavy metals	Result	Reference
Gender	Hair	Cr, Ni, Cr, Pb	The levels of all metals in hair samples of girls were higher than boy.	Li Li et al. (2018)
	Hair	As, Cd, Cr, Pb	The levels of As and Pb in hair samples of females were much higher than males.	Peter O. et al. (2012)
	Hair, Nail	As	The level of As in hair and nail samples in females was higher than males.	Rakib et al. (2013)
Occupation	Hair, Nail	Cd, Cr, Cu, Ni, Pb, Zn	The level of Pb in hair and nail samples of farmers was lower than rural businessmen.	Sukumar and Subramanian (2007)
Age	Hair	As, Cd, Cr, Pb	The level of Cd in hair samples of older groups was higher than younger groups.	Liang et al. (2017)
Working time	Hair	Cd, Cr, Mn, Ni, Pb	The levels of Mn and Ni in hair samples were higher in workers who had the longer lifetime of working experience.	Gil et al. (2011)
	Hair	Pb, Cu	The levels of Pb and Cu in hair samples were associated with longer duration of overtime work.	Amanah et al. (2015)
Secondhand smoking habit	Hair	As, Cd, Cr, Mn, Ni, Pb	The levels of Cd and Pb in hair samples of second- hand smokers are higher than non - secondhand smokers.	Li Li et al. (2018)

Factor	Biomarker	Heavy metals	Result	Reference
Smoking habit	Hair, Nail	Cd, Pb, Hg	The levels of Cd, Pb, Hg in hair and nail samples of smoker were higher than non-smoker.	Mortada et al. (2002)
	Nail	Cd, Pb, Cr, Mn, Fe, Ni, Cu, Zn	The levels of all metals in nail samples of smoker were higher than non-smoker.	Mehra and Juneja (2005)
	Hair	Cd, Cu, Mn, Pb, Zn	The levels of Pb and Cd in hair samples of smoker were higher than non-smoker.	Afridi et al. (2011)
	Hair	As	The level of As in hair samples of smoker was higher than hair samples for non-smoker.	Arain et.al (2009)
Eating habit	Hair, Nail	As, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Zn	The levels of As, Mn, Ni, Pb, Zn in hair and nail samples of workers who eating diet and drinking in contaminated heavy metals ground water area were high level.	Samanta et. al (2004)
	Hair, Nail	Cd, Cr, Cu, Pb	The levels of Cd, Cr, Cu, Pb hair and nail samples were higher in residents who are fish consumption.	Oyoo-Okoth et al. (2010)

CHAPTER 3

METHODOLOGY

The study areas are Daeng Yai Sub-district, Ban Mai Chaiyapot district and Ban Pao Sub-district, Puttatisong district, Buriram province where is the e-waste separating area in Northeast Thailand. In addition, the control area in this study was assigned as approximately 5 kilometers (km) away from the electronic waste separating area. The control area is the only village that is non e-waste separating area. The locations are shown in Figure 2.

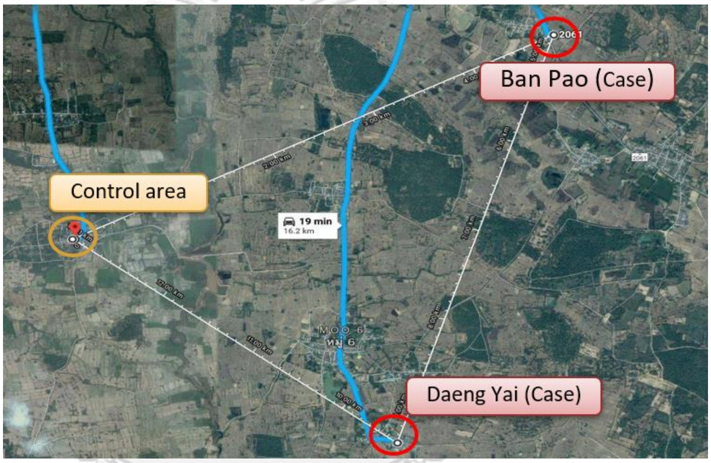


Figure 2 The location of the study area in Dang Yai Sub-district, Ban Mai Chaiyapot district and Ban Pao Sub-district, Puttatisong district.

Sampling group

In this study, total target samples of 162 persons from both villages. The total target samples were divided into two groups. First, 134 participants for collected hair samples, and they divided into 102 of e-waste workers and 32 of non-e-waste workers. Second, 136 participants for collected nails samples, and they divided into 105 of e-waste workers and 31 of non-e-waste workers.

Sampling Technique

Ethic processing must be informed consent before collect hair and nails samples. In this study, the ethics process was approved and got a certificate, COA No.217/2561, from Ethic Review committee for research that involve human research subjects and health science group, Chulalongkorn University by the principle of The International Conference on Harmonization - Good Clinical Practice (ICH - GCP).

3.1 Sampling collection.

3.1.1 Participants

There are electronic waste workers in 173 households. For each household has electronic waste workers approximately four workers, so this study area contains total has electronic waste workers 692 workers.

For the manual sample size calculation

$$n = \frac{N}{1+Ne^2}$$

n = Sample size

N = Total population

e = Error (At the confidence level of 90% is 0.10

$$n = \frac{692}{1 + 692(0.10)^2}$$

n = 87

For the sample size calculation was compared with Yamanae (1973) at the 90% confidence level, it was 87 samples.

Additionally, the N4Studies program also was used for sample size calculation. From this statistic program calculation, it was 29 samples (Figure 3) (Bernard, 2000; Srogi, 2006).

$$n_1 = \frac{(z_{1-\frac{\alpha}{2}} + z_{1-\beta})^2 \left[\sigma_1^2 + \frac{\sigma_2^2}{r}\right]}{\Delta^2}$$

$$r = \frac{n_2}{n_1},\ \Delta = \mu_1 - \mu_2$$

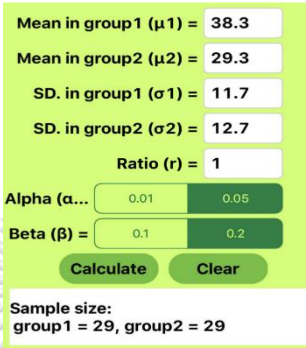


Figure3 N4Studies program for sample size calculation

From the results of both sample size calculations, 130 of e-waste workers and 32 non-e-waste workers were set as the target groups to collect hair and nails samples (total 162 participants). Due to the target sample size of 162 was over the maximum sample size required from both calculation methods, the number of sample size in this study was then suitable for statistical analysis. Moreover, this study aimed to investigate the concentration of heavy metals in e-waste workers, so the number of e-waste workers group were set more than non-e-waste workers group for explicit results of heavy metals concentrations in hair and nails. All participants were convenient sampling from randomly village No. in the study area (Figure 4). The selection criteria for all sampling groups was defined as the followings:

Inclusion criteria

1. Exposure group are male or female as electronic waste workers for at least six months
2. Non - exposure group or control group are males or females as non - electronic workers or have other jobs and live away from electronic waste area 5 kilometers.
3. Both groups are 18 to 65 years old.

4. Both groups live in the study area at least than six months.
5. Both groups contain natural hair or chemical hairstyles without two months including color, bleach, straighten, and rebounding.
6. Both groups contain natural fingernails and without fingernails polish.
7. Both groups are healthy and are not disabled.
8. Both groups are participated and having Thai communication skills to interview by questionnaire.

Exclusion criteria.

1. Person does not include in exposure group and non - exposure group.
2. A person is disabled that cannot work about separate electronic waste and answer questionnaire including problems about the hand, arms, and legs, blind, deaf.
3. A person does not have fingernails and hair (Glabrous or Skinhead), and patients who are undergoing chemotherapy or radiation therapy.
4. A person has life threatening diseases and associated with data analysis include scalp infections, hand, foot and mouth disease, neurological conditions.

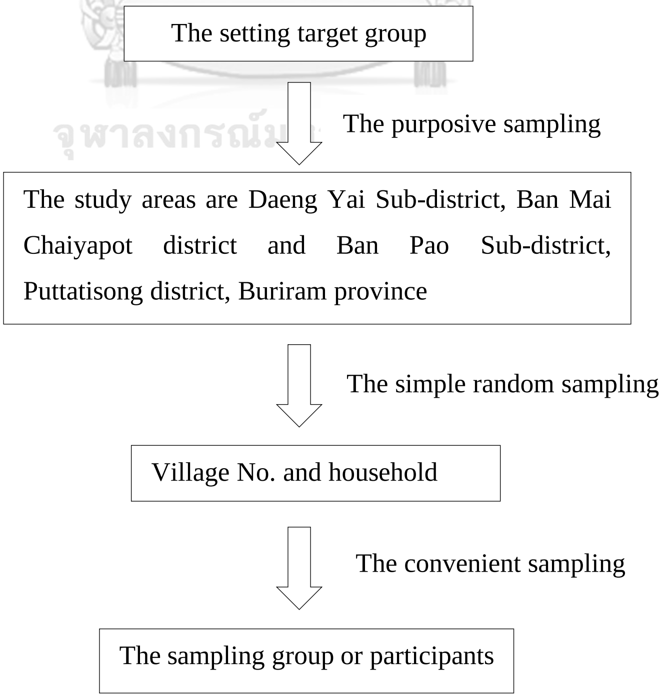


Figure 4 The selection of participants in this study

From total 162 participants, 134 participants were collected hair samples (102 e-waste workers and 32 non-e-waste workers) and 136 participants were collected nails samples (105 e-waste workers and 31 non-e-waste workers) ; moreover, within the total participants, 108 participants were collected both hair and nails (77 e-waste workers and 31 none-waste workers) (Table 9).

Table 9 The sampling group or participants in this study.

Samples	Total participants	E-waste worker (people)	Non-e-waste worker (people)
Hair	134	102	32
Nails	136	105	31
Both hair and nails	108	77	31

3.1.2 Hair and nails samples collection.

1.) Hair samples were collected from back of the head or behind the ear by using a stainless-steel scissor for hair cutting from total of 134 people as samples groups. The average growth rate of human hair is approximately 1 cm per month, so hair samples in this study were the first 1–2 cm from the scalp as the newly grown hair in the last 1–2 months. For each person, hair samples were collected 100 mg from total of 134 samples (Wongsasuluk, Chotpantarat, Siriwong, & Robson, 2018). Hair samples were sealed separately in labeled polyethylene zip lock bags and they were not opened before reach to the laboratory for cleaning.

2.) Nail samples were collected from fingernails with sterilized stainless-steel scissors for nail cutting from total of 136 people as samples groups. For each person, nail samples were collected 10 mg from total of 136 samples (Gault et al., 2008; Mehra, 2005). Nails samples were collected in a polyethylene bottle and they were not opened before reach to the laboratory for cleaning.

In addition, the personal information of the participants or sampling group were collected by using questionnaire to investigate the associated factors to exposure heavy metals. The questionnaire interview consisted of three parts including socio-demographic factors, behavioral factors, and working condition and PPE using.

Furthermore, e-waste data in this area were collected as additional data. The information as shown in Table 10. and the questionnaire was shown in Appendix A.

Table 10 Personal information of the participants used for investigating associated factors with the heavy metals in hair and nails.

Factors	Contents	Unit/ Term
Socio-demographic factors	- Gender	- Male or Female
	- Weight	- kg
	- Height	-cm
	- BMI	- kg/m^3
	- Age	- Years
	- Occupation	- E-waste or Non e-waste
	- Living time	-Years
	- Family member	- People
Behavioral factors	- Smoking	- No or Yes (Unit/day)
	- Second smoking	- No of Yes
	- Alcohol consumption	- No or Yes (time/day and bottle/ time)
	- Seafood consumption	- No or Yes (time/week)
	- Bare feet walking direct expose to soil	- No or Yes
	- Congenital disease	- No or Yes
	- Medicine	- No or Yes
	- Source water for bathing and washing	- Ground water or Tap water
	- Cooking in household	- Yes or No
	- Cleaning kitchenware before cooking	- Yes or No
	- Using fertilizer in agricultural	- Yes or No
Working condition factors	- Working period	- Years
	- Duration working hours	- Hours
	- Duration working days	- Days
	- PPE using	- No or Sometimes or Always
Additional data	- Pattern of e-waste dismantling, and e-waste products and valuable material amount	- Only dismantling e-waste product, Both dismantling e-waste products and buying separated material, or Only buying separated material
	- Having knowledge about harmful from e-waste dismantling	- Yes or No

3.2 Sampling preparation

3.2.1 Hair samples preparation

Hair samples were washed with baby shampoo for cleaning of dust particles and sodium content in hair samples to removed organic compounds from hair samples by purification. Next, Hair samples were cut into small pieces of 5 mm in length and were washed with acetone by following the method recommended guidelines in the International Atomic Energy Agency or IAEA (acetone – water – water – water – acetone) to remove external contamination. After washing and cleaning procedures, hair samples were dried in an oven at 50 °C overnight (Gault et al., 2008; Samanta, Sharma, Roychowdhury, & Chakraborti, 2004; Wang et al., 2009; Wongsasuluk et al., 2018).

3.2.2 Nail samples preparation

Nails samples were scrapped and were cleaned by brushing to remove surface contaminants. Next, nail samples were soaked and were washed with acetone by following the method recommended guidelines in the International Atomic Energy Agency or IAEA to remove external contamination. After washing and cleaning procedures, nails samples were dried in an oven at 50 °C overnight (Samanta et al., 2004; Wongsasuluk et al., 2018; Zheng et al., 2011).

3.3 Sampling extraction

Since there was no standard for hair and nails sampling extraction, this study modified extraction method from U.S.EPA 3051a standard method. 5 ml of 65% (v/v) nitric acid was added to hair samples, 100 mg and nail samples, 10 mg for purifying organic matter. Hair and nails samples were digested in microwave digester, following The MARS5 digester method to complete digestion a solution (step: 1,200 W at 200℃ ramp time for 15 minutes, hold time for 10 minutes and cool down around 30 min). The solution 5 ml was transferred to PTFE beaker and was evaporated the solution until 0.1 ml, and then it was adjusted with Type I water to the volume 5 ml in a volumetric flask. Finally, the solution 5 ml was stored in a polyethylene bottle before analysis by Inductively Coupled Plasma Spectrometry-Mass Spectrometry (ICP-MS).

3.4 Analysis of heavy metals concentration in the sample.

The concentrations of heavy metals in hair and nail samples include arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn) were analyzed using Inductively Coupled Plasma Spectrometry-Mass Spectrometry (ICP-MS). Heavy metal concentrations were calculated using the following equation:

Mass of heavy metal (µg) = Heavy metal concentration (µg/mL) X volume of sample solution (ml) (1)

The concentration of heavy metal in the hair and nail (µg/mg) = mass of heavy metal (µg) / Mass of hair and nail (mg) (2)

- Quality control and quality assurance

  The Limits of detection (LOD) were estimated base on three times the standard deviation for digestion blank for five times. The blank solution was injected into ICP-MS, and mean and standard deviation of the measured data was calculated as the following equation;

LOD = 3 x S (3)

LOQ = 10 x S (4)

The detection limit of ICP-MS in this study was 1.50 µg/L for As and Cr and 1.00 µg/L for Cd, Cu, Mn, Ni, Pb and Zn.

Moreover, the calculation of relative standard deviation percentage (%RSD) was examined for the precision of ICP-MS as following equation;

%RSD = (S/X) x 100 (5)

Where S = Standard deviation.

X = Mean of the standard solution measured ten times replicating.

The percentage of the relative standard deviation of the instrument was 20.0, 22.4, 8.0, 10.3, 10.2, 13.1, 1.7, and 4.7% for As, Cd, Cr, Cu, Mn, Ni, Pb and Zn, respectively.

The recovery test was implemented to determine the efficiency of the extraction method. The mix standard solution at 200 ppb was used instead of a sample and extracted through the same method as samples for seven replicates. Then, they were analyzed by ICP-MS to find the exact concentrations in order to calculate the percentage of recovery. The recover percentages of heavy metals were 92.4, 88.6, 113.6, 89.5, 89.4, 92.4, 89.2, and 87.2% for As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn, respectively.

3.5 Data Analysis

The statistical analysis of personal information from questionnaire interview of participants and concentration of heavy metals in hair and nails were performed using the SPSS program. The analysis are as follows;

1. Kolmogrov - Smirnov test (K-S test) was used to investigate the normal distribution of heavy metal concentrations in hair and nails.

2. Mann-Whitney U-test (2-tailed) were used to investigate the mean difference in heavy metal concentrations in hair and nails between two groups for non - normal distribution or nonparametric statistics.

3. Chi-squared ($\chi 2$) was used to analyze associated risk factors.

4. Statistic parameters including range, mean, median, and standard deviation were investigated as descriptive statistics.

5. Spearman test was used to investigate the correlation between heavy metals concentration in hair and nails.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 The general and background information of participants and e-waste amount

4.1.1 Socio-demographic of participants

From the survey on personal information of 162 participants in this study area by the questionnaire as shown in Table 11, the result shows that all target participants consisted of 130 e-waste workers and 32 non-e-waste workers. Within 130 e-waste workers, there were 67 males (51.5%) and 63 females (48.5%). Their average age was 46.2±10.8 years old and ranged from 23.0 to 66.0 years old. Their average weight, height, and BMI were 61.1±11.0 kg, 159.9±7.4 cm, and 23.9±3.9, respectively. They have lived in this area for 31.8±19.6 years and ranged from 6 months to 66 years. The occupation of e-waste dismantling only accounted for 37 workers (28.5%), and the participants who work on both e-waste dismantling and farmer were 93 workers (71.5%). While non-e-waste workers comprised 10 males (31.3%) and 22 females (68.7%). Their average age was 51.4±9.6 years old and ranged from 22.0 to 65.0 years old. Their average weight, height, and BMI were 61.1±9.1 kg, 159.2±7.6 cm, and 24.2±3.9 respectively. They have lived in this area for 41.1±16.3 years and ranged from 3 to 65 years. The occupation of farmers accounted for 29 subjects (90.6%), and the other 3 workers (9.4%) were farmers and merchants.

The average age of the workers in this study was higher when compared with the e-waste dismantling workers in Ghana (26 years), Nigeria (30 years), Sweden (38 years), and China (30 years) (Julander et al., 2014; Ohajinwa, Van Bodegom, Vijver, & Peijnenburg, 2017; Qu et al., 2007; Srigboh et al., 2016). The local participants have lived in this area and have been a rice farmer for a long time. Traditionally, the farmers in this area earn income from rice cultivation once a year, which is uncertain depending on weather conditions. They estimated the income from rice cultivation in the range of 980 to 1600 USD per year which is quite low. Whilst, if they dismantle e-waste mostly every day, they can make income up to 13000 to 23000 USD per year. Therefore, the local people would then intentionally change from being a farmer only to be e-waste dismantling workers.

Table 11 The general and background personal information of participants in this study

Factors	Number of participants (N=130 ^{EW}, N=32 ^{NE})	Range	Mean (S.D)	Median
Gender				
Male				
E-waste workers group	67 (51.5%)			
Non-e-waste workers group	10 (31.3%)			
Female				
E-waste workers group	63 (48.5%)			
Non-e-waste workers group	22 (68.7%)			
Occupation				
E-waste workers group				
E-waste dismantling	37 (28.5%)			
E-waste dismantling and farmer	93 (71.5%)			
Non-e-waste workers group				
Farmer	29 (90.6%)			
Farmer and merchant	3 (9.4%)			
Age (years)				
E-waste workers group		23.0-66.0	46.2 (10.8)	45.0
Non-e-waste workers group		22.0-65.0	51.4 (9.6)	52.5
Weight (Kg)				
E-waste workers group		41.0-94.0	61.1 (11.0)	60.5
Non-e-waste workers group		46.0-95.0	61.1 (9.1)	61.0
Height (cm)				
E-waste workers group		145.0-180.0	159.9 (7.4)	160.0
Non-e-waste workers group		150.0-177.0	159.2 (7.6)	159.2
BMI (kg/m^2)				
E-waste workers group		17.7-38.1	23.9 (3.9)	23.6
Non-e-waste workers group		17.7-36.2	24.2 (3.9)	23.9
Living time in area (years)				
E-waste workers group		0.5-66.0	31.8 (19.6)	31.0
Non-e-waste workers group		3.0-65.0	41.1 (16.3)	46.0

^{EW} = E-waste worker group, ^{NE} = Non e-waste worker group

4.1.2 Lifestyle and consumption of the participants

The information on the behavior of local people relating to their consumption and lifestyle, including seafood consumption, smoking habits, secondhand smoking habits, alcohol consumption, bare feet walking on soil, a water source for consumption and washing purpose, was gathered from 162 participants by using a questionnaire. The behavior information of 130 e-waste workers and 32 non-e-waste workers is shown in Table 12. The survey revealed that all 130 participants were seafood consumption, and the most frequency of seafood consumption was 1 to 4 times/week (56.9%). They were 33 smokers (25.4%) and mostly smoking at 10 cigarettes/day (39.4%); moreover, there were 47 secondhand smokers (36.2%). There were 66 alcohol drinker (50.8%) and most drinking were 1 to 5 times/week (42.4%). Additionally, 61 workers (46.9%) walked with bare feet and directly exposed to the soil. For non-e-waste workers, all 32 participants also were seafood consumption and 56.9% of this group consumed 1 to 4 times/month. Only 5 subjects (15.6%) were smokers and 60.0% smoking at 10 cigarettes/day, and there were 8 secondhand smokers (25.0%). Eighteen people (56.3%) drank alcohol and 50.0% of them drank lower than once a week. There were 40.2% of bare feet walking on the soil. All 162 participants used tap water for washing and cleaned kitchenware before cooking every time. They usually bought 20L PET water bottle for drinking.

Table 12 Lifestyle and consumption of the participants.

Factors	E-waste worker group (N=130)	Non-e-waste worker group (N=32)
Seafood consumption (times)		
1-4 times/week	74 (56.9%)	8 (25.0%)
1-4 times/month	40 (30.8%)	18 (56.2%)
1-4 times/6month	16 (12.3%)	6 (18.8%)
Smoking habits		
No	97 (74.6%)	27 (84.4%)
Yes	33 (25.4%)	5 (15.6%)
Lower10 cigarettes/Day	12 (36.4%)	0
10 cigarettes/Day	13 (39.4%)	2 (40.0%)
Higher 10 cigarettes/Day	8 (24.2%)	3 (60.0%)

Secondhand smoking		
No	83 (63.8%)	24 (75.0%)
Yes	47 (36.2%)	8 (25.0%)
Alcohol consumption		
No	64 (49.2%)	14 (43.7%)
Yes	66 (50.8%)	18 (56.3%)
7 times/week	17 (25.8%)	1 (5.6%)
1-5 times/week	28 (42.4%)	8 (44.4%)
Lower 1 times /week	21 (31.8%)	9 (50.0%)
Bare feet walking direct expose to soil		
No	69 (53.1%)	19 (59.4%)
Yes	61 (46.9%)	13 (40.2%)
Source of water for washing		
Tap water	130 (100.0%)	32 (100.0%)
Source of drinking water		
20L PET water bottle	130 (100.0%)	32 (100.0%)
Cleaning kitchenware before cooking		
No	0	0
Yes	130 (100.0%)	32 (100.0%)

4.1.3 Working condition and using PPE of e-waste workers

The characteristics of electronic waste dismantling were collected from 130 participants and the results are shown in Table 13. The working condition of all participants was explained with working times, including working period, working hour, and working day. Using personal protective equipment or PPE of the worker, e.g. gloves, shoes, and mask, was also observed. From the questionnaire, it was found that their average working period was 6.7±5.4 years, ranged from 1 month to 22 years and a median of 6 years. Their working hours of participants averaged as 7.4±1.8 hours/day, in the range of 1 to 13 hours/day and median 8 hours/day. They worked 5.4±2.0 days a week at average, ranged from haft a day to 7 days a week and median 6.5 days/week. When compare with other countries, the working time of workers in this study was higher than Ghana. The workers in Ghana worked for 1 to 7 years; their working hours were between 10 to 12 hours/day and worked for 5-6 days/week. However, the working time of workers in this study was lower than China, the average working period of workers in China was 20 years 12 (Akormedi, Asampong, & Fobil, 2013; Asampong et al., 2015; Wang et al., 2009; Zheng et al., 2011). Disassembly of e-waste by a physical process such as cutting, scattering, splitting and removing parts of e-waste for a long time can pose long-term health effects for the workers. The health problems from these activities could be observed as back pain, leg pain, muscle pain, wrist pain, and other joint pain. The average age and working time of the workers in this study are higher than in other counties, so the workers in this area tend to get such health problems easily. Additionally, previous studies found that working time was related to the level of heavy metals in biomarkers of workers.

Additionally, the observational result revealed that the workers in the study area have worked without appropriate personal protective equipment for a long time. They have mainly used gloves, shoes, and mask as personal protective equipment (PPE). The results found that there were 124 workers (95.4%) use PPE every time, and 6 workers (4.6%) worked without wearing the PPE. However, there were only 75 workers use PPE every time (60.5%). Most workers use a short glove and fabric glove (94.4%), sneakers (80.8%), mask (93.8%) and most workers use fabric masks (86.9%). The behavior of using PPE in this study was better than the workers in Nigeria (18.0% and 43.0%) but lower than in China (90.0%) (Ohajinwa et al., 2018; Ohajinwa et al., 2017; Wang et al., 2009). Using of PPE is one way for avoiding exposure to hazardous pollutants and heavy metals in e-waste that released during the dismantling processes directly to the body.

Table 13 The using PPE of e-waste workers participants.

Factors	Number of participants (N=130)
PPE using	
No	6 (4.6%)
Yes	124 (95.4%)
Every time	75 (60.5%)
Sometimes	49 (39.5%)
Short glove	
No	6 (4.6%)
Yes	124 (95.4%)
Fabric glove	117 (94.4%)
Rubber glove	7 (5.6%)

Shoes	
Sneakers	105 (80.8%)
Sock and sandals	12 (9.2%)
Boots	5 (3.9%)
Sandals	8 (6.1%)
Mask	
No	8 (6.2%)
Yes	122 (93.8%)
Fabric mask	106 (86.9%)
Hygienic mask	14 (11.5%)
N95	2 (1.6%)

4.1.4 Amount of e-waste and valuable material estimated by e-waste dismantling operator

The situation of e-waste in Thailand has been increased every year. The report of the Pollution Control Department found that the trend of electronic waste that is popularly used in households has increased. The common household e-waste includes computers, television, air conditioners, washing machines, refrigerator, DVD/VCD players, mobile phones, and cameras (Kunacheva, Juanga, & Visvanathan, 2009; Vasssanadumrongdee.S, 2015). The e-waste amount in this study area was collected from 47 households from a total of 173 households. Regarding the different patterns of e-waste dismantling, it could be divided into three groups. First, there was only dismantling the e-waste, 27 households (57.4%) as group A. Second, 11 households (23.4%) were both dismantling e-waste products and buying separated material from the junkshop as group B. Last, the household bought only separated material without disassembly of e-waste which was 9 households (19.2%) as group C. The results are shown in Table 14.

Table 14 The estimation of e-waste amount in the household of the participants in the study area (units/household/year).

Product	A	B	C	Total
Television	12-2400	12-480	12-1200	12-2400
Washing machine	12-2400	12-480	24-600	12-2400
Computer	12-2400	12-480	12-24	12-2400
Refrigerator	12-1440	12-480	24-84	12-1440
Air conditioner	12-600	12-240	12-24	12-600
Total	**60-9240**	**60-2160**	**84-1932**	**60-9240**

The results found that the total amount of e-waste in the study area was estimated at 60 to 9,240 units/household/year. The total amount of televisions, washing machines, and computers were ranked the highest and ranged from 12 to 2400 units/household/year. Meanwhile, total refrigerators and air conditioners were estimated lower with the range of 12 to 1440 and 12 to 600 units/household/ year, respectively. When compared among the three groups, the total amount of e-waste being separated by group A was the highest and followed by group B and C respectively. The operational scale for the local community was found depending on investment potency, income, number of workers and market price of the separated material. Moreover, the e-waste also provides a source of valuable materials for sale. The compositions in e-waste are normally different in association with electronic and electrical products. The main valuable materials that could be recovered from the total e-waste were iron (40%-70%), plastic (20%-30%), aluminum (5%-15%), copper (5%-15%), and others such as brass, glass, wood, cement, etc. (Department of Health, 2005). From this survey, the valuable materials from the dismantling of e-waste were found in the descending order as iron, aluminum, plastic, copper, and brass, as shown in Table 15.

Table 15 The estimation amount of valuable materials recovered from e-waste dismantling in study area (tons/ household/year).

Material	A	B	C	Total
Iron	9.60-72.00	0.12-36.00	0.12-24.00	0.12-72.00
Plastic	0.24-24.00	0.24-12.00	1.20-48.00	0.24-48.00
Aluminum	0.01-12.00	0.01-12.00	0.01-3.60	0.12-12.00
Copper	0.24-8.40	0.01-6.00	0.01-3.60	0.01-8.40
Brass	0.01-1.20	0.01-1.20	0.01-1.40	0.01-1.40
Total	**10.10-117.60**	**0.39-67.20**	**1.35-80.6**	**0.50-141.80**

From Table 15, the total amount of valuable materials in the range of 0.50 to 141.80 tons/household/year could be obtained. All valuable materials separated from group A showed the highest in exception for plastic, that was found the highest in group C. Due to iron and plastic are the main compositions in many types of e-waste, so the workers in all groups could recover a large amount of iron and plastic higher than other materials. On the other hand, the lowest amount of brass could be separated, because it is not the main material used in electrical and electronic products. The operator in groups A and B could receive a large amount of iron, aluminum, and copper higher than group C, which reflected a positive proportion of input and output of the material flow through the disassembly of e-waste in this area. As well as, group C received the highest amount of plastic because they directly bought a lot of plastic bottles more than other waste types.

4.2 Heavy metals in hair and nails of e-waste dismantling workers

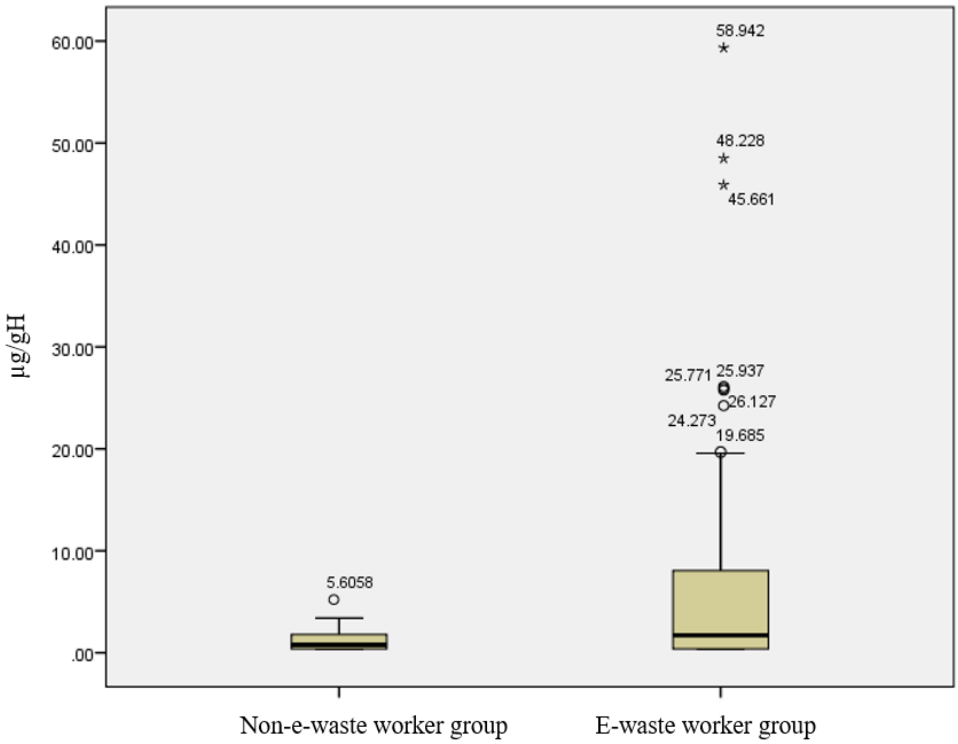
4.2.1 Heavy metals in hair

The hair samples of 134 participants from all 162 participants were taken to investigate the concentration of eight heavy metals, including As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn. From a total of 134 participants, these were divided into 102 e-waste dismantling workers and 32 non-e-waste workers. The result showed that the average concentration of As and Cd in the hair of all 134 participants were less than LOD. The LOD was 0.75 µg/g-hair (µg/gH) for As and Cr and 0.50 µg/gH for Cd, Cu, Mn, Ni, Pb, and Zn. This study is mainly focused on the concentration of Cr, Cu, Mn, Pb, and Zn in hair samples of all participants, as shown in Table 4.6. Five heavy metals found in the hair of the e-waste workers group were higher than those of the non-e-waste worker group except Ni. The concentration of Ni in the hair of the non-e-waste worker group was slightly higher than the e-waste workers group. The average concentrations of Cr, Cu, Mn, Pb, Ni, and Zn in the hair of the e-waste workers group were 6.44, 18.38, 2.85, 2.32, 6.64, and 185.51 µg/gH, respectively. While for the non-e-waste workers group, the average concentrations of Cr, Cu, Mn, Pb, Ni, and Zn in the hair were 1.24, 6.68, 1.35, 2.43, 1.28, and 121.56 µg/gH, respectively. The concentration of heavy metals in the hair of both participants groups are shown in Table 16 and Figure 5.

Table 16 The concentration of heavy metals in the hair of participants (µg/gH).

Heavy metal	**Median**		**Mean (S.D.)**		**Range**	
	EW	**NE**	**EW**	**NE**	**EW**	**NE**
H-As	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75
H-Cd	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
H-Cr	1.73	0.77	6.44 (10.23)	1.24 (1.20)	< 0.75-58.94	< 0.75-5.61
H-Cu	15.53	6.61	18.38 (10.90)	6.68 (2.36)	3.04-73.11	1.60-13.14
H-Mn	2.06	0.98	2.85 (2.34)	1.35 (1.00)	< 0.50-11.37	< 0.50-3.99
H-Ni	0.89	0.79	2.31 (3.80)	2.43 (5.47)	< 0.50-22.92	< 0.50-29.67
H-Pb	4.16	0.56	6.64 (7.23)	1.28 (3.65)	< 0.50-40.53	< 0.50-21.14
H-Zn	174.74	121.08	185.51(71.06)	121.56 (49.00)	20.34-530.87	46.52-335.41

EW = E-waste workers group, NE = Non-e-waste workers group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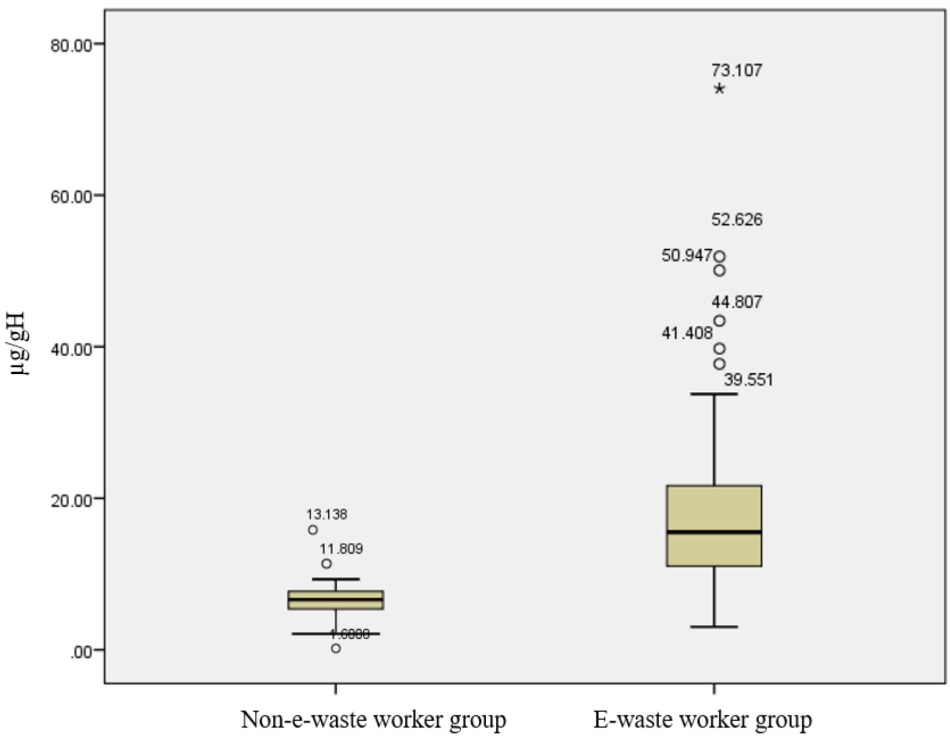
Non-e-waste worker group
E-waste worker group

a (H-Cr)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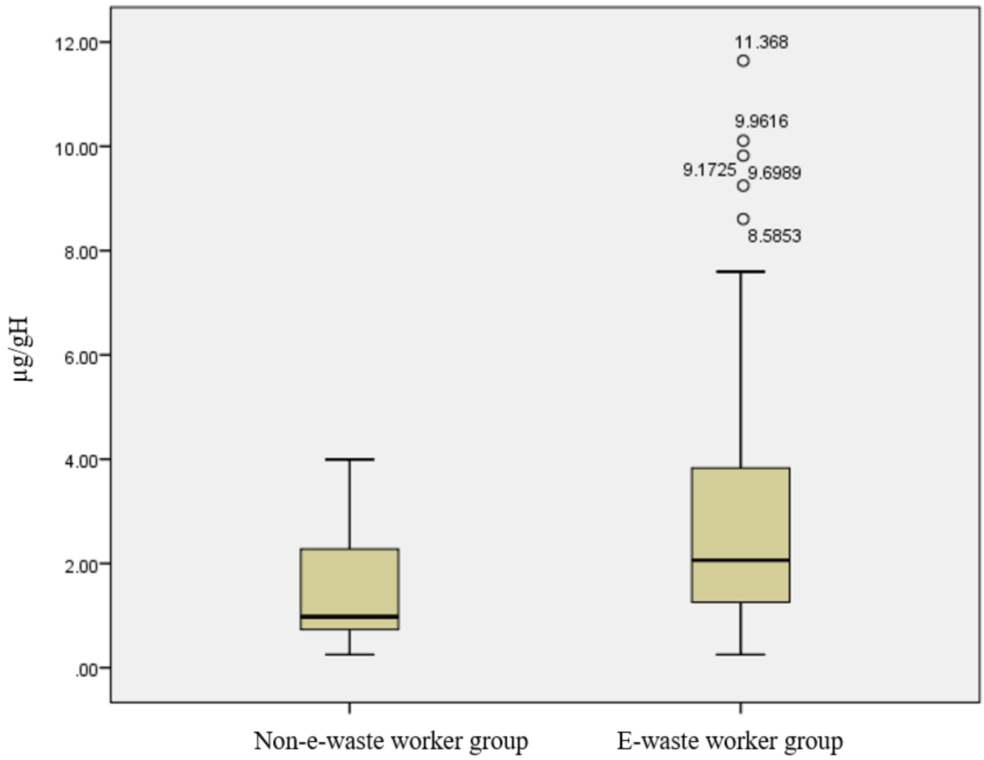
Non-e-waste worker group
E-waste worker group

b (H-Cu)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2.00
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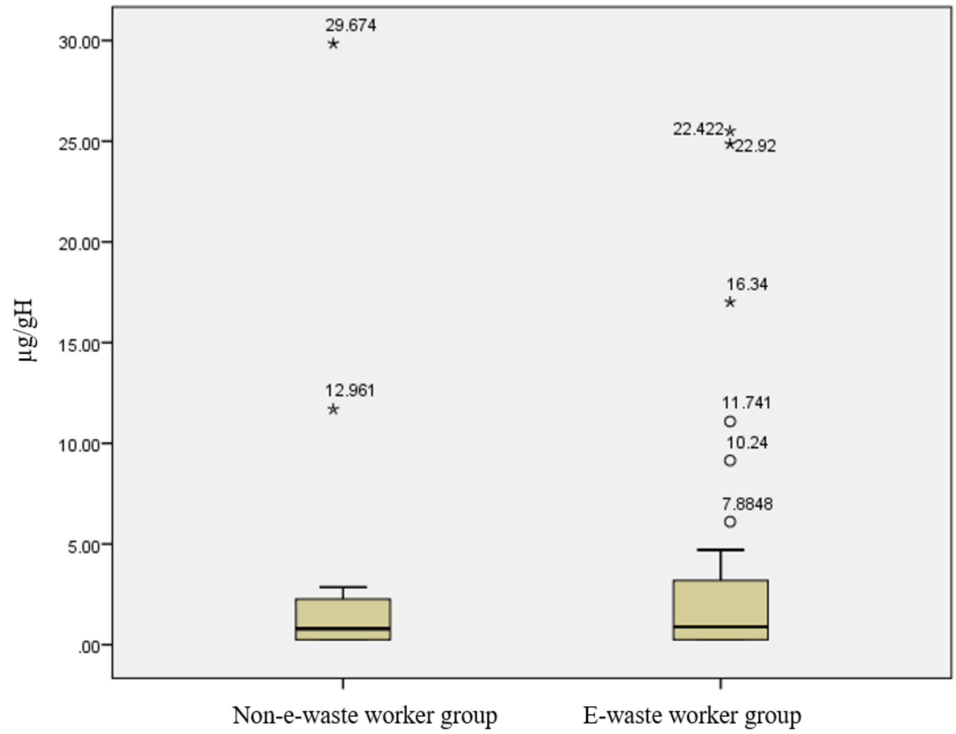
Non-e-waste worker group
E-waste worker group

c (H-Mn)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10.00
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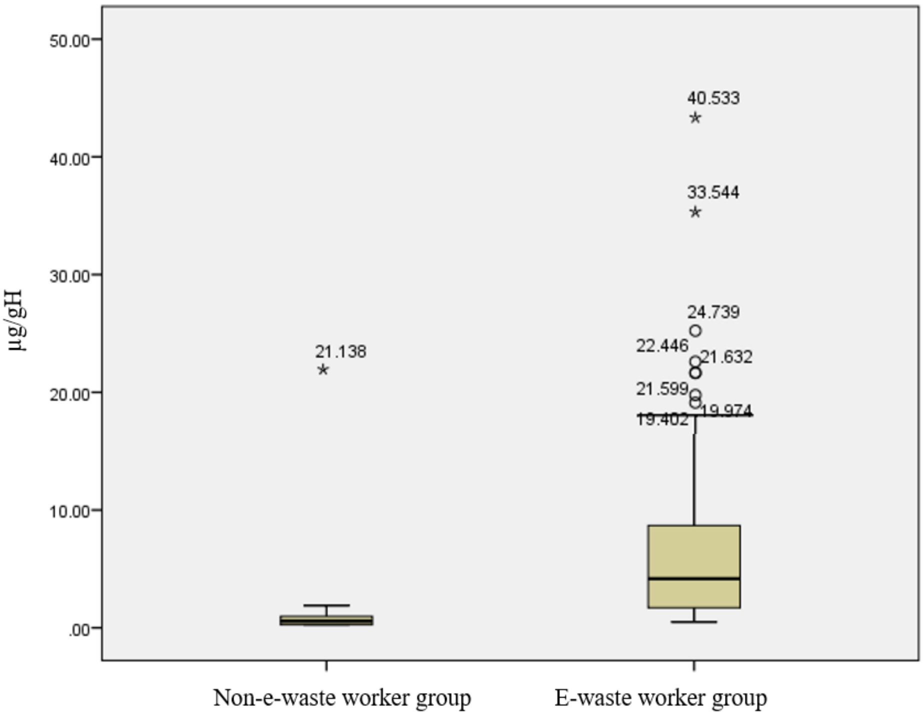
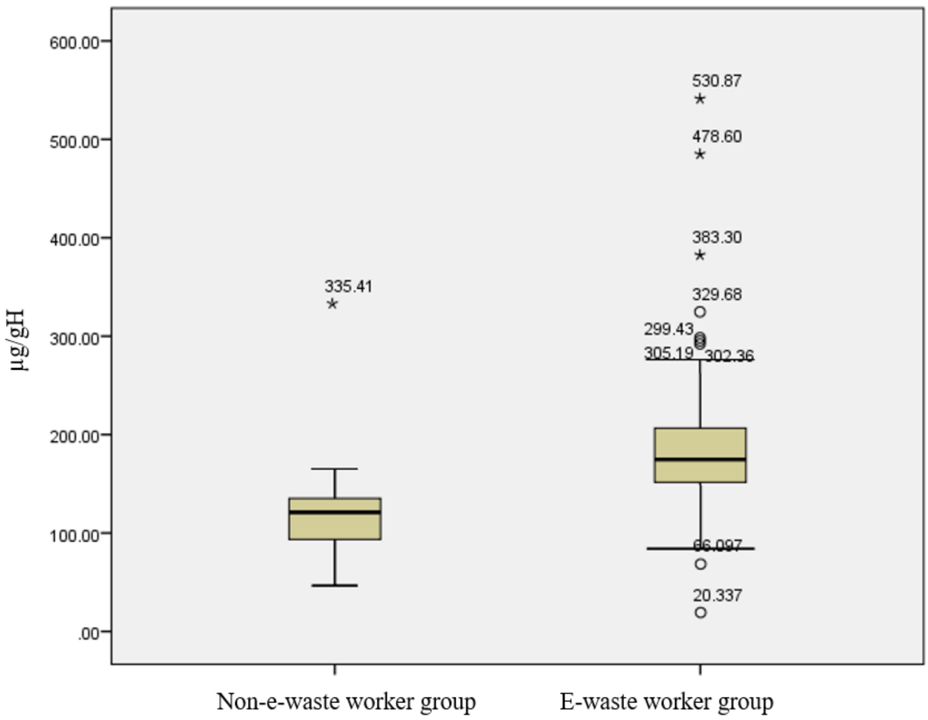
11.741
10.24
7.8848
Non-e-waste worker group
E-waste worker group

d (H-Ni)



e (H-Pb)



f (H-Zn)

Figure 5 The concentration of heavy metals in hair of participants (µg/gH)

(a = Cr in hair, b = Cu in hair, c = Mn in hair, d = Ni in hair, e = Pb in hair, f = Zn in hair)

From Table 16 and Figure 5, the results showed that the average, median and maximum concentration of Cr, Cu, Mn, Pb, and Zn in the hair of e-waste workers group were higher than the non-e-waste workers group. Whereas for Ni in the e-waste workers group were slightly lower than non-e-waste workers group. Mann-Whitney (U-test) was used to investigate the mean difference of heavy metals concentration in hair between both groups. The results show that Cr (*p*=0.017), Cu (*p*=0.000), Mn (*p*=0.000), Pb (*p*=0.000), and Zn (*p*=0.000) in hairs was a significant difference between e-waste workers group and non-e-waste workers group, whereas there was no significant difference between two groups for Ni (*p*=0.391).

Since there is currently no standard setting for heavy metals in the hair as well as the data of heavy metals concentration in this study were non-normal distribution, the median derived from both target groups was then applied as the cut point to separate participants to be two groups. The first group, concentration of heavy metals in hair and nails were lower than median, and the second group was higher than the median. With respect to this consideration, the %contribution of the subjects found the heavy metals higher than the median was calculated and compared between two groups. The result is shown in Table 17 and Figure 7.

Table 17 The number and %contribution of the subjects having the heavy metal concentrations in hair higher than the median.

Heavy metal	**Median of both groups (N=134)**	**E-waste workers group (N=102)**		**Non-e-waste workers group (N=32)**	
		> Median	≤ Median	> Median	≤ Median
H-As	< 0.75	-	-	-	-
H-Cd	< 0.5	-	-	-	-
H-Cr	1.20	55 (53.92%)	47 (46.08%)	12 (37.50%)	20 (62.50%)
H-Cu	12.60	66 (64.71%)	36 (35.29%)	0	32 (100.00%)
H-Mn	1.71	59 (57.84%)	43 (42.16%)	9 (28.13%)	23 (71.87%)
H-Ni	0.84	51 (50.00%)	51 (50.00%)	15 (46.88%)	17 (53.12%)
H-Pb	2.72	66 (64.71%)	36 (35.29%)	1 (3.13%)	31 (96.87%)
H-Zn	160.76	67 (66.69%)	35 (34.31%)	3 (9.38%)	29 (90.62%)

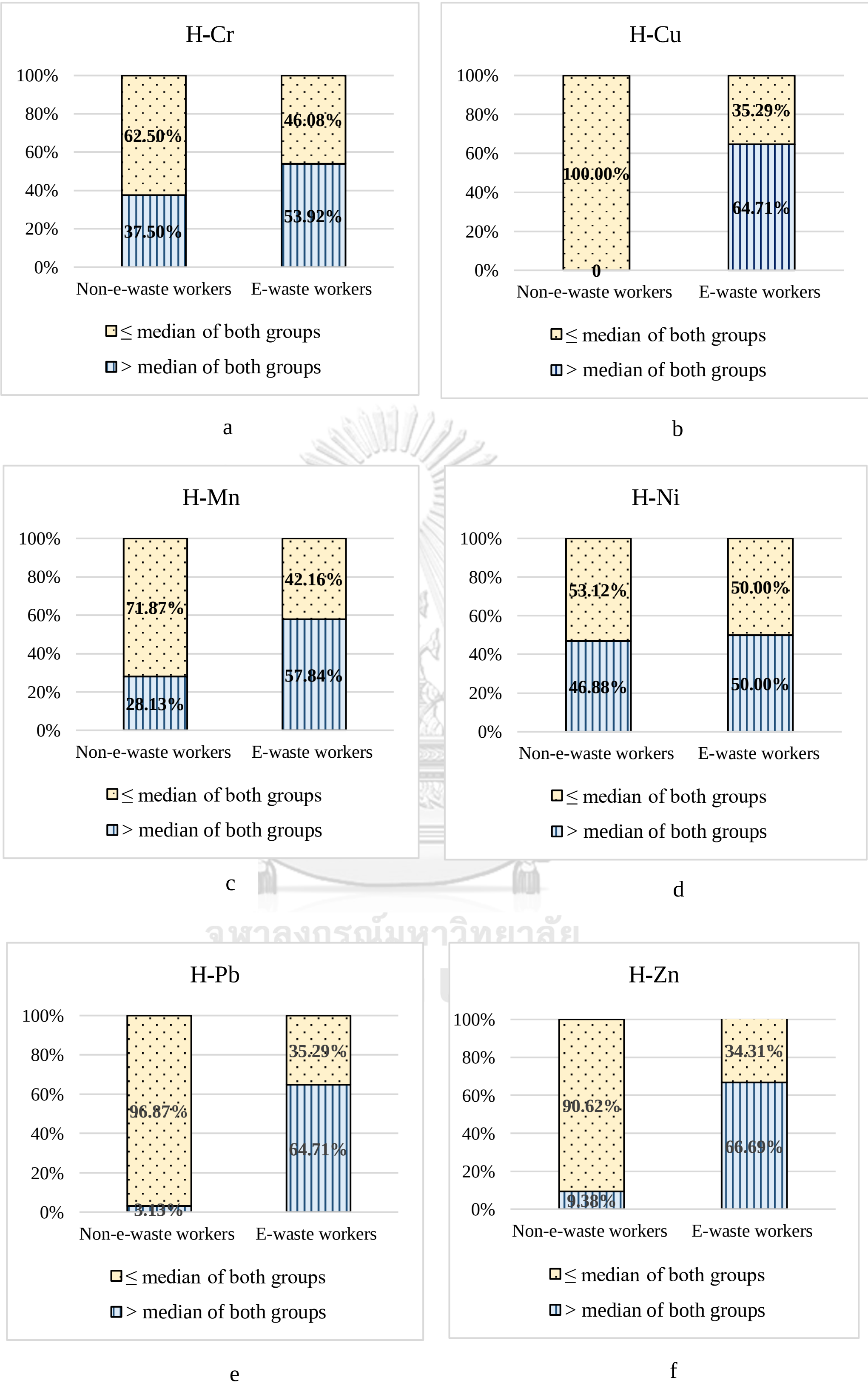


Figure 6 The comparison of heavy metal concentrations in hair between two groups (μg/gH)

The median concentrations of Cr, Cu, Mn, Ni, Pb, and Zn in the hair analyzed from all 134 participants were 1.20, 12.60, 1.71, 0.84, 2.72, and 160.76 µg/gH, respectively. Those concentrations of 102 e-waste workers reveal that they had the concentration of all five heavy metals in hair higher than the median with the exception of Ni. The result showed that 53.92% of the e-waste workers group had Cr concentration in the hair higher than the median, as well as 64.71% for Cu, 57.84% for Mn, 64.71% for Pb, 50% for Ni and 66.69% for Zn. On the other hand, there was 37.50% of non-e-waste workers group had Cr concentration in hair higher than median, 28.13% for Mn, 46.8% for Ni, 3.13% for Pb, and 9.38% for Zn; meanwhile, there was no participants in non-e-waste workers group had concentration of Cu higher than the median. Consequently, this might imply that e-waste dismantling activities could pose the accumulation of heavy metals in the hair of the workers in particular Cr, Cu, Mn, Pb, and Zn.

Moreover, when comparing the median ratio of each heavy metal concentration in hair between e-waste workers group and non-e-waste workers group, it found that the concentration of all six heavy metals in hair of e-waste worker groups were higher than non-e-waste workers group. The ratio of Cr, Cu, Mn, Ni, Pb, and Zn were 2.24, 2.35, 2.10, 1.12, 7.42, and 1.44 times, respectively (Figure 7).

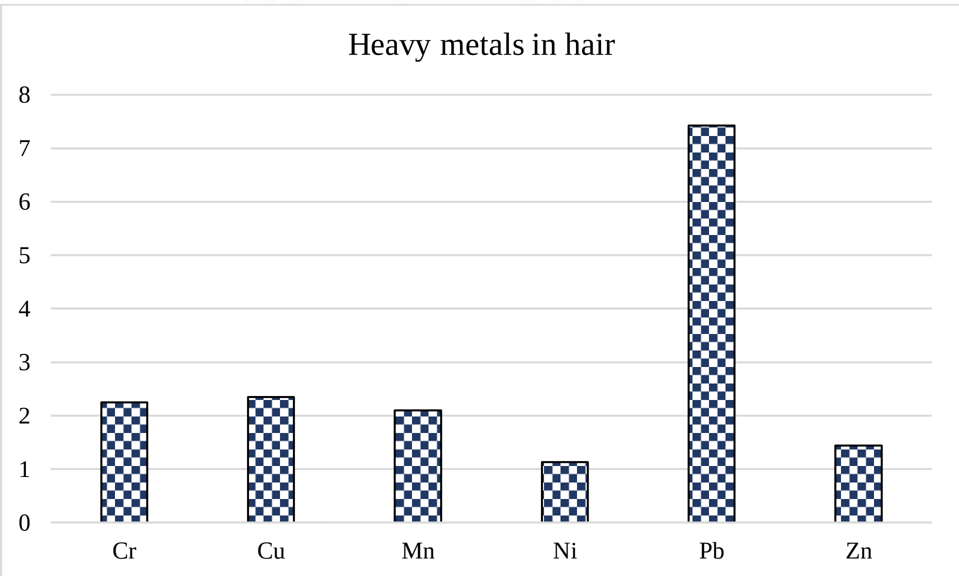


Figure 7 The ratio of heavy metal concentrations in hair of e-waste workers groups and non-e-waste workers group

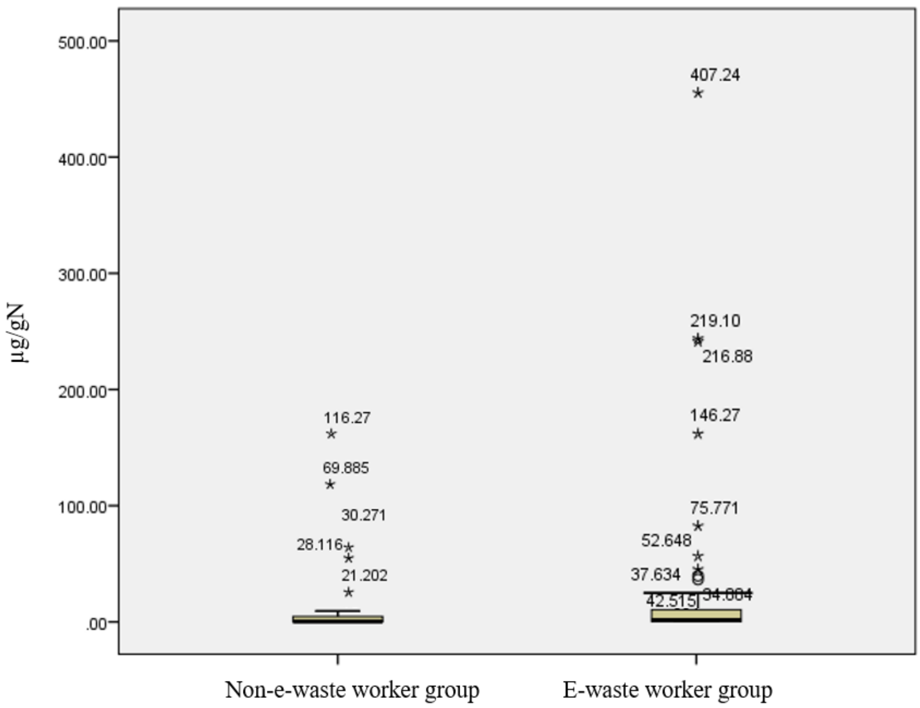
4.2.2 Heavy metals in nails

From all 162 participants, 136 participants were taken to investigate the concentration of eight heavy metals in nails. (As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn). They were divided into 105 e-waste dismantling workers and 31 non-e-waste workers. The result showed that the average concentration of As and Cd in the nail of all 136 participants were also less than LOD as same as in hair. The LOD was 0.75 µg/g-Nail (µg/gN) for As and Cr and 0.5 µg/gN for Cd, Cu, Mn, Ni, Pb and Zn. Thus, this study focused on six heavy metals (Cr, Cu, Mn, Ni, Pb, and Zn) in nails samples of all participants. Six heavy metals found in nails of the e-waste worker group were higher than those non-e-waste workers. The average concentration of Cr, Cu, Mn, Pb, Ni and Zn in nails of e-waste workers group were 15.91, 39.71, 3.78, 8.56, 4.92, and 140.00 µg/gN, respectively. Meanwhile, the average concentration of Cr, Cu, Mn, Pb, Ni and Zn in nails for non-e-waste workers group were 9.73, 18.33, 1.78, 6.70, 1.76, and 125.98 µg/gN, respectively, as shown in Table 18 and Figure 8.

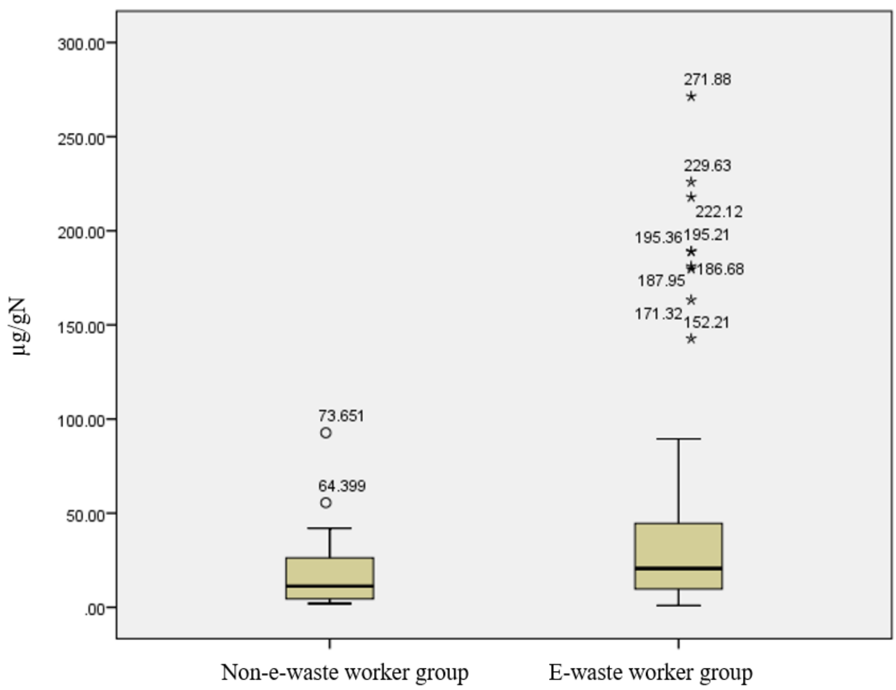
Table 18 The concentration of heavy metals in the nails of participants (µg/gN).

Heavy metal	Median		Mean (S.D.)		Range	
	EW	NE	EW	NE	EW	NE
N-As	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75
N-Cd	< 0.50	< 0.50	< 0.50	< 0.50	< 0.05	< 0.50
N-Cr	1.68	< 0.75	15.91 (51.37)	9.73 (24.38)	< 0.75-407.24	< 0.75-116.27
N-Cu	20.60	11.27	39.71 (54.04)	18.33 (18.39)	0.91-271.88	2.02-73.65
N-Mn	3.03	1.16	3.78 (3.02)	1.78 (2.06)	< 0.50-14.75	< 0.50-7.15
N-Ni	5.46	4.19	8.56 (16.85)	6.70 (9.00)	< 0.50-170.37	0.91-46.91
N-Pb	2.72	1.80	4.92 (10.90)	1.76 (1.08)	< 0.50-105.41	< 0.50-4.90
N-Zn	126.54	130.74	140.00 (65.28)	125.98 (31.98)	< 0.50-526.65	55.49-198.32

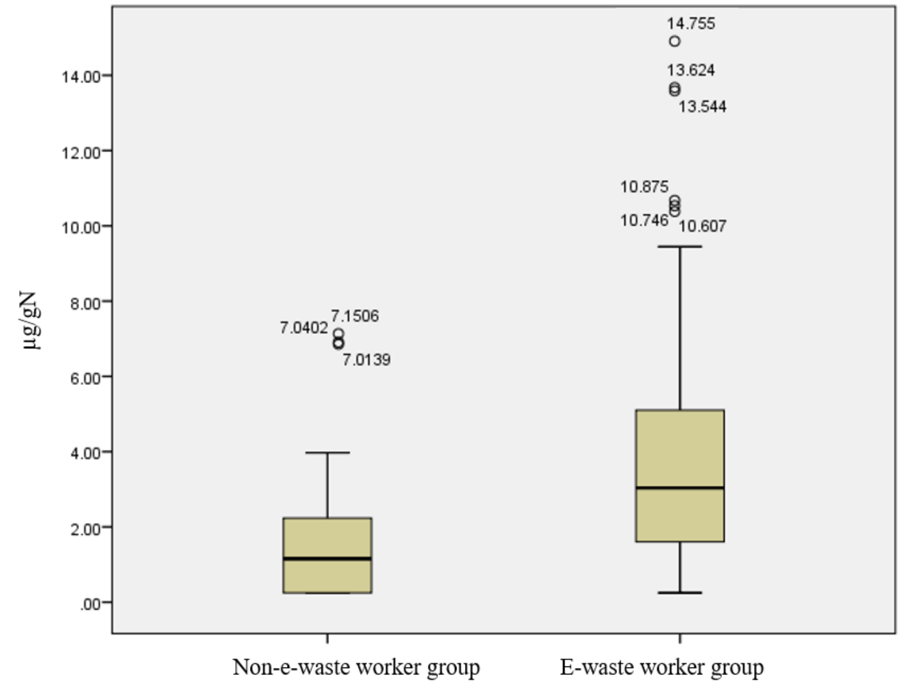
EW = E-waste workers group, NE = Non-e-waste workers group


500.00
400.00
300.00
200.00
100.00
.00
µg/gN
407.24
219.10
216.88
146.27
75.771
52.648
37.634
42.515
34.804
116.27
69.885
30.271
28.116
21.202
Non-e-waste worker group
E-waste worker group

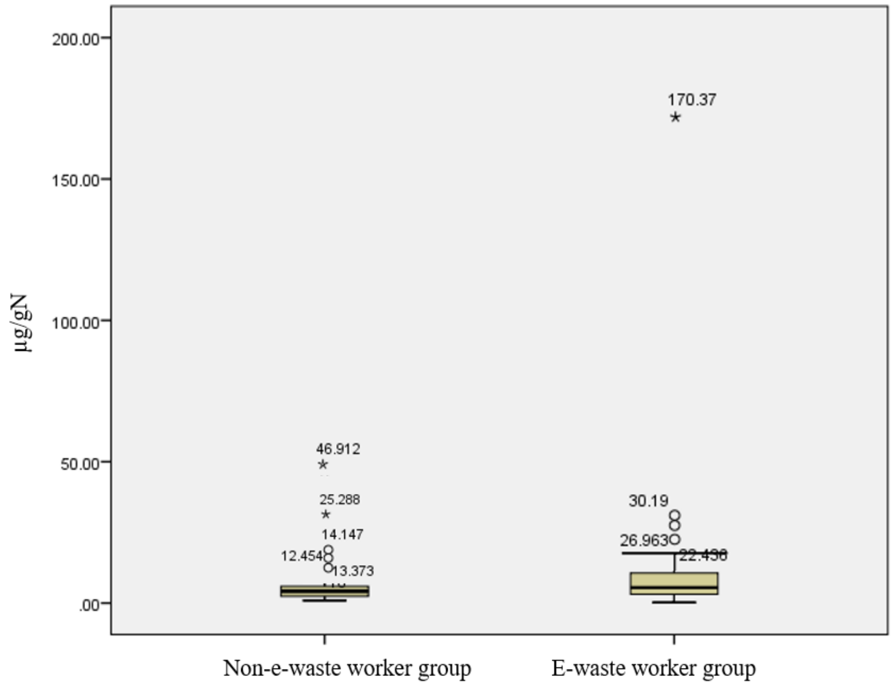
a (N-Cr)


300.00
250.00
200.00
150.00
100.00
50.00
.00
µg/gN
271.88
229.63
222.12
195.36
195.21
187.95
186.68
171.32
152.21
73.651
64.399
Non-e-waste worker group
E-waste worker group

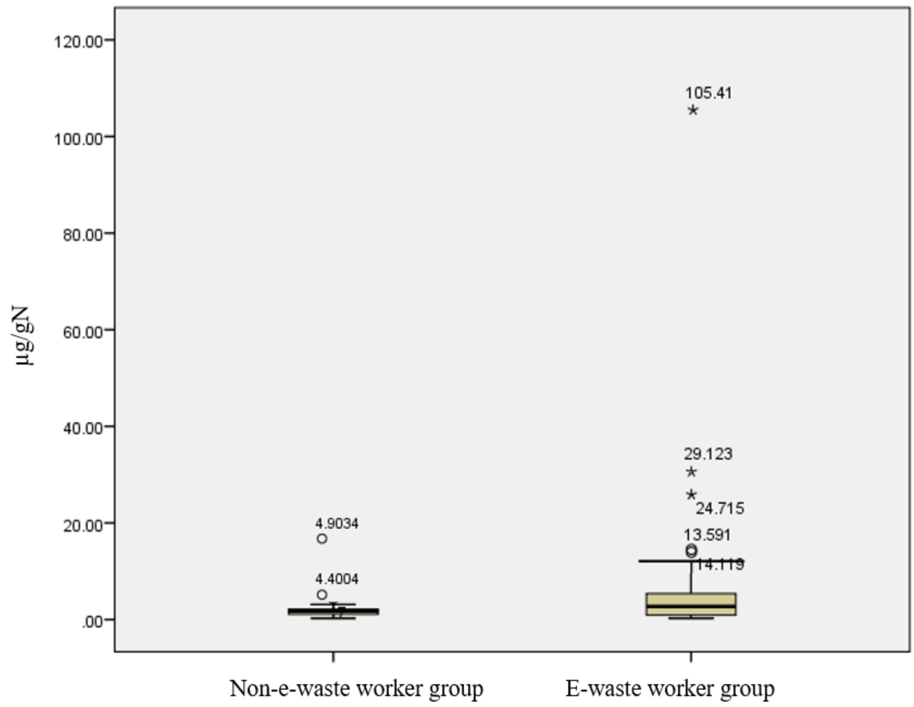
b (N-Cu)


µg/gN
14.00
12.00
10.00
8.00
6.00
4.00
2.00
.00
7.0402
7.1506
7.0139
14.755
13.624
13.544
10.875
10.746
10.607
Non-e-waste worker group
E-waste worker group

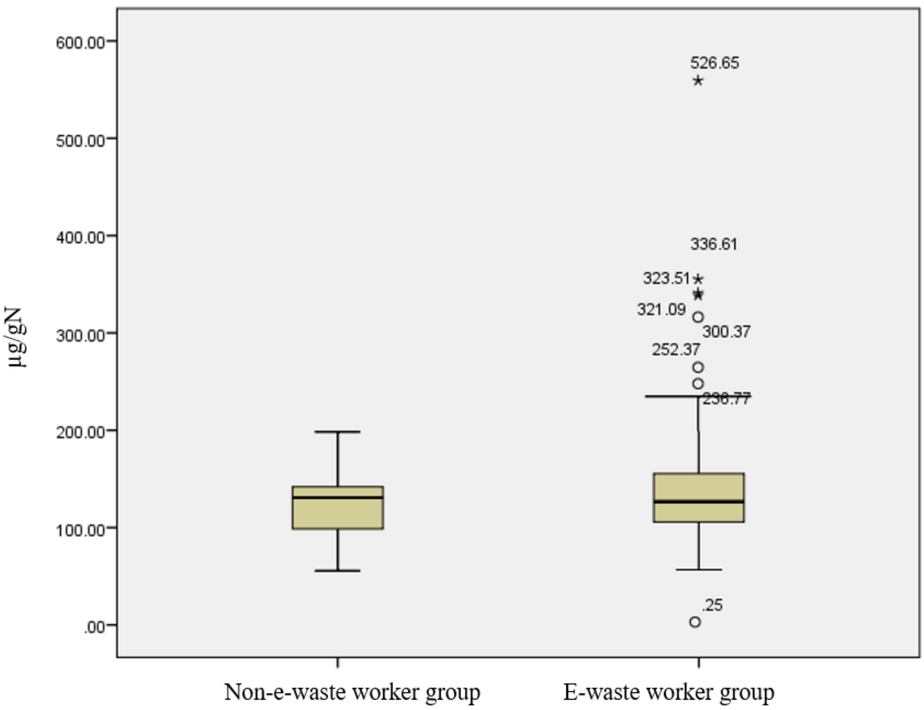
c (N-Mn)


µg/gN
200.00
150.00
100.00
50.00
.00
46.912
25.288
14.147
12.454
13.373
170.37
30.19
26.963
22.436
Non-e-waste worker group
E-waste worker group

c (N-Ni)



e (N-Pb)



f (N-Zn)

Figure 8 The concentration of heavy metals in nails of participants (µg/gN)

(a = Cr in nails, b = Cu in nails, c = Mn in nails, d = Ni in nails, e = Pb in nails, f = Zn in nails)

The results from Table 18 and Figure 8 showed that the average, median and maximum concentration of all six heavy metals in the nails of the e-waste workers group were higher than the non-e-waste workers group. However, the median concentration of Zn in the e-waste workers group was slightly lower than the non-e-waste worker group. Mann-Whitney (U-test) was used to investigate the mean difference concentration of heavy metals in nails between both groups. As the study findings, it was found that Cr (p=0.045), Cu (p=0.006), Mn (p=0.000), and Pb (p=0.009) in nails was found significant difference between e-waste workers group and non-e-waste workers group; meanwhile, there was no significant difference between two groups for Ni (p=0.122) and Zn (p=0.801).

With respect to no standard setting for heavy metals in the nails, the same criteria as used for the hair samples was then applied for the nail sample as well. The %contribution of the subjects found the heavy metals higher than the median derived from all subjects was calculated and compared between two groups as same as the hair samples. The result is shown in Table 19 and Figure 9.

Table 19 The number and %contribution of the subjects having the heavy metal concentrations in nails higher than the median

Heavy metal	**Median of both groups (N=136)**	**E-waste workers group (N=105)**		**Non-e-waste workers group (N=31)**	
		> Median	≤ Median	> Median	≤ Median
N-As	< 0.75	-	-	-	-
N-Cd	< 0.5	-	-	-	-
N-Cr	1.22	57 (54.29%)	48 (45.71%)	10 (32.26%)	21 (67.74%)
N-Cu	18.15	58 (55.24%)	47 (44.76%)	11 (35.48%)	20 (64.52%)
N-Mn	2.68	62 (59.05%)	43 (40.95%)	6 (19.35%)	25 (80.64%)
N-Ni	4.95	57 (54.29%)	48 (45.71%)	10 (32.26%)	21 (67.74%)
N-Pb	2.22	62 (59.05%)	43 (40.95%)	5 (16.12%)	26 (83.88%)
N-Zn	128.31	50 (47.62%)	55 (52.38%)	18 (58.06%)	13 (41.94%)

Figure 9 The comparison of heavy metal concentrations in nails between two groups (µg/gN)

From Table 19 and Figure 9, the median concentration of Cr, Cu, Mn, Ni, Pb and Zn in nails which analyzed from all 136 participants were 1.22, 18.15, 2.68, 4.95, 2.22, and 128.31 µg/gN. The results of heavy metals concentration in nails of 105 e-waste workers reveal that they had the concentration of all five heavy metals in nails higher than the median. But this could not be found for Zn. The e-waste workers group 54.29% had Cr concentration in nails higher than the median, as well as 55.24%, 59.05%, 54.29, 59.05%, and 47.62% for Cu, Mn, Ni, Pb, and Zn, respectively. Whereas, there was 58.06% of non-e-waste workers group had a concentration of Zn in nails higher than the median. So, this might be implied that e-waste dismantling activities could pose the accumulation of heavy metals in nails of the workers in particular Cr, Cu, Mn, Ni and Pb.

Furthermore, when considering the median ratio of each heavy metal concentration in nails between the e-waste workers group and the non-e-waste workers group, it was found that the five heavy metals concentration in nails of e-waste workers group were higher than non-e-waste workers group in the exception of Zn. The ratio of Cr, Cu, Mn, Ni, and Pb were 2.24, 1.83, 2.61, 1.30, and 1.50 times, respectively. Meanwhile, the ratio of Zn concentration in nails of e-waste workers was lower than the non-e-waste workers group about 1.03 times (Figure 10).

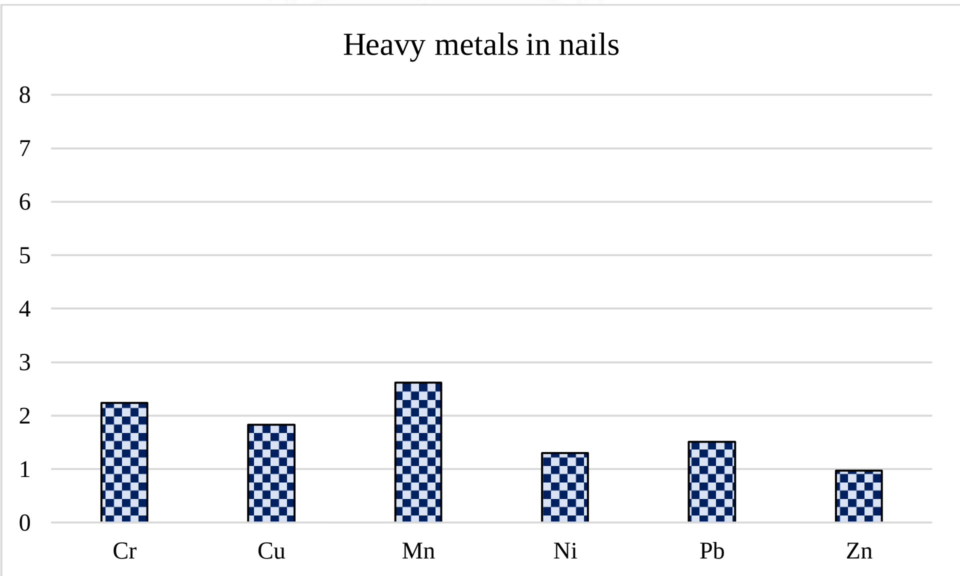


Figure 10 The ratio of heavy metal concentrations in nails of e-waste workers groups and non-e-waste workers group

4.3 The correlation between heavy metals concentration in hair and nails of participants

The analysis results of Spearman correlation between all six heavy metals concentration in hair and nails showed that concentrations of Cu, Mn, Ni, and Pb in hair and nails were significantly correlated at 0.01 level ($p<0.01$). The correlation of heavy metals concentration between hair and nails are shown in Table 20.

Table 20 The correlation of heavy metals concentration between hair and nails.

Heavy metal	p-value	Spearman correlation coefficient
H-Cr and N-Cr	0.138	0.144
H-Cu and N-Cu	0.001**	0.317
H-Mn and N-Mn	0.003**	0.288
H-Ni and N-Ni	0.002**	0.296
H-Pb and N-Pb	0.000**	0.386
H-Zn and N-Zn	0.344	0.92

** = significant level at p-value < 0.01

Zn and Cr (3+) were found in food, drinking water, and the natural environment. Moreover, these are essential elements for the body such as helping to maintain the enzyme and cell systems in the body. So, it might be that some parts of these elements were accumulated in the body and hard to excrete; moreover, the excretion of heavy metals via hair and nails was considerably due to the nutritional status of each participant.

However, nails samples were observed to accumulate at higher concentration of heavy metals when compared to hair samples. It might be attributed to the incorporation of elements into the keratin structure of hair which takes place by blinding to SH-group that are present in the protein. The detergents such as soap and shampoos actually compete with the complexing ability of these reactive sites. So, it affects the metal profile in hair and few metals can be easily washed out of hair during treatments, which may lead to low levels in the hair (Mehra and Juneja, 2005; Abdulrahman et al., 2012).

As all above results, to examine how heavy metals in the environment affect the body of the e-waste workers, their accumulation in hair and nails could be utilized as a biomarker. Typically, heavy metals can accumulate in the body and excrete by the pharmacokinetics process. The pharmacokinetics process includes 4 steps. First, heavy metals pass through skin, respiratory system, and gastrointestinal by absorption process. Second, heavy metals are accumulated in blood about 90%-95% and travel into soft tissue and organ, such as kidneys, liver, brain, muscle, heart, and some heavy metals accumulate in bone and teeth about 90%-95% in the distribution process. Next, heavy metals move to the metabolism process of each heavy metals. Finally, heavy metals are excreted via urine about 75%-80%; meanwhile, some heavy metals are excreted via feces, sweat, breast milk, hair, and nails about 15% (Tosokhowong, 2014).

Both hair and nails are rich in compact protein, Alpha keratin. Alpha keratin contains abundant cysteine residues and amino acid. Cysteine makes up approximately 10 to 14 percentages in hair and 22 percentages in nails. Hair and nails have a high affinity for metals because metals are bound to sulfhydryl groups (SH groups) in cysteine (Mandal B. et al., 2003; Katz, 1998). Moreover, metals can bind to hair structure through melanin. Melanin is polyanionic polymer that contains negatively charged carboxyl groups and semiquinones at physiological pH; meanwhile; metals ions contain positively charged at physiological pH. So, metals ions have a high melanin affinity because positively charged in metals ions interact with negatively charged in melanin by electrostatic forces (Srogi K., 2006). The concentration of heavy metals in hair and nails in this study were compared with other studies in Table 21 and Table 22.

Table 21 The comparison of heavy metals concentration in hair (µg/gH).

Site	Subject	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
E-waste site in Buriram, Thailand	E-waste worker	<0.75	<0.50	6.44	18.38	2.85	2.31	6.64	185.51	This study (2019)
	Non-e-waste workers	<0.75	<0.50	1.24	6.68	1.35	2.43	1.18	121.56	
E-waste site in Bagalore, India	E-waste worker	-	0.05	0.40	22.80	1.86	-	16.10	141.00	Ha et al. (2009)
	Non-e-waste workers	-	0.08	0.42	7.77	2.11	-	2.61	116.00	
E-waste site in Qingyuan, China	E-waste worker	-	1.15	-	29.81	-	0.74	40.07	138.95	Zheng et al. (2011)
	Non-e-waste workers	-	0.05	-	9.85	-	0.85	2.94	122.99	
Groundwater area in West Bengal, India	Groundwater drinking group	0.73	1.07	-	14.76	15.48	1.59	8.03	152.4	Samanta et al. (2004)
Welding industry in Pakistan	Arc welders	-	0.54	2.03	11.80	2.96	3.29	14.20	161.80	Khalique et al. (2006)
Waste disposal site in Russia	Resident in the area	0.02	0.11	0.28	10.40	1.60	0.43	2.48	107.00	Drobyshev et al. (2017)

Table 22 The comparison of heavy metals concentration in nails (µg/gN).

Site	Subject	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn	Reference
E-waste site in Buriram, Thailand	E-waste workers	<0.75	<0.50	15.91	39.71	3.78	8.56	4.92	140.00	This study (2019)
	Non-e-waste workers	<0.75	<0.50	9.73	18.33	1.78	6.70	1.76	125.98	
Groundwater area in West Bengal, India	Groundwater drinking group	7.24	0.32	-	11.10	22.26	3.89	10.99	97.71	Samanta et. al (2004)
Urban area in New Delhi, India	Farming as resident	-	2.50	2.30	16.00	-	1.80	9.20	218.80	Sukumar And Subramanian (2007)
Urban area in Kenya	Student	-	0.73	-	-	-	-	27.50	94.8	Hussein et al (2008)
Industry area in Pakistan	Industrial workers	-	-	-	43.25	-	-	29.31	-	Shan and Ikram (2012)
Industry area in Pakistan	Industrial workers	-	1.50	0.90	50.10	-	7.20	16.00	91.00	Batool et al. (2015)

According to the results of heavy metals concentration in hair and nails, it found that the concentration of As in this study was lower than LOD (<0.75 µg/g). When compared with other studies in the e-waste separating area, the concentration of As in hair of e-waste workers was low (0.33 µg/g) and not significantly higher than non-e-waste workers (0.27 µg/g) (Wang et al., 2009). Arsenic (As) is a trace amount in e-waste. It is small quantities in the form of gallium arsenide within light-emitting diodes and circuit board in mobile phone and computer parts (Solid and Hazardous Waste Management, 2017; Robinson, 2009). The e-waste workers can intake the heavy metals through inhaling the dust during the e-waste dismantling process; however, the inhalation is a minor route of exposure, oral is the main route for As exposure and better absorption to the body. Likewise, the participants of both groups in this study area had the same lifestyle for water drinking. Then, e-waste dismantling activity might not be the significant routes of As exposure. Moreover, hair and nails are improper biomarkers for measuring the level of As. It is likely that As^{3+} occurred in e-waste is hard acid property, it can then interact at low efficiency with sulfhydryl groups (-SH) in proteins in hair and nails (Kuntadee,2019). Measurement of As levels in urine is generally accepted as the most reliable indicator of recent As exposure (ATSDR, 2007).

When compared the concentration of Cd in e-waste separating area of this study with other previous studies (Table 21 and Table 22), they could detect Cd in hair and nails while those levels of this study were lower than LOD (<0.5 µg/g). This might due to the different e-waste types that had been taken to dismantle. Cadmium (Cd) is the main component in batteries, semiconductors, laptops, and computer parts like circuit boards, which were separated in the previous study area. Meanwhile, circuit boards and those products were not mainly presented in this study area. In addition, the lower concentration of Cd found in hair and nails for this study might be related to its existence in the study area. Regarding the previous study of Puangprasert and Prueksasit (2019) and the present study of Wongsapsakul which studied at the same time as this study, they observed that Cd in PM_{10} was the lowest concentration when compared with other heavy metals. Additionally, the concentration of Cd in the soil at the e-waste dismantling area was also the lowest (Amphalop, 2017).

From the result of Zn, the concentration in hair and nails was the highest in this study. Similarly, the other studies showed the same range level of Zn, as shown in Table 21 and Table 22 According to Zn is frequently found in natural ambient air and environment, this might result in no significant difference between the concentration of Zn in nails of e-waste workers and non-e-waste workers. However, Zn in the hair and nails of the e-waste workers were observed to be higher than those of non-e-waste workers. Zn is one of the main components in e-waste because it is used in the interior of the CRT screen and mixed with rare earth metals (Solid and Hazardous Waste Management, 2017). Consequently, e-waste workers can expose to Zn in particular via inhalation during the e-waste dismantling process, and inhalation is considered as the predominant route of exposure to Zn (ATSDR, 2005). Furthermore, the previous study in the same study site as this study found the level of Zn in the e-waste dismantling area was greater than that of the non-e-waste area (Chanthahong and Kanghae, 2017). The recommended value of 175 µg/g for concentration in hair was reported by Iyenger and Woitie, 1998 (Samata et al., 2004). The levels of Zn in the hair of e-waste workers (185.00 µg/g) in this study were higher than the recommended value, while levels of Zn in hair of non-e-waste workers (121.56 µg/g) were lower. This result might suggest that the accumulation of Zn in hair and nails of the workers partially caused by exposing to Zn from e-waste dismantling activity. Further, the previous studies found the background concentration of Zn in hair presented in large amount and greater than in nails (Samanta et al., 2004; Mehra and Juneja 2005). Actually, Zn is an essential mineral for the human body, and it provides cell structure, regulates communication between cells and supports a healthy immune system. Moreover, it also helps other nutrient to work in the body. Zn deficiency has been associated with growth retardation, and it can increase cancer risk, but it can be neurotoxic when intake Zn in excess level (Zheng et al., 2011; Cai et al., 2005; Dreosti et al., 2011).

For Cu and Pb in hair and nails in this study, it was found that the concentration of Cu and Pb in the e-waste workers group was significantly higher than those of non-e-waste workers, similar to those measured in the other studies, see Table 21 and Table 22. Copper (Cu) and Lead (Pb) are the bulk elements in e-waste. Typically, unused televisions and computers are the main sources of various types of heavy metals. The components in television and computer are CRT screen, LCD screen, plasma screen, cathode ray tube, electronic board, wire cable, and plastics. These components are a source of many heavy metals especially Cu and Pb (PCD, 2002; Department of Health, 2005; Robinson, 2009). As a result of Table 15, the total amount of televisions and computers were ranked the highest from the e-waste amount estimation, and copper was the 4th top rank of the valuable recovery material in this study. This high amount of e-waste had been separated in this area could be considered to cause the high concentration of Cu and Pb in PM_{10} measured by Chanthahong and Kanghae (2017), and the present study result of Wongsapsakul. Although Cu is an essential mineral for the human body that is a component of various enzymes and involved in the transportation of iron, energy production, and the pigmentation of skin, hair, and eyes, its accumulation can be elevated by overexposure to Cu in the environment. Interestingly, the ratio of Pb concentration in the hair of the e-waste workers group was about 7 times higher than that of the non-e-waste workers group (Fig 7) and was quite higher than other metals. This might be explained by lead (Pb) in the form of ions, Pb^{+2}, classified as the soft acid, can bind well with sulfhydryl groups (-SH) in proteins in hair, they can then interact at high efficiency by hard-soft acid-base theory (Kuntadee,2019).

From the results of Cr and Mn, it showed that the levels of Cr and Mn in e-waste workers were significantly different from those of non-e-waste workers. It was found that the concentration of Mn in this study was in the same range as found at the other e-waste sites in China and India; however, it was lower than the concentration in groundwater site (Table 21 and 22). Manganese is normally the trace component in e-waste that can be found in batteries, and it also occurs naturally in surface soil and groundwater (Wang et al., 2009). However, batteries could not observe in study area. Chromium (Cr) is the main type of heavy metal that can be found in air conditioners and refrigerators with regarding to it contains in refrigerant or coolant that is the main component in air conditioners and refrigerators (Robinson, 2009; PCD, 2002). As the estimation of the e-waste amount in this study (Table 4.4), refrigerators and air conditioners were the top 5th ranked e-waste in this area. Moreover, the workers in this study removed refrigerant from the refrigerators by improper method causing leakage into the soil. This activity might reflect a high opportunity of the workers exposure to Cr. And ATSDR mentioned that exposure to higher than normal levels of chromium may result in an increase of chromium levels in hair, and nails (ATSDR, 2012).

For the result of Ni in hair and nails, it was found that there was no significant difference between the e-waste and non-e-waste workers groups, which agreed with other studies those found no significant difference of Ni in the hair in the e-waste site (Wang et al.,2009; Zheng et al.,2011). However, when compared with the other study sites such as groundwater area, urban area, waste disposal site and industry area, the concentration of Ni in e-waste site were higher than those at the other sites (Table 21 and Table 22). It could then be pointed out that the concentration of Ni in the hair and nails of the participants was not solely from e-waste dismantling activity because of no significant difference between the workers and general people. Additionally, the concentration of Ni in the hair of the e-waste worker group was not mostly found higher than the median of all 134 participants as well as showing the lowest concentration when compared with the other five heavy metals. Therefore, there would have other associated factors that affected the concentration of Ni in the hair of the participants.

However, more than the sources of heavy metals the people exposed to, the concentration of each heavy metals in hair and nail was considerably varied due to geographical differences, nutritional status, and environmental factors (Samanta et al., 2004). Therefore, this study would also investigate the associated risk factors of the presence of heavy metals in hair and nails, as mentioned in the later section.

4.4 Associated factors of heavy metals accumulation in hair and nails of participants

4.4.1 Associated factors of heavy metals accumulation in hair

From the survey on personal information of 162 participants, it was found that all participants used the same source of water consumption such as tap water for washing, 20L PET water bottle for drinking, and they always cleaned kitchenware before cooking every time. So, these factors were not taken to investigate as the associated factors of heavy metals accumulation in the hair.

From all 162 participants, 134 participants had a consent to give their hair samples, which consisted of 102 e-waste workers and 32 non-e-waste workers. The personal information of all target subjects was asked using a questionnaire to investigate possible factors associated with heavy metals in the hair, which divided into three parts. First, socio-demographic data include occupation, gender, weight, height, BMI and living time; the second section was about the subjects' behavior like seafood consumption, smoking habits, secondhand smoking habits, alcohol consumption, bare feet walking direct expose to soil; and the last parts was the working condition and using PPE information. First two parts were collected from all 134 participants, while the third part was assigned for 102 e-waste workers solely. All information of the target subjects are concluded in Table 23 and Table 24.

Table 23 The working condition and using PPE of 102 participants

Factors	Number of participants (N=102)	Range	Mean (S.D)	Median
Working periods (years)		0.083-22.0	6.5 (5.7)	5.0
Working hours (hours)		1.0-13.0	7.4 (1.9)	8.0
Working days (days)		0.5-7.0	5.3 (2.0)	6.0
PPE using				
No and sometimes	64 (62.7%)			
Every time	38 (37.2%)			

Table 24 The socio-demographic and behavior of 134 participants

Factors	Number of participants (N=134)	Range	Mean (S.D)	Median
Age (years)		22.0-66.0	46.6 (11.0)	49.0
Weight (Kg)		42.0-65.0	61.0 (11.2)	60.0
Height (cm)		145.0-180.0	160.0 (7.6)	160.0
BMI		17.7-38.1	23.8 (4.1)	23.44
Living time in area (years)		0.5-66.0	32.3 (19.2)	32.5
Occupation				
E-waste dismantling	102 (76.1%)			
Non-e-waste dismantling	32 (23.9%)			
Gender				
Male	60 (44.8%)			
Female	74 (55.2%)			
Seafood consumption (times)				
< 1 time/week	69 (51.5%)			
≥ 1time/week	65 (48.5%)			
Smoking habits				
Yes	35 (26.1%)			
No	99 (73.9%)			
Secondhand smoking				
Yes	43 (32.1%)			
No	91 (67.9%)			
Alcohol consumption				
Yes	57 (42.5%)			
No	77 (57.5%)			
Bare feet walking direct expose to soil				
Yes	57 (42.5%)			
No	77 (57.5%)			

Chi square was used to examine which factors would have an effect on the accumulation of the heavy metals in the hair of 134 participants. Due to no standard level of six heavy metals in the human hair, then the median concentration of six heavy metals was used as the criteria level to analyze in the Chi-square test of this study. The chi square analysis results for six heavy metals in the hair are shown in

Table 25. The result showed that the significant associated factor of Cr and Ni in hair was only one factor, i.e., using PPE and working days, respectively. For Cu, occupation, gender, height, living time, smoking habits, and PPE using were found to be the significant associated factors. For Mn, the analysis gave the associated factors of occupation, gender, and smoking habits. For Pb, the significant associated factors were occupation, gender, height, smoking habits, working periods, working days, and PPE using. And those of Zn were occupation and seafood consumption.

Table 25 The significant associated factors of heavy metals in hair.

Factors	**p-value of heavy metals in hair**					
	Cr	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
E-waste occupation	0.127	**0.000***	**0.003***	0.758	**0.000***	**0.000***
Gender	0.848	**0.001***	**0.003***	0.848	**0.002***	0.203
Age	0.726	0.733	0.165	0.733	0.604	0.086
Weight	0.306	0.983	0.743	0.499	0.384	0.775
Height	0.165	**0.010***	0.138	0.261	**0.048***	0.388
BMI	0.302	0.486	0.726	0.733	0.226	0.988
Living time	0.300	**0.038***	0.300	1.000	0.388	0.166
Seafood consumption	0.168	0.486	0.085	0.996	0.863	**0.036***
Smoking habits	0.925	**0.014***	**0.039***	0.626	**0.011***	0.063
Secondhand smoking habits	0.122	0.122	0.122	0.663	0.195	0.098
Alcohol consumption	0.979	0.076	0.746	0.979	0.116	0.669
Bare feet direct to soil	0.085	0.307	0.707	0.085	0.116	0.938
Working periods	0.259	0.091	0.230	0.163	**0.004***	0.148
Working hours	0.690	0.514	0.067	0.539	0.623	0.469
Working days	0.080	0.207	0.267	**0.000***	**0.040***	0.539
PPE using	**0.036***	**0.001***	0.210	0.101	**0.001***	0.987

* Chi-square test means p value < 0.05

4.4.2 Associated factors of heavy metals accumulation in nails

Similarly to the Chi-square test of hair samples, the same questionnaire was used to collect the data for analysis of associated factors. The information on source of water consumption were also not used to investigate the associated risk factors of heavy metals in nails. The information used to analyze derived from 136 participants, including 105 e-waste workers and 31 non-e-waste workers. The results are shown in Table 26 and Table 27.

Likewise, there was no standard guideline of the heavy metal in nail, the median of six heavy metals analyzed from all participants was used as the criteria. The Chi square test results for heavy metals in nails are shown in Table 28.The significant associated factor of Cu, Mn, Ni, and Zn in nails was only one factor that was bare feet walking direct to soil, occupation, secondhand smoking habits, and working period, respectively. For Cr, the significant associated factors were occupation and working hours. And those of Pb were occupation, seafood consumption, working period and working days.

Table 26 The working condition and using PPE of 105 participants.

Factors	Number of participants (N=105)	Range	Mean (S.D)	Median
Working periods (years)		0.167-22.0	7.2 (5.7)	6.0
Working hours (hours)		2.0-12.0	7.3 (1.6)	8.0
Working days (days)		0.5-7.0	5.5 (2.0)	7.0
PPE using				
No and sometimes	64 (61.0%)			
Every time	41 (39.0%)			

Table 27 The socio-demographic and behavior of 136 participants

Factors	**Number of participants (N=136)**	**Range**	**Mean (S.D)**	**Median**
Age (years)		22.0-66.0	48.0 (10.1)	49.0
Weight (Kg)		41.0-95.0	61.6 (10.5)	60.0
Height (cm)		145.0-177.0	159.3 (7.2)	160.0
BMI		17.7-18.1	24.2 (3.8)	23.88
Living time in area (years)		0.5-66.0	34.9 (19.1)	39.0
Occupation				
E-waste dismantling	105 (77.2%)			
Non-e-waste dismantling	31 (22.8%)			
Gender				
Male	59 (43.4%)			
Female	77 (56.6%)			
Seafood consumption (times)				
< 1 time/week	67 (49.3%)			
≥ 1time/week	69 (50.7%)			
Smoking habits				
Yes	29 (21.3%)			
No	107 (78.7%)			
Secondhand smoking				
Yes	44 (32.4%)			
No	92 (67.6%)			
Alcohol consumption				
Yes	59 (43.4%)			
No	77 (56.6%)			
Bare feet walking direct expose to soil				
Yes	55 (40.4%)			
No	81 (59.6%)			

Table 28 The significant associated factors of heavy metals in nails.

Factors	**p-value of heavy metals in nails**					
	Cr	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
E-waste occupation	**0.000***	0.053	**0.000***	0.066	**0.000***	0.307
Gender	0.178	0.712	0.387	0.387	0.088	0.387
Age	0.831	0.233	0.731	0.492	0.599	0.169
Weight	0.510	0.998	0.864	0.391	0.733	0.607
Height	0.533	0.762	0.585	0.855	0.951	0.362
BMI	0.070	0.391	0.732	0.493	0.391	0.170
Living time	0.078	0.494	0.607	0.864	0.494	0.059
Seafood consumption	0.957	0.494	0.059	0.230	**0.039***	0.607
Smoking habits	0.059	0.904	0.530	0.143	0.256	0.295
Secondhand smoking habits	0.939	0.539	0.271	**0.028***	0.804	0.463
Alcohol consumption	0.462	0.475	0.119	0.226	0.310	0.387
Bare feet direct to soil	0.254	**0.016***	0.600	0.861	0.152	0.861
Working periods	0.491	0.499	0.782	0.616	**0.038***	**0.014***
Working hours	**0.043***	0.468	0.585	0.173	0.486	0.527
Working days	0.063	0.141	0.706	0.926	**0.041***	0.206
PPE using	0.903	0.498	0.377	0.186	0.356	0.602

* Chi-square test means *p*-value < 0.05

According to the Chi-square analysis results, the presence of heavy metals in both hair and nail was influenced by e-waste occupation. Additionally, other working conditions, e.g. working time were considered to affect heavy metals accumulation in hair and nail. The study of Gil et al. (2011) found that the concentrations of Ni in hair were higher in workers who had longer lifetime working experience, that was like this study result showing Ni and Pb in nail could be affected by working time. PPE using was one factor that affected heavy metals existing in hair and nails. Using PPE is one way of avoiding exposure to hazardous pollutants and heavy metals directly to the body. However, types of PPE were found to be important, for example, heavy metals could accumulate on the surface of a fabric mask. So, awareness of cleaning the PPE after using could help to decrease risk of exposure to hazardous pollutants in e-waste that released during the dismantling processes (Decharat, 2016; Wongsasuluk et al., 2018).

Furthermore, the subjects' behavior was the other factors affecting the heavy metals in hair and nails. The concentration of Cd and Pb in hair and nails of smoker were found significantly higher than that of the non-smoker in the study of Afridi et al. (2011) and Mortada et al. (2002). Similary to this study, which found the concentration of Pb in the hair and nail of a smoker and of Ni in a secondhand smoker at a higher level than a non-smoker. Regarding to, Ni, Cd, and Pb are major components of cigarette smoking (Ajab et al., 2014; Mortada, Sobh, El-Defrawy, & Farahat, 2002). In addition, the study of Oyoo-Okoth et al. (2010) found that the levels of Cd, Cr, Cu, Pb in hair and nail samples were higher in residents who consumed fish contaminated with heavy metals (Baki et al., 2018). Typically, heavy metals can be deposited into aquatic organisms; for examples, fish, crabs, lobster and shrimp through the effects of bioconcentration, bioaccumulation and the food chain (Vanloon, 1977). Furthermore, the study of Abdulrahman et al. (2012) found the level of heavy metals in hair and nails of liquor users which were higher than non-liquor users. The main sources of heavy metals in the production of alcohol beverages are process equipment such as bronze pot stills, pipes, casks, and barrels. And these equipment are the usual source of Al, Cd, Cr, Cu, Fe, and Zn (Pohl, 2007). Additionally, gender was the one factor that affecting the heavy metal in hair. The previous studies observe that the heavy metals concentration in woman were significantly higher than men (Peter et al., 2012; Rakib et al., 2013; Li Li et al., 2018).

CHAPTER 5

CONCLUSIONS AND RECOMMEDATIONS

5.1 Conclusions

This research aimed to study the concentration of heavy metals (As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn) in hair and nails of e-waste dismantling workers in Buriram province, Thailand. Hair and nails samples were collected from the e-waste workers group and non-e-waste workers group at Daeng Yai subdistrict, Ban Mai Chaiyaphot district, and Ban Pao subdistrict, Putthaisong district, Buriram province during December 2018 to January 2019. The overall results could be concluded as follow:

1. The concentrations of Cr, Cu, Mn, Pb and Zn in hair of the e-waste workers group were significantly greater than those of the non-e-waste worker group. The average concentration of Cr, Cu, Mn, Pb and Zn in the hair of e-waste workers group were 6.44, 18.38, 2.85, 6.64 and 185.51 µg/g-Hair, respectively; meanwhile for non-e-waste workers groups were 1.24, 6.68, 1.35, 1.28 and 121.56 µg/g-Hair, respectively.

2. The concentrations of Cr, Cu, Mn, and Pb in nails of the e-waste workers group were significantly higher than those observed in the non-e-waste worker group. The average concentration of Cr, Cu, Mn, and Pb in nails of e-waste workers group were 15.91, 39.71, 3.78, and 4.92 µg/g-Nail, respectively, while non-e-waste workers groups were 9.73, 18.33, 1.78, and 1.76 µg/g-Nail, respectively.

3. The correlations of concentration of Cu, Mn, Ni, and Pb in hair were significantly correlated with the concentrations in nails between e-waste workers group and non-e-waste workers group.

4. The associated risk factors of the heavy metals accumulation in hair and nails of the e-waste workers group were e-waste dismantling occupation, working time and PPE use. Furthermore, gender, height, living time, and the behavior of participants, including seafood consumption, bare feet direct walking expose to the soil, smoking, and secondhand smoking habits were also detected as the associated risk factors.

5.2 Recommendation

1. The result in this study would be the baseline data of heavy metals in hairs and nails of e-waste dismantling workers and their possible associated factors of heavy metals accumulation in the study area. Then the risk communication is necessary to be implemented to inform the potential hazard of heavy metals in e-waste dismantling which may cause health effects.

2. The concentrations of heavy metals in e-waste dismantling workers in this study were greater than non-e-waste workers, so the dismantling workers are necessary to wear appropriate personal protective equipment (PPE). For a mask, the suggestion is KN95 and N95 masks for preventing PM_{10} that released during the dismantling process. For gloves, the recommendation is rubber cleaning gloves or double layers of sanitary hand gloves.

3. The awareness of cleaning the PPE after using and washing hands and body after working could also help to decrease the risk of exposure to hazardous pollutants in e-waste dismantling activities. In addition to e-waste dismantling, the behaviors of participants in this study were associated with the level of heavy metals in hair and nails. So, some behavior adjustments can probably reduce the health risk; for example, change smoking behavior and seafood consumption into less frequent, wear shoes whenever direct walking on the soil in the e-waste dismantling area.

4. The local administrative government should propose the management plan or control policy for protecting the e-waste workers and residents from exposure to hazardous substances in this study area. For example, The local government should present the alternative way for workers to increase the knowledge about proper personal protective equipment for preventing hazardous particular from e-waste dismantling in long term exposure.

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APPENDIX A
QUESTIONNAIRES OF PARTICIPANTS

ชุดที่...............
ชื่อผู้สัมภาษณ์....................................
วันที่สัมภาษณ์....................................

_แบบสอบถามข้อมูล_ผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ จังหวัดบุรีรัมย์

แบบสอบถามนี้จัดทำขึ้นสำหรับใช้ในโครงการ "การประเมินความเสี่ยงและการเฝ้าระวังด้านสุขภาพของผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ จังหวัดบุรีรัมย์" โดยมีวัตถุประสงค์เพื่อสำรวจข้อมูลพื้นฐานของชุมชนคัดแยกขยะอิเล็กทรอนิกส์ใน จังหวัดบุรีรัมย์ ทั้งนี้ คณะผู้วิจัยจะเก็บข้อมูลของท่านเป็นความลับและจะนำเสนอผลการศึกษาในภาพรวมเท่านั้น

<u>ตอนที่ 1</u> ข้อมูลส่วนบุคคล (เน้นสัมภาษณ์หัวหน้าครัวเรือน)

1.1 รหัสผู้ตอบแบบสอบถาม...

1.2 เพศ ☐ ชาย ☐หญิง

1.3 อายุ..................ปี

1.4 น้ำหนัก................................กิโลกรัม ส่วนสูง....................................เซนติเมตร

1.5 ท่านอาศัยอยู่ที่นี่เป็นระยะเวลา............................ปี

1.6 จำนวนสมาชิกในครอบครัวที่อาศัยอยู่ด้วยกัน............................คนจำนวนเด็กที่มีอายุต่ำกว่า 12 ปี......................คน

1.7 อาชีพหลักของครอบครัว

☐คัดแยกขยะอิเล็กทรอนิกส์ ☐พนักงานบริษัท
☐เกษตรกร ☐ค้าขายสินค้าอุปโภคบริโภคทั่วไป
☐ข้าราชการ ☐อื่นๆ(ระบุ)..

<u>ตอนที่ 2</u> ข้อมูลสุขภาพและพฤติกรรมเสี่ยง

2.1 ท่านรับประทานอาหารทะเลเป็นประจำหรือไม่

☐เป็นประจำทุกวัน ☐เป็นประจำสัปดาห์ละ...............ครั้ง
☐เป็นประจำเดือนละ.................ครั้ง ☐ น้อยกว่าเดือนละครั้ง

2.2 ท่านสูบบุหรี่หรือไม่

☐ ไม่เคย
☐เคยสูบ_____มวน/วัน แต่เลิกสูบมาแล้ว_____ปี
☐ สูบ_____มวน/ วัน

2.3 ครอบครัวท่านมีคนสูบบุหรี่หรือไม่ ☐ไม่มี ☐มี_____คน

2.4 ท่านดื่มสุราหรือเครื่องดื่มมึนเมาหรือไม่

☐ไม่
☐ดื่มนานๆครั้ง______ครั้ง/สัปดาห์ ดื่มครั้งละ______ขวด/ครั้ง ปริมาณ____มล./ครั้ง
☐ดื่มเป็นประจำ______ครั้ง/สัปดาห์ ดื่มครั้งละ______ขวด/ครั้ง ปริมาณ____มล./ครั้ง

2.5 ท่านมีโรคประจำตัวหรือไม่ ☐ไม่มี
☐มี(ระบุ)..เป็นมาแล้ว..........ปี
....เป็นมาแล้ว..........ปี

2.6 ยาที่รับประทานเป็นประจำ ☐ไม่มี
☐มี(ระบุยาสำหรับโรค)...ทานมาแล้ว...........

2.7 ท่านมีการใช้น้ำจากแหล่งน้ำธรรมชาติในพื้นที่หรือไม่

☐ใช้น้ำผิวดิน	☐เพื่อดื่ม	☐อาบ	☐ซักล้าง	☐เกษตรกรรม
☐ใช้น้ำใต้ดิน	☐เพื่อดื่ม	☐อาบ	☐ซักล้าง	☐เกษตรกรรม
☐ใช้น้ำประปาเท่านั้น	☐เพื่อดื่ม	☐อาบ	☐ซักล้าง	☐เกษตรกรรม

เลขที่โครงการวิจัย 159.1/61
วันที่รับรอง 10 ก.ย. 2561
วันหมดอายุ - 9 ก.ย. 2562

2.8 ท่านมีการสัมผัสกับดินในพื้นที่หรือไม่

☐มี กรณี ☐เกษตรกรรม ☐เดินเท้าเปล่า ☐อื่นๆระบุ..

☐ไม่มี

2.9 ท่านมีการใช้เตาถ่านในการประกอบกิจกรรมหรือไม่

☐ ไม่มี ☐ มี กรณี...

2.10 ท่านมีการทำอาหารภายในครัวเรือนหรือไม่

☐ ไม่มี (ข้ามข้อ 2.11และ 2.12)

☐ มี

2.11 ท่านมีการล้างวัตถุดิบ/ ล้างมือ/ล้างอุปกรณ์ ก่อนการทำอาหารหรือไม่

☐ ไม่มี

☐ มี กรณี ☐ ล้างวัตถุดิบ ☐ล้างมือ ☐ ล้างอุปกรณ์

2.12 ท่านมีการใช้อุปกรณ์ประเภทใดในการทำอาหาร

☐ ไม้ ☐โลหะ สเตนเลส

2.13 ท่านมีการใช้หรือเก็บผลิตภัณฑ์รักษาเนื้อไม้ไว้ภายในบ้านหรือไม่

☐ ไม่มี ☐ มี

2.14 ท่านมีการใช้ปุ๋ยหรือยาปราบศัตรูพืชในการทำการเกษตรหรือไม่

☐ ไม่มี ☐ มี

<u>ตอนที่ 3</u> ข้อมูลด้านการประกอบอาชีพ

3.1 ท่านประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์รวมทั้งสิ้นเป็นเวลา..............................ปี..........................เดือน

3.2 จำนวนสมาชิกในครอบครัวที่ทำงานคัดแยกขยะอิเล็กทรอนิกส์.........................คน ชาย.................คน หญิง................คน

3.3 ลักษณะการทำงานคัดแยกขยะอิเล็กทรอนิกส์ของท่าน (ตอบได้มากกว่า 1 ข้อ)

☐รับซื้อขยะอิเล็กทรอนิกส์จากบ้านเรือน/ ร้านขายของเก่าแล้วนำมาคัดแยกชิ้นส่วน

☐รับซื้อเศษวัสดุที่ได้จากการคัดแยกขยะอิเล็กทรอนิกส์

☐รับจ้างคัดแยกชิ้นส่วนขยะอิเล็กทรอนิกส์ ได้รับค่าจ้าง.....................บาทต่อวัน

☐อื่นๆ ระบุ...

3.4 ใน 1 วัน ท่านใช้เวลาทำงานคัดแยกขยะอิเล็กทรอนิกส์จำนวน.................ชั่วโมง

3.5 ใน 1 สัปดาห์ ท่านใช้เวลาทำงานคัดแยกขยะอิเล็กทรอนิกส์จำนวน................วัน

3.6 ท่านมีวันหยุดพักผ่อนหรือไม่ ☐ ไม่มี ☐ มี ....วันต่อสัปดาห์ ☐ ไม่แน่นอน

3.7 ท่านคิดว่าจะประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์จนถึงอายุ.....................ปี

3.8 ท่านทราบหรือไม่ว่าในขยะอิเล็กทรอนิกส์มีสารอันตรายซึ่งอาจส่งผลกระทบต่อสุขภาพของผู้ทำงาน

☐ไม่ทราบ ☐ทราบ จากช่องทาง..

3.9 ในระหว่างทำงาน ท่านมีการสวมอุปกรณ์ป้องกันอันตรายส่วนบุคคลหรือไม่

☐ไม่มี (ข้ามไปข้อ 3.11) ☐มี สวมใส่เป็นบางครั้ง ☐ มี สวมใส่ทุกครั้ง

3.10 หากมีการสวมใส่อุปกรณ์ป้องกันอันตรายส่วนบุคคล อุปกรณ์ที่ท่านใช้ ได้แก่ (ตอบได้มากกว่า 1 ข้อ)

☐ถุงมือยาวถึงศอก ชนิด☐ ผ้า ☐หน้ากาก ชนิด ☐ หน้ากากผ้า

☐ถุงมือสั้นระดับข้อมือ ☐ยาง ☐ หน้ากากอนามัย

☐ หน้ากากป้องกันฝุ่นละออง

☐แว่นตานิรภัย ☐รองเท้านิรภัยหรือรองเท้าหุ้มส้นที่ปิดมิดชิด

☐เสื้อแขนยาว ☐กางเกงขายาว

☐หมวกผ้า/ฟาง ☐หมวกพลาสติก

3.11 ขยะอิเล็กทรอนิกส์ที่ท่านรับซื้อและคัดแยกในแต่ละครั้งได้แก่อะไรบ้าง โปรดระบุ

☐โทรทัศน์	จำนวน................เครื่อง	☐ตู้เย็น	จำนวน................เครื่อง
☐เครื่องซักผ้า	จำนวน................เครื่อง	☐คอมพิวเตอร์	จำนวน................เครื่อง
☐เครื่องปรับอากาศ	จำนวน................เครื่อง	☐อื่นๆ............................	จำนวน................เครื่อง
☐อื่นๆ.......................	จำนวน................เครื่อง	☐อื่นๆ............................	จำนวน................เครื่อง

3.12 ในหนึ่งเดือน ท่านรับซื้อและคัดแยกขยะอิเล็กทรอนิกส์เป็นจำนวน.........................ครั้ง

3.13 วัสดุที่คัดแยกได้จากขยะอิเล็กทรอนิกส์ได้แก่อะไรบ้าง โปรดระบุ

☐เหล็ก	จำนวน................กิโลกรัม	☐ทองแดง	จำนวน..............กิโลกรัม
☐อะลูมิเนียม	จำนวน................กิโลกรัม	☐ทองเหลือง	จำนวน..............กิโลกรัม
☐พลาสติก	จำนวน................กิโลกรัม	☐อื่นๆ......................	จำนวน..............กิโลกรัม
☐อื่นๆ.............	จำนวน................กิโลกรัม	☐อื่นๆ......................	จำนวน..............กิโลกรัม

3.14 ท่านขายวัสดุที่คัดแยกได้จากขยะอิเล็กทรอนิกส์ที่ใด

☐ ร้านค้าในพื้นที่ ☐ร้านค้านอกพื้นที่ ระบุ.................................... ☐อื่นๆ ระบุ...

3.15 ท่านมีการเผาสายไฟหรือวัสดุอื่นๆ เพื่อให้ได้วัสดุมีค่าหรือไม่

☐ไม่มี ☐มี ทำการเผา..............ครั้งต่อเดือน ครั้งละประมาณ................กิโลกรัม

3.16 ท่านจัดการขยะหรือเศษวัสดุที่เหลือจากการคัดแยกวัสดุมีค่าออกแล้วอย่างไร

☐ทิ้งบริเวณ.................................... ☐เผาบริเวณ.................................. ☐ ฝังบริเวณ................................

3.17 ก่อนทำการเจาะเลือด ท่านทำการเผาขยะอิเล็กทรอนิกส์มาแล้วเป็นเวลา............วัน

****

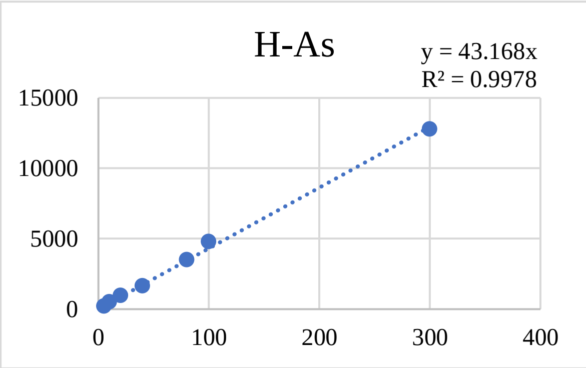
ขอขอบคุณทุกท่านที่ให้ความร่วมมือในการให้ข้อมูลตามความเป็นจริง

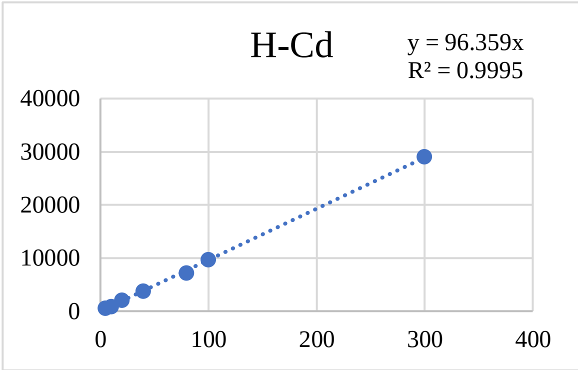
เลขที่โครงการวิจัย 159.1/61

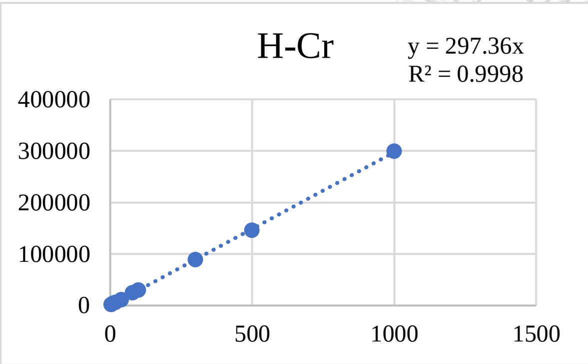
วันที่รับรอง 10 ก.ย. 2561

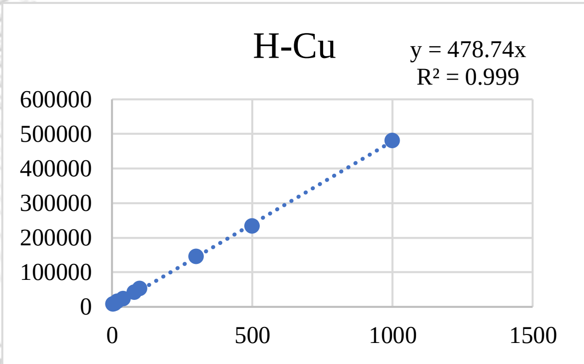
วันหมดอายุ - 9 ก.ย. 2562

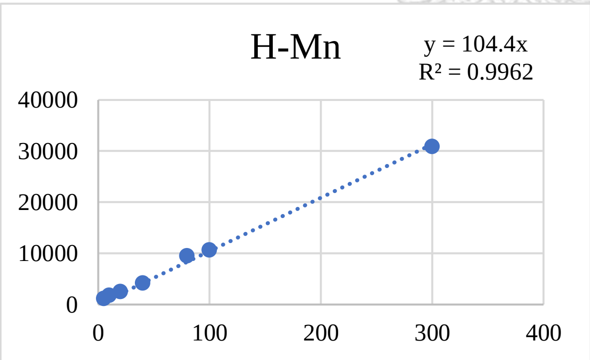
APPENDIX B
GRAPH PLOTTED OF STANDARD CALIBRATION CURVES

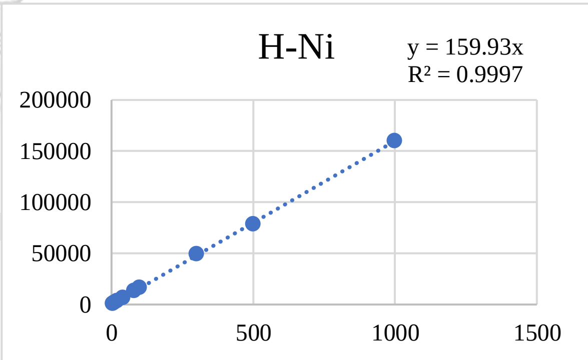


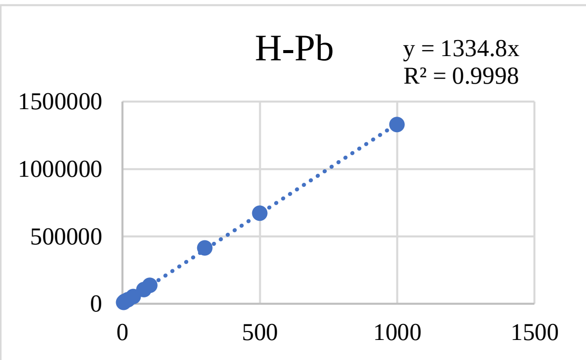


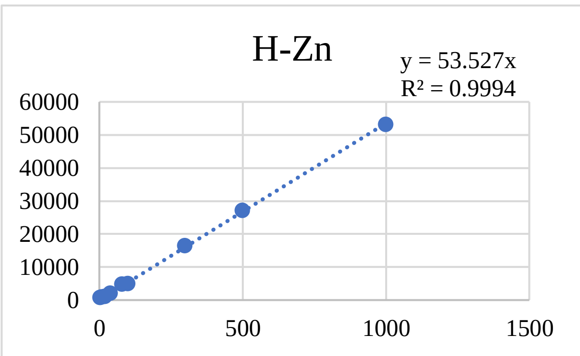


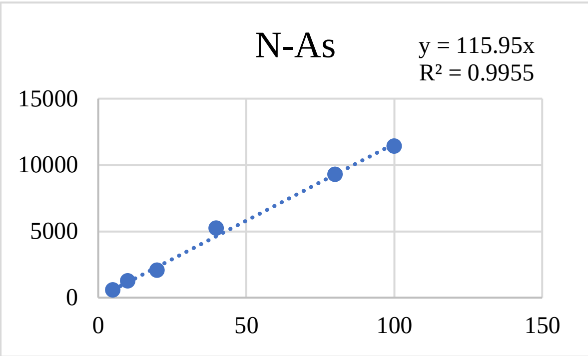


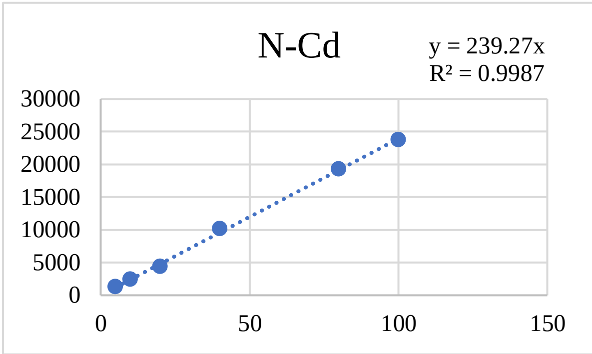


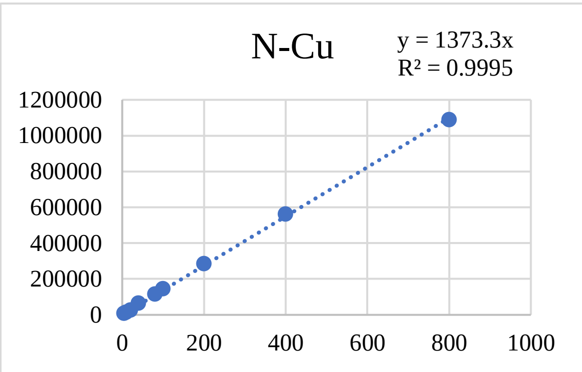


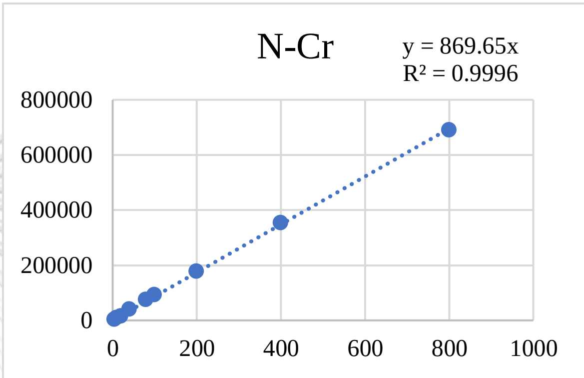


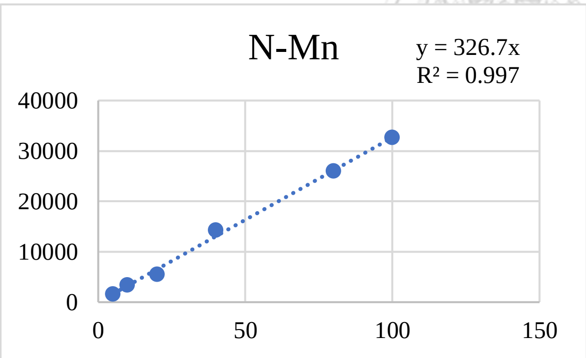


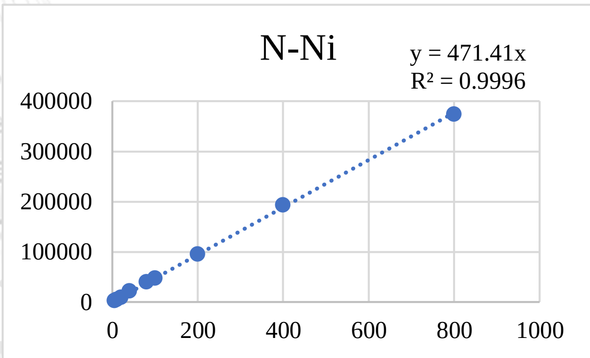

N-As
y = 115.95x
R^2 = 0.9955

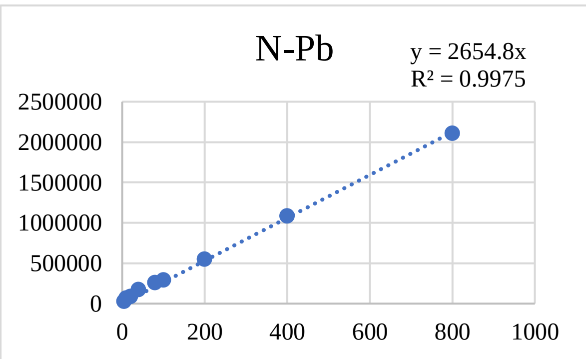

N-Cd
y = 239.27x
R^2 = 0.9987

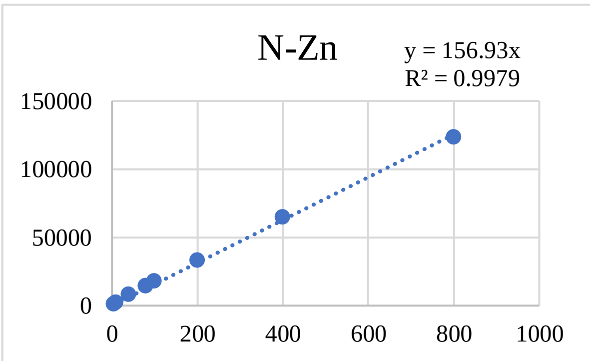

N-Cu
y = 1373.3x
R^2 = 0.9995


N-Cr
y = 869.65x
R^2 = 0.9996


N-Mn
y = 326.7x
R^2 = 0.997


N-Ni
y = 471.41x
R^2 = 0.9996


N-Pb
y = 2654.8x
R^2 = 0.9975


N-Zn
y = 156.93x
R^2 = 0.9979

APPENDIX C
STATISTICAL RESULTS FROM SPSS PROGRAM

1. Mann-Whitney (U-test)

Test Statistics[a]

	H-Cr
Mann-Whitney U	1195.500
Wilcoxon W	1723.500
Z	-2.376
Asymp. Sig. (2-tailed)	.017

Test Statistics[a]

	H-Cu
Mann-Whitney U	198.000
Wilcoxon W	726.000
Z	-7.483
Asymp. Sig. (2-tailed)	.000

Test Statistics[a]

	H-Mn
Mann-Whitney U	850.000
Wilcoxon W	1378.000
Z	-4.083
Asymp. Sig. (2-tailed)	.000

Test Statistics[a]

	H-Ni
Mann-Whitney U	1471.000
Wilcoxon W	1999.000
Z	-.858
Asymp. Sig. (2-tailed)	.391

Test Statistics[a]

	H-Pb
Mann-Whitney U	356.000
Wilcoxon W	884.000
Z	-6.664
Asymp. Sig. (2-tailed)	.000

Test Statistics[a]

	H-Zn
Mann-Whitney U	459.000
Wilcoxon W	987.000
Z	-6.121
Asymp. Sig. (2-tailed)	.000

Test Statistics[a]

	N-Cr
Mann-Whitney U	1261.000
Wilcoxon W	1757.000
Z	-2.003
Asymp. Sig. (2-tailed)	.045

Test Statistics[a]

	N-Cu
Mann-Whitney U	1095.000
Wilcoxon W	1591.000
Z	-2.762
Asymp. Sig. (2-tailed)	.006

Test Statistics[a]

	N-Mn
Mann-Whitney U	824.000
Wilcoxon W	1320.000
Z	-4.174
Asymp. Sig. (2-tailed)	.000

Test Statistics[a]

	N-Ni
Mann-Whitney U	1329.000
Wilcoxon W	1825.000
Z	-1.548
Asymp. Sig. (2-tailed)	.122

Test Statistics[a]

	N-Pb
Mann-Whitney U	1124.000
Wilcoxon W	1620.000
Z	-2.617
Asymp. Sig. (2-tailed)	.009

Test Statistics[a]

	Zn
Mann-Whitney U	1579.000
Wilcoxon W	2075.000
Z	-.252
Asymp. Sig. (2-tailed)	.801

2. Spearman correlation

Correlations

			N_Cr	H_Cr
Spearman's rho	N_Cr	Correlation Coefficient	1.000	.144
		Sig. (2-tailed)	.	.138
		N	108	108
	H_Cr	Correlation Coefficient	.144	1.000
		Sig. (2-tailed)	.138	.
		N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

			N_Cu	H_Cu
Spearman's rho	N_Cu	Correlation Coefficient	1.000	.317**
		Sig. (2-tailed)	.	.001
		N	108	108
	H_Cu	Correlation Coefficient	.317**	1.000
		Sig. (2-tailed)	.001	.
		N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

			N_Mn	H_Mn
Spearman's rho	N_Mn	Correlation Coefficient	1.000	.288**
		Sig. (2-tailed)	.	.003
		N	108	108
	H_Mn	Correlation Coefficient	.288**	1.000
		Sig. (2-tailed)	.003	.
		N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

			N_Ni	H_Ni
Spearman's rho	N_Ni	Correlation Coefficient	1.000	.296**
		Sig. (2-tailed)	.	.002
		N	108	108
	H_Ni	Correlation Coefficient	.296**	1.000
		Sig. (2-tailed)	.002	.
		N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

			N_Pb	H_Pb
Spearman's rho	N_Pb	Correlation Coefficient	1.000	.386**
		Sig. (2-tailed)	.	.000
		N	108	108
	H_Pb	Correlation Coefficient	.386**	1.000
		Sig. (2-tailed)	.000	.
		N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

			N_Zn	H_Zn
Spearman's rho	N_Zn	Correlation Coefficient	1.000	.092
		Sig. (2-tailed)	.	.344
		N	108	108
	H_Zn	Correlation Coefficient	.092	1.000
		Sig. (2-tailed)	.344	.
		N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX D

The information for associated factors

Socio-demographic and behavior factors	Total (N=134)	H-Cr exposure		P-Value
		High (N=66)	Low (N=68)	
Occupation				0.127
E-waste	102 (76.1%)	54 (52.9%)	48 (47.1%)	
Non-e-waste	32 (23.9%)	12 (37.5%)	20 (62.5%)	
Gender				0.848
Male	60 (44.8%)	29 (48.3%)	31 (51.7%)	
Female	74 (55.2%)	37 (50.0%)	37 (50.0%)	
Age				0.726
> 49 years	65 (48.5%)	31 (47.7 %)	34 (52.3%)	
≤ 49 years	69 (51.5%)	35 (54.2%)	34 (45.8%)	
Weight				0.306
> 60 kg	59 (44.0%)	32 (54.2%)	27 (45.8%)	
≤ 60 kg	75 (56.0%)	34 (45.3%)	41 (54.7%)	
Height				0.165
> 160 cm	49 (36.6%)	28 (57.1%)	21 (42.9%)	
≤ 160 cm	85 (63.4%)	38 (44.7%)	47 (55.3%)	
BMI				0.302
> 23.44	65 (48.5%)	35 (53.8%)	30 (46.2%)	
≤ 23.44	69 (51.5%)	31 (44.9%)	38 (55.1%)	
Living time				0.300
> 32.5 years	67 (50.0%)	30 (44.8%)	37 (55.2%)	
≤ 32.5 years	67 (50.0%)	36 (53.7%)	31 (46.3%)	
Seafood consumption				0.168
≥ 1 times/week	65 (48.5%)	36 (55.4%)	29 (44.6%)	
< 1 times/week	69 (51.5%)	30 (43.5%)	39 (56.5%)	
Smoking habit				0.925
Yes	35 (26.1%)	17 (48.6%)	18 (51.4%)	
No	99 (73.9%)	49 (49.5%)	50 (505%)	
Secondhand smoking				0.122
Yes	43 (32.1%)	17 (39.5%)	26 (60.5%)	
No	91 (67.9%)	49 (53.8%)	42 (46.2%)	
Alcohol consumption				0.979
Yes	57 (42.5%)	28 (49.1%)	29 (50.9%)	
No	77 (57.5%)	38 (49.4%)	39 (50.6%)	
Bare feet walking on the soil				0.085
Yes	57 (42.5%)	33 (57.9%)	24 (42.1%)	
No	77 (57.5%)	33 (42.9%)	44 (57.1%)	

Working condition factors	**Total (N=102)**	**H-Cr exposure**		**P-Value**
		High (N=54)	**Low (N=48)**	
Working period				0.259
> 5 years	45 (44.1%)	21 (46.7%)	24 (53.3%)	
≤ 5 years	57 (55.9%)	33 (57.9%)	24 (42.1%)	
Working hour				0.690
> 8 hours	12 (11.8%)	7 (58.3%)	5 (41.7%)	
≤ 8 hours	90 (88.2%)	47 (52.2%)	43 (47.8%)	
Working day				0.080
> 6 days	48 (47.1%)	21 (43.8%)	27 (56.2%)	
≤ 6 days	54 (52.9%)	33 (61.1%)	21 (38.9%)	
PPE using				*0.036
Every time	64 (62.7%)	39 (60.9%)	25 (39.1%)	
No and sometimes	38 (37.2%)	15 (39.5%)	23 (60.5%)	

Socio-demographic and behavior factors	Total (N=134)	H-Cu exposure		P-Value
		High (N=68)	Low (N=66)	
Occupation				*0.000
E-waste	102 (76.1%)	68 (66.7%)	34 (33.3%)	
Non-e-waste	32 (23.9%)	0	32 (100.0%)	
Gender				*0.001
Male	60 (44.8%)	40 (66.7%)	20 (33.3%)	
Female	74 (55.2%)	28 (37.8%)	46 (62.2%)	
Age				0.733
> 49 years	65 (48.5%)	32 (49.2%)	33 (50.8%)	
≤ 49 years	69 (51.5%)	36 (52.2%)	33 (47.8%)	
Weight				0.983
> 60 kg	59 (44.0%)	30 (50.8%)	29 (49.2%)	
≤ 60 kg	75 (56.0%)	38 (50.7%)	37 (49.3%)	
Height				0.010
> 160 cm	49 (36.6%)	32 (65.3%)	17 (34.7%)	
≤ 160 cm	85 (63.4%)	36 (42.4%)	49 (57.6%)	
BMI				0.486
> 23.44	65 (48.5%)	35 (53.8%)	30 (46.2%)	
≤ 23.44	69 (51.5%)	33 (47.8%)	36 (52.2%)	
Living time				0.038
> 32.5 years	67 (50.0%)	28 (41.8%)	39 (58.2%)	
≤ 32.5 years	67 (50.0%)	40 (59.7%)	27 (40.3%)	
Seafood consumption				0.486
≥ 1 times/week	65 (48.5%)	35 (53.8%)	30 (46.2%)	
< 1 times/week	69 (51.5%)	33 (47.8%)	36 (52.2%)	
Smoking habit				*0.014
Yes	35 (26.1%)	24 (68.6%)	11 (31.4%)	
No	99 (73.9%)	44 (44.4%)	55 (55.6%)	
Secondhand smoking				0.122
Yes	43 (32.1%)	26 (60.5%)	17 (39.5%)	
No	91 (67.9%)	42 (46.2%)	49 (53.8%)	
Alcohol consumption				0.076
Yes	57 (42.5%)	34 (59.6%)	23 (40.4%)	
No	77 (57.5%)	34 (44.2%)	43 (55.8%)	
Bare feet walking on the soil				0.307
Yes	57 (42.5%)	26 (45.6%)	31 (54.4%)	
No	77 (57.5%)	42 (54.5%)	35 (45.5%)	

Working condition factors	Total (N=102)	H-Cu exposure		P-Value
		High (N=68)	Low (N=34)	
Working period				0.091
> 5 years	45 (44.1%)	34 (75.6%)	11 (24.4%)	
≤ 5 years	57 (55.9%)	23 (40.4%)	34 (59.6%)	
Working hour				0.514
> 8 hours	12 (11.8%)	7 (58.3%)	5 (41.7%)	
≤ 8 hours	90 (88.2%)	61 (67.8%)	29 (32.2%)	
Working day				0.207
> 6 days	48 (47.1%)	35 (72.9%)	13 (27.1%)	
≤ 6 days	54 (52.9%)	33 (61.1%)	21 (38.9%)	
PPE using				*0.001
Every time	64 (62.7%)	35 (54.7%)	29 (45.3%)	
No and sometimes	38 (37.3%)	33 (86.8%)	5 (13.2%)	

Socio-demographic and behavior factors	Total (N=134)	H-Mn exposure		P-Value
		High (N=68)	Low (N=66)	
Occupation				*0.003
E-waste	102 (76.1%)	59 (57.8%)	43 (42.2%)	
Non-e-waste	32 (23.9%)	9 (28.1%)	23 (71.9%)	
Gender				*0.003
Male	60 (44.8%)	39 (65.0%)	21 (35.0%)	
Female	74 (55.2%)	29 (39.2%)	45 (60.8%)	
Age				0.165
> 49 years	65 (48.5%)	37 (56.9%)	28 (43.1%)	
≤ 49 years	69 (51.5%)	31 (44.9%)	38 (55.1%)	
Weight				0.743
> 60 kg	59 (44.0%)	29 (49.2%)	30 (50.8%)	
≤ 60 kg	75 (56.0%)	39 (52.0%)	36 (48.0%)	
Height				0.138
> 160 cm	49 (36.6%)	29 (59.2%)	20 (40.8%)	
≤ 160 cm	85 (63.4%)	39 (45.9%)	46 (54.1%)	
BMI				0.726
> 23.44	65 (48.5%)	34 (52.3%)	31 (47.7%)	
≤ 23.44	69 (51.5%)	34 (49.3%)	35 (50.7%)	
Living time				0.300
> 32.5 years	67 (50.0%)	31 (46.3%)	36 (53.7%)	
≤ 32.5 years	67 (50.0%)	37 (55.2%)	30 (44.8%)	
Seafood consumption				0.085
≥ 1 times/week	65 (48.5%)	28 (43.1%)	37 (56.9%)	
< 1 times/week	69 (51.5%)	40 (58.0%)	29 (42.0%)	
Smoking habit				*0.039
Yes	35 (26.1%)	23 (65.7%)	12 (34.3%)	
No	99 (73.9%)	45 (45.5%)	54 (54.5%)	
Secondhand smoking				0.122
Yes	43 (32.1%)	26 (60.5%)	17 (39.5%)	
No	91 (67.9%)	42 (46.2%)	49 (53.8%)	
Alcohol consumption				0.746
Yes	57 (42.5%)	28 (49.1%)	29 (50.9%)	
No	77 (57.5%)	40 (51.9%)	37 (48.1%)	
Bare feet walking on the soil				0.707
Yes	57 (42.5%)	30 (52.6%)	27 (47.4%)	
No	77 (57.5%)	38 (49.4%)	39 (50.6%)	

Working condition factors	**Total (N=102)**	**H-Mn exposure**		**P-Value**
		High (N=59)	**Low (N=43)**	
Working period				0.230
> 6 years	45 (44.1%)	29 (64.4%)	16 (35.6%)	
≤ 6 years	57 (55.9%)	30 (52.6%)	27 (47.4%)	
Working hour				0.067
> 8 hours	12 (11.8%)	4 (33.3%)	8 (66.7%)	
≤ 8 hours	90 (88.2%)	55 (61.1%)	35 (38.9%)	
Working day				0.267
> 6 days	48 (47.1%)	25 (52.1%)	23 (47.9%)	
≤ 6 days	54 (52.9%)	34 (63.0%)	20 (37.0%)	
PPE using				0.210
Every time	64 (62.7%)	34 (53.1%)	30 (46.9%)	
No and sometimes	38 (37.3%)	25 (65.8%)	13 (34.2%)	

Socio-demographic and behavior factors	Total (N=134)	H-Ni exposure		P-Value
		High (N=66)	Low (N=68)	
Occupation				0.758
E-waste	102 (76.1%)	51 (50.0%)	51 (50.0%)	
Non-e-waste	32 (23.9%)	15 (46.9%)	17 (53.1%)	
Gender				0.848
Male	60 (44.8%)	29 (48.3%)	31 (51.7%)	
Female	74 (55.2%)	37 (50.0%)	37 (50.0%)	
Age				0.733
> 49 years	65 (48.5%)	33 (50.8%)	32 (49.2%)	
≤ 49 years	69 (51.5%)	33 (47.8%)	36 (52.2%)	
Weight				0.499
> 60 kg	59 (44.0%)	31 (52.5%)	28 (47.5%)	
≤ 60 kg	75 (56.0%)	35 (46.6%)	40 (53.3%)	
Height				0.261
> 160 cm	49 (36.6%)	21 (42.9%)	28 (57.1%)	
≤ 160 cm	85 (63.4%)	45 (52.9%)	40 (47.1%)	
BMI				0.733
> 23.44	65 (48.5%)	33 (50.8%)	32 (49.2%)	
≤ 23.44	69 (51.5%)	33 (47.8%)	36 (52.2%)	
Living time				1.000
> 32.5 years	67 (50.0%)	33 (49.3%)	34 (50.7%)	
≤ 32.5 years	67 (50.0%)	33 (49.3%)	34 (50.7%)	
Seafood consumption				0.996
≥ 1 times/week	65 (48.5%)	32 (49.2%)	33 (50.8%)	
< 1 times/week	69 (51.5%)	34 (49.3%)	35 (50.7%)	
Smoking habit				0.626
Yes	35 (26.1%)	16 (45.7%)	19 (54.3%)	
No	99 (73.9%)	50 (50.5%)	49 (49.5%)	
Secondhand smoking				0.663
Yes	43 (32.1%)	20 (46.5%)	23 (53.5%)	
No	91 (67.9%)	46 (50.6%)	45 (49.4%)	
Alcohol consumption				0.979
Yes	57 (42.5%)	28 (49.1%)	29 (50.9%)	
No	77 (57.5%)	38 (49.3%)	39 (50.7%)	
Bare feet walking on the soil				0.085
Yes	57 (42.5%)	33 (57.9%)	24 (42.1%)	
No	77 (57.5%)	33 (42.9%)	44 (57.1%)	

Working condition factors	Total (N=102)	H-Ni exposure		P-Value
		High (N=51)	Low (N=51)	
Working period				0.163
> 6 years	45 (44.1%)	19 (42.2%)	26 (57.8%)	
≤ 6 years	57 (55.9%)	32 (56.1%)	25 (43.9%)	
Working hour				0.539
> 8 hours	12 (11.8%)	5 (41.7%)	7 (58.3%)	
≤ 8 hours	90 (88.2%)	46 (51.1%)	44 (48.9%)	
Working day				*0.000
> 6 days	48 (47.1%)	15 (31.3%)	33 (68.7%)	
≤ 6 days	54 (52.9%)	36 (66.7%)	18 (33.3%)	
PPE using				0.101
Every time	64 (62.7%)	36 (56.3%)	28 (43.7%)	
No and sometimes	38 (37.3%)	15 (39.5%)	23 (60.5%)	

Socio-demographic and behavior factors	Total (N=134)	H-Pb exposure		P-Value
		High (N=67)	Low (N=67)	
Occupation				*0.000
E-waste	102 (76.1%)	66 (64.7%)	36 (35.3%)	
Non-e-waste	32 (23.9%)	1 (3.1%)	31 (96.9%)	
Gender				*0.002
Male	60 (44.8%)	39 (65.0%)	21 (35.0%)	
Female	74 (55.2%)	28 (37.8%)	46 (62.2%)	
Age				0.604
> 49 years	65 (48.5%)	34 (52.3%)	31 (47.7%)	
≤ 49 years	69 (51.5%)	33 (47.8%)	36 (52.2%)	
Weight				0.384
> 60 kg	59 (44.0%)	32 (54.2%)	27 (45.8%)	
≤ 60 kg	75 (56.0%)	35 (46.7%)	40 (53.3%)	
Height				*0.048
> 160 cm	49 (36.6%)	30 (61.2%)	19 (38.8%)	
≤ 160 cm	85 (63.4%)	37 (43.5%)	48 (56.5%)	
BMI				0.226
> 23.44	65 (48.5%)	36 (55.4%)	29 (44.6%)	
≤ 23.44	69 (51.5%)	31 (44.9%)	38 (55.1%)	
Living time				0.388
> 32.5 years	67 (50.0%)	31 (46.3%)	36 (53.7%)	
≤ 32.5 years	67 (50.0%)	36 (53.7%)	31 (46.3%)	
Seafood consumption				0.863
≥ 1 times/week	65 (48.5%)	32 (49.2%)	33 (50.8%)	
< 1 times/week	69 (51.5%)	35 (50.7%)	34 (49.3%)	
Smoking habit				*0.011
Yes	35 (26.1%)	24 (68.6%)	11 (31.4%)	
No	99 (73.9%)	43 (43.4%)	56 (56.6%)	
Secondhand smoking				0.195
Yes	43 (32.1%)	25 (58.1%)	18 (41.9%)	
No	91 (67.9%)	42 (46.1%)	49 (53.9%)	
Alcohol consumption				0.116
Yes	57 (42.5%)	33 (57.9%)	24 (42.1%)	
No	77 (57.5%)	34 (44.2%)	43 (55.8%)	
Bare feet walking on the soil				0.116
Yes	57 (42.5%)	33 (57.9%)	24 (42.1%)	
No	77 (57.5%)	34 (44.2%)	43 (55.8%)	

Working condition factors	**Total (N=102)**	**H-Pb exposure**		**P-Value**
		High (N=66)	**Low (N=36)**	
Working period				*0.004
> 6 years	45 (44.1%)	36 (80.0%)	9 (20.0%)	
≤ 6 years	57 (55.9%)	30 (52.6%)	27 (43.4%)	
Working hour				0.623
> 8 hours	12 (11.8%)	7 (58.3%)	5 (41.7%)	
≤ 8 hours	90 (88.2%)	59 (65.6%)	31 (34.4%)	
Working day				*0.040
> 6 days	48 (47.1%)	36 (75.0%)	12 (25.0%)	
≤ 6 days	54 (52.9%)	30 (55.6%)	24 (44.4%)	
PPE using				*0.001
Every time	64 (62.7%)	34 (53.1%)	30 (46.9%)	
No and sometimes	38 (37.3%)	32 (84.2%)	6 (15.8%)	

Socio-demographic and behavior factors	Total (N=134)	H-Zn exposure		P-Value
		High (N=70)	Low (N=64)	
Occupation				*0.000
E-waste	102 (76.1%)	67 (65.7%)	35 (34.3%)	
Non-e-waste	32 (23.9%)	3 (9.4%)	29 (90.6%)	
Gender				0.203
Male	60 (44.8%)	35 (58.3%)	25 (41.7%)	
Female	74 (55.2%)	35 (47.3%)	39 (52.7%)	
Age				0.086
> 49 years	65 (48.5%)	29 (44.6%)	36 (55.4%)	
≤ 49 years	69 (51.5%)	41 (59.4%)	28 (40.6%)	
Weight				0.775
> 60 kg	59 (44.0%)	30 (50.8%)	29 (49.2%)	
≤ 60 kg	75 (56.0%)	40 (53.3%)	35 (46.7%)	
Height				0.388
> 160 cm	49 (36.6%)	28 (57.1%)	21 (42.9%)	
≤ 160 cm	85 (63.4%)	42 (49.4%)	43 (50.6%)	
BMI				0.988
> 23.44	65 (48.5%)	34 (52.3%)	31 (47.7%)	
≤ 23.44	69 (51.5%)	36 (52.2%)	33 (47.8%)	
Living time				0.166
> 32.5 years	67 (50.0%)	31 (46.3%)	36 (53.7%)	
≤ 32.5 years	67 (50.0%)	39 (58.2%)	28 (41.8%)	
Seafood consumption				*0.036
≥ 1 times/week	65 (48.5%)	40 (61.5%)	25 (38.5%)	
< 1 times/week	69 (51.5%)	30 (43.5%)	39 (56.5%)	
Smoking habit				0.063
Yes	35 (26.1%)	23 (65.7%)	12 (34.3%)	
No	99 (73.9%)	47 (47.5%)	52 (52.5%)	
Secondhand smoking				0.098
Yes	43 (32.1%)	18 (41.9%)	25 (58.1%)	
No	91 (67.9%)	52 (57.1%)	39 (42.9%)	
Alcohol consumption				0.669
Yes	57 (42.5%)	31 (54.4%)	26 (45.6%)	
No	77 (57.5%)	39 (50.6%)	38 (49.4%)	
Bare feet walking on the soil				0.938
Yes	57 (42.5%)	30 (52.6%)	27 (47.4%)	
No	77 (57.5%)	40 (51.9%)	37 (48.1%)	

Working condition factors	Total (N=102)	H-Zn exposure		P-Value
		High (N=67)	Low (N=35)	
Working period				0.148
> 6 years	45 (44.1%)	33 (73.3%)	12 (26.7%)	
≤ 6 years	57 (55.9%)	34 (59.6%)	23 (40.4%)	
Working hour				0.469
> 8 hours	12 (11.8%)	9 (75.0%)	3 (25.0%)	
≤ 8 hours	90 (88.2%)	58 (64.4%)	32 (35.6%)	
Working day				0.539
> 6 days	48 (47.1%)	33 (68.8%)	15 (31.2%)	
≤ 6 days	54 (52.9%)	34 (63.0%)	20 (37.0%)	
PPE using				0.987
Every time	64 (62.7%)	42 (65.6%)	22 (34.4%)	
No and sometimes	38 (37.3%)	25 (65.8%)	13 (34.2%)	

Socio-demographic and behavior factors	Total (N=136)	N-Cr exposure		P-Value
		High (N=12)	Low (N=124)	
Occupation				0.000*
E-waste	105 (77.2%)	2 (1.9%)	103 (98.1%)	
Non-e-waste	31 (22.8%)	10 (32.3%)	21 (67.7%)	
Gender				0.178
Male	59 (43.4%)	3 (5.1%)	56 (94.9%)	
Female	77 (56.6%)	9 (11.7%)	68 (88.3%)	
Age				0.831
> 49 years	64 (47.1%)	6 (9.4%)	58 (90.6%)	
≤ 49 years	72 (52.9%)	6 (8.3%)	66 (91.7%)	
Weight				0.510
> 60 kg	67 (49.3%)	7 (10.4%)	60 (89.6%)	
≤ 60 kg	69 (50.7%)	5 (7.2%)	64 (92.8%)	
Height				0.533
> 160 cm	45 (33.1%)	3 (6.7%)	42 (93.3%)	
≤ 160 cm	91 (66.9%)	9 (9.9%)	82 (90.1%)	
BMI				0.070
> 23.88	68 (50.0%)	9 (13.2%)	59 (86.8%)	
≤ 23.88	68 (50.0%)	3 (9.9%)	65 (95.6%)	
Living time				0.078
> 39 years	69 (50.7%)	9 (13.0%)	60 (87.0%)	
≤ 39 years	67 (49.3%)	3 (4.5%)	64 (95.5%)	
Seafood consumption				0.957
≥ 1 times/week	69 (50.7%)	6 (8.7%)	63 (91.3%)	
< 1 times/week	67 (49.3%)	6 (9.0%)	61 (91.9%)	
Smoking habit				0.059
Yes	29 (21.3%)	0	29 (100.0%)	
No	107 (78.7%)	12 (11.2%)	95 (88.8%)	
Secondhand smoking				0.939
Yes	44 (32.4%)	4 (9.1%)	40 (90.9%)	
No	92 (67.6%)	8 (8.7%)	84 (91.3%)	
Alcohol consumption				0.462
Yes	59 (43.4%)	4 (5.8%)	55 (93.2%)	
No	77 (56.6%)	8 (10.4%)	69 (89.6%)	
Bare feet walking on the soil				0.254
Yes	55 (40.4%)	3 (5.5%)	52 (94.5%)	
No	81 (59.6%)	9 (11.1%)	72 (88.9%)	

Working condition factors	Total (N=105)	N-Cr exposure		P-Value
		High (N=53)	Low (N=52)	
Working period				0.491
> 6 years	47 (44.8%)	24 (51.1%)	23 (48.9%)	
≤ 6 years	58 (55.2%)	29 (50.0%)	29 (50.0%)	
Working hour				0.043*
> 8 years	10 (9.5%)	2 (20.0%)	8 (80.0%)	
≤ 8 years	95 (90.5%)	51 (53.7%)	44 (46.3%)	
Working day				0.063
< 7 days	55 (52.4%)	23 (41.8%)	32 (58.2%)	
7 days	50 (47.6%)	30 (60.0%)	20 (40.0%)	
PPE using				0.903
Every time	64 (61.0%)	32 (50.0%)	32 (50.0%)	
No and sometimes	41 (39.0%)	21 (51.2%)	20 (48.8%)	

Socio-demographic and behavior factors	Total (N=136)	N-Cu exposure		P-Value
		High (N=69)	Low (N=67)	
Occupation				0.053
E-waste	105 (77.2%)	58 (55.2%)	47 (44.8%)	
Non-e-waste	31 (22.8%)	11 (35.5%)	20 (64.5%)	
Gender				0.712
Male	59 (43.4%)	31 (52.5%)	28 (47.5%)	
Female	77 (56.6%)	38 (49.4%)	39 (50.6%)	
Age				0.233
> 49 years	64 (47.1%)	29 (45.3%)	35 (54.7%)	
≤ 49 years	72 (52.9%)	40 (55.6%)	32 (44.4%)	
Weight				0.998
> 60 kg	67 (49.3%)	34 (50.7%)	33 (49.3%)	
≤ 60 kg	69 (50.7%)	35 (50.7%)	34 (49.3%)	
Height				0.762
> 160 cm	45 (33.1%)	22 (48.9%)	23 (51.1%)	
≤ 160 cm	91 (66.9%)	47 (51.6%)	44 (48.4%)	
BMI				0.391
> 23.88	68 (50.0%)	32 (47.1%)	36 (52.9%)	
≤ 23.88	68 (50.0%)	37 (54.4%)	31 (45.6%)	
Living time				0.494
> 39 years	69 (50.7%)	37 (53.6%)	32 (46.4%)	
≤ 39 years	67 (49.3%)	32 (47.8%)	35 (52.2%)	
Seafood consumption				0.494
≥ 1 times/week	69 (50.7%)	37 (53.6%)	32 (46.4%)	
< 1 times/week	67 (49.3%)	32 (47.8%)	35 (52.2%)	
Smoking habit				0.904
Yes	29 (21.3%)	15 (51.7%)	14 (48.3%)	
No	107 (78.7%)	54 (50.5%)	53 (49.5%)	
Secondhand smoking				0.539
Yes	44 (32.4%)	24 (54.5%)	20 (45.5%)	
No	92 (67.6%)	45 (48.9%)	47 (51.1%)	
Alcohol consumption				0.475
Yes	59 (43.4%)	32 (54.2%)	27 (45.8%)	
No	77 (56.6%)	37 (48.1%)	40 (51.9%)	
Bare feet walking on the soil				0.016*
Yes	55 (40.4%)	21 (38.2%)	34 (61.8%)	
No	81 (59.6%)	48 (59.3%)	33 (40.7%)	

Working condition factors	**Total (N=105)**	**N-Cu exposure**		**P-Value**
		High (N=52)	**Low (N=53)**	
Working period				0.499
> 6 years	47 (44.8%)	25 (53.2%)	22 (46.8%)	
≤ 6 years	58 (55.2%)	27 (46.6%)	31 (53.4%)	
Working hour				0.468
> 8 years	10 (9.5%)	6 (20.0%)	4 (40.0%)	
≤ 8 years	95 (90.5%)	46 (48.4%)	49 (51.6%)	
Working day				0.141
< 7 days	55 (52.4%)	31 (56.4%)	24 (42.6%)	
7 days	50 (47.6%)	21 (42.0%)	29 (58.0%)	
PPE using				0.498
Every time	64 (61.0%)	30 (46.9%)	34 (53.1%)	
No and sometimes	41 (39.0%)	22 (53.7%)	19 (46.3%)	

Socio-demographic and behavior factors	Total (N=136)	N-Mn exposure		P-Value
		High (N=68)	Low (N=68)	
Occupation				0.000*
E-waste	105 (77.2%)	62 (59.0%)	43 (41.0%)	
Non-e-waste	31 (22.8%)	6 (19.4%)	25 (80.6%)	
Gender				0.387
Male	59 (43.4%)	32 (54.2%)	27 (45.8%)	
Female	77 (56.6%)	36 (46.7%)	41 (53.2%)	
Age				0.731
> 49 years	64 (47.1%)	33 (51.6%)	31 (38.4%)	
≤ 49 years	72 (52.9%)	35 (48.6%)	37 (51.4%)	
Weight				0.864
> 60 kg	67 (49.3%)	33 (49.3%)	34 (50.7%)	
≤ 60 kg	69 (50.7%)	35 (50.7%)	34 (49.3%)	
Height				0.585
> 160 cm	45 (33.1%)	24 (53.3%)	21 (46.7%)	
≤ 160 cm	91 (66.9%)	44 (48.4%)	47 (51.6%)	
BMI				0.732
> 23.88	68 (50.0%)	35 (51.5%)	33 (48.5%)	
≤ 23.88	68 (50.0%)	33 (48.5%)	35 (51.5%)	
Living time				0.607
> 39 years	69 (50.7%)	36 (52.2%)	33 (47.8%)	
≤ 39 years	67 (49.3%)	32 (47.8%)	35 (52.2%)	
Seafood consumption				0.059
≥ 1 times/week	69 (50.7%)	40 (58.0%)	29 (42.0%)	
< 1 times/week	67 (49.3%)	28 (41.8%)	39 (58.2%)	
Smoking habit				0.530
Yes	29 (21.3%)	13 (44.8%)	16 (55.2%)	
No	107 (78.7%)	55 (51.4%)	52 (48.6%)	
Secondhand smoking				0.271
Yes	44 (32.4%)	25 (56.8%)	19 (43.2%)	
No	92 (67.6%)	43 (46.7%)	49 (53.3%)	
Alcohol consumption				0.119
Yes	59 (43.4%)	25 (42.4%)	34 (57.6%)	
No	77 (56.6%)	43 (55.8%)	34 (44.2%)	
Bare feet walking on the soil				0.600
Yes	55 (40.4%)	29 (52.7%)	26(47.3%)	
No	81 (59.6%)	39 (48.1%)	42 (51.9%)	

Working condition factors	Total (N=105)	N-Mn exposure		P-Value
		High (N=44)	Low (N=61)	
Working period				0.782
> 6 years	47 (44.8%)	19 (40.04%)	28 (59.6%)	
≤ 6 years	58 (55.2%)	25 (43.1%)	33 (56.9%)	
Working hour				0.585
> 8 years	10 (9.5%)	5 (50.0%)	5 (50.0%)	
≤ 8 years	95 (90.5%)	39 (41.1%)	56 (58.9%)	
Working day				0.706
< 7 days	55 (52.4%)	24 (43.6%)	31 (56.4%)	
7 days	50 (47.6%)	20 (40.0%)	30 (60.0%)	
PPE using				0.377
Every time	64 (61.0%)	29 (45.3%)	35 (54.7%)	
No and sometimes	41 (39.0%)	15 (36.6%)	26 (63.4%)	

Socio-demographic and behavior factors	Total (N=136)	N-Ni exposure		P-Value
		High (N=68)	Low (N=68)	
Occupation				0.066
E-waste	105 (77.2%)	57 (54.3%)	48 (45.7%)	
Non-e-waste	31 (22.8%)	11 (35.5%)	20 (64.5%)	
Gender				0.387
Male	59 (43.4%)	27 (45.8%)	32 (54.2%)	
Female	77 (56.6%)	41 (53.2%)	36 (46.8%)	
Age				0.492
> 49 years	64 (47.1%)	30 (46.9%)	34 (53.1%)	
≤ 49 years	72 (52.9%)	38 (52.8%)	34 (47.2%)	
Weight				0.391
> 60 kg	67 (49.3%)	36 (53.7%)	31 (46.3%)	
≤ 60 kg	69 (50.7%)	32 (46.4%)	37 (53.6%)	
Height				0.855
> 160 cm	45 (33.1%)	22 (48.9%)	23 (51.1%)	
≤ 160 cm	91 (66.9%)	46 (50.5%)	45 (49.5%)	
BMI				0.493
> 23.88	68 (50.0%)	32 (47.1%)	36 (52.9%)	
≤ 23.88	68 (50.0%)	36 (52.9%)	32 (47.1%)	
Living time				0.864
> 39 years	69 (50.7%)	34 (49.3%)	35 (50.7%)	
≤ 39 years	67 (49.3%)	34 (50.7%)	33 (49.3%)	
Seafood consumption				0.230
≥ 1 times/week	69 (50.7%)	31 (44.9%)	38 (55.1%)	
< 1 times/week	67 (49.3%)	37 (55.2%)	30 (44.8%)	
Smoking habit				0.143
Yes	29 (21.3%)	11 (37.9%)	18 (62.1%)	
No	107 (78.7%)	57 (53.3%)	50 (46.7%)	
Secondhand smoking				0.028*
Yes	44 (32.4%)	28 (63.6%)	16 (36.4%)	
No	92 (67.6%)	40 (43.5%)	52 (56.5%)	
Alcohol consumption				0.226
Yes	59 (43.4%)	26 (44.1%)	33 (55.9%)	
No	77 (56.6%)	42 (54.5%)	35 (45.5%)	
Bare feet walking on the soil				0.861
Yes	55 (40.4%)	28 (50.9%)	27 (49.1%)	
No	81 (59.6%)	40 (49.4%)	41 (50.6%)	

Working condition factors	**Total (N=105)**	**N-Ni exposure**		**P-Value**
		High (N=52)	**Low (N=53)**	
Working period				0.616
> 6 years	47 (44.8%)	22 (46.8%)	25 (53.2%)	
≤ 6 years	58 (55.2%)	30 (51.7%)	28 (49.3%)	
Working hour				0.173
> 8 years	10 (9.5%)	7 (70.0%)	3 (30.0%)	
≤ 8 years	95 (90.5%)	45 (47.4%)	50 (52.6%)	
Working day				0.926
< 7 days	55 (52.4%)	27 (49.1%)	28 (50.9%)	
7 days	50 (47.6%)	25 (50.0%)	25 (50.0%)	
PPE using				0.186
Every time	64 (61.0%)	35 (54.7%)	29 (45.3%)	
No and sometimes	41 (39.0%)	17 (41.5%)	24 (58.5%)	

Socio-demographic and behavior factors	Total (N=136)	N-Pb exposure		P-Value
		High (N=67)	Low (N=69)	
Occupation				*0.000
E-waste	105 (77.2%)	62 (59.0%)	43 (41.0%)	
Non-e-waste	31 (22.8%)	5 (16.1%)	26 (83.9%)	
Gender				0.088
Male	59 (43.4%)	34 (57.6%)	25 (42.4%)	
Female	77 (56.6%)	33 (42.9%)	44 (57.1%)	
Age				0.599
> 49 years	64 (47.1%)	30 (46.9%)	34 (53.1%)	
≤ 49 years	72 (52.9%)	37 (51.4%)	35 (48.6%)	
Weight				0.733
> 60 kg	67 (49.3%)	34 (50.7%)	33 (49.3%)	
≤ 60 kg	69 (50.7%)	33 (47.8%)	36 (52.2%)	
Height				0.951
> 160 cm	45 (33.1%)	22 (49.9%)	23 (51.1%)	
≤ 160 cm	91 (66.9%)	45 (49.5%)	46 (50.5%)	
BMI				0.391
> 23.88	68 (50.0%)	36 (52.9%)	32 (47.1%)	
≤ 23.88	68 (50.0%)	31 (45.6%)	37 (54.4%)	
Living time				0.494
> 39 years	69 (50.7%)	32 (46.4%)	37 (53.6%)	
≤ 39 years	67 (49.3%)	35 (52.2%)	32 (47.8%)	
Seafood consumption				*0.039
≥ 1 times/week	69 (50.7%)	40 (58.0%	29 (42.0%)	
< 1 times/week	67 (49.3%)	27 (40.3%)	40 (59.7%)	
Smoking habit				0.256
Yes	29 (21.3%)	17 (58.6%)	12 (41.4%)	
No	107 (78.7%)	50 (46.7%)	57 (53.3%)	
Secondhand smoking				0.804
Yes	44 (32.4%)	21 (47.7%)	23 (52.3%)	
No	92 (67.6%)	46 (50.0%)	46 (50.0%)	
Alcohol consumption				0.310
Yes	59 (43.4%)	32 (54.2%)	27 (45.8%)	
No	77 (56.6%)	35 (45.4%)	42 (54.6%)	
Bare feet walking on the soil				0.152
Yes	55 (40.4%)	23 (41.8%)	32 (58.2%)	
No	81 (59.6%)	44 (54.3%)	37 (45.7%)	

Working condition factors	**Total (N=105)**	**N-Pb exposure**		**P-Value**
		High (N=53)	**Low (N=52)**	
Working period				0.038*
> 6 years	47 (44.8%)	29 (61.7%)	18 (38.3%)	
≤ 6 years	58 (55.2%)	24 (41.4%)	34 (58.6%)	
Working hour				0.486
> 8 years	10 (9.5%)	4 (40.0%)	6 (60.0%)	
≤ 8 years	95 (90.5%)	49 (51.6%)	46 (48.4%)	
Working day				0.041*
< 7 days	55 (52.4%)	33 (60.0%)	22 (40.0%)	
7 days	50 (47.6%)	20 (40.0%)	30 (60.0%)	
PPE using				0.356
Every time	64 (61.0%)	30 (46.9.%)	34 (53.1%)	
No and sometimes	41 (39.0%)	23 (56.1%)	18 (43.9%)	

Socio-demographic and behavior factors	**Total (N=136)**	**N-Zn exposure**		**P-Value**
		High (N=68)	**Low (N=68)**	
Occupation				0.307
E-waste	105 (77.2%)	50 (47.6%)	55 (52.4%)	
Non-e-waste	31 (22.8%)	18 (58.1%)	13 (41.9%)	
Gender				0.387
Male	59 (43.4%)	27 (45.8%)	32 (54.2%)	
Female	77 (56.6%)	41 (53.2%)	36 (46.8%)	
Age				0.169
> 49 years	64 (47.1%)	28 (43.8%)	36 (56.2%)	
≤ 49 years	72 (52.9%)	40 (55.6%)	32 (44.4%)	
Weight				0.607
> 60 kg	67 (49.3%)	35 (52.2%)	32 (47.8%)	
≤ 60 kg	69 (50.7%)	33 (47.8%)	36 (52.2%)	
Height				0.362
> 160 cm	45 (33.1%)	20 (44.4%)	25 (55.6%)	
≤ 160 cm	91 (66.9%)	48 (52.7%)	43 (47.3%)	
BMI				0.170
> 23.88	68 (50.0%)	38 (55.8%)	30 (44.1%)	
≤ 23.88	68 (50.0%)	30 (44.1%)	38 (55.8%)	
Living time				0.059
> 39 years	69 (50.7%)	29 (42.0%)	40 (58.0%)	
≤ 39 years	67 (49.3%)	39 (58.2%)	28 (41.8%)	
Seafood consumption				0.607
≥ 1 times/week	69 (50.7%)	36 (52.2%)	33 (47.8%)	
< 1 times/week	67 (49.3%)	32 (47.8%)	35 (52.2%)	
Smoking habit				0.295
Yes	29 (21.3%)	12 (41.4%)	17 (58.6%)	
No	107 (78.7%)	56 (52.3%)	51 (47.7%)	
Secondhand smoking				0.463
Yes	44 (32.4%)	20 (45.5%)	24 (54.5%)	
No	92 (67.6%)	48 (52.2%)	44 (47.8%)	
Alcohol consumption				0.387
Yes	59 (43.4%)	32 (54.2%)	27 (45.8%)	
No	77 (56.6%)	36 (46.8%)	41 (53.2%)	
Bare feet walking on the soil				0.861
Yes	55 (40.4%)	27 (49.0%)	28 (51.0%)	
No	81 (59.6%)	41 (50.6%)	40 (49.4%)	

Working condition factors	**Total (N=105)**	**N-Zn exposure**		**P-Value**
		High (N=52)	**Low (N=53)**	
Working period				0.014*
> 6 years	47 (44.8%)	17 (36.2%)	30 (63.8%)	
≤ 6 years	58 (55.2%)	35 (60.3%)	23 (39.7%)	
Working hour				0.527
> 8 years	10 (9.5%)	4 (40.0%)	6 (60.0%)	
≤ 8 years	95 (90.5%)	48 (50.5%)	47 (49.5%)	
Working day				0.206
< 7 days	55 (52.4%)	24 (43.6%)	31 (56.4%)	
7 days	50 (47.6%)	28 (56.0%)	22 (44.0%)	
PPE using				0.602
Every time	64 (61.0%)	33 (51.6%)	31 (38.4%)	
No and sometimes	41 (39.0%)	19 (46.3%)	22 (53.7%)	

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