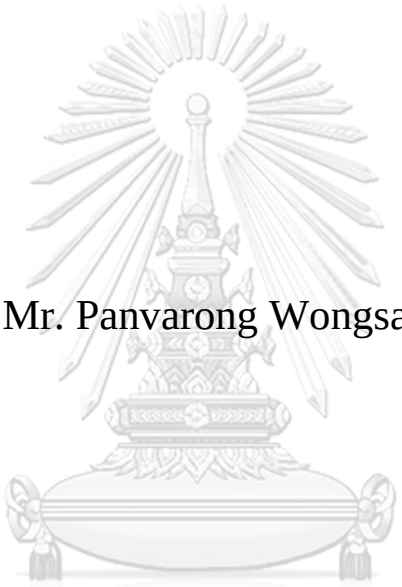
Inhalation exposure and urinary level of heavy metals of electronic waste dismantling workers in Buriram, Thailand.

Mr. Panvarong Wongsabsakul



A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Hazardous Substance and
Environmental Management
Inter-Department of Environmental Management
Graduate School
Chulalongkorn University
Academic Year 2019

การรับสัมผัสโลหะหนักผ่านทางการหายใจและปริมาณที่พบในปัสสาวะของผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ในพื้นที่จังหวัดบุรีรัมย์ ประเทศไทย

นายพันธ์วรงค์ วงศ์ทรัพย์สกุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาการจัดการสารอันตรายและสิ่งแวดล้อม สหสาขาวิชาการจัดการสิ่งแวดล้อม
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Thesis Title	Inhalation exposure and urinary level of heavy metals of electronic waste dismantling workers in Buriram, Thailand.
By	Mr. Panvarong Wongsabsakul
Field of Study	Hazardous Substance and Environmental Management
Thesis Advisor	Assistant Professor Dr. TASSANEE CHETWITTAYACHAN
Thesis Co Advisor	Dr. Pokkate Wongsasuluk

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

..... Dean of the Graduate School
()

THESIS COMMITTEE

..... Chairman
(Assistant Professor Dr. CHANTRA TONGCUMPOU)
..... Thesis Advisor
(Assistant Professor Dr. TASSANEE CHETWITTAYACHAN)
..... Thesis Co-Advisor
(Dr. Pokkate Wongsasuluk)
..... Examiner
(Assistant Professor Dr. PENRADEE CHANPIWAT)
..... External Examiner
(Assistant Professor Dr. Pensri Watchalayann)

พันธ์วรงค์ วงศ์ทรัพย์สกุล :

การรับสัมผัสโลหะหนักผ่านทางการหายใจและปริมาณที่พบในปัสสาวะของผู้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ในพื้นที่จังหวัดบุรีรัมย์ ประเทศไทย. (Inhalation exposure and urinary level of heavy metals of electronic waste dismantling workers in Buriram, Thailand.) อ.ที่ปรึกษาหลัก : ผู้ช่วยศาสตราจารย์ ดร.ทรรศนีย์ พฤกษาสิทธิ์, อ.ที่ปรึกษาร่วม : ดร.ปกเกศ วงศาสุลักษณ์

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อประเมินความเสี่ยงต่อสุขภาพของผู้คัดแยกขยะอิเล็กทรอนิกส์ที่สัมผัสกับโลหะหนักในฝุ่นละอองขนาดไม่เกิน 10 ไมครอน (PM_{10}) โดยใช้โลหะหนักในปัสสาวะเป็นดัชนีชี้วัดทางชีวภาพ ทำการเก็บตัวอย่างปัสสาวะของผู้คัดแยกขยะอิเล็กทรอนิกส์และผู้ที่ไม่ได้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ (กลุ่มควบคุม) พร้อมทั้งเก็บตัวอย่าง PM_{10} เพื่อวิเคราะห์ปริมาณโลหะหนักที่กลุ่มเป้าหมายได้รับสัมผัสผ่านทางการหายใจในตำบลแดงใหญ่ อำเภอบ้านใหม่ไชยพจน์ และตำบลบ้านเป้า อำเภอพุทไธสง จังหวัดบุรีรัมย์ ระหว่างเดือนกุมภาพันธ์ถึงมีนาคม พ.ศ. 2562 ระหว่างการเก็บตัวอย่างได้เก็บข้อมูลเพิ่มเติมของประชากรด้วยการสัมภาษณ์แบบตัวต่อตัวโดยใช้แบบสอบถาม วิเคราะห์ปริมาณโลหะหนักในฝุ่นและปัสสาวะด้วยเครื่อง ICP-MS ผลการศึกษาพบว่า ความเข้มข้นของโลหะหนักใน PM_{10} ที่ผู้คัดแยกขยะอิเล็กทรอนิกส์ได้รับสัมผัสสูงกว่ากลุ่มที่ไม่ได้ประกอบอาชีพคัดแยกขยะอิเล็กทรอนิกส์ (กลุ่มควบคุม) โดยเฉพาะอย่างยิ่งค่าความเข้มข้นเฉลี่ยของทองแดงและตะกั่วใน PM_{10} ของผู้คัดแยกขยะอิเล็กทรอนิกส์ (0.37±0.29 และ 0.37±0.22 ไมโครกรัม/ลูกบาศก์เมตร) สูงกว่ากลุ่มควบคุม (0.20±0.17 และ 0.22±0.11 ไมโครกรัม/ลูกบาศก์เมตร) อย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95 % ค่าเฉลี่ยของแคดเมียมและตะกั่วในปัสสาวะของกลุ่มผู้คัดแยกขยะอิเล็กทรอนิกส์ มีค่าเท่ากับ 0.90±0.47 และ 8.19±6.13 ไมโครกรัมต่อกรัมครีเอตินิน ตามลำดับ ซึ่งพบสูงกว่ากลุ่มควบคุมที่ตรวจวัดได้ 0.72±0.53 และ 4.38±3.32 ไมโครกรัมต่อกรัมครีเอตินิน ตามลำดับ อย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95 % ปริมาณของตะกั่วในปัสสาวะที่ตรวจวัดจากทั้งสองกลุ่มตัวอย่างมีความสัมพันธ์เชิงบวกกับความเข้มข้นของตะกั่วใน PM_{10} ที่รับสัมผัสผ่านทางการหายใจอย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95% ผลการประเมินความเสี่ยงของสารที่ไม่ใช่สารก่อมะเร็งพบว่า ค่า 95% CI ของ HQ ของกลุ่มผู้คัดแยกขยะอิเล็กทรอนิกส์ที่รับสัมผัสสารหนู โครเมียม และแมงกานีส มีค่า16.7-28.6, 3.4-5.3, และ 4.2-5.5 และกลุ่มควบคุมเป็น 12.6-18.5, 1.8-3.8 และ 2.81-4.4 ตามลำดับ ซึ่งสูงกว่าค่าความเสี่ยงที่ยอมรับได้ (HQ >1) สำหรับค่า 95% CI ของความเสี่ยงในการก่อเกิดมะเร็ง (LCR) ตลอดอายุขัย 70ปี ของประชากรทั้งสองกลุ่มเป้าหมายพบว่า การรับสัมผัสแคดเมียม โครเมียม และนิกเกิลในพื้นที่ศึกษานี้เกินเกณฑ์ที่ยอมรับได้ (10^{-6}) โดยมีค่า LCR ของกลุ่มผู้คัดแยกขยะอิเล็กทรอนิกส์เป็น $8.61\text{-}11.9\times10^{-6}$ $1.45\text{-}2.48\times10^{-3}$, $4.20\text{-}6.39\times10^{-6}$ และสำหรับกลุ่มควบคุมมีค่า $4.62\text{-}8.80\times10^{-6}$, $0.84\text{-}1.80\times10^{-3}$, $3.22\text{-}6.62\times10^{-6}$ ตามลำดับ

สาขาวิชา	การจัดการสารอันตรายและสิ่งแวดล้อม	ลายมือชื่อนิสิต .....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....
		ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

6087582020 : MAJOR HAZARDOUS SUBSTANCE AND ENVIRONMENTAL MANAGEMENT
KEYWOR D: Heavy metals, E-waste, Biomarkers, Thailand

Panvarong Wongsabsakul : Inhalation exposure and urinary level of heavy metals of electronic waste dismantling workers in Buriram, Thailand.. Advisor: Asst.Prof.Dr. TASSANEE CHETWITTAYACHAN Co-advisor: Dr. Pokkate Wongsasuluk

The main objective of this study was to assess the health risk of electronic waste dismantling workers exposed to heavy metal (As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn) in PM_{10} using urinary heavy metals as a biomarker. The levels of heavy metals in the urine of non- and e-waste dismantling workers in consequence of the exposure to heavy metals in PM_{10} were investigated at Daengyai sub-district, Banmaichaiyapot district, and Banpao sub-district, Phutthaisong district, Buriram province, from February to March 2019. A face-to-face interview using a questionnaire was carried out to get additional information from the target participants. The heavy metals in PM_{10} and urine were analyzed by ICP-MS. The result showed that the mean concentration of heavy metals in PM_{10} of e-waste dismantling workers (exposure group) was significant higher than that of non-e-waste dismantling workers (control group) at $p < 0.05$, especially the concentrations of Cu (0.37±0.29 μg/m^3) and Pb (0.37±0.22 μg/m^3)for the exposure group were higher than those of the control groups, i.e. 0.20±0.17 and 0.22±0.11 μg/m^3, respectively. The mean concentration of Cd and Pb in the urine of the exposure group (0.90±0.47 and 8.19±6.13 μg/g creatinine) were higher than the control groups (0.72±0.53 and 4.38±3.32 μg/g creatinine, respectively) at $p < 0.05$. The amount of Pb in the urine of both target groups was positive significantly correlated to its concentration in PM_{10} ($p < 0.05$). The health risk assessment of non-carcinogenic substances found that 95% CI of HQ of the e-waste dismantling worker exposed to As, Cr, and Mn were 16.7-28.6, 3.4-5.3 and 4.2-5.5, respectively, and those of the control group were 12.6-18.5, 1.8-3.8 and 2.81-4.4 respectively, which were higher than the acceptable risk (HQ >1). For the 95% CI of lifetime cancer risk (LCR) over the life expectancy of 70 years of both groups, the LCR of exposure to Cd, Cr and Ni in this study area was found to exceed an acceptable criteria (10^{-6}), the LCRs of the e-waste dismantling workers were 8.61 - 11. 9 × 10^{-6}, 1.45-2.48 × 10^{-3}, and 4.20-6.39 × 10^{-6}, and those for the control group were the values of 4.62-8.80 × 10^{-6}, 0.84-1.80 × 10^{-3}, and 3.22-6.62 × 10^{-6}, respectively.

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

ACKNOWLEDGEMENTS

I would like to thank my thesis advisors Assistant Professor Tassanee Prueksasit, Ph.D. Department of Environmental Science and Dr. Pokkate Wongsasuluk, Ph.D. College of Public Health Sciences at Chulalongkorn University. The door to my advisor's office was always open whenever I ran into a trouble spot or had a question about my research or writing. They steered me in the right direction whenever they thought I needed it. Thanks for your valuable support in the lab during my experiments.

Besides my advisors, I would like to thank the rest of my thesis committee: Assistant Professor Chantra Tongcumpou, Assistant Professor Penradee Chanpiwat, Assistant Professor Pensri Watchalayan, for their encouragement, insightful comments, and hard questions.

I would also like to thank the participants who joined the research project in the Daengyai sub-district in Banmaichaiyapot district and Banpao sub-district in the Phutthaisong district, Buriram province, Thailand.

This research was mainly supported by The Research Program of Municipal Solid Waste and Hazardous Waste Management, Center of Excellence on Hazardous Substance Management (HSM), The S&T Postgraduate Education and Research Development Office (PERDO), and The Office of Higher Education Commission (OHEC). Moreover, my research was partially supported by the Center of Excellence on Hazardous Substance Management (HSM) and the International Postgraduate Programs in Environmental Management, Graduate School, Chulalongkorn University.

Panvarong Wongsabsakul

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

List of figures

Page

CHAPTER I
INTRODUCTION

1.1 Background and problem addressed

At present, the amount of e-waste has been generating and increasing because of the improvement of new technologies in the electronic equipment industry (Ballatori et al., 2012; Pookkasorn & Sharp, 2016). When new electronic equipment reaches the market, the old electronics will have dumped. These discarded electronic and electronics are non-working and reached the end of their useful life was called "Electronic waste or E-waste" (Vassanadumrongdee, 2015). Due to the increasing consumption and short lifespan of electronic material cause the electronic waste problem. E-waste has become an emerging global environmental issue because it is increasing 2 to 5 million tons of e-waste is generated around the world every year (Balde et al., 2015; UNEP, 2005).

In Thailand, e-waste has increased dramatically in recent years. Pollution Control Department (PCD) reported the amount of electronic waste generated in 2017 is 618,749 tons. Due to a large amount of electronic waste and no suitable disposal methods, this has led to the career of electronic waste separation such as cutting, chipping, split, and smash. Electronic waste workers dismantle the scrap in electronic equipment to recover precious components such as gold, copper, silver, aluminum, iron, and brass for sale (Yu et al., 2017). In some places, the livelihood of many villagers depends on the income generated from these activities. However, an inappropriate e-waste dismantling as mentioned is able to direct impact on workers' health (Prakash et al., 2010), because these activities can cause severe pollution of highly toxic heavy metals *(*Deng et al., *2007*; Gullett et al., *2007*; Qingbin Song, *2014*; Wei & Liu, *2012)*. In addition, after their usage time, they become a complex waste which consists of many hazardous heavy metals such as antimony, arsenic, beryllium, cadmium, chromium, cobalt, indium, lead, mercury, nickel, copper and zinc (Azuka & J., 2009; Ceballos & Dong, 2016; Deng et al., 2007; Gullett et al., 2007; Julander et al., 2014; Kiddee et al., 2013; Lim & Schoenung, 2010; Robinson, 2009).

Dismantling or separating e-waste by hand or torn for LCD and CRT monitor will release heavy metals including Cr, Pb, and Mn into the atmosphere (Fang et al., 2013; Srithawirat et al., 2016; J. Zheng et al., 2013). In addition, other studies found the concentration of heavy metals (Pb, Cd, Cu, Zn, Cr and Ni) in respirable dust (PM_{10}) around e-waste dismantling site (Gangwar et al., 2016; Guo et al., 2010; Oguri et al., 2018; R. B. Singh et al., 2015). Consequently, the worker can expose to heavy metals in dust through inhalation exposure during their work. Although, heavy metals being only a small fraction of the total mass in PM_{10}, they have been of concern due to their adverse health effects (Kolias et al., 2014). PM_{10} can produce damage to the respiratory system since it can be absorbed into human lung tissues during breathing (Finlayson-Pitts & Pitts Jr, 1999; Pereira et al., 2007)They are the carrier of metals into the lung structure and these metals may release free radicals in lung fluid via the Fenton reaction. (INTECH, 2015; Pereira et al., 2007). The metals can lead to acute and chronic toxicological effects, such as damage to central and peripheral nervous systems, blood composition, lungs, kidneys, liver, and death (Leung et al., 2008; R. B. Singh et al., 2015; Tchounwou et al., 2012).

Several studies have investigated heavy metals from e-waste recycling in China; they reported the soaring levels of toxic heavy metals in e-waste sites. Heavy metals can accumulate in the body. Also, some metals are human carcinogens caused by inhalation of contaminated fumes and dust (Chan et al., 2007; Roberts et al., 2009; Xing et al., 2009; L. Zheng et al., 2008). Heavy metals in urine were used to find a relationship between inhalation exposure to heavy metals and their potential effects on the body as a biomarker representing daily excretion. Many studies used urine as a biomarker that has been used to investigate the level of heavy metals in human (Bureau, 2008; Nathalie, 2012; Saravanabhavan et al., 2017; Wongsasuluk et al., 2018). The level of urinary heavy metals could be associated with the level of heavy metals in air and shown evidence of the risk of inhaling heavy metals contaminated in the air (Julander et al., 2014)It is an important indicator of health risk analysis (Wang et al., 2011). However, there are a few studies that evaluate the relationship between heavy metals in the air and those in the urine.

According to a variety of heavy metals have been detected in the e-waste dismantling site in Northeast Thailand, Buriram province. Possible that the heavy metals from the e-waste dismantling or separating process can be attached to particulate matters (PM_{10}) resulting in increasing heavy metals concentration in air. In addition, this dust will cause health risks to workers in this site and cause some effects on their health. Moreover, most e-wastes often contain dust particles embedded within their various components and as a cause of health risks when dismantled and separated in stores without proper disposal. However, heavy metals are bio-accumulating in the human body and cause serious health effects with varied symptoms depending on the metals dose and associated factor. This study aims to investigate heavy metals in the urine of workers in consequence of the exposure to heavy metals in PM_{10} at Daengyai subdistrict, Banmaichaiyapot district and Banpao subdistrict, Phutthaisong district, Buriram province, and their associated factors.

1.2 Research Question

The research questions for this study are:

1. How much heavy metals concentration in urine and dust of electronic waste dismantling workers?
2. Are the heavy metals concentration in electronic waste dismantling workers and non-electronic waste dismantling workers difference?
3. What associated factors are relevant?
4. Is there a health risk in electronic waste dismantling workers?

1.3 Research Objective

This research consisted of two major objectives, which could be divided into the main objective and sub-objectives as follows.

The main objective is to assess the health risk of electronic waste dismantling workers exposed to heavy metal in the dust using urinary heavy metals as a biomarker.

Sub-Objectives:

1. To measures exposure concentration of heavy metals in dust and heavy metals in the urine of electronic waste dismantling workers.
2. To compare heavy metals concentration in urine between electronic waste dismantling workers and non-electronic waste dismantling workers.
3. To investigate associate factors related with heavy metals in urine of electronic waste dismantling workers.

1.4 Research Hypothesis

1. The concentration of heavy metals in urine would be significantly correlated with heavy metals in dust from electronic waste dismantling.
2. Electronic waste dismantling workers would have higher risks of exposure to heavy metals in dust than non-electronic waste dismantling workers.
3. The concentration of heavy metals in the urine of electronic waste dismantling workers would be higher than non-electronic waste dismantling workers.
4. There would have some factors related to the concentration of heavy metals in the urine of electronic waste dismantling workers.

1.5 Scope of the study

1.5.1 Study Areas

1. The sampling and questionnaire collected area was conducted at the e-waste dismantling site in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district, Buriram province, Thailand. At present, there is a risk of heavy metal arising from electronic waste dismantling in this area. The danger of heavy metals affects dismantling worker's health.

2. The laboratory experiment was conducted at the laboratory of the Department of Environmental Science, and Environmental Science Graduate school, Chulalongkorn University.

1.5.2 Population and the target sample

In this study, the populations in Dangyai and Banpao sub-district, there are 9 big villages with 1,091 households in Banpao sub-district including electronic waste dismantling workers 68 households. In Dangyai sub-district has 12 villages with 1,315 households including electronic waste dismantling workers 105 households. Both villages include total electronic waste dismantling workers 173 households. The target samples total of 130 participants were divided into 2 groups include 100 of the exposure group and 30 of the non-exposure group. Urine and PM_{10} samples were collected from January 2018 to February 2018. A sample must be randomly collected to represent the entire population in area.

1.5.3 Sampling Technique

1. The urine and PM_{10} samples were collected at electronic waste and non-electronic waste dismantling houses in Dangyai and Banpao district, Buriram province.
2. The urine sample was collected by using a glass bottle and the PM_{10} sample will be collected by using a personal air sampler (Gillian Brand, GilAir-5 version).
3. Personal information was collected using a questionnaire with a face-to-face interview technique.

1.5.4 Analytical Technique

1. Samples preparation was performed following the guidelines of occupational safety and health administration (OSHA).
2. Air samples were extracted by using microwave digestion (Gillian Brand, GilAir-5 version) and the concentration of heavy metals (As,

Cd, Cr, Cu, Pb, Ni, Mn, and Zn) in air sample were analyzed by Inductively coupled plasma optical emission spectrometry (ICP-MS).

3. Urine samples were extracted by using microwave digestion and the concentration of heavy metals in urine (As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn) were analyzed by Inductively coupled plasma mass spectrometry (ICP-MS).

1.5.5 Data Analysis

1. The worker's health risk was calculated by the equation of human health risk assessment.
2. The SPSS Statistics 22.0 program was used for statistical analysis of the data including Kolmogorov-Smirnov tests, Mann-Whitney U tests, Spearman correlation tests, and Chi-square tests.

1.6 Operational Definition

Electronic waste (E-waste)

The disposal of broken or obsolete electronic components and materials. E-waste materials may be valuable and recyclable such as TV screen, fans, refrigerator, washing machine, computer, and printer.

Heavy metals

The heavy metals in this study were defined as Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), lead (Pb), Nickel (Ni), Manganese (Mn), and zinc (Zn).

Biomarkers

The biomarker in this study is heavy metals in the urine of the workers including the concentration of As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn.

Exposure group

People who separate electronic waste workers in Dangyai Sub-district, Banmaichaiyapot district, and Banpao Sub-district, Phutthaisong district, Burirum Province.

Non-exposure group

People who do not separate electronic waste workers in Dangyai Subdistrict, Banmaichaiyapot district, and Ban Pao Subdistrict, Phutthaisong district, Burirum Province.

Independent Variables

In this study, independent variables were defined as 4 groups of factors: (1) Socio-demographic factor; gender, body weight, age, height, BMI, occupation, (2) Exposure factors; Duration work hours, E-waste burning, and PPE using, and (3) Personals factors; Smoking, Members of the house who smoke, Eating seafood, and Drinking alcohol.

Dependent Variables

In this study, dependent variables were defined as the heavy metal concentrations in urine.

Participants

The participants in this study were randomly selected from the group of local volunteers who permanently live in the study site, under inclusion and exclusion criteria.

Personal Protective Equipment (PPE)

Personal protective equipment included gloves, a mask, boots, and eye glass to protect the human body and decrease risk or exposure doses.

Personal Protective Equipment Using (PPE using)

Use of personal protective equipment (PPE) at work sites, which is equipment that will protect the user against health or safety risks at work such as gloves and mask.

1.7 Research Expected Outcomes

1. To obtain the data of heavy metals concentration in urine of electronic waste workers and heavy metals in PM_{10} from the e-waste dismantling processing area.

2. To know important associate factors related to heavy metals in urine of electronic waste workers.

3. To recommend the workers to have better protection from exposure to heavy metals during their working period from the evidence of heavy metals accumulation in the human body.

CHAPTER II
LITERATURE REVIEWS

2.1 Electronic waste (E-waste)

Electronic waste is defined as electronic products that have become unwanted, non-working and have essentially reached the end of their useful life (Vassanadumrongdee, 2015). Because technology advances at such a high rate, many electronic devices become trash after a few short years of use. E-waste is created from anything electronic: computers, TVs, monitors, cell phones, refrigerators, CD players, rice cookers, printers, etc. Most electronics that are improperly thrown away contain some form of hazardous substances such as cadmium, mercury, and lead (Needhidasan et al., 2014). These materials might be trace elements, but when added up in the environment. Electronic scrap components, such as CPUs, circuit boards, and cathode-ray tubes, contain potentially harmful components such as lead, and cadmium. At present, disposal and separation of e-waste is a concern because heavy metals in e-waste affect the health of the e-waste worker (Riyad et al., 2014 ; Sivaramanan, 2013)

2.1.1 Heavy metals in electronics waste

E-waste dismantling such as separating e-waste by hand or torn apart of the e-waste component could release contaminated dust into the air. These hazardous substances cause serious pollution and put laborers in danger when the items are produced and thrown out. The concern is the exposure of kids and pregnant ladies to lead and cadmium. These metals are poisonous that harm youngsters and developing fetuses even at low degrees. Electronic devices are a complex mixture of several hundred materials. Many of these contain toxic heavy metals such as Cadmium (Cd), Chromium (Cr), Copper (Cu), Arsenic (As), Nickel (Ni), Manganese (Mn) lead (Pb), and zinc (Zn) (Gu et al., 2010; Robinson, 2009). Many studies have studied heavy metals concentration in electronics waste from electronic waste dismantling sites.

Lead (Pb)

Lead was used in electronics products including metallic lead is used in electrical solder primarily on printed circuit boards. Lead oxide is used in the cathode ray tubes (CRTs) in monitors. CRTs contain about 1 kg of lead (Restrepo et al., 2016). They also contain small amounts of other toxic metals including cadmium (Cd), chromium (Cr), copper (Cu), and zinc (Zn) (Lee and His, 2002; Robinson, 2009; Wassanadamrongdee, 2015). One disadvantage of using lead is its high toxicity (Cann, 2005). In the general non-smoking adult population, the major exposure pathway is from water, air and food. airborne particles lead may encourage significantly to occupational exposure and exposure of smokers. In adult, approximately 10% of the dietary lead is absorbed, but children as much as 50% of dietary lead is absorbed. The human can accumulate lead from exposure to lead dust and fumes. The critical effects of lead from inhaled including damage to the nervous system, blood system, kidneys and reproductive system (Canfield et al., 2003). Absorbed lead is rapidly taken up into blood, tissue, slower distribute to bone, and finally, it was excreted into the urine. In addition, it can result in a wide range of biological effects depending on the level and duration of exposure. Their effects have ranged from inhibition of enzymes to the production of morphological changes and death. (WHO, 2019)

Cadmium (Cd)

Cadmium is compared to other heavy metals, relatively water-soluble. They tend to accumulate in the soil (World Health Organization, 2010). Cadmium is utilized in switches and numerous notebook computers that used nickel-cadmium (Ni-Cd) batteries. CdS has also been used in an older cathode ray tube as a phosphor coating, a material used on the interior surface of the screen to produce light (OECD 2003; Robinson, 2009; Vasanadamrongdee, 2015). This metals exposure can occur occupationally through inhalation of dust containing cadmium or its compounds. Cadmium is a cumulative toxicant when breath in the cadmium oxide dust can affect the respiratory system and long-term exposure can damage the kidney and bone toxicity. The accumulation of cadmium in the kidney (in the renal cortex) leads to dysfunction of the kidney with impaired reabsorption of, for example, proteins,

glucose, and amino acids. They found smoking 1% of all Sweden women with low iron concentration in the body may have adverse kidney effects due to the cadmium load. It causes high blood pressure in the body, heart disease and cancer (Elinder and Jarup, 1996; WHO 1992; Hellstrom et al, 2001; DHSS, 2002).

Chromium (Cr)

Chromium has many uses in electronics including compounds in rechargeable batteries and some switches. Mostly in the form of Hexavalent chromium, it can soluble in water than other forms of chromium. So, making it more mobile in the environment (Mukherjee, 2006; Robinson, 2009; Wassanadamrongdee, 2015). It is a metal that humans require in trace amounts. It is found primarily in two forms: Trivalent (Cr III), which is biologically active and found in food and hexavalent (Cr VI), a toxic form that results from industrial pollution. Mostly, we found chromium in the form of chromium VI because other forms of chromium can be trace nutrients for humans, but Cr VI is highly toxic can damage the kidney and liver. Dermal exposure of the public to Cr can occur from contact with products containing chromium. Mostly, occupational exposure to airborne Cr VI causes lung cancer in the worker (ATSDR, 2000; IARC, 1990). In addition, other studies have been found that chromium produces significantly increases in enzyme activity and serves an important function in carbohydrate metabolism, stimulation of fatty acid and cholesterol synthesis from acetate in the liver, and improved sugar metabolism through the activation of insulin (Anderson, 1997). Furthermore, it has been reported that chromium deficiency may be the reason for an increase in hematological parameters such as hemoglobin, hematocrit, erythrocytes, leukocytes, and mean erythrocyte volume. (Agustin et al., 2012).

Copper (Cu)

Copper occurs naturally in element form, and it is a component of minerals. Copper is used instead of aluminum in computer chips because copper's superior electrical conductivity can enable conductor channel lengths and widths to be reduced. The result is much faster operating speeds, and greater circuit integration

300-400 million transistors can be packed onto a single chip. (COWI, 2002; Robinson, 2009; Vasanadamrongdee, 2015). Cu is a basic component found in plants and animals. The human body only contains about 150 mg of this vital mineral. The established recommended dietary allowance for Cu in normal healthy adults is 2 mg/day (National Research Council, Food Nutrition Board, 1980). Cu is distributed to other tissues and transported into the liver that related to the protein ceruloplasmin, which carries the majority of Cu in blood. Ceruloplasmin also carries Cu that is excreted in milk and is particularly well absorbed as a Cu source (Hellman and Gitlin, 2002; O'Brien and Bruce, 2009). When humans exposed to copper dust may cause a symptom, for example, cough and muscle ache. In addition, it has an impact on the body system such as drowsiness and gastrointestinal disturbances (USAF, 1990).

Zinc (Zn)

Zinc is used primarily in galvanized metals and metal alloys; they are also used for making batteries and electronics include CRT screens, plasma screens, circuit boards, CD players, and hard disks. (Lloyd, 1984: ATSDR, 1989; Robinson, 2009). Zinc in electronic waste is usually in the form of Zinc sulfide (ZnS) used in monitor glass. Exposure to zinc from dismantling of computer monitors and inhalation of zinc smoke generally caused by recycling processes affecting dismantling workers health. When the worker exposed to zinc, it causes a symptom of this reversible syndrome generally begin a few hours after acute exposure include fever, muscle soreness, nausea, fatigue, nausea, hair loss, mental apathy, reproductive, growth disorders, and respiratory effects like chest pain, cough, and dyspnea (Environmental research and public health, 2010).

Arsenic (As)

The toxic of inorganic arsenic depends on its valence, trivalent arsenic (As^{+3}) compounds are generally more toxic than pentavalent arsenic (As^{+5}) compounds. Trivalent arsenic is more likely to cause chronic pulmonary effects when inhaled. Arsenic can be found in circuit boards, semiconductors, LCD displays, and computer chips. When these items are sent to landfills, arsenic can leach into the soils and the

groundwater. When arsenic is burned in the burning site, it can enter the atmosphere. Workers close to site or nearby areas can also be exposed to arsenic, which can lead to severe skin problems. The symptoms from lead exposure include abdominal pain, convulsion, hypertension, renal dysfunction, loss of appetite, and sleeplessness (Brigden et al., 2005; United States Geological Survey, 2015; Robinson, 2009; Vasanadamrongdee, 2015).

Table 1 Source of heavy metals from e-waste

Metals	E-waste source	Equipment
Cadmium	Computer, Laptop, and Monitors	Computer chips Switch laptop Circuit board
Chromium	Computer, Floppy disks, and Monitors	LCD screens CTR screens Circuit board
Copper	Computer, Laptop, Fan, and Wiring	Computer chips Switch laptop Circuit board Fan motors
Lead	Batteries, Keyboards and Monitors	Printed circuit boards Printed wiring boards LCD screens CTR screens
Zinc	Computer, Batteries, CD player, and Monitors	CTR screens Plasma screens Hard disks
Arsenic	Keyboards and Monitors	Printed circuit boards Printed wiring boards LCD screens CTR screens Plasma screens
Nickel	Batteries, CD player, Computer, and Monitors	Floppy disks Hard disks LCD screens Plasma screens Circuit boards.
Manganese	Batteries	-

Source: Robinson (2009), Perkins et al. (2014), Wassanadamrongdee (2015)

Table 2 Human health effects from heavy metals

Heavy metals	Human health effects
Cadmium	Fragile bone, alopecia, anemia, migraines, growth impairment, and cardiovascular disease (chronic effect).
Chromium	Gastroenteritis, hematemesis, hepatic necrosis, renal failure (acute effect).
Copper	Nausea, vomit, diarrhea, liver damage, and kidney damage (chronic effect).
Lead	Mood swings, nausea, seizures, and body weights (chronic effect).
Zinc	Stomach cramps, nausea, vomit (acute effect), anemia (chronic effect).
Arsenic	Hyperpigmentation, keratosis, and possible vascular complication (chronic effect).
Nickel	Decreased body and organ weights (chronic effect).
Manganese	the inflammatory response in the lung (acute effect), Weakness and lethargy (chronic effect).

Source: Brigden et al. (2005), Wongsasuluk (2016)

2.1.2 Heavy metals in respirable dust (PM_{10}) in e-waste dismantling sites

Particulate Matter (PM) is the sum of all solid and liquid particles suspended in air, many of which are hazardous. It can be characterized by the origins of these

components, or by their particle sizes. Total suspended particles (TSP) include particles of any size suspended in the air. EPA is concerned about particles that are 10 μm in diameter or smaller because they can pass through the throat and nose and enter the lungs. The respirable fraction of particulate matter is composed of the very fine dust which can reach the lower bronchioles and alveolar regions of the lung. This PM has been implicated to have the potential to carry a high loading of contaminated species such as heavy metals (Ahmed and Ishiya, 2006). PM_{10} are particles with an aerodynamic diameter of less than 10. When inhaled, some PM can cause violent damage to the lungs and other organs (Wilson et al., 2004). The large particles can be stored in upper aviation routes through sedimentation or impaction and infiltrated into the alveolar area of the lung, includes the respiratory bronchioles, the alveolar ducts and sacs (Andrea Geiger and John Cooper, 2010). Smaller particle size can spread to the lower respiratory tract and translocate to blood circulating and be deposited in the liver and spleen (Falcon-Rodriguez et al., 2016) as shown in Figure 1 and Figure 2

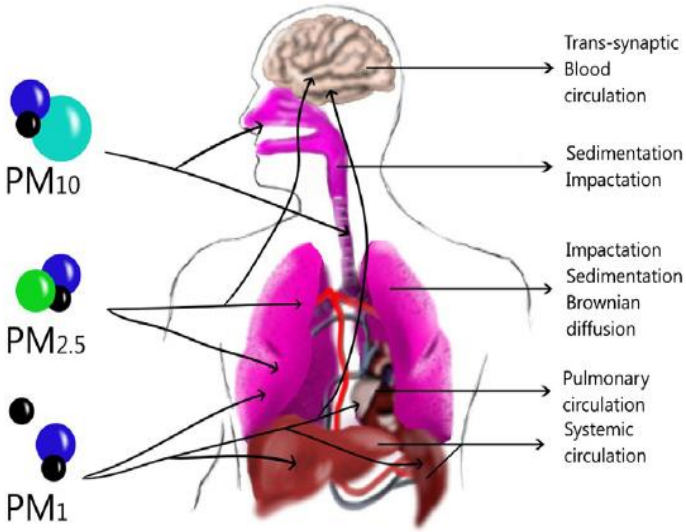


Figure 1 Size and dynamics of particles in the lung and other tissues
(Source: Carlos et al., 2016)

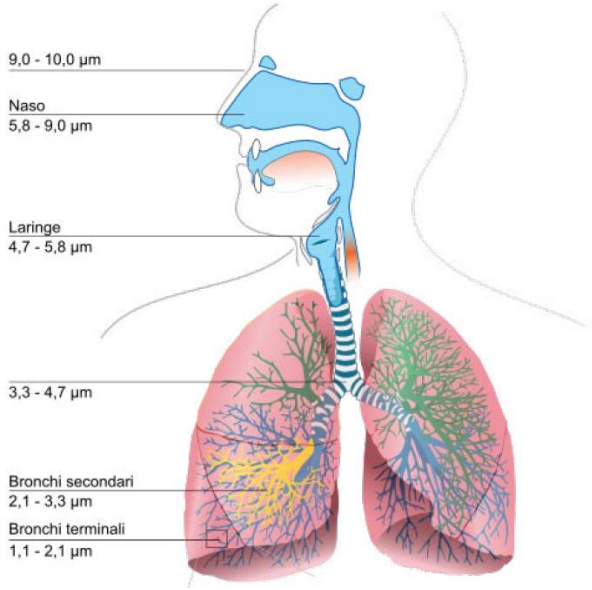


Figure 2 Particulate size with associated depth of lung deposition
(Source: Geiger & Cooper, 2010)

The metals, especially ionic forms of metals will be most bioavailable, and therefore, it is very likely to affect cells and organs. Several studies have evaluated the

relative importance of bioavailable metal to that of the mass dose of PM. They reported that the lung dose of bioavailable transition metal is determinant of the acute inflammatory response, not instilled PM mass (Costa and Dreher, 1997). Metal is good conductor electricity and heat. At high concentrations, it can have harmful effects on human health especially transition metals such as iron, nickel, chromium, copper, and zinc). Iron release from PM in the air or other redox metals can stimulate the generation of hydroxyl radicals (HO•) by Fenton reactions, causing extensive oxidative damage to cellular macromolecules. Its toxicity based on its ability to support electron exchange and generate reactive oxygen species (ROS) in biological tissue (Ghio et al., 2002; Chen and Lippmann 2009). The toxic hydroxyl radicals are carcinogenic and damage to the lungs (Knaapen et al., 2004). Scientific evidence proves that several metals play different roles in the emergence of PM biological effects. In order to protect or reduce harmful effects of metals, The Directive of the European Parliament establishes annual target values for the concentration of metals, include Arsenic (6 ng/m^3), Cadmium (5 ng/m^3) and lead (500 ng/m^3) in ambient air (PM_{10}) (Tchounwou, 2012).

The activities of e-waste such as dismantling create fine particulates matter, which is linked to pulmonary and cardiovascular disease (McAllister, 2013). The PM_{10} is usually used as the monitoring parameter of air quality. Some of the major sources that emit heavy metals such as, As, Cr, Cd, Cu, Pb, Ni, Mn and Zn into ambient air and its surroundings are domestic, e-waste combustion, e-waste dismantling, transportation or mobile emission and industrial processes (Zheng et al., 2010; Van et al., 2014). Heavy metals can be bound in organic or inorganic molecules or attached to the particle in the air (AMAP, 1997). Particulate matter (PM) released into the ambiance of each dismantling line during these physical processes, which can go through the alveolus and arrive at parts of the body by the blood circulatory system, and the quantity of small particle matter constitutes 96% of all particles were absorbed and deposited in the lung parenchyma. Furthermore, heavy metals (Cu, Cr, Cd, As, Ni, Mn Zn, and Pb) with a high concentration will be adhered on the particles, which will cause various health problems to the workers in the workshops and

factory. Heavy metals have attached to PM_{10} from the e-waste dismantling process as shown in Figure 3

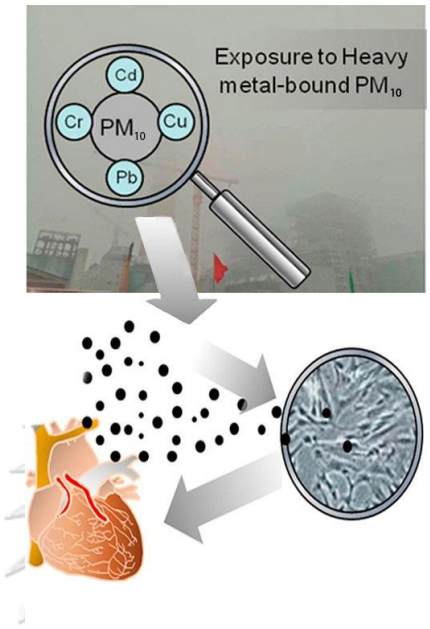


Figure 3 Heavy metals bound to fine particulate matter from e-waste recycling process
(Source: Adapted from Wenxiong et al., 2013; Yingying et al., 2016)

There are many studies that have investigated and discussed heavy metals in particulate matter from e-waste dismantling sites. They investigated the concentrations of antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), indium (In), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), platinum (Pt), thallium(Tl), tungsten (W), vanadium (V) and zinc (Zn) (Julander et al., 2014; Leung et al., 2006). These metals can bind to particles of dust and accumulate in dismantling workers via inhalation exposure. Heavy metals concentration in the air at dismantling sites from previous studies as shown in Table 3 and heavy metals concentration in PM_{10} samples in comparison of each country in the world as shown in Table 3

Table 3 Heavy metals content in air (mg/m^3) at dismantling sites

Country of dismantling sites	As	Cd	Cr	Cu	Pb	Ni	Mn	Zn	Reference
Chandigarh and Ludhiana, Punjab, India	0.019	0.004	0.131	1.564	0.019	0.089	-	2.044	Singh et al., 2018
Moradabad, India	-	0.388	0.439	0.051	0.139	0.809	0.239	0.134	Gangwar et al., 2016
Lagos, Nigeria	-	0.0018	0.0001	-	0.0159	-	-	0.213	Adaramodu et al., 2012
Shanghai, China	-	0.398	0.436	31.80	2.043	0.459	-	-	Fang et al., 2013
South China	-	0.120	-	15.028	4.489	0.294	-	4.764	Zheng et al., 2013
Eastern China	-	0.056	1.350	7.880	0.350	0.20	-	2.060	Zhou et al., 2014
Sweden	0.042	0.180	0.450	2.20	7.0	0.49	2.20	14.0	Julander et al., 2014
Buriram, Thailand	0.859	0.070	0.646	0.509	0.521	0.225	0.114	24.197	Junhong and Gunghae, 2017

2.2 Biomarkers

A biomarker (biological marker) is the body's molecules that can be used as an indicator of normal biological processes or pharmacological responses to a therapeutic intervention (Strimbu & Tavel, 2010). Blood and urine have been used as biological monitoring for occupational exposures of various pollutants, and hazardous substances. The World Health Organization (WHO) defined a biomarker as the substance, structure, or process that can be measured in the body or predict disease (Strimbu and Tavel, 2010). In addition, it is measures used to assess chronic human exposure to toxic and non-toxic metals. Many studies used biomarkers to investigate the level of toxic metals in humans. They studied the correlation between symptoms and the level of toxic metals excreted in the urine and blood (Adams J., 2017). Some studies used alone or in combination to assess the health or disease state of an individual (PRB, 2008; Marcin et al., 2011). This study used urine to monitor and predict health states in people. The major objective of this paper is to examine the levels of urinary heavy metals in a population exposed to heavy metals in the e-waste dismantling site, Buriram province.

2.2.1 Urine

Urine is a very popular human fluid for biomarker analysis because it can be collected in large volumes. Urine has been used as an indicator of current exposure because it is the main route of excretion produced by the kidneys. Urine consists of cell elements, biochemicals, and proteins obtained from glomerular filtration of plasma, renal tubule excretion, and urogenital tract excretion. (Nathalie et al., 2012). The urinary system is removing waste, urea, extra salt, and water that end up in the blood (Wongsasuluk et al., 2018). From the kidneys, urine flows through tubes called ureters, and into the bladder as shown in Figure 2.4

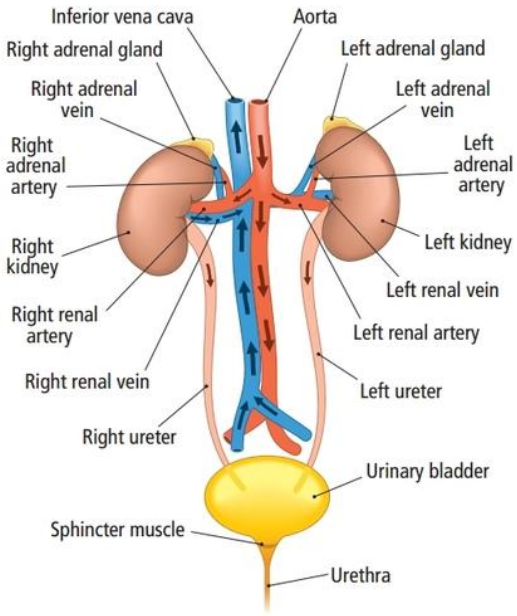


Figure 4 Urinary system
(Source: leavingcertbiology, 2018 [online])

Urine is a biomarker that has been frequently used in health research, for example, health effects from heavy metal exposure. About 90% - 95% of all intake heavy metals accumulated in the blood, and 75% - 80% is excreted via urine . The heavy metals level in urine has regularly been used as an indicator of current exposure because urine is a biomarker representing daily excretion of heavy metals, but total heavy metal analysis may also get interference from some food such as seafood (Nathalie et al., 2012). Several studies used urine as a biomarker representing daily excretion of Cd, Cr, Mn, Ni, and Pb, As and Hg (Gil et al., 2011; Li et al., 2011; Nathalie et al., 2012). Moreover, Many research about dismantling sites have discovered urine tests from e-waste workers in recycling sites likewise demonstrated that the workers were more presented metals concentration than non-workers or office workers (Julander et al., 2014).

Advantages of using urine as biomarkers

Using urine as biomarkers can be considered reliable indicators. Its advantages are as follows:

1. Urine as a biomarker that can be easily collected and large volume.

2. Urine levels can represent daily excretion of doses of many heavy metals.
3. Urine testing is the most common screening method and reliable.
4. Urine testing is easily reproducible and can be performed daily as a baseline measurement, and it can diagnose many varieties of conditions.

Urine samples were digested with certified metal-free acids involving closed vessel microwave digestion. For sample dilution, ultrapure water was used. Testing was performed via Inductively coupled plasma mass spectrometry (ICP-MS). The result of urine measuring for metal analysis was validated through the QA/QC using a certified standard. To avoid the potentially great margin of error that can result from the fluid intake and sample volume, the results were reported in µg/g creatinine for all elements, except calcium, magnesium and zinc. For these element values were reported in mg/g creatinine (Harpole et al., 2016).

The International Continence Society (ICS) defined urinary incontinence (UI) is any complaint of urine loss, regardless of the degree of social. UI affects 57% of women aged between 20 and 89 years due to the lower length of the urethra, the anatomy of the pelvic floor, pregnancy, and delivery. In general, the importance of risk factors for UI are related to sociodemographic aspects, diseases, and life habits, for example smoking, caffeine consumption and sedentary lifestyle (Silva et al., 2017).

2.2 Associated factors of urinary heavy metals

Risk factors for urinary heavy metals, including cigarette smoking and occupational exposure to heavy metals, seafood consumption, and genetic susceptibility, are widely recognized and discussed. However, there are many studies that are interested in these factors because they affect the results of the analysis (Asante et al., 2012).

2.2.1 Cigarette Smoking

Cigarette smoking is a major risk factor for cancer in the urothelial bladder, and more than 50% of all cancer is attributed to smoking. The IARC recognized

tobacco smoking as a carcinogen, and sufficient evidence associates it with urinary bladder cancer. In addition, The European Union announced an expanded danger of bladder cancer growth with a longer span of smoking, and a higher number of cigarettes smoked every day. However, the effect of smoking on urothelial bladder carcinogenesis remains debatable. Cigarette smoke contains a complex chemical mixture more than 4000 chemicals. The major components of cigarette smoke include nicotine, tar, carbon monoxide and environmental pollutants, such as the heavy metals As, Cd, Cr, Ni and Pb. These metals might contaminate in the soil that tobacco is grown, accumulate in the tobacco and lead to human exposure (Chang et al., 2016). Due to particle sizes are small, it can deposition in the lung tissue of passive smokers reaches deeper into the alveolar spaces (Chiba & Masironi, 1992).

The International Working Group of experts found a positive association between tobacco smoking and cancers of the lung (IARC, 1986). Adverse health impacts of ongoing cigarette smoking are understood and widely reported. (Mallampalli & Guntupalli, 2006; Bernhard et al., 2005). They reported smoking is an important source of chronic exposure to numerous xenobiotics, including heavy metals such as cadmium and lead (Chiba & Masironi, 1992; Borgerding & Klus, 2005; Bernhard et al., 2005). Cigarette smoke can be divided into two different phases, including the gaseous phases and particulate matter. Both phases are harmful, contain high concentrations of toxic and carcinogenic compounds (IARC, 1992) and are both associated with many diseases, especially cancer. The particulate matter can cause cancer of the upper aerodigestive tract by carcinogenic elements, for example, Cd, Ni, As and Cr.

The most dominant of these diverse toxic components are heavy metals (Galażyn-Sidorczuk et al., 2008). Some of these metals are essential at very low concentrations (Verma et al., 2010), but others are toxic at very low concentrations (Rubio et al., 2012). The tobacco plant prefers absorbing metals such as Pb, Cd and Zn, although it absorbs much more Cd than Pb due to the greater mobility of the latter, and preferably accumulates them in its leaves (Kazi et al., 2009; Becker, 2012; Satarug and Moore, 2012).

2.2.2 Seafood Consumption

At present, The quantity of manufacturing plants and the population has expanded quickly. The large amounts of domestic wastewater and industrial effluents are transported by rivers and discharge into the sea, and rivers. The anthropological pollution mentioned are the main sources of heavy metal contaminants in the ocean. These contaminants entering the aquatic ecosystem may not directly damage organisms. However, that can be deposited into aquatic organisms through the effects of bioconcentration, bioaccumulation and the food chain process and finally adversely affect the health of humans by seafood consumption (Van Loon, 1982).

The heavy metal contaminated seafood is becoming a global problem (Ahmed et al., 2015). The human health risk associated with the consumption of food contaminated by toxic metals has been known for a long time (Cooke et al., 1990, Gupta et al., 2008). Human organs, such as the liver, kidney, central nervous system, intestinal tract, and reproductive system may become severely damaged if sea fish is contaminated by heavy metals (Siddique et al., 2012). The characteristics of heavy metals are freely dissolved and are readily taken up by aquatic organisms such as fish. Food, water and sediment-traced metal can be accumulated by marine organisms, for example, fish, lobster, shrimp, and crabs (Yilmaz et al., 2007).

2.2.3 Alcohol drinking

The concentration of metals in alcoholic beverages can be an important factor affecting their consumption and conservation. Metals can through various sources in alcoholic beverages including raw materials, brewing, process type and equipment, bottling. The main sources of heavy metals in the production of alcoholic beverages are the bronze pot stills. In addition, the equipment in the process such as pipes, casks, and barrels are the usual source of Al, Cd, Cr, Cu, Fe, and Zn (Moutsatsou et al., 2003; Pohl, 2007). There are several research studies on metal in alcoholic beverages. They reported that wine consumption provides important amounts of nutritional requirements of several essential metals, include As, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Ni, and Zn (Ibanez et al., 2008).

2.3.4 Fertilizer using

The concentrations of Cd, Co, Cu, Ni, Pb, Zn, Fe and Mn in Inorganic fertilizer which has components consisting of urea, calcium superphosphate, copper sulfate, and pesticides are the difference. They are evaluated together with the contribution of these metals in soils from their use. The study about rice farming areas in Spain. The results showed that superphosphate is the fertilizer that contains the highest concentrations of Cd, Co, Cu and Zn. They found that copper sulfate has mostly found concentrations of Pb and they are the only fertilizers which Ni was detected (Gimeno-García et al., 1996).

2.3 Possible factors association with heavy metals in urine

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 the urine. There are examples of previous studies found the different concentration of heavy metals in difference factors groups as shown in Table 4.

Table 4 The associated factors to heavy metals in urine

Groups of factors	Factor	Biomarker	Heavy metals	Result
Socio-demographic factors	Gender	urine	As, Cr, Ni, Pb	The levels of all metals in urine samples of females were higher than males.
	Occupation	urine	Cd, Cu	The level of cd in urine samples of occupation-exposed higher than non-occupation-exposed groups.
	Age	urine	Cd	The level of Cd in urine samples of older groups was higher than the younger groups.

Exposure factors	Working time	urine	Pb	The levels of Pb in urine samples of occupation-exposed higher than non-occupation-exposed groups.
Behavior and health factors	smoking	urine	Cu, Mn, Pb, Cd, Zn	The levels of all metals in urine samples of smokers were higher than a non-smoker.
	Eating	urine	Cu, Pb	The levels of Cu, Pb in urine samples of workers who eat, and drink contaminated water were high level.
	Eating	urine	Cu	The levels of Cu in urine samples of workers who eat seafood and fish were high level.
	Wear gloves	urine	Cd	The levels of Cd in urine samples of workers who wear gloves were low level.

Source: Hongmei et al. (2011)

2.4 Health risk assessment

A human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future (EPA, 2017). Health risk assessment collects and evaluates relevant information about the potential health effects of environmental health hazards and provides us with information to make informed decisions. In this study, perform a health risk assessment of workers who may be exposed to heavy metals via inhalation in the contaminated working environment at dismantling sites. Human health risk assessment includes four basic steps as shown in Figure 5

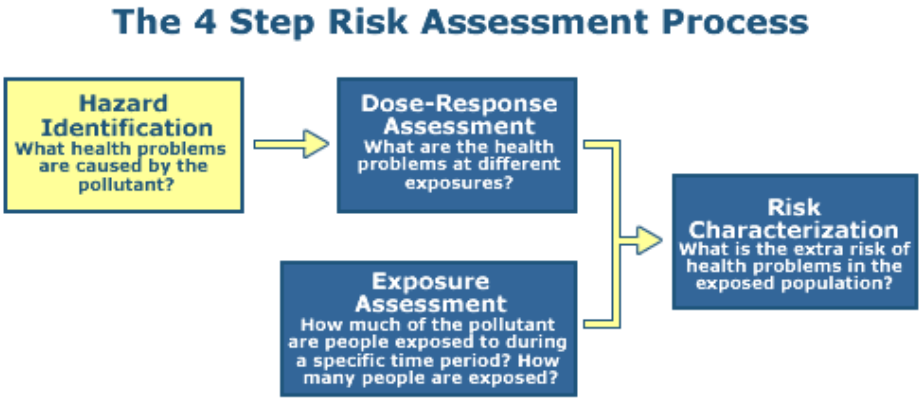


Figure 5 The four basic steps risk assessment process
(Source: United States Environmental Protection Agency [online])

Step 1 Hazard Identification

Hazard Identification is the process of determining whether exposure to a stressor can cause an increase in the incidence of specific adverse health effects (e.g., cancer, birth defects). It is also whether the adverse health effect is likely to occur in humans. In this study, the hazard of heavy metals can be identified as non-carcinogenic and carcinogenic substances depending on their critical effects.

Step 2 Dose-Response Assessment

Dose-Response Assessment is an indicator of the likelihood and severity of adverse health effects (the responses) are related to the amount and condition of exposure to an agent (the dose provided). The term "exposure-response" relationship may be used to describe either a dose-response or a concentration-response, or other specific exposure conditions. In this study, an inhalation reference concentration (RfC) and cancer slope factor (CSF) derived from a study of the relationship between the amount of heavy metal exposure and its effect was applied for calculating non-carcinogenic as shown in Table 5 and carcinogenic risk as shown in Table 6, respectively.

Table 5 Inhalation RfCs of each heavy metal (non-carcinogenic substance)

Heavy metal	Inhalation RfC (mg/m^3)	Reference
Cr (VI)	1.00×10^{-4}	IRIS EPA, 1998
Cd	7.00×10^{-4}	Buchet et al., 1990
Ni	1.50×10^{-4}	EPA, 2001a
Cu	2.00×10^{-3}	EPA, 2001a
As	1.50×10^{-5}	CALEPA
Mn	5.00×10^{-5}	IRIS, 1993

Source: Chanthahong and Kanghae (2017).

Table 6 Inhalation CSFs of each heavy metal (carcinogenic substance)

Heavy metal	Cancer slope factor $(mg/kg.day)^{-1}$	Reference
Cr (VI)	4.10×10^{1}	EPA, 1991a
Cd	1.50×10^{1}	OEHHA, 2009
Ni	9.10×10^{-1}	OEHHA, 2009
Pb	4.20×10^{-2}	OEHHA, 2009
As	4.30×10^{-3}	IRIS, 1995

Source: Chanthahong and Kanghae (2017).

Step 3 Exposure Assessment

Exposure Assessment is the process of measuring or estimating the magnitude, frequency, and duration of human exposure to an agent in the environment or estimating future exposures for an agent that has not yet been released. An exposure assessment includes some discussion of the size, nature, and types of human populations exposed to the agent, as well as discussion of the uncertainties in the above information.

In this study, routes of exposure were assessed, including dust particles (PM_{10}) inhalation. The heavy metal concentration measured from worker's exposure on the day, some exposure factors using the data either from the questionnaire and U.S. EPA handbook guideline was used to calculate the amount of exposure in one day by dividing into two terms including exposure concentration (EC) and chronic daily intake (CDI) as follows:

1) Exposure concentration (EC) was calculated for non-carcinogenic metals using the equation;

$$EC = [(C \times ET \times EF \times ED / AT)] \times CF$$

2) Chronic daily intake (CDI) was calculated for carcinogenic metals using the equation;

$$CDI = [(C \times IR \times ET \times EF \times ED) / (BW \times AT)] \times CF$$

Where,

CDI = Chronic Daily Intake (mg/kg-day)

C = Inhalation exposure concentration of heavy metal for the individual ($\mu g/m^3$)

IR = intake rate (m^3/day)

EC = Exposure concentration (mg/m^3)

EF = Exposure frequency (day/year)

ED = Exposure duration (year)

ET = Exposure Time (hr/day)

BW = Body weight (kg)

AT = Average time (day)

CF = Conversion factor (mg/μg)

Step 4 Risk Characterization

A risk characterization conveys the risk assessor's judgment as to the nature and presence or absence of risks, along with information about how the risk was assessed, where assumptions and uncertainties still exist, and where policy choices will need to be made. Risk characterization takes place in both human health risk assessments and ecological risk assessments.

The risk assessment method was applied to estimate the rate of human heavy metals exposure through the main exposure pathway, for example, inhalation exposure. Some of these metals are carcinogenic therefore must evaluate cancer risk of heavy metals bound in PM_{10}. There are several research studies about the health risk assessment of the workers exposed to the heavy metals in electronic waste recycling sites**.** They reported cancer risk assessment was based upon intake through inhalation of dust (M. Singh et al., 2018).

Non-carcinogenic and carcinogenic risk could be estimated by the following calculation.

1) Non-carcinogenic metals

This equation was used for the estimation of non-carcinogenic risk with the term of hazard quotient (HQ).

$$\text{Hazard quotient (HQ)} = EC / RfC \qquad \text{(Eq. 14)}$$

where RfC = Reference Concentrations (mg/m^3)

If HQ ≤ 1, it was considered as no adverse effect on humans.

HQ >1, it was concerned as an adverse effect on human health from metals exposure.

Hazard index (HI) could be estimated by using the below equation to aggregate all HQ of the substances that will have a similar effect to organ or target. The total value of residents exposed to non-cancer heavy metals is derived from the following equation.

$$\text{Hazard index (HI)} = \Sigma HQ \qquad \text{(Eq. 15)}$$

where HI = The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways that resident and worker will be received.

2) Carcinogenic metals

$$\text{Lifetime Cancer Risk} = \text{CDI} \times \text{CSF} \qquad \text{(Eq. 16)}$$

where CSF= Inhalation Cancer Slope Factor $(\text{mg/kg. day})^{-1}$

An acceptable level is $\leq 10^{-6}$, which means the probability is that 1 person per 1,000,000 will develop cancer because of the exposure.

CHAPTER III
METHODOLOGY

3.1 Study areas

The study area was the Daengyai sub-district in Banmaichaiyapot district and Banpao sub-district in the Phutthaisong district, Buriram province, Thailand. The e-waste dismantling area were divided into two areas, including e-waste dismantling houses at Daengyai and Banpao sub-district as mentioned above. The control area was far away from the e-waste separation areas approximately 4-5 kilometers (Village No.1 Daengyai sub-district). The locations of the areas are shown in Figure 6.

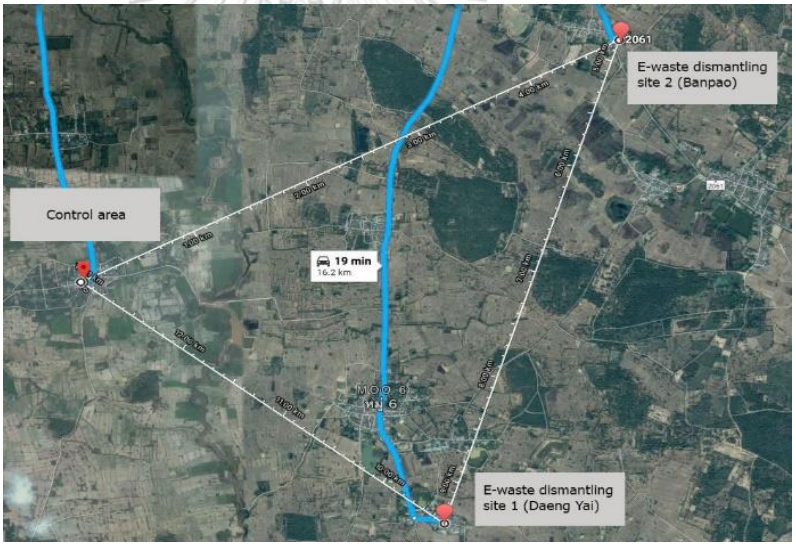


Figure 6 Sampling area at Daengyai subdistrict in Banmaichaiyapot district, Buriram province, Thailand.

3.2 Participants

3.2.1 Sample size calculation

In these two subdistricts, there were approximately 173 households of dismantling workers. For each household, there were four electronic waste workers, so this study area contains a total 692 of dismantling workers. The Yamane (1973)

equation was used for the sample size calculation as expressed in Eq. 3.1 (use 90% confidence interval).

$$n = \frac{N}{1 + Ne^2} \qquad \text{(Eq. 3.1)}$$

$$n = \frac{4(173)}{1 + 692(0.10)^2}$$

$$n = 87$$

where;

n = Sample size

N = Total population

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

From the calculation above, the sample was 87 samples. In this study, 100 of e-waste dismantling workers and 30 of non-e-waste dismantling workers in the control areas were assigned for this study. The total target samples of 130 participants from both areas were randomly selected among those who lived in these study areas. A total of 130 participants was asked for collecting urine, and only 100 participants were requested for the sampling of PM_{10}. These 100 participants consist of 80 e-waste dismantling workers and 20 non-e-waste dismantling workers.

In addition, this study also used G*Power program to calculate the sample size (Cohen, 1988; Faul et al., 2009). The data of the test calculated from the different mean concentrations and standard deviation of heavy metals such as Zn (77.0±4.11 and 13.5 ±0.65) derived from the study of e-waste dismantling workers and non-e-waste dismantling workers at e-waste recycling sites from Agbogbloshie, Accra in Ghana (Asante et al., 2012). The power of test calculated from the significant level is 95 % or Alpha (α) is 0.05 as shown in Figure 7.

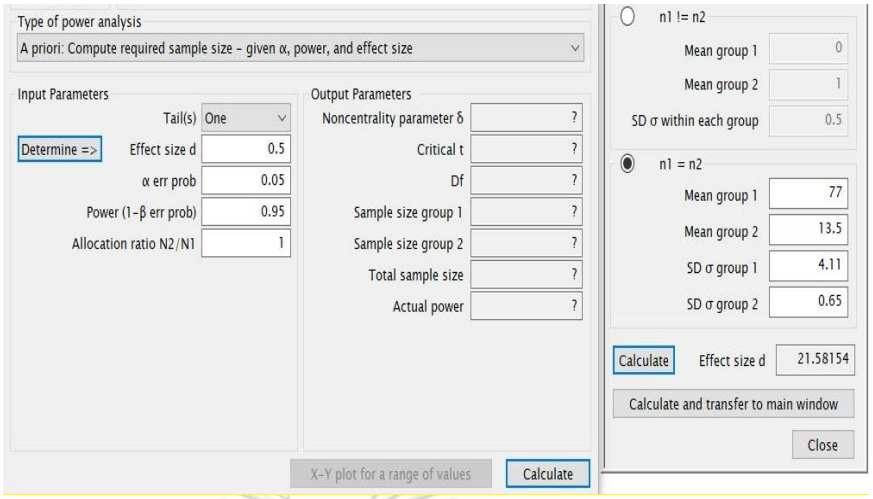


Figure 7 Sample size calculation from G*Power program

From the calculation above, the sample size was 21 samples. After the result was calculated for known values, the ten percent error formula was used to determining the precision of calculation; therefore, the sample size was 23 samples. In this study, the non-e-waste dismantling workers (control group) was set as 30 subjects, which was more than the calculated value. However, the collected number of all target samples was over the values from both calculations.

According to the sampling of participants in this study, usually, the population is too large for the researcher to attempt to survey all of its members, but carefully chosen samples can be used to represent the population. The target group setting was divided according to various survey sampling techniques as the following flowchart (Fig. 8).

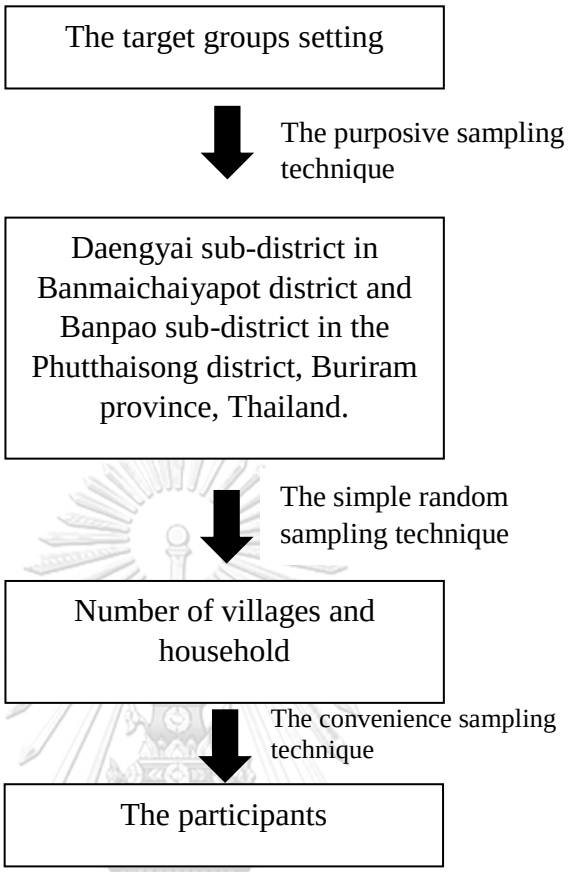


Figure 8 The sampling technique of participants in this study

The participants in this research was divided into two main groups: the exposure group and the non-exposure group. The exposure group was 100 participants who were worked in the electronic waste separating area. The non-exposure group was 30 participants who were not worked in the area of electronic waste separation and living far from the e-waste dismantling area about 4 -5 km. as illustrated in (Fig. 6). The inclusion criteria of the exposure and control group are as following;

1) Exposure group

The exposure group was 100 participants who were working in the electronic waste separating area. Inclusion criteria of the exposure group are as following;

- 18 - 65 years of age (adults).

- Not physical disability person.
- Worked on the process at least 6 months.
- Having the ability to read Thai.

The exclusion criteria of the exposure group are as following;

- Over 18 - 65 years of age.
- Disability person and have kidney problems.
- Worked on the process of less than 6 months.
- Not able to read Thai.

2) Control group

The control group was 30 participants who were not working in the area of electronic waste separation and living far from the e-waste dismantling area about 4 km as illustrated in Fig. 3.1. The inclusion criteria of the control group are as follows;

- 18 - 65 years of age (adults).
- Never lived in the electronic waste separation area.
- Not physical disability person.
- Ability to read Thai

3) The exclusion criteria of the control group are as follows;

- Over 18 - 65 years of age.
- Live in the electronic waste separation area.
- Disability person and have kidney problems.
- Not able to read Thai.

All participants were asked for personal information through face-to-face interviews such as gender, age, weight, height, working hour, and smoking behavior. Personal information will be investigated the associated factors to exposure to heavy metals. The interview questionnaire consisted of four parts including socio-demographic factors, personal factors, exposure factors, and environmental factors (Table 7).

Table 7 Questionnaire information

Socio Demographic factors	Personal factors	Exposure factors
-Gender -Age -Weight and Height (BMI) -Occupation	-Smoking -Smoking family member -Alcohol drinking -Seafood consumption -Fertilizer using	-Working hour -PPE using -E-waste burning

The involvement of participants in this study was under approval by the Committee for Research Involving Human Research Subjects, Health Science Group, responsible for ethics on human experimentation with the certificate of approval number (COA. No.) 217/2018.

3.3 Sampling preparation

3.3.1 PM_{10} sampling preparation

1) Filter preparation

A glass fiber filter was immersed in acetone for 10 minutes and let it dry at room temperature for 10 minutes, and then stored in a desiccator at a temperature of 20-30°C and humidity 30 - 40 % for at least two days.

2) Gravimetric analysis

A mass of each filter was determined by weighing with the analytical microbalance (7 decimal) both before and after sampling. Prior to weighing, standard pendulums of 100 and 200 mg were weighted for quality control and then a filter was weighted three times for calculating the average weight. After that, a weighed filter was put in a filter cassette and sealed with parafilm. Finally, pendulums were weighted again. All cassettes contained with the filter are kept in a zip-lock plastic bag for taking to the sampling sites (Chanthahong and Kanghae, 2017) . After weighting, PM_{10} concentration will be calculated by equation (3.2) - (3.6) as follows;

PM_{10} concentration ($\mu g/m^3$) = mass of PM_{10} (μg) / air volume (m^3)

(Eq.3.2)

Mass of PM_{10} (μg) = weight of the filter A $_{(after\ sampling)}$ - weight of the filter B $_{(before\ sampling)}$ (Eq. 3.3)

Weight of the filter before sampling (mg) = (the first weight +…+ third weight)/3

(Eq. 3.4)

Weight of the filter after sampling (mg) = (the first weight +…+ third weight)/3

(Eq. 3.5)

Air volume (m^3) = air flow rate (m^3/min) x sampling time (min)

(Eq. 3.6)

3.4 Sample Collection

3.4.1 Urine Sampling

There are 130 samples of urine from the target group which was collected from 100 e-waste, workers and 30 non-e-waste people. Urinary heavy metals values vary considerably during a 24-hour period, and most test methods are based on normal values for first morning samples. The first urine in the morning is preferred because it has a more uniform volume and concentration and a lower pH, which helps preserve the formed elements (Akerstrom et al., 2014; Bolden, 2017). In this study, a first-morning urine sample was then collected and completed at the same time, 8–9 a.m. The workers must drop the first urinal, then keep urine about 30 ml. in a prepared glass bottle. Each sample was collected using a glass bottle with a screw cap and a parafilm cover. After that, the samples will be kept in an ice bucket at 4 °C for transport to the urine laboratory (the aliquots stored at 4°C should be analyzed within two weeks). If the samples cannot analyze during this period, they have frozen and kept at -20°C (Horng et al., 2002; Srigboh et al., 2016).

3.4.2 PM_{10} Sampling

The samples of particulate matters smaller than 10 microns (PM_{10}) were collected from 80 in 100 e-waste workers and 20 in 30 people of non-e-waste. A set of air sampling equipment (Gillian Brand, GilAir-5 version), a personal air pump connected to a cassette containing a filter with a nylon PM_{10} cyclone, was attached on the breathing zone of the target group (see Fig. 9) or was placed at the height of 1.0 - 1.5 m. approximately from the ground. Nylon Cyclone was used in conjunction with 37mm filter cassettes to separate dust particles by size with the respirable particles being collected on the filter and larger particles being removed. The collection efficiency meets the standards set forth by standards of ACGIH, (1999); ISO (1995); CEN, (1993) for a respirable curve with a median 50% cut point of 4μm when operated at a flow rate of 1.7 L/min. The samples were collected for 8 hours in real working time. Before each sampling, a personal air pump connected with nylon cyclone and filter cassette was set at a flow rate. The filter cassettes were sealed with parafilm and keep in zip lock bag during the transportation of the sample to analyzed in the laboratory.

Figure 9 Personal air sampling
Source: Retrieved from http://www.swtestingltd.co.uk/airsampling.html

3.5 Analytical Technique

3.5.1 Extraction and analysis of heavy metals concentration in PM_{10} samples (3051A)

The filter samples were digested in a microwave digester (CEM MARS-5). 10 ml extraction solution (40% HNO_3) was added into the filter and let them stay for at least 30 min before digestion and transfer the extracted solution to a PTFE beaker, then evaporate to 1 ml. The solution was filtered through PTFE syringe filter, then adjusted the volume to 5 ml in volumetric flask by Type 1 water. In each round of digestion, the blank extracted solution was prepared by using a blank filter sample and blank acid (40% HNO_3) with the same extraction method. After that, the extraction solution was stored in a polyethylene bottle before further analysis by Inductively coupled plasma mass spectrometry (ICP-MS). After qualitative and quantitative analysis, the heavy metal concentration was calculated using the equation 3.7 - 3.9;

Mass of heavy metal (µg) = heavy metal concentration (µg/mL) x sample solution volume (ml)

(Eq. 3.7)

Concentration of heavy metal in the air (µg/m3) = mass of heavy metal (µg)/ air volume (m^3)

(Eq. 3.8)

Heavy metal content in PM_{10} (mg/g) = mass of heavy metal (mg)/ mass of PM_{10} (g) (Eq. 3.9)

3.5.2 Extraction and analysis of heavy metals concentration in urine

For measurement of heavy metals in urine, arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), Manganese (Mn) and zinc (Zn) were analyzed using by Inductively coupled plasma mass spectrometry (ICP-MS). The heavy metals in urine were determined using inductively coupled plasma mass spectrometry calibration with multielement standard and use rhodium as an internal standard. In extraction and analysis of heavy metals concentration in urine will follow these steps;

1) Urine samples (0.5 mL) were digested in 30 mL Teflon screw-cap vials. 0.5 mL nitric acid 65% was added to the urine sample.
2) The vials were capped and warmed on a hot plate at medium heat for 3 hours, reaching a temperature of 95 °C.
3) The digest solution was left for room temperature and then are transferred to a volumetric flask and diluted to 5 mL with de-ionized water.
4) Rhodium was added as an internal standard (0.1 mg/L) to all samples except the blanks.
5) The solution was analyzed by Inductively coupled plasma mass spectrometry (ICP-MS). These element values were reported in µg metal/g creatinine and µg metal/L (Vaughan et al., 1991).

After qualitative and quantitative analysis, the heavy metal concentration was calculated using the Eq. 3.10.

Concentration of heavy metal in urine (µg/dL)/Urine creatinine (mg/dL) = µg/g creatinine

(Eq. 3.10)

3.6 Quality control for sample analysis

Limits of detection (LOD) is the lowest concentration level that can be determined to be reliably distinguished from zero and Limit of quantification (LOQ) is the level above which quantitative results may be obtained with a specified degree of confidence. LOD and LOQ can be obtained by measuring the signal of the blank solution for all eight times. Then, the blank solution is injected into ICP-MS, and the mean and the standard deviation of the measured data was calculated. LOD and LOQ were calculated using the following equation (3.11) - (3.12).

$$LOD = 3 \times \text{standard deviation} \quad \text{(Eq. 3.11)}$$

$$LOQ = 10 \times \text{standard} \quad \text{(Eq. 3.12)}$$

In addition, the precision of ICP-MS was examined through the calculation of the relative standard deviation percentage (%RSD) as in equation 3.13.

$$\%RSD = (S/X) \times 100 \quad \text{(Eq. 3.13)}$$

Where S = Standard deviation

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

The quality control results of ICP-MS that use for PM_{10} analysis in this study as shown in Table 8.

Table 8 The quality control results of ICP-MS

Heavy metals	LOD (μg/l)	LOQ (μg/l)	%RSD
As	1.50	5.00	5.99
Cr	1.50	5.00	2.61
Cd	1.00	3.33	5.77
Cu	1.00	3.33	1.49
Pb	1.00	3.33	1.27
Ni	1.00	3.33	4.75
Mn	1.00	3.33	2.17
Zn	1.00	3.33	1.06

3.7 Data analysis

Statistical analysis of the data was performed using the SPSS program. The analysis was as follows;

1) To Compare heavy metal concentration in biomarkers and heavy metal concentration in PM_{10} of the e-waste worker and non-e-waste worker, the Kolmogorov-Smirnov test (K-S test) was used to investigate the normal distribution.

2) To investigate the difference between the two-independent group of continuous data for multiple heavy metals, the Mann-Whitney (U-test) was used for normal and abnormal distribution data, respectively.

3) The relationship between heavy metals in PM_{10} and heavy metals in urine was examined by Spearman correlation tests for non-parametric data which were abnormal distribution data.

4) Chi-Square test (χ^2) was used to investigate the relationship between associate factor that may affect heavy metal accumulation in humans and heavy metals in the urine of e-waste worker for categorical data, for example, smoking behaviors, age, and gender and continuous data for example, Height, weight, and Body Mass Index (BMI).

3.8 Human health risk assessment

The probability of adverse health effects in workers who may be exposed to heavy metals via inhalation in the contaminated working environment at dismantling sites can be estimated following human health risk assessment protocol and framework for metals risk assessment recommended by the United States Environmental Protection Agency (U.S. EPA) as following these steps;

3.8.1 Hazard identification

Hazard Identification is the process of determining whether exposure to a stressor can cause an increase in the incidence of specific adverse health effects. Heavy metals from electronic waste dismantling can contaminate the air by attaching to dust particles (PM_{10}). The hazard of heavy metals can be identified as non-carcinogenic and carcinogenic substance depending on their critical effects and target organs as Table 9.

Table 9 Hazard identification of heavy metals

Heavy metal	Non-carcinogenic effect	Carcinogenic effect	reference
Cr	**Acute Toxicity** Severe tracheobronchial irritation **Chronic Toxicity** Gastroenteritis, hematemesis, hepatic necrosis, renal failure **Clinical effects** Lactate dehydrogenase in bronchioalveolar lavage fluid and nasal septum atrophy. **Target organs:** Pulmonary	**Classification B1;** Probable human carcinogen Inhalation: Lung cancer	IRIS, 1998 OEHHA, 2008 Mahurpawar, 2015

Cd	**Acute Toxicity** Cough, dryness and irritation of the nose and throat, headache, dizziness, weakness, fever, chills, and chest pain. **Chronic Toxicity** Fragile bone, alopecia, anemia, migraines, growth impairment, and cardiovascular disease **Clinical effects** Kidney, lung and bone damage. **Target organs:** Renal, Skeletal, Pulmonary	**Classification A;** Human carcinogen Inhalation: Lung, trachea, bronchus cancer	IRIS, 1998 Mahurpawar, 2015
Ni	**Acute Toxicity** Initial headache, nausea, vomiting, and chest pain, progressing to hyperpnea, cyanosis, respiratory failure, asthmatic disease and death if the exposure is severe. **Chronic Toxicity** Respiratory disorders such as asthma, bronchitis, rhinitis, sinusitis, and	**Classification A;** human carcinogen Inhalation: Lung cancer	RAIS, 1995 Mahurpawar, 2015

	pneumoconiosis. **Target organs:** Pulmonary, Skin		
Cu	**Acute Toxicity** Temporary gastrointestinal distress with symptoms such as nausea, vomiting, and abdominal pain. **Chronic Toxicity** liver and kidneys damage **Target organs:** Liver, kidney, lung, bone and the central nervous and immune systems	**Classification D;** Not classifiable as to human carcinogenicity	IRIS, 1992 OEHHA, 2008 Fisher Scientific, 2007
As	**Acute Toxicity** Respiratory irritation and mucous membrane damage leading to rhinitis. **Chronic Toxicity** Neurological, cardiovascular, renal, gastro-intestinal, haematological and reproductive effects. **Target organs:** Pulmonary, Nervous System, Skin	**Classification A;** human carcinogen Inhalation: Lung cancer	RAIS, 1992 Mahurpawar, 2015
Mn	**Acute Toxicity** Inflammatory response in	**Classification D;** Not classifiable as to	IRIS, 1993 RAIS, 1992

	the lung **Chronic Toxicity** Weakness and lethargy **Clinical effects** Central and Peripheral Neuropathies. **Target organs:** Nervous System and Pulmonary	human carcinogenicity	Mahurpawar, 2015
Pb	**Acute Toxicity** Mood swings, nausea, seizures, and body weights **Chronic Toxicity** Central nervous disorders, Anemia **Clinical effects** Encephalopathy, Peripheral Neuropathy, Central Nervous Disorders, Anemia. **Target organs:** Nervous System, Hematopoietic System, Renal, Pulmonary	**Classification B2**; probable human carcinogen Inhalation: Lung cancer	RAIS, 1994 Mahurpawar, 2015
Zn	**Acute Toxicity** Stomach cramps, nausea, vomit **Chronic Toxicity** Anemia **Clinical effects** Chest pain, cough, dyspnea, reduced lung	**Classification D;** Not classifiable as to human carcinogenicity	IRIS, 2005 RAIS, 1992

	volumes, nausea, chills, malaise, and leukocytosis. Respiratory system diseases **Target organs:** Muscle and bone		

3.8.2 Dose-response assessment

Dose-response assessment, the second step of a human health risk assessment quantitates the hazards identified in the previous step. It determines the relationship between dose and incidence of effects in humans. An inhalation reference concentration (RfC) and cancer slope factor (CSF) derived from a study of the relationship between the amount of heavy metal exposure, and its effect was applied for calculating non-carcinogenic as shown in Table 10 and carcinogenic risk as shown in Table 11, respectively.

Table 10 Inhalation RfCs of each heavy metal (non-carcinogenic substance)

Heavy metal	Inhalation RfC (mg/m^3)	Reference
Cr (VI)	1.00×10^{-4}	IRIS EPA, 1998
Cd	7.00×10^{-4}	Buchet et al., 1990
Ni	1.50×10^{-4}	EPA, 2001a
Cu	2.00×10^{-3}	EPA, 2001a
As	5.00×10^{-5}	CALEPA
Mn	5.00×10^{-5}	IRIS, 1993

Source: Chanthahong and Kanghae (2017).

Table 11 Inhalation CSFs of each heavy metal (carcinogenic substance)

Heavy metal	Cancer slope factor $(mg/kg.day)^{-1}$	Reference
Cr (VI)	4.10×10^{1}	IRIS, 1998
Cd	1.50×10^{1}	OEHHA, 2009
Ni	9.10×10^{-1}	OEHHA, 2009
Pb	4.20×10^{-2}	OEHHA, 2009
As	4.30×10^{-3}	IRIS, 1995

Source: Chanthahong and Kanghae (2017).

3.8.3 Exposure assessment

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human exposure to an environmental agent. Exposure concentrations are derived from measured and monitored in the environment. In this study, exposure to contaminants can occur via inhalation, including dust particles (PM_{10}). The heavy metal concentration measured from worker's exposure on the day, some exposure factors using the data either from a questionnaire and U.S. EPA handbook guideline was used to calculate the amount of exposure in one day by dividing into two terms including exposure concentration (EC) and chronic daily intake (CDI) as follows:

1) Exposure concentration (EC) was calculated for non-carcinogenic metals using Eq.3.14;

$$EC = [(C \times ET \times EF \times ED / AT)] \times CF \quad \text{(Eq. 3.14)}$$

2) Chronic daily intake (CDI) was calculated for carcinogenic metals using Eq. 3.15;

$$CDI = [(C \times IR \times ET \times EF \times ED) / (BW \times AT)] \times CF \quad \text{(Eq. 3.15)}$$

Table 12 Meaning of the variable in the risk calculation equation

Variable	Meaning
CDI	Chronic daily intake (mg/kg-day)
C	Inhalation exposure concentration of heavy metal for the individual (μg/m3) This study
EC	Exposure concentration (mg/m3)
CF	Conversion factor (0.001 mg/μg)
IR	Inhalation Rate (2.1 m^3/hrs)
ET	Exposure Time (hrs/day)
EF	Exposure Frequency (350 days/years)
ED	Exposure Duration (years) for control group: 30 years
BW	Body Weight (kg)
AT	Averaging time of exposure for carcinogenic: 70 (y) x 365 (days/y) Averaging time of exposure for non-carcinogenic: ED (y) x 36 (days/y) x 24 (hrs/d)

3.8.4 Risk characterization

The non-carcinogenic and carcinogenic risk can be estimated by the following calculation.

1) Non-carcinogenic metals

This equation was used for the estimation of non-carcinogenic risk with the term of hazard quotient (HQ).

$$\text{Hazard quotient (HQ)} = EC / RfC \quad \text{(Eq. 3.16)}$$

where RfC = Reference Concentrations (mg/m^3)

If HQ ≤ 1 is considered as no adverse effect on the human.

HQ >1 is concerned as an adverse effect on human health from metals exposure.

Hazard index (HI) could be estimated by using the below equation to aggregate all HQ of the substances that will have a similar effect to organ or target. The total value of participants exposed to non-cancer heavy metals was derived from the following equation.

$$\text{Hazard index (HI)} = \Sigma HQ \qquad \text{(Eq. 3.17)}$$

where HI = The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways that residents and workers will be received.

2) Carcinogenic metals

This equation was used for the estimation of carcinogenic risk with the term of lifetime cancer risk (LCR).

$$\text{Lifetime Cancer Risk} = CDI \times CSF \qquad \text{(Eq. 18)}$$

where CSF= Inhalation Cancer Slope Factor $(mg/kg.\ day)^{-1}$

An acceptable level is $\leq 10^{-6}$, which means the probability is that one person per 1,000,000 will develop cancer because of the exposure.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Demographics information and characteristics of non- and e-waste workers

The participants in this study were requested to provide demographic information through structural questionnaires and face-to-face interviews. Table 13 lists the information of demographic characteristics. The mean (SD) age of the e-waste dismantling workers and non-e-waste dismantling workers were 47.6 (9.7) and 49.7 (6.2) years old, and they ranged in age from 20 to 65 years old (Table 12). The participants of the exposure group comprised 51 males and 49 females. Their average weight was 61.7 ± 10.3 kg, and the average height was 160.2 ± 7.2 cm. The body mass index (BMI) of the exposure group was 24.0 ± 3.7 kg/$m^{2,}$ which calculated from their weight and height. The participants of the control group comprised 10 males and 21 females. Their average weight was 59.7 ± 8.1 kg, and the average height was 162 ± 7.4 cm. The body mass index (BMI) of the exposure group was 23.9 ± 4.5 kg/m^2. According to the results, the mean age and height of the e-waste dismantling workers were slightly lower than non-e-waste dismantling workers. The mean weight and BMI of the e-waste dismantling workers were slightly higher than non-e-waste dismantling workers.

Table 13 Demographical information of the participants

Variable	Case group (n=100) Mean ± SD	Control group (n=31) Mean ± SD
Age (years)	47.61 ± 9.68	49.68 ± 6.25
Gender		
Male	52 (52.0%)	10 (32.0%)
Female	48 (48.0%)	21 (68.0%)
Weight (kg)	61.71 ± 10.31	59.71 ± 8.10
Height (cm)	160.22 ± 7.19	162.03 ± 7.39
Body Mass Index (BMI)	24.02 ± 3.65	23.86 ± 4.45

The mean (SD) number of working periods for the e-waste dismantling group or exposure group was 11.2 (8.5) years, with a range between 6 months and 60 years (Table 4.2). Almost half (45.0%) of the participants in the exposure group had eaten seafood 1-2 times per week. Over half (58.0%) of the participants in the control group had eaten seafood 1-2 times per month. The percentage of seafood consumption of the exposure group was lower than that of the control group. The percentages of fertilizer using by the exposure and control groups were 58.0% and 27%, respectively. The percentage of using personal protective equipment (PPE) of the exposure group accounted for 42.0%. In addition to separating or dismantling e-waste, 40% of participants also have burned e-waste. Both of these characteristics were not found in the control group. All e-waste workers separated the e-waste by primitive method, i.e., hand or torn. The type of e-waste separated during the sampling was not much different which mainly consisted of TV screens and printed circuit boards.

The contribution of smokers in exposure and control groups were 30% and 8%, respectively. The percentage of smokers was approximately 3-fold higher in the exposure group than in the control group. The percentages of participants whose family members are smokers in the exposure group and control group were 27% and 2%, respectively. The percentage of participants whose family members are smokers was approximately 13-fold higher in the exposure group than in the control group. Over half of the participants in the exposure group (58%) and almost half of the participants in the control group (48%) drank alcohol. The percentage of alcohol drinking was higher in the exposure group than in the control group as shown in Table 14. However, the percentage of these factors cannot indicate that they are related to the concentration of heavy metals in the urine. Therefore, these factors required a chi-square test to analyze the relationship with the concentration of heavy metals in the urine.

Table 14 Information of associated factors related to the heavy metals in urine

Variable	Exposure group (n=100)	Control group (n=31)
Exposure Data		
Number of years worked in e-waste	11.24 ± 8.52	
Seafood Consumption		
No more than 1 time per month	18 (18.0%)	7 (23.0%)
Everyday	16 (16.0%)	0 (0.0%)
1 - 2 times per week	45 (45.0%)	5 (16.0%)
3 - 4 times per week	7 (7.0%)	1 (3.0%)
1 - 2 times per month	11 (11.0%)	18 (58.0%)
3 - 4 times per month	3 (3.0%)	0 (0.0%)
Using PPE		
Yes	42 (42.0%)	0 (0.0%)
No	3 (3.0%)	0 (0.0%)
Yes-sometime	55 (55.0%)	0 (0.0%)
E-waste Burning		
Yes	40 (40.0%)	0 (0.0%)
No	60 (60.0%)	0 (0.0%)
Smoking Behavior		
Yes	20 (20.0%)	4 (13.0%)
1 - 3 cigarette per day	6 (6.0%)	0 (0.0%)
4 - 6 cigarette per day	4 (4.0%)	0 (0.0%)
More than 10 day per day	10 (10.0%)	4 (8.0%)
Ex-smoker	10 (10.0%)	0 (74.0%)
No	70 (70.0%)	27 (87.0%)
Family Smoking		
Yes	27 (27.0%)	2 (6.0%)
No	73 (73.0%)	29 (94.0%)
Alcohol Drinking Behavior		
No	42 (42.0%)	16 (52.0%)
1 - 2 times per week (not often)	38 (38.0%)	9 (29.0%)
1 - 4 times per week (often)	10 (10.0%)	5 (16.0%)
More than 4 times per week (often)	10 (10.0%)	1 (3.0%)

4.2 Heavy metal concentrations in PM_{10}

The heavy metal concentrations (As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn) in the particulate matter smaller than 10 microns (PM_{10}) exposed by the participants was collected from 80 e-waste dismantling workers in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district, and 20 of non-e-waste dismantling workers in Village No.1, Daengyai sub-district, Buriram province. The sampling of PM_{10} distributed in the working area of the e-waste workers and the residential area of the control group were investigated in September 2019. The sampling had been conducted at two different groups of participants including exposure group (n=80) and control group (n=20) for 8 hours. The samples were digested in a microwave digester (CEM MARS-5) and the heavy metals were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

4.2.1 Comparison of exposure concentrations of heavy metal in PM_{10} between occupational e-waste dismantling workers and non-occupational people

The result of heavy metals concentration in PM_{10} sample was shown in Table 15. The average±(SD) and median concentration of As in PM_{10} of the participants in exposure group and control group were 1.165±1.304 and 0.876 μg/m^3, ranging from 0.010 to 5.885 μg/m^3, and 0.731±0.294 and 0.813 μg/m^3, ranging from 0.084 to 1.175 μg/m^3, respectively. The average (SD) and median concentration of Cd in PM_{10} of the participants in exposure group and control group were 0.021±0.013 and 0.018 μg/m^3, ranging from 0.001 to 0.077 μg/m^3, and 0.012±0.009 and 0.011 μg/m^3, ranging from 0.001 to 0.030 μg/m^3, respectively. The average (SD) and median concentration of Cr in PM_{10} of the participants in exposure group and control group were 1.521±1.384 and 1.148 μg/m^3, ranging from 0.033 to 9.016 μg/m^3, and 0.927±0.664 and 0.609 μg/m^3, ranging from 0.077 to 2.343 μg/m^3, respectively. The average (SD) and median concentration of Cu in PM_{10} of the participants in exposure group and control group were 0.374±0.285 and 0.280 μg/m^3, ranging from 0.011-1.378 μg/m^3 and 0.204±0.169 and 0.132 μg/m^3, ranging from 0.056 to 0.778 μg/m^3, respectively. The average (SD) and median concentration of Pb in PM_{10} of the participants in exposure group and control group were 0.368±0.222 and 0.336 μg/m^3, ranging from 0.011 to 1.128 μg/m^3 and 0.218±0.107 and 0.226 μg/m^3, ranging from

0.019-0.418 µg/m^3, respectively. The average (SD) and median concentration of Ni in PM_{10} of the participants in exposure group and control group were 0.176±0.175 and 0.129 µg/m^3, ranging from 0.004 to 1.368 µg/m^3 and 0.148±0.109 and 0.132 µg/m^3, ranging from 0.017 to 0.370 µg/m^3, respectively. The average (SD) and median concentration of Ni in PM_{10} of the participants in exposure group and control group were 0.176±0.175 and 0.129 µg/m^3, ranging from 0.004 to 1.368 µg/m^3 and 0.148±0.109 and 0.132 µg/m^3, ranging from 0.017 to 0.370 µg/m^3, respectively. The average (SD) and median concentration of Mn in PM_{10} of the participants in exposure group and control group were 0.771±0.453 and 0.683 µg/m^3, ranging from 0.003 to 2.308 µg/m^3 and 0.599±0.250 and 0.132 µg/m^3, ranging from 0.017 to 0.370 µg/m^3, respectively. The average (SD) and median concentration of Mn in PM_{10} of the participants in exposure group and control group were 1,018.311±776.673 and 884.394 µg/m^3, ranging from 64.619 to 4,629.525 µg/m^3 and 913.831±340.500 and 897.537 µg/m^3, ranging from 33.134 to 1,405.307µg/m^3, respectively.

As a result, this can be implied that the average concentration of heavy metals in PM_{10} of e-waste dismantling workers to be exposed was higher than that of the non-e-waste dismantling group. It was possible that e-waste activities in dismantling sites elevating these heavy metal levels in PM_{10}. The median of Zn concentration in the air of non-dismantling people was much higher than that of the e-waste dismantling workers. This might be caused by Zn is frequently found in natural ambient air and soil (EPA, 1980). Some studies showed that in Zn concentrations in the ambient air PM_{10} were 151 µg/m^3 in southwest Iran, 590 µg/m^3 in Baoshan, China, and 892 µg/m^3 in Hangzhou, China, (Chen et al., 2013; Goudarzi et al., 2018). In addition, it can be found in the natural released to the environment or natural emissions and the use of commercial products such as fertilizers (ATSDR, 2005: online). It was possible that the soil in that area has high zinc and easily spread out from the soil into the air. Also, the soil mostly found was sandy loam which is coarse soil and these soil particles were easily lifted into the air by the wind. Kaminski and Landsberger (2000) reported that the concentrations of Zn of soils in urban topsoils were ranged from 79 to 10,360 µg/g. However, the Zn concentration in the air inhale of -waste dismantling worker in this site was quite high, which may be due to the Zn in the soils. Wong et al. (2007) reported that the concentrations of Zn of

soils at the e-waste site in Guiyu, China was 546–5298 μg/g air-dry weight. It seemed that Zn in the soil in that area also affects the Zn concentration in the air.

When comparing the heavy metal concentrations of e-waste dismantling workers in this study with other studies (as in Figure 18), it illustrates that the concentrations of Cd in this study are similar levels as observed in the e-waste site in Jiangsu, China (Xue et al., 2011). The concentrations of Cu and Ni in this study are similar to the levels found in the e-waste site in Shanghai, China (Fang et al., 2013). When compared with standard, All of the heavy metal concentrations of non- and e-waste dismantling workers were lower than the ACGIH standard, as shown in Figure 19. The ACGIH (TLVs) 2019 standard of As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn were 10, 2, 5, 100, 50, 100, 100, and 1000 $\mu g/m^3$, respectively. This standard was listed in the order of 8-hour time-weighted averages (TWAs), which measured as total dust, so the standard values are highly concentrated. The particulate matter in this study was less than 10 microns (PM_{10}), which suspended in the air for a long time and supposed to have less concentration of heavy metals than the overall concentration of the heavy metals in the dust. To better state the problem situation, the heavy metals concentration would then be taken to assess health risk, which the result is present in the section 4.5.

Table 15 Heavy metal concentrations in PM_{10} inhale of occupational dismantling workers and non-occupational dismantling workers

Heavy Metals ($\mu g/m^3$)	Exposure group (n=80)			Control group (n=20)		
	Mean ± SD	Median	Range	Mean ± SD	Median	Range
As-PM_{10}	1.165±1.304	0.876	0.010-5.885	0.731±0.294	0.813	0.084-1.175
Cd-PM_{10}	0.021±0.013	0.018	0.001-0.077	0.012±0.009	0.011	0.001-0.030
Cr-PM_{10}	1.521±1.384	1.148	0.033-9.016	0.927±0.664	0.609	0.077-2.343
Cu-PM_{10}	0.374±0.285	0.280	0.011-1.378	0.204±0.169	0.132	0.056-0.778
Pb-PM_{10}	0.368±0.222	0.336	0.011-1.128	0.218±0.107	0.226	0.019-0.418
Ni-PM_{10}	0.176±0.175	0.129	0.004-1.368	0.148±0.109	0.132	0.017-0.370
Mn-PM_{10}	0.771±0.453	0.683	0.003-2.308	0.599±0.250	0.648	0.086-0.902
Zn-PM_{10}	1018.311 ±776.673	884.394	64.619-4629.525	913.831 ±340.500	897.537	33.134-1405.307

Data were presented as mean ± standard deviation (mean ± SD), median and range (min-max).

LOD = 1.0 µg/L

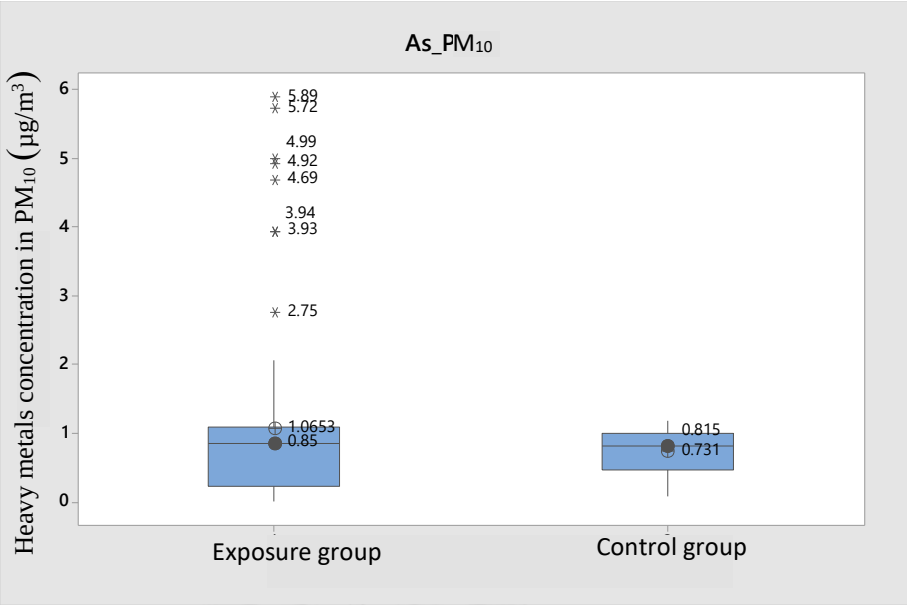


Figure 10 Box plot of As concentrations of PM_{10} inhale in exposure and control groups

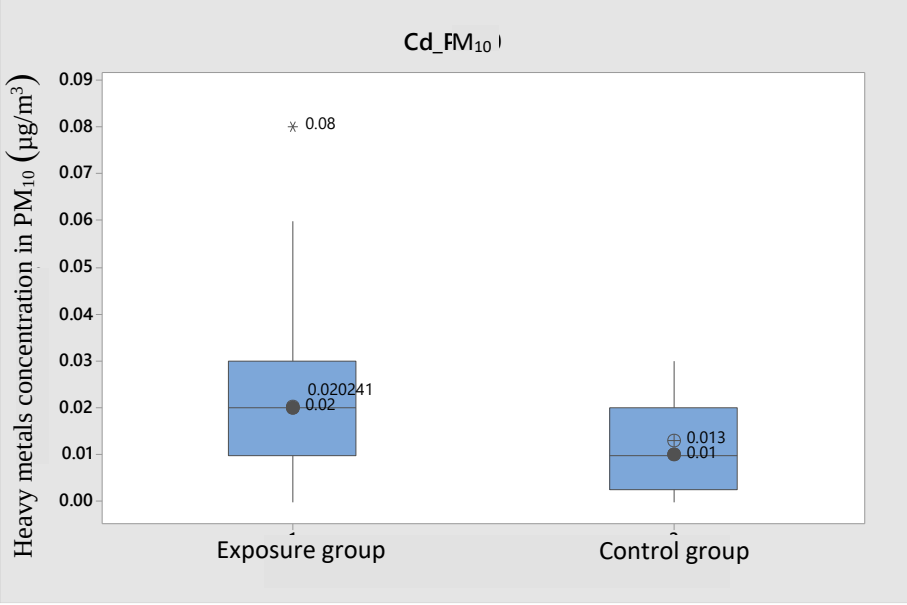


Figure 11 Box plot of Cd concentrations of PM_{10} inhale in exposure and control groups

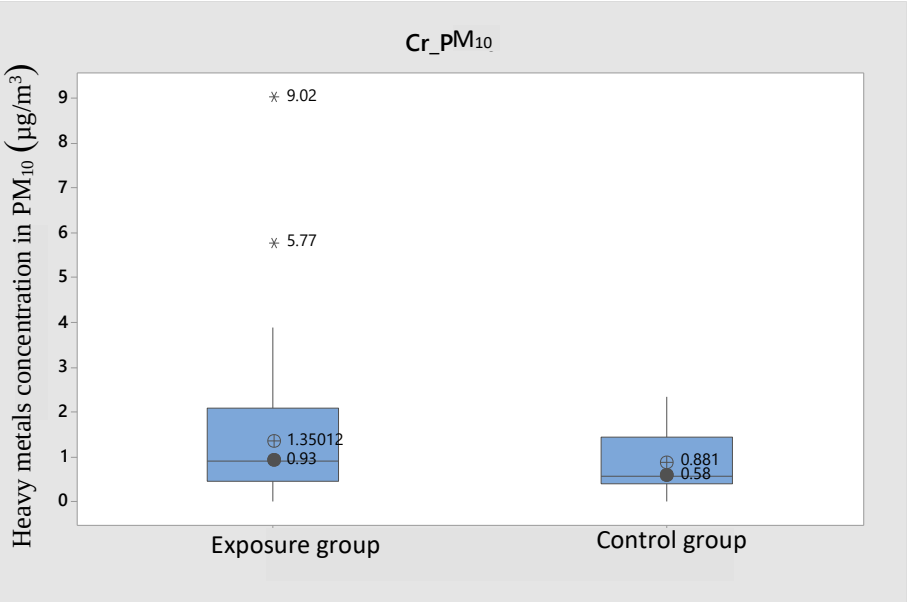


Figure 12 Box plot of Cr concentrations of PM_{10} in inhale exposure and control groups

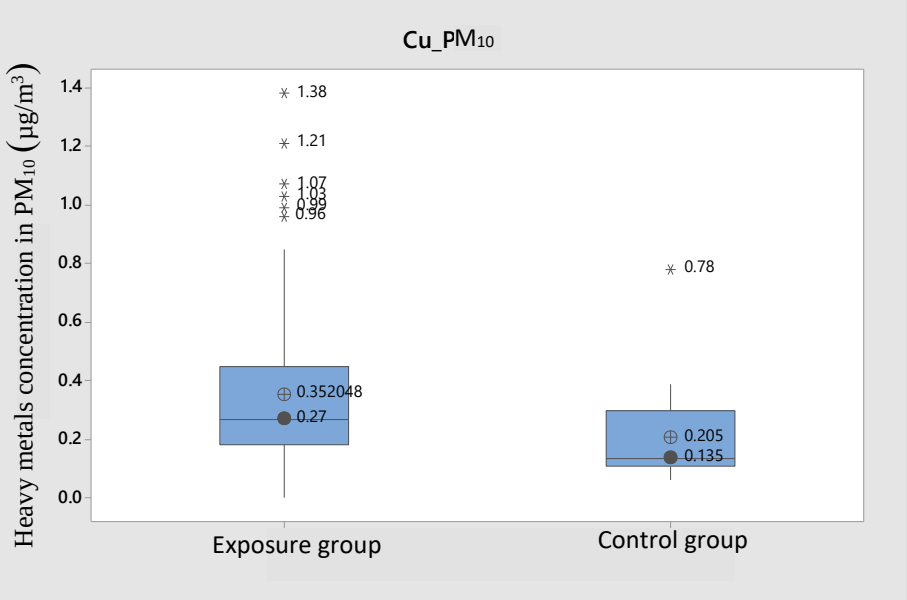


Figure 13 Box plot of Cu concentrations of PM_{10} inhale in exposure and control groups

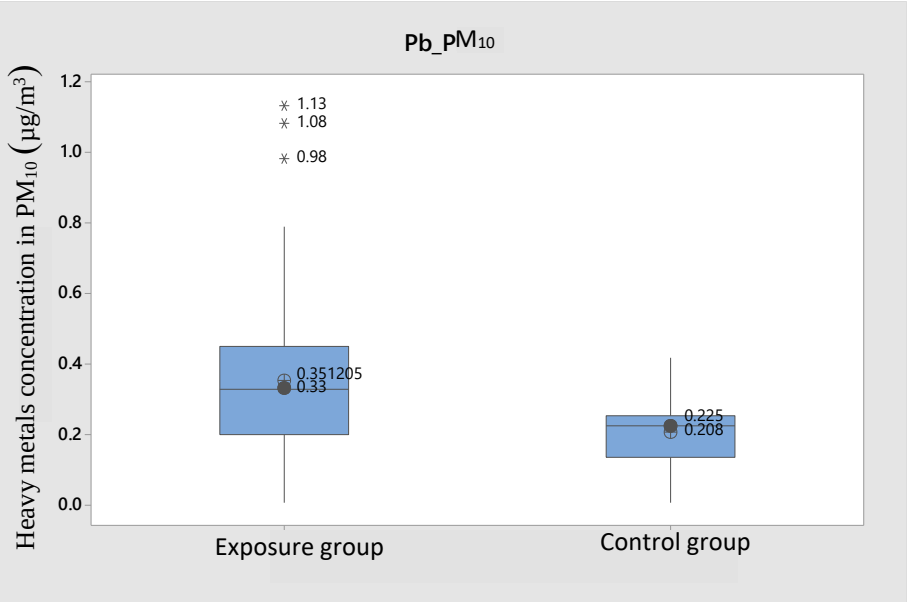


Figure 14 Box plot of Pb concentrations of PM_{10} inhale in exposure and control groups

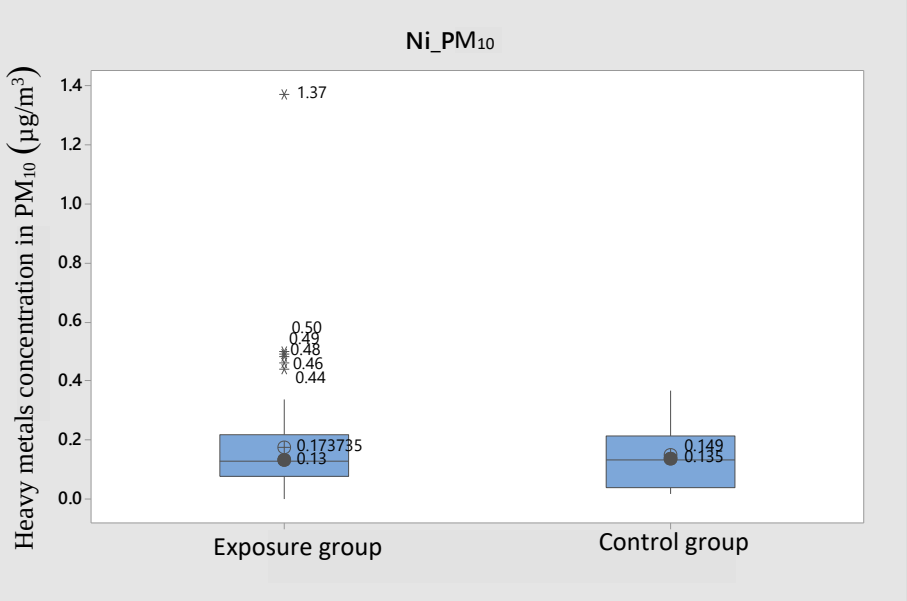


Figure 15 Box plot of Ni concentrations of PM_{10} inhale in exposure and control groups

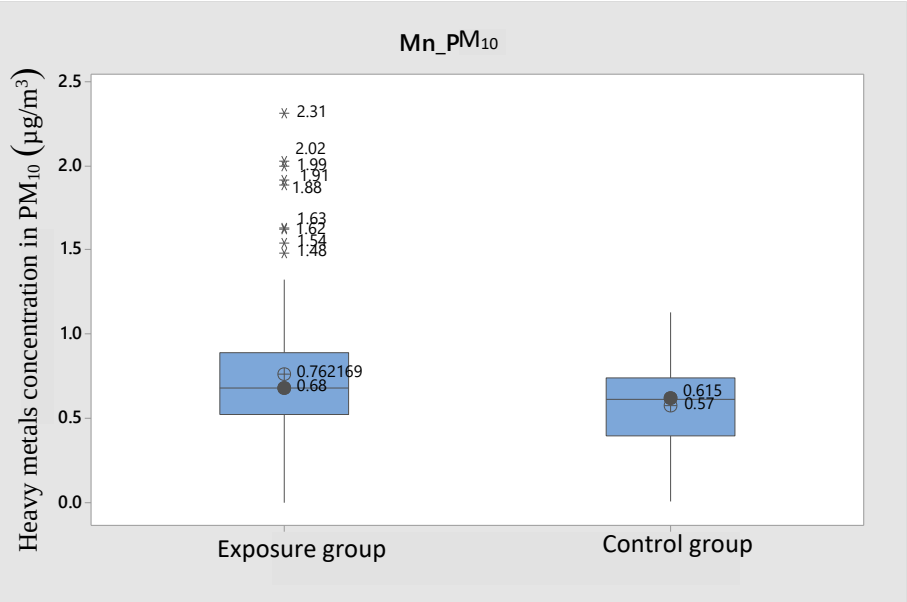


Figure 16 Box plot of Mn concentrations of PM_{10} inhale in exposure and control groups

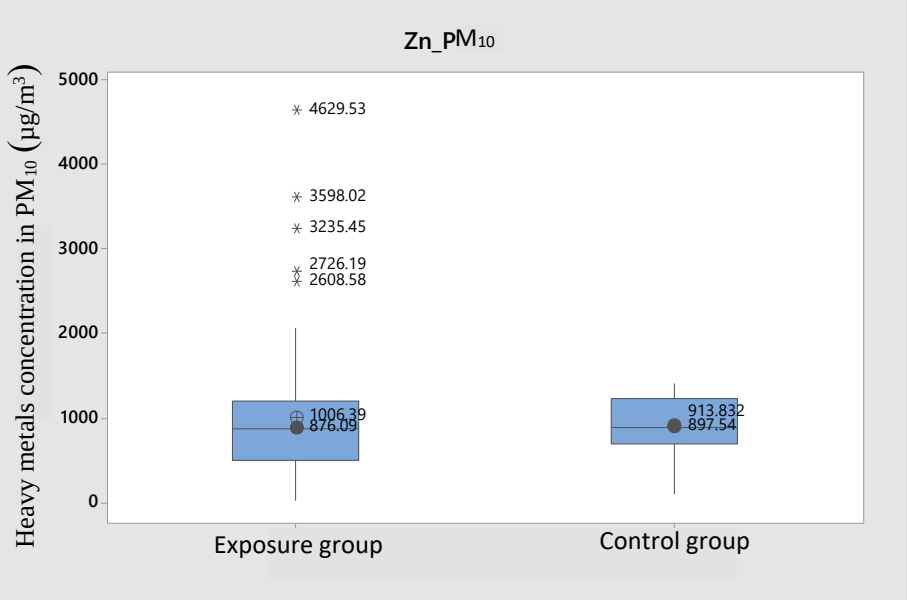


Figure 17 Box plot of Zn concentrations of PM_{10} inhale in exposure and control groups

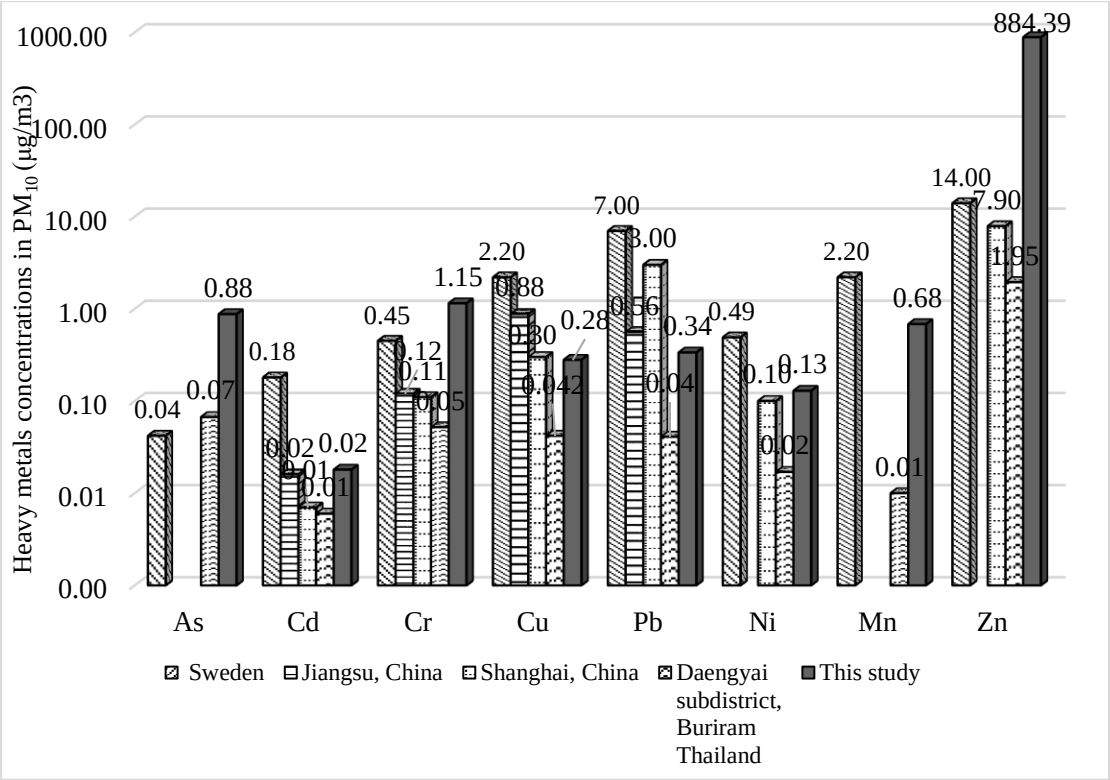


Figure 18 Heavy metals concentration in PM_{10} inhale of e-waste workers at the e-waste dismantling sites from previous studies

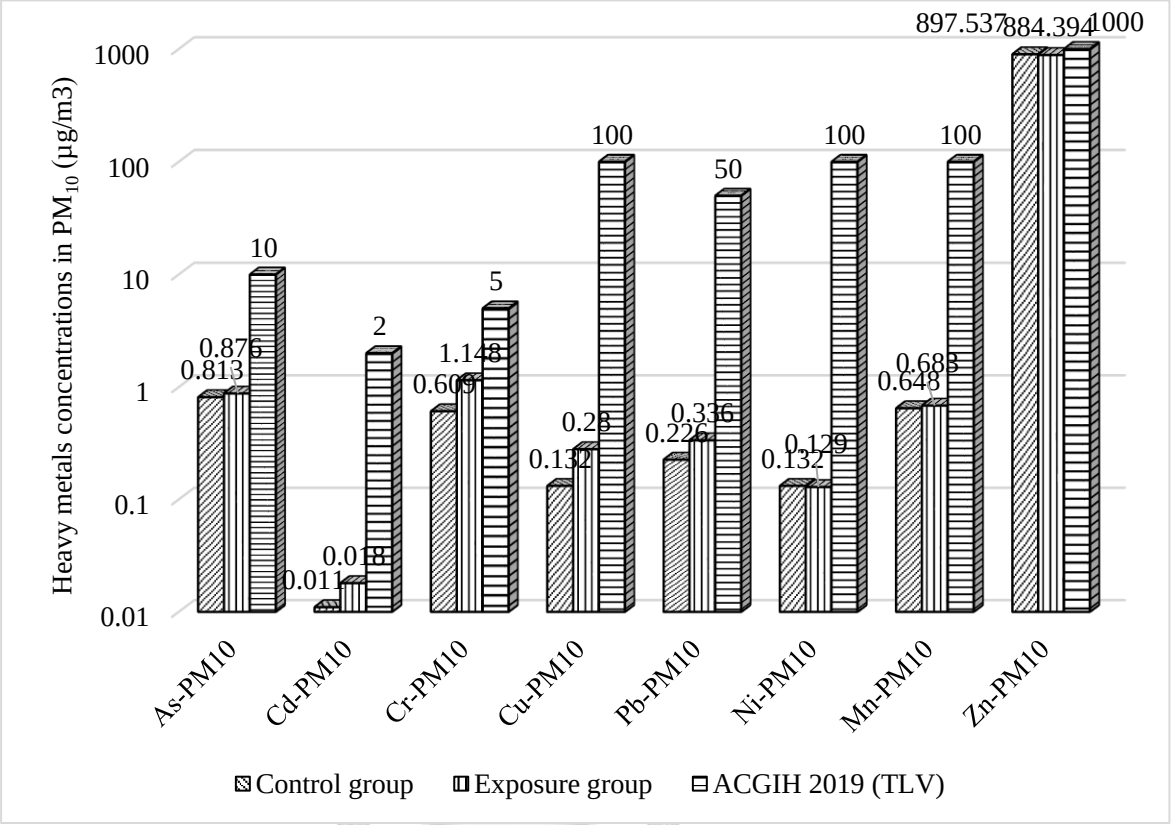


Figure 19 Heavy metal concentrations in PM_{10} inhale of non-dismantling e-waste workers and dismantling e-waste workers compared with standard concentrations.

4.2.2 The difference of exposure concentrations of heavy metals in PM_{10} between e-waste workers and control groups

The normality tests were done by Kolmogorov-Smirnov test (K-S test) in the SPSS program. From the normality tests, The heavy metal concentrations in PM_{10} have a p-value greater than 0.05 (p-value>0.05), which indicates the normal distribution of data. According to the results, the heavy metal concentrations in PM_{10} of e-waste dismantling workers (exposure group) were not normal distribution except Mn, i.e. p=0.002, p=0.000, p= 0.000, p=0.026, p=0.001, p=0.001 p=0.494, and p=0.000 for As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn, respectively. The heavy metal concentrations in PM_{10} of the control group were normal distribution except Cu, with the p values of 0.403, 0.274, 0.098, 0.000, 0.431, 0.078, 0.080, and 0.366 for As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn, respectively. Regarding the data were not a normal distribution, nonparametric testing would then be applied. A nonparametric test is one that does not assume the data fits a specific distribution type. The nonparametric test used in this study was the Mann-Whitney U Test, which was used to compare the differences between two independent groups.

The difference in exposure concentrations of heavy metal in PM_{10} between e-waste dismantling workers and non-occupational people (control group) was presented in Table 16. The result shows that Cu and Pb in PM_{10} of e-waste and non-e-waste dismantling workers were significantly different, with the p values of 0.014 and 0.019, respectively. Although other heavy metals were not significantly different, the results of PM_{10} from the air at the working space of e-waste dismantling workers seemed to be higher than those of non-e-waste dismantling workers.

Table 16 The difference of exposure concentrations of heavy metals in PM_{10} between e-waste workers and control groups

Heavy Metals ($\mu g/m^3$)	Exposure group		Control group		
	Mean ± SD	**Median**	**Mean ± SD**	**Median**	**p-value**
As-PM_{10}	1.165±1.304	0.876	0.731±0.294	0.813	0.892
Cd-PM_{10}	0.021±0.013	0.018	0.012±0.009	0.011	0.103
Cr-PM_{10}	1.521±1.384	1.148	0.927±0.664	0.609	0.199
Cu-PM_{10}	0.374±0.285	0.280	0.204±0.169	0.132	**0.014***
Pb-PM_{10}	0.368±0.222	0.336	0.218±0.107	0.226	**0.019***
Ni-PM_{10}	0.176±0.175	0.129	0.148±0.109	0.132	0.614
Mn-PM_{10}	0.771±0.453	0.683	0.599±0.250	0.648	0.441
Zn-PM_{10}	1018.311 ±776.673	884.394	913.831 ±340.500	897.537	0.448

* = Mann-Whitney U test, p-value < 0.05

4.3 Heavy metal concentrations in urine

The heavy metal concentrations (As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn) in urine of e-waste dismantling workers (n=100) in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district and non-e-waste dismantling workers (n=30) in Village No.1 Daengyai sub-district, Buriram province were investigated in June 2019. The urine samples were collected from all of 130 participants in the morning of the day after the PM_{10} sampling. The standard method of ACGIH was used to analyze the heavy metals in urine, and the analysis of urine samples was done by the certified Special Lab Center Clinic of Thailand. The heavy metals in urine were qualitative and quantitative analyzed by Inductively Coupled Plasma with Mass Spectrometry (ICP-MS). The samples were calibrated with multielement standard, and rhodium was used as the internal standard. The analysis result was reported in µg metal/g creatinine and µg metal/L correspondingly with the standard values.

4.3.1 Comparison of heavy metal concentrations in urine between exposure and control group

The results of heavy metals in the urine sample are summarized in Table 17 and also illustrated in Figure 20 – 27. The averages (±SD) of As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn in the urine of the exposure group were 55.23±34.91 µg/L, 0.90±0.47, 2.55±2.47, 25.47±16.48, 8.19±6.13, 3.45±2.97, 1.98±1.32 and 351.11±253.95 µg/g creatinine, respectively. Whereas, those of the control group were 46.02±36.86 µg/L, 0.72±0.53, 1.95±1.31, 23.17±17.61, 4.38±3.32, 4.31±2.71, 2.07±1.173 and 363.20±204.75 µg/g creatinine, respectively. The median concentrations of 47.70 µg/L, 0.77, 1.69, 19.90, 6.36, 2.68, 1.75, and 280.00 µg/g creatinine, respectively, were obtained for the exposure group. For the control group, the median concentrations were 32.04 µg/L, 0.55, 1.61, 15.49, 3.97, 3.67, 1.72 and 320.00 µg/g creatinine, respectively. The median concentrations of all heavy metals found in the exposure group were relatively higher than the control group, in exception for Mn and Zn.

Table 17 Heavy metal concentrations in the urine of exposure and control groups

Heavy Metals	**Exposure group** (n=100)			**Control group** (n=30)		
	Mean ± SD	**Median**	**Range**	**Mean ± SD**	**Median**	**Range**
As-U (µg/L)	55.229±34.906	47.70	6.28-175.73	46.02±36.86	32.04	12.30-164.88
Cd-U (µg/g creatinine)	0.895±0.47	0.77	0.29-2.57	0.72±0.53	0.55	0.28-2.71
Cr-U (µg/g creatinine)	2.547±2.466	1.69	0.47-16.27	1.95±1.305	1.610	0.40-6.60
Cu-U (µg/g creatinine)	25.469±16.483	19.90	5.58-80.68	23.17±17.61	15.49	8.22-82.17
Pb-U (µg/g creatinine)	8.194±6.126	6.36	0.64-36.86	4.37±3.32	3.97	0.69-14.93
Ni-U (µg/g creatinine)	3.452±2.971	2.68	0.14-15.80	4.31±2.71	3.67	0.19-10.61
Mn-U (µg/g creatinine)	1.978±1.324	1.76	0.10-6.48	2.07±1.17	1.72	0.17-4.88
Zn-U (µg/g creatinine)	351.111±253.954	280.00	60.00-1340.00	363.20±204.75	320.00	100.00-1140.00

Data are presented as mean ± SD, median and range (min-max).
LOD = 0.03 µg/L

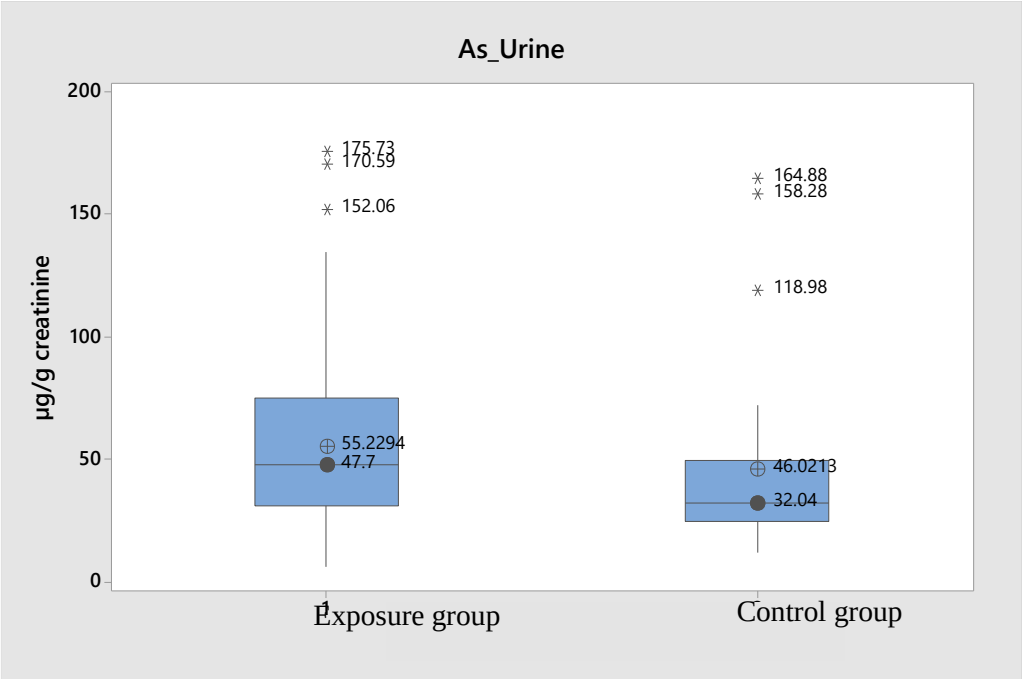


Figure 20 Box plot of As concentrations of urine in exposure and control groups

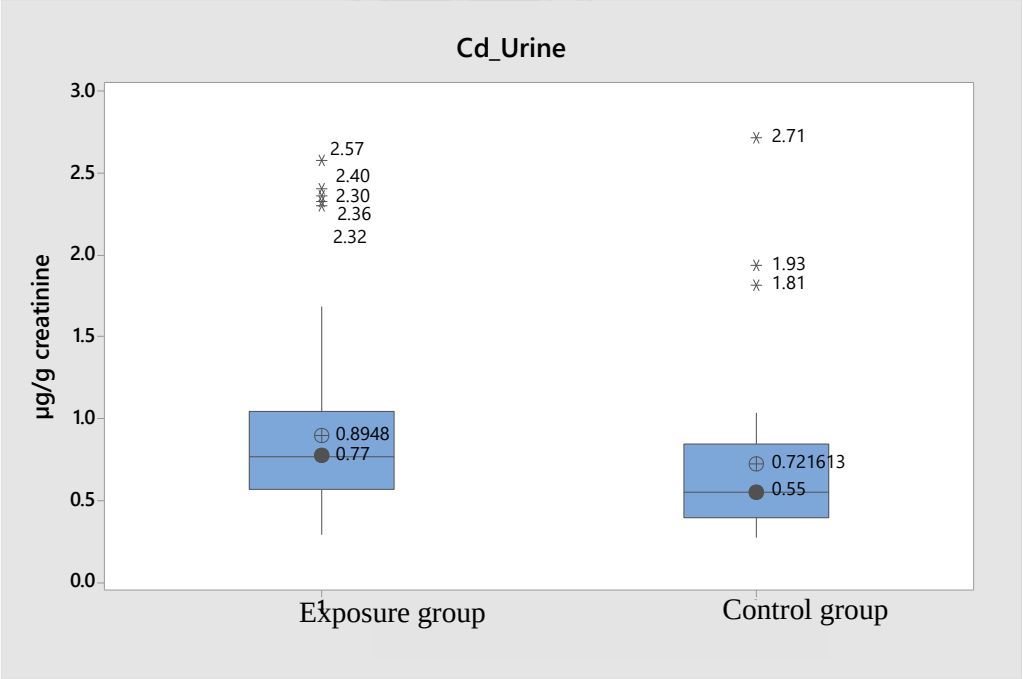


Figure 21 Box plot of Cd concentrations of urine in exposure and control groups

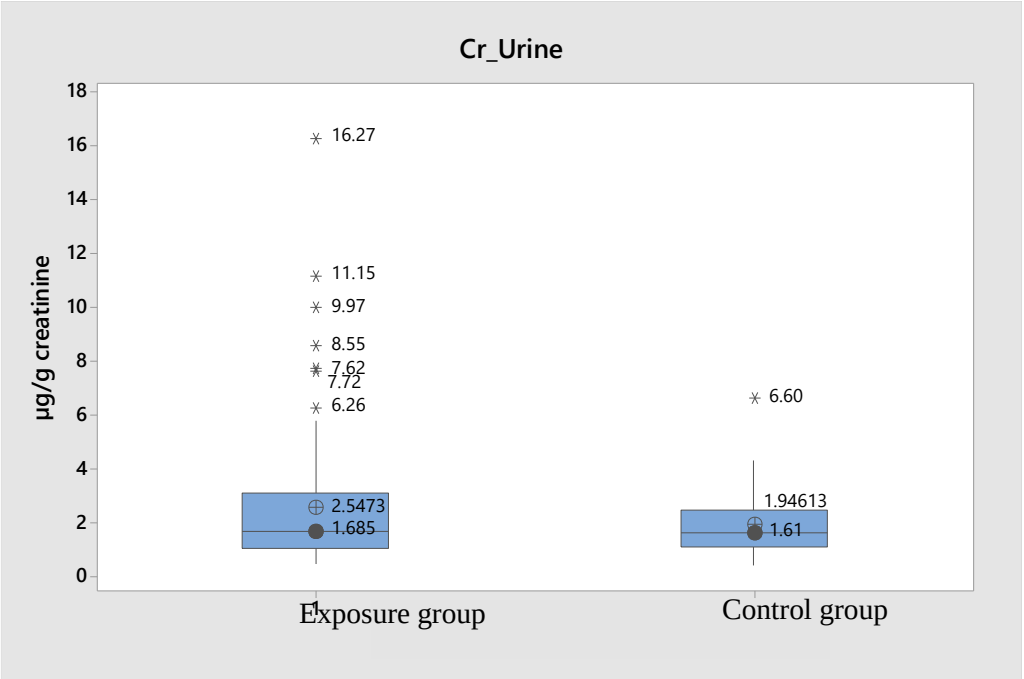


Figure 22 Box plot of Cr concentrations of urine in exposure and control groups

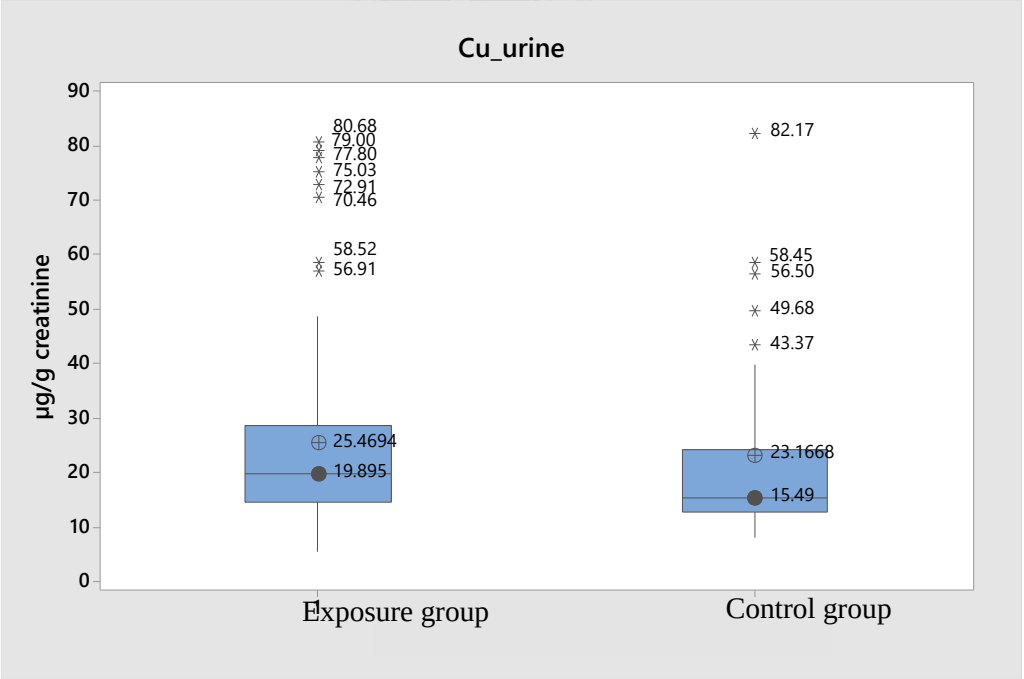


Figure 23 Box plot of Cu concentrations of urine in exposure and control groups

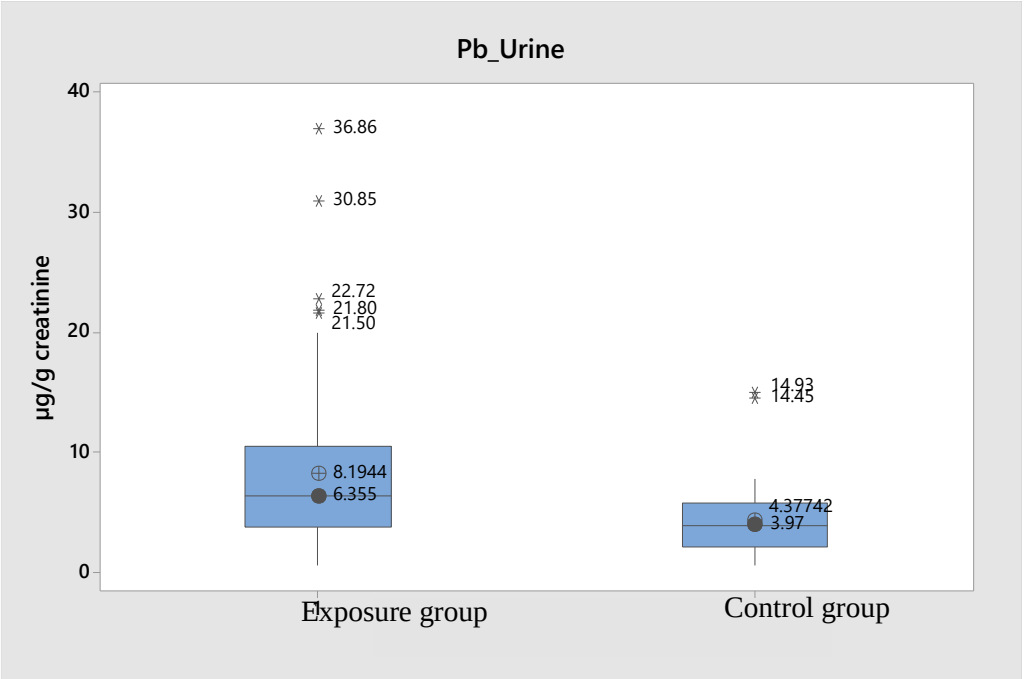


Figure 24 Box plot of Pb concentrations of urine in exposure and control groups

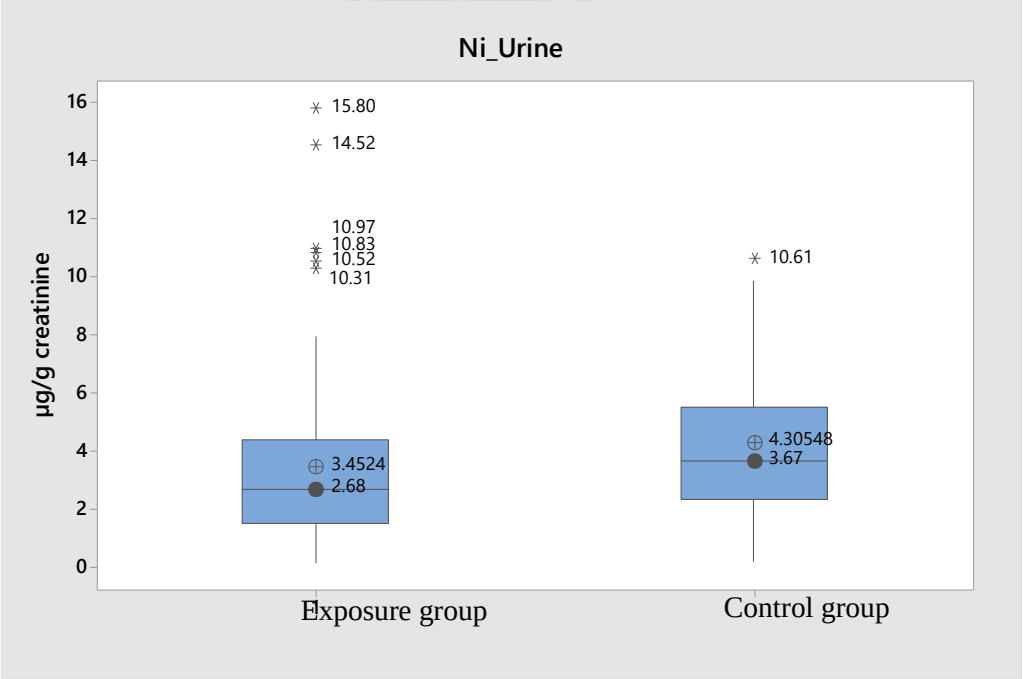


Figure 25 Box plot of Ni concentrations of urine in exposure and control groups

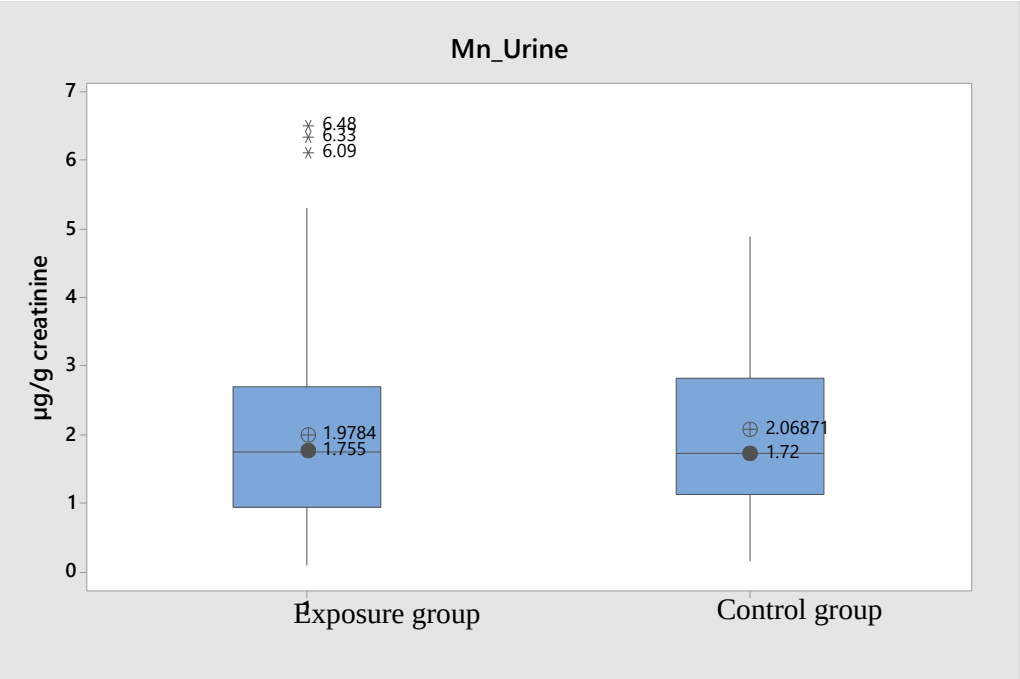


Figure 26 Box plot of Mn concentrations of urine in exposure and control groups

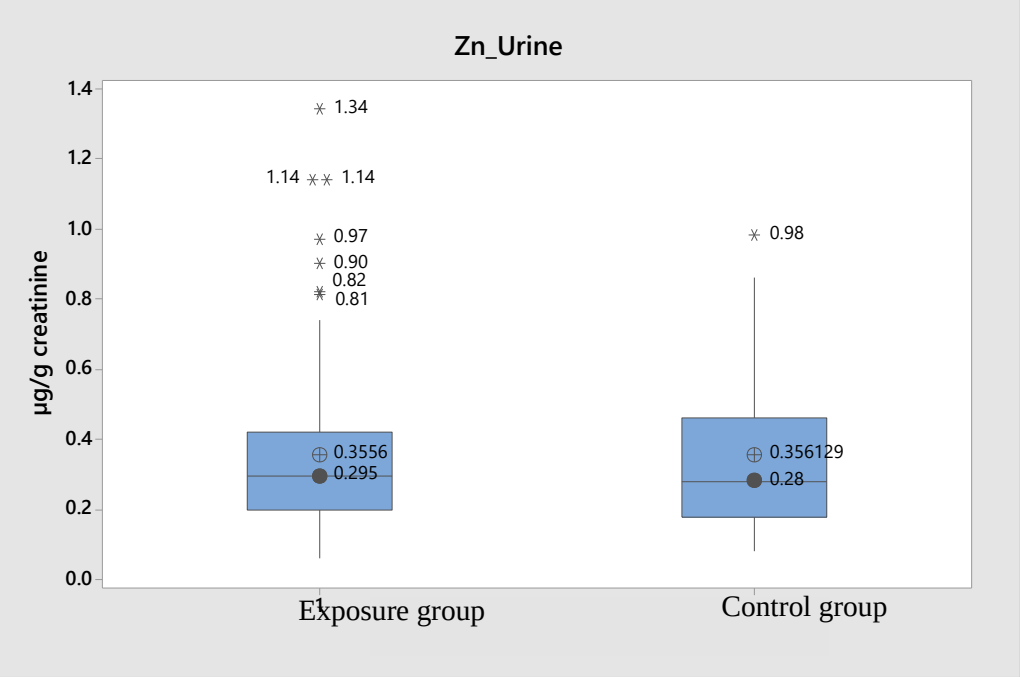


Figure 27 Box plot of Zn concentrations of urine in exposure and control groups

The urinary heavy metals reported as µg/g of creatinine following the American Conference of Governmental Industrial Hygienists (ACGIH) standard because these heavy metals can cause adverse effects on the kidney. As for arsenic (As), the value was expressed as µg/L following the ACGIH standard because creatinine is not a suitable correction factor for these heavy metals in the urine. Regarding the obtained results that were summed up in Table 16 and Figure 20-27. The data in boxplot were presented as a comparison between the occupational e-waste dismantling people (exposure group*)* and the *non*-occupational people (control group).

When comparing the urinary metals of the exposure and control groups, this can be implied that the average concentration of heavy metals in the urine of e-waste dismantling workers was higher than that of non-e-waste dismantling workers. The heavy metal concentrations in urine had similar trend with the heavy metal concentrations in dust, As, Cr, Cd, Cu, Pb, and Mn concentrations of e-waste dismantling workers was higher than heavy metals concentrations of non-e-waste dismantling workers. The urinary data of this study is taken to compare with the study of Srigboh et al. (2016,) that previously measured urinary heavy metals in 58 e-waste workers at Agbogbloshie, Ghana (see Figure 28). There were six urinary heavy metals found the same, including As, Cr, Cu, Pb, Ni, and Zn. It has been reported that the mean concentrations of As, Ni, and Zn in the urine of participants were 77.50 µg/L, 15.9 and 659 µg/g of creatinine, respectively, which higher than those detected for the workers in the present study. Similarly, the urine concentration of As was higher than other heavy metals. The average (SD) concentration of Cu (25.47 ± 16.48 µg/g of creatinine), and Pb (8.72 ± 5.24 µg/g of creatinine) in the urine of participants in this study were in the same range, 23.8 (11.9) and 9.0 (8.0) µg/g of creatinine. While the concentration of Cr, 0.9 (0.5) µg/L, was lower than that of this study. The results of this study indicated that the levels of As concentration is higher than other heavy metals and over the standard like the study by Srigboh et al. (2016). Asante et al. (2012) reported that the cconcentrations of heavy metals in urine of e-waste recycling workers in Accra and were As (4.34 µg/l, and 76.4 µg/l), Cd (0.37 and 0.35 µg/g creatinine), Cu (254 and 77 µg/g creatinine), Cr (15 and 2.2 µg/g creatinine), Pb (6.06 and 2.34 µg/g creatinine), Mn (3.47 and 2.54 µg/g creatinine), and Zn (614 and 713 µg/g creatinine). All of the heavy metals in this present study were lower than

Asante et al. (2012) study, whereas the concentrations of Cd and Pb were higher. Another research in China, the median concentration As in the urine of dismantling worker, 13.0 µg/L, was considerably lower than that found in the present study. The median Cr, Cd, Pb concentration in the urine of dismantling workers were 0.74 µg/g of creatinine, 0.37 µg/g of creatinine, and 1.8 µg/g of creatinine, respectively, which were lower than those observed in this study. They pointed out that seafood consumption was probably the origin of the elevated urine in As concentration (Julander et al, 2014).

The ACGIH standard values of As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn in urine were 10, 2, 5, 100, 50, 100, 100, and 1000 µg/g of creatinine, respectively (see figure 29). When comparing with the standard, the average concentration of As in urine of the participants was higher than the ACGIH standard of 35 µg/L. There was 70% of the dismantling workers who had As in the urine over the standard. The standard of Cu in the urine was 50 µg/g of creatinine, and 8% of the dismantling workers were found to have Cu in the urine over the standard. There were 21% and 4% of the dismantling workers who had Mn and Zn in the urine over the standard of 3 and 900 µg/g of creatinine, respectively. For the control group, there were 48.4%, 9.7%, 19.4% and 3.2% of the dismantling workers who have As, Cu, Mn and Zn in the urine over the standard. As a result, the large proportion of the workers who had the As concentrations in the urine higher than the standard level could be found, which might be caused by the exposure to As which is the major heavy metal found in LCD screens, CTR screens, and PCB during the sampling. This e-waste was the most common e-waste in e-waste dismantling activities (see in APPENDIX B, Table B1 Main e-waste group founded in this site). For the control group, some participants who had the As concentrations in the urine higher than the standard might be caused by exposure to elevated levels of inorganic arsenic through ingestion, including drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, eating contaminated food and smoking tobacco. The study of Ruangwises et al. (2012) showed that the higher concentration of total arsenic in rice and rice bran samples in Thailand was 2,361 ng/g. Some research indicated that the source of As the urine mainly comes from the As contaminated drinking groundwater. They found the average As concentration in the urine of groundwater-drinking

participants was 36.97 µg/L, which was higher than the association advancing occupational and environmental health (ACGIH) standard of 35 µg/L (Wongsasuluk et al., 2018)

The Cu concentrations in the urine of some workers in this area could be found higher than the standard level. This might be caused by the exposure to Cu during separating copper wire as the major component of many devices (See Appendix B, Table B1 Main e-waste group founded in this area during the sampling). Some studies showed that Cu was mostly found in computer chips and cathode ray tube (CRT) in computer monitors. Other previous studies also proved that high level of urinary As and Cu concentration of participants caused by directly exposed to the chemicals without PPE using, such as gloves and masks as well as the intake of contaminated food and drinking water (Wang et al, 2011; Wongsasuluk et al, 2018). The present study found that PPE using affects the As concentration in urine of the participants. However, the high Cu concentration in urine might also depend on other associated factors. Wang et al. (2011) showed some important exposure factors, such as seafood from the outside market had a positive correlation with the level of Cu concentration in urine. Although, this factor was not associated with As concentration in urine of participants in this area, but they may be related because of half of the participants ate seafood. As for the concentration of Mn and Zn, these metals are essential trace elements of the human body, which some people may have a higher metal value due to alcohol drinking. There are numerous researches on metal in alcoholic beverages. They reported that alcohol consumption provides important amounts of nutritional requirements of several essential metals such as Zn. The high concentration of Mn and Zn were supported by the study of Ibanez et al. (2008).

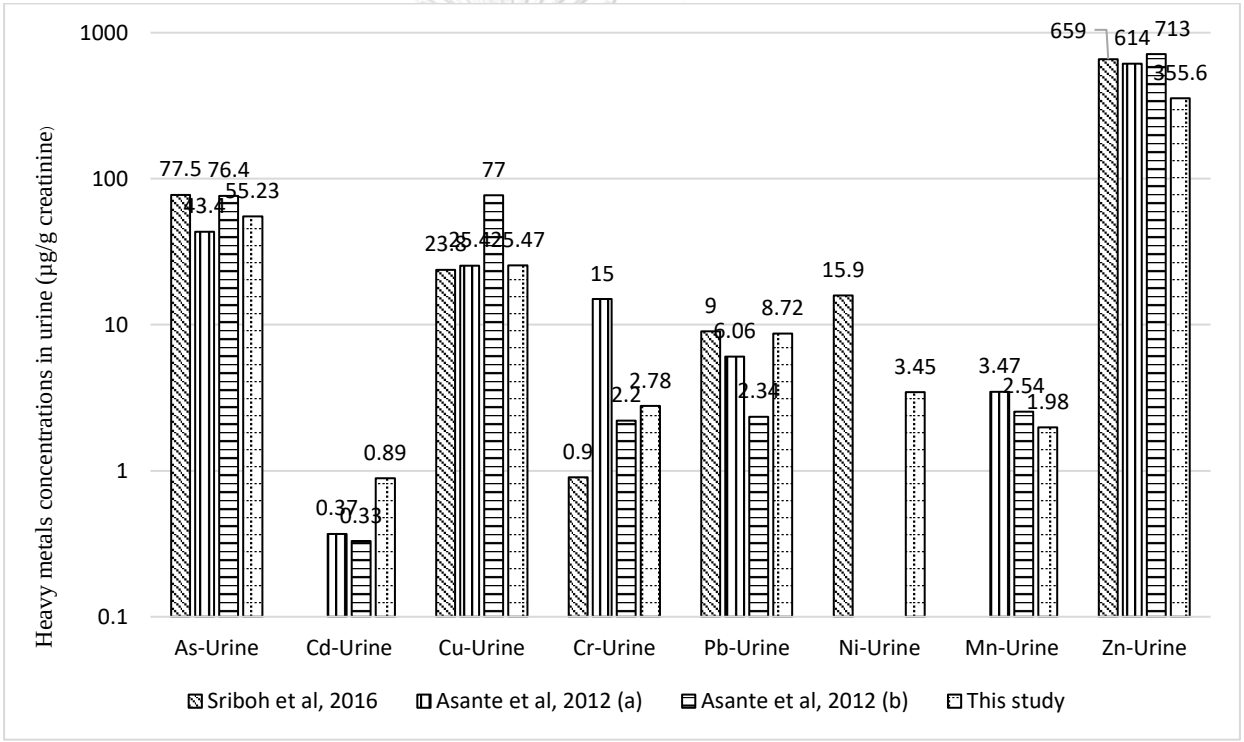


Figure 28 Heavy metals concentration in urine of e-waste workers at the e-waste dismantling site from previous studies

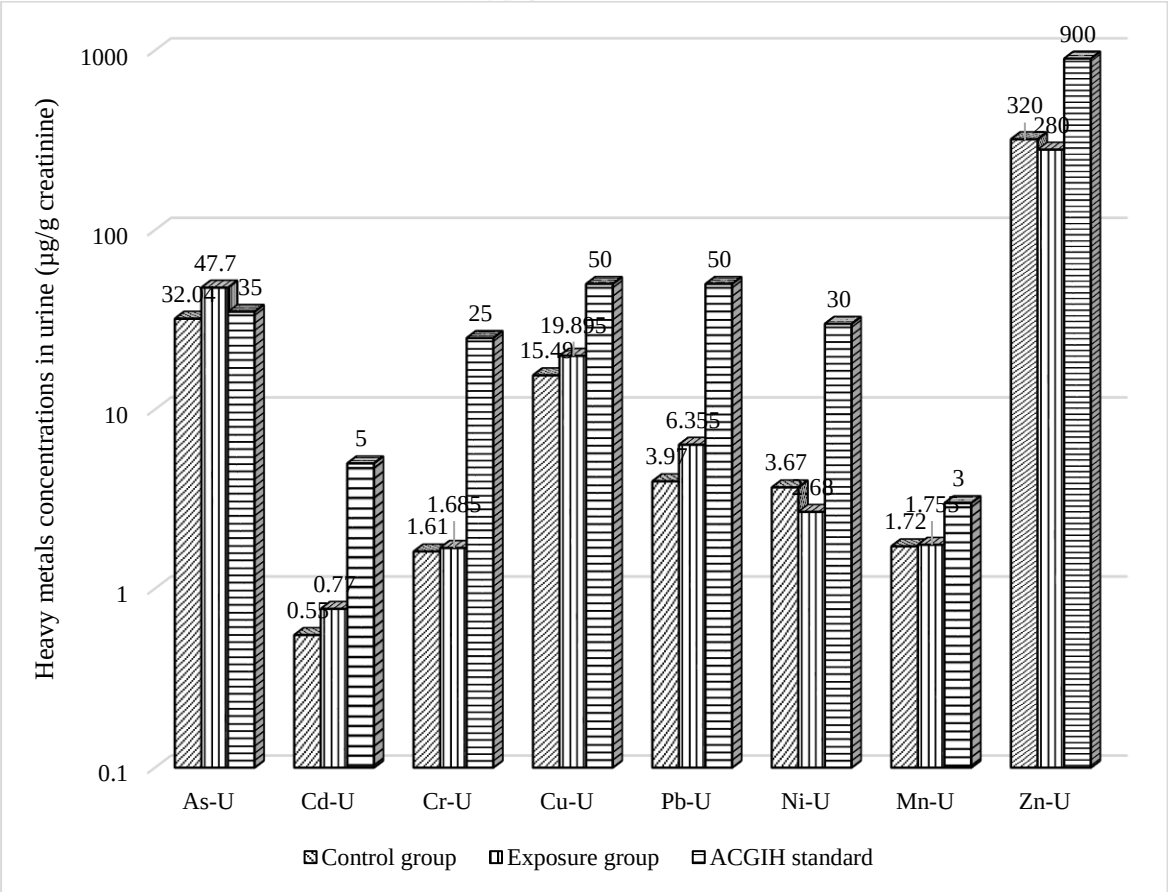


Figure 29 Heavy metal concentrations in the urine of non-e-waste dismantling workers and e-waste dismantling workers compared with standard concentrations.

4.3.2 The difference of heavy metal concentrations in urine between exposure and control groups

The Kolmogorov-Smirnov test (K-S test) in the SPSS program version 22 was used for normality testing. From the normality tests, the p-value greater than 0.05 (p-value>0.05) indicates the normal distribution of data. According to the results, the heavy metal concentrations in urine of occupational dismantling people (exposure group) were not normal distribution, as the p-values of 0.018, 0.000, 0.000, 0.000, 0.000, 0.001, 0.001, and 0.000, for As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn, respectively. The heavy metal concentrations in the urine of non-occupational people (control group) were normal distribution showing the p values of 0.000 for As, Cd, Cr, Cu, and Pb, and of 0.030 for Mn and 0.002 for Zn, but excepted for Ni (p=0.058). Due to all data were not a normal distribution, a nonparametric test would then be chosen to analyze. The Mann-Whitney U Test was used to compare differences between two independent groups, the heavy metal concentrations in the urine of occupational dismantling people (exposure group) and non-occupational dismantling people (control group).

The difference between heavy metal concentrations in urine of exposure group and control group, was examined by using U test analysis and the results were presented in Table 18, the result shows that Cd and Pb in urine of exposure were significantly higher than those of control groups (p= 0.003 and 0.000, respectively), while the Ni in urine of the exposure group was significantly lower than the control group (p= 0.033).

Table 18 The difference of heavy metals concentration in urine between exposure and control groups

Heavy Metals (µg/g creatinine)	Exposure group		Control group		
	Mean ± SD	Median	Mean ± SD	Median	p-value
As-U	55.229±34.906	47.70	46.021±36.856	32.04	0.061
Cd-U	0.895±0.47	0.77	0.722±0.533	0.55	**0.003***
Cr-U	2.547±2.466	1.69	1.946±1.305	1.61	0.480
Cu-U	25.469±16.483	19.90	23.167±17.608	15.49	0.093
Pb-U	8.194±6.126	6.36	4.377±3.32	3.97	**0.000***
Ni-U	3.452±2.971	2.68	4.305±2.714	3.67	**0.033***
Mn-U	1.978±1.324	1.76	2.069±1.173	1.72	0.681
Zn-U	351.111±253.954	280.00	363.20±204.754	320.00	0.989

* = Mann-Whitney U test, (p-value < 0.05)

The Spearman correlation analysis between concentration of heavy metals in urine and heavy metals in PM_{10} of e-waste and non-e-waste dismantling workers at the significant level of 0.05 which are presented in Table 19, the result shows the significant positive correlation for Pb with *r* of 0.203 (p = 0.045), in contrast, the level of Cr in urine and heavy metals in PM_{10} gave significant negative correlation with *r* = -0.201 (p = 0.042). With respect to the significant correlation of Pb concentration in urine and PM_{10}, Pb was considered to be the basic component in PM_{10} in this area which could be possible to release from various types of e-waste, for examples, fan and monitors, which led to elevate its urinary of the e-waste dismantling workers in the sites. Some studies showed that Pb was used in electronics products, printed circuit boards and the cathode ray tubes (CRTs) in monitors (OECD, 2003). Further, most of the inhaled lead that enters the body of workers would be excreted in urine (Oscar et al, 2017). It could be implied that e-waste dismantling activities were the source of Pb in the body of dismantling workers.

Table 19 Correlation between heavy metals in Urine and PM_{10} of e-waste and non-e-waste dismantling workers

Heavy Metals	*r*	p-value
As	-0.046	0.652
Cd	0.050	0.620
Cr	-0.201	0.042*
Cu	-0.102	0.316
Pb	0.203	**0.045***
Ni	0.116	0.250
Mn	0.092	0.356
Zn	0.133	0.179

* = Spearman Correlation tests, (p-value < 0.05)
r = Correlation Coefficient

4.4 Associated factors of urinary metals of the participants

Regarding to the research hypothesis 1, this study was hypothesized that the concentration of heavy metals in urine has a significant relationship to heavy metals in dust from electronic waste dismantling. As the results of the Spearman correlation tests that are presented in Table 19 reveal that only Pb concentration in PM_{10} from electronic waste dismantling gave a significant relationship to the concentration of Pb in the urine. It seems that exposure to the heavy metals in the PM_{10} emitted from e-waste disassembly might not be a direct factor of the heavy metals existing in the urine and there should have some other associated factors. Chi-square was then applied to investigate the relationship of all associated factors which may affect the presence of heavy metals in dismantling workers' urine. The associated factors of subjects were divided into two groups, including general and occupational characteristics; the analysis results are shown in Table 20 and 21.

4.4.1 General characteristic of the participants

Associated factors about the general characteristics of a total of 131 participants that may affect the heavy metals in urine were examined by using the Chi-square test. The general characteristics defined as an associated factor for urinary heavy metals, including gender, age, height, weight, BMI, seafood consumption, smoking behavior, secondhand smoking, alcohol drinking, fertilizer using, and occupation of e-waste. The analysis results of the Chi-square test for all urinary heavy metals are summarized and shown in Appendix A, (Table A4 Chi-square test of heavy metals in urine and associated factors of non- and e-waste dismantling workers in SPSS program).

The result shows that the significant factor associated with As in urine was alcohol drinking (p = 0.042) as shown in Table 20. The percentage of participants drinking alcohol had As concentration in urine higher than the median was approximately 57.5% and higher than those in the participants who not drunk alcohol (39.7%). Alcohol drinking behavior may be a factor in the increase of arsenic in the urine of participants. In addition, the people in this community are also making herbal liquor for sale. The water that is mixed to make herbal liquor may be

contaminated with As, causing the As contamination in herbal liquor to probably be high. Other previous research also proved that the ingredients in beer and wine are high in arsenic. It is also possible that arsenic is added during the filtration process (Bahar, 2013). Bae et al. (2013) reported that alcohol intake was associated with As concentration in urine in Aguilera et al. (2008) study. Several studies reported that lifestyles such as drinking habits may affect the metabolism of As in the body (Bae et al., 2013). As a result, As concentrations in the urine of workers could be found higher than the standard level that might be caused by this factor.

The significant relationship between Pb in urine and occupation of e-waste could be obtained (p = 0.002). The percentage of occupation of e-waste in participants who were dismantling workers and found to have high Pb concentration in urine (57.0%) was higher than in the participants who were not dismantling workers and had high Pb concentration in urine (25.8%). The occupation of e-waste might then be an important source of Pb exposure in which consequently increasing the concentration in urine. This result concise with the result of the positive relationship between the concentration of Pb in urine and its concentration in PM_{10} of non-e-waste dismantling and e-waste dismantling workers from Spearman correlation tests. As above mentioned, e-waste dismantling activities such as electronics waste dismantling can be considered as the possible contribution source of Pb contaminated in PM_{10} in the air. Further, this relationship between Pb in urine and occupation of e-waste was supported by a study from Julander et al. (2014), who investigate the Pb concentration in urine of participants in e-waste dismantling sites in Sweden and found a significant relationship between biomarkers and Pb contaminated in PM_{10}. Although, other factors found no significant association in heavy metals in the urine except these two factors (occupation of e-waste in participants and PPE using). However, the air concentrations of Pb were 1.7 times higher in the e-waste dismantling workers compared to the non-e-waste dismantling workers.

Table 20 General characteristic of participants in association to heavy metals in urine

General characteristic	p-value							
	Heavy metals in Urine							
Total (n=131)	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Mn**	**Zn**
Gender	0.665	0.061	0.775	0.665	0.138	0.333	0.537	0.919
Age	0.660	0.181	0.248	0.191	0.191	0.928	0.660	0.938
Height	0.307	0.233	0.976	0.510	0.510	0.248	0.428	0.374
Weight	0.789	0.103	0.679	0.934	0.665	0.333	0.934	0.423
BMI	0.431	0.095	0.543	0.930	0.930	0.794	0.431	0.433
Seafood consumption	0.965	0.312	0.828	0.630	0.965	0.204	0.693	0.105
Smoking behavior	0.298	0.863	0.644	0.085	0.589	0.589	0.350	0.722
Secondhand smoke	0.431	0.400	0.145	0.251	0.771	0.945	0.945	0.382
Alcohol drinking	**0.042***	0.369	0.458	0.435	0.257	0.435	0.435	0.906
Fertilizer using	0.417	0.292	0.873	0.095	0.918	0.802	0.802	0.689
Occupation of e-waste	0.164	**0.006***	0.231	0.164	**0.002***	0.058	0.875	0.638

***= Chi-square test , (p-value < 0.05)

4.4.2 Occupational characteristic of participants

Associated factors about occupational characteristics of 100 e-waste dismantling workers participants that may have an effect on the heavy metals in urine were examined by using the Chi-square test. The associated factors relating to the participant's occupation were defined as e-waste burning, grove&mask using, grove using, mask using, and working hour. According to the result, there was a significant relationship between e-waste burning and As in urine with the *p*-value of 0.046, as shown in Table 21. The percentage of participants who did e-waste burning and had high As concentration in urine (60.0%) was higher than those not burned e-waste but had high As concentration in urine (40.0%). This result implies that e-waste burning would possibly cause of high exposure to As and finally result in high concentration in urine of the participants besides alcohol drinking. Moreover, the mean and median concentrations of As in urine were higher in the exposure group than those of the control group.

Moreover, the statistical analysis results showed that the associated factor related to urinary Pb was the use of personal protective equipment (PPE) by participants. Considering the criteria to be set as a cut point at two pieces of PPE wearing, including masking and wearing gloves. The PPE using was divided into three groups, including grove&mask using, grove using, and mask using. The Pb in urine was significantly associated with the workers who used grove&mask (p = 0.012). The analysis result reflects that the percentage of participants using grove&mask and had high Pb concentration in urine (26.1%) was lower than in the participants who did not wear both grove and mask and had high Pb concentration in urine (55.8%). This result pointed out that PPE using could decrease Pb found in the urine of the participants. Some previous research also examined PPE using such as masking at e-waste dismantling sites in association with the Pb concentration urine and found levels of Pb in the urine of the workers who did not use PPE higher than the workers who use PPE (Wang et al., 2011). However, workers in the e-waste separation area use inappropriate PPE, such as gloves and masks that do not protect against exposure to heavy metals. Other research also proved that e-waste dismantling workers were at risk of being exposed to toxic levels of Pb through inhalation of fumes like the present study. For seafood consumption and smoking factor, some

studies showed seafood consumption from the outside market and smoking were important exposure factors which have a positive correlation with the level of Cu concentrations in urine (Wang et al., 2011). The present study showed no significant differences in their Cu concentrations in urine, though our findings showed the concentrations of Cu in the urine of occupational dismantling workers in the dismantling area were higher than those in the and non-occupational dismantling workers.

Table 21 Occupational characteristic of participants in association with heavy metals in urine

Occupational characteristic	**p-value**							
	Heavy metals in Urine							
Total (n=100)	As	Cd	Cr	Cu	Pb	Ni	Mn	Zn
E-waste burning	**0.046***	0.161	0.841	0.230	0.161	0.689	0.424	0.230
Grove&mask using	0.812	0.411	0.729	0.476	**0.012***	0.476	0.812	0.235
Grove using	0.817	0.419	0.419	0.488	0.051	0.817	0.817	0.248
Mask using	1.000	1.000	0.238	1.000	0.238	0.495	1.000	1.000
Workhour	0.617	0.618	0.118	0.617	0.967	1.000	0.617	0.617

*****= Chi-square test , (p-value < 0.05)

4.5 Health risk assessment of the worker exposed to heavy metals via inhalation

With regard to the results of the heavy metals via inhalation in section 4.2 found that the heavy metal concentrations (As, Cd, Cr, Cu, Pb, Ni, Mn, and Zn) in dust (PM_{10}) of non- and e-waste dismantling worker in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district and non-e-waste dismantling workers in Village No.1, Daengyai sub-district, Buriram province was lower than the ACGIH and TLV standard (2019), but unable to conclude whether the exposure was harmful or not. Therefore, the concentration of heavy metal exposure was used to calculate the health risk assessment. The hazard of heavy metals can be identified as non-carcinogenic and carcinogenic. The target organ of inhalation exposure to non-carcinogenic metals (As, Cd, Cr, Cu, Ni, and Mn) having chronic problems is the pulmonary system (see Table 9 Hazard identification of all target heavy metals). Therefore, the summation of hazard quotients for all substances, as becoming to HI, could be done because these metals affect the same target organs. The results are summarized as follows;

4.5.1 Non-carcinogenic risk level of the non- and e-waste dismantling workers exposed to heavy metals via inhalation

Hazard Quotient (HQ) and Hazard Index (HI) of exposure to heavy metal for the participants living in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district and Village No.1 Daengyai sub-district was examined separately regarding the concentration obtained from non- and e-waste dismantling workers. From Table 22, 95% confidence interval (95% CI) of HQ for each non-carcinogenic heavy metal include As, Cd, Cr, Cu, Ni and Mn of e-waste dismantling workers at e-waste dismantling sites were 16.727-28.642, 0.008-0.011, 3.367-5.306, 0.046-0.066, 0.289-0.452, and 4.233-5.512, respectively, and Hazard Index (HI) was 25.413-39.134. There were 75, 65, 4, 77 participants from the total of 83 who had the HQ of As, Cr, and Mn exceed the acceptable risk (>1). As for non-e-waste dismantling workers, the 95% CI of 12.648-18.508, 0.004-0.007, 1.804-3.832, 0.020-0.045, 0.206-0.424, and 2.811-4.470 were acquired for As, Cd, Cr, Cu, Mn and

Ni, respectively and that of HI was 18.67-26.11. There were 20, 16, and 18 participants from a total of 20 who had the HQ of As, Cr, and Mn exceeds the acceptable risk. The averages of HQs of e-waste dismantling workers and non-e-waste dismantling workers were 22.68, 9.0×10^{-3}, 4.34, 5.6×10^{-2}, 3.7×10^{-1}, and 4.87 and 15.58, 6.0×10^{-3}, 2.82, 3.3×10^{-2}, 3.1×10^{-1}, and 3.64 for As, Cd, Cr, Cu, Ni and Mn, respectively. The HQs of all non-carcinogenic heavy metals are ranked in the order as As > Mn > Cr >Ni > Cu > Cd for non- and e-waste dismantling workers. Nevertheless, the HQ of As, Cr and Mn were over acceptable risk (HQ>1) for both non- and e-waste dismantling workers.

The result of HQs of non-carcinogenic metals in the study of Singh et al. (2018) found that HQs of As, Cd, Cr, Cu and Ni were 1.52×10^{-5}, 1.02×10^{-6}, 1.03×10^{-5}, 9.17×10^{-6} and 1.04×10^{-6}, respectively in PM_{10} of e-waste workers at e-waste recycling sites in India which are lower than this study. No severe health risk was observed in workers for HI values for exposure from all the metals were lower than acceptable level of 1. It was possible that both e-waste dismantling sites and associated factors were different. Research in e-waste dismantling workshops in China reported that the values of HQs and HIs for each non-carcinogenic metal were Cr (4.24×10^{-3}), Ni (7.11×10^{-6}), Cu (3.82×10^{-6}), Cd (1.19×10^{-5}), and Pb (6.79×10^{-4}) and that of HIs was 4.52×10^{-3}, respectively (Fang et al.,2018). When comparing with this present study, the values of HQs and HIs were higher than the study of Fang et al. (2018). Due to previous studies were conducted in the e-waste dismantling workshop, which is a closed area. On the other hand, the present study conducted in e-waste dismantling sites which might be affected by other activities extensively, for example, many types of electronic waste separation activities are close to each other, so it has more dust than a closed area.

Table 22 Non-carcinogenic risk level of the non- and e-waste dismantling workers exposed to heavy metals via inhalation

Heavy metals	Exposure group					Control group				
	EC (mg/m^3)	HQ		HI		EC (mg/m^3)	HQ		HI	
	Min Max	Min Max	95%CI Lower Upper	Min Max	95%CI Lower Upper	Min Max	Min Max	95%CI Lower Upper	Min Max	95%CI Lower Upper
As	2.35×10^{-6} 1.88×10^{-3}	0.160 125.41	16.73 28.64	0.83 151.99	25.41 39.13	2.68×10^{-5} 3.75×10^{-4}	1.79 25.03	12.65 18.51	3.38 34.62	18.67 26.11
Cd	3.77×10^{-10} 2.45×10^{-5}	5.38×10^{-7} 0.04	8.0×10^{-3} 0.01			3.48×10^{-7} 9.45×10^{-6}	5×10^{-4} 0.0135	4.0×10^{-3} 7.0×10^{-3}		
Cr	2.35×10^{-6} 2.88×10^{-3}	0.02 28.82	3.367 5.306			2.86×10^{-6} 7.49×10^{-4}	0.029 7.490	1.804 3.832		
Cu	1.57×10^{-6} 4.40×10^{-4}	0.001 0.220	0.046 0.066			1.80×10^{-5} 2.49×10^{-4}	0.009 0.124	0.020 0.045		
Ni	1.18×10^{-10} 4.37×10^{-4}	7.85×10^{-7} 2.914	0.289 0.452			5.40×10^{-6} 1.18×10^{-4}	0.036 0.789	0.206 0.424		
Mn	9.83×10^{-7} 5.18×10^{-4}	0.020 10.362	4.233 5.512			1.90×10^{-6} 2.88×10^{-4}	0.038 5.769	2.811 4.470		

4.5.2 Lifetime cancer risk of the non- and e-waste dismantling workers exposed to heavy metals via inhalation

Lifetime cancer risk (LCR) of exposure to heavy metal for the participants living in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district and Village No.1 Daengyai sub-district was examined separately regarding the concentration obtained from non- and e-waste dismantling workers. From Table 23, 95% confidence interval (95% CI) of LCR for each carcinogenic heavy metal including As, Cd, Cr, Pb and Ni. These metals affect the same target organs were the lungs, the LCR values of each carcinogenic metals could then be summed and reported as TLCR values. The LCR of e-waste dismantling workers at e-waste dismantling sites were 1.13×10^{-7}-2.18×10^{-7}, 8.61×10^{-6}-1.19×10^{-5}, 1.45×10^{-3}-2.48×10^{-3}, 4.25×10^{-7}-5.97×10^{-7}, and 4.20×10^{-6}-6.39×10^{-6}, respectively, and TLCR was 1.50×10^{-3}-2.50×10^{-3}. There were 39, 80, 1, and 10 participants from the total of 83 who had the LCR of Cd, Cr, Pb and Ni exceed the acceptable risk ($>10^{-6}$). As for non-

e-waste dismantling workers, the 95% CI of 9.33×10^{-8}-1.37×10^{-7}, 4.62×10^{-6}-8.80×10^{-6}, 8.45×10^{-4}-1.80×10^{-3}, 2.36×10^{-7}-4.0×10^{-7}, and 3.22×10^{-6}-6.62×10^{-6} were acquired for As, Cd, Cr, Pb and Ni, respectively and that of TLCR was 1.30×10^{-3}-1.80×10^{-3}. There were 5, 20, and 3 participants from the total of 20 who had the risk level of Cd, Cr and Ni over the acceptable risk. The average of LCR of e-waste dismantling workers and non-e-waste dismantling workers were 1.63×10^{-7}, 1.03×10^{-5}, 3.99×10^{-3}, 5.03×10^{-7}, and 5.25×10^{-6} and 1.15×10^{-7}, 6.71×10^{-6}, 1.32×10^{-3}, 3.18×10^{-7}, and 4.92×10^{-6} for As, Cd, Cr, Pb and Ni, respectively. The LCR of all carcinogenic heavy metals are ranked in the order as Cr > Cd > Ni > Pb > As for non- and e-waste dismantling workers. However, the LCR of Cd, Cr, and Ni were over acceptable risk (LCR>10^{-6}) for both non- and e-waste dismantling workers.

Table 23 Carcinogenic risk level of the non- and e-waste dismantling workers exposed to heavy metals via inhalation

	Exposure group					Control group				
Heavy metals	CDI (mg/m^3)	LCR		TLCR		CDI (mg/m^3)	LCR		TLCR	
	Min Max	Min Max	95%CI Lower Upper	Min Max	95%CI Lower Upper	Min Max	Min Max	95%CI Lower Upper	Min Max	95%CI Lower Upper
As	1.49×10^{-7} 3.05×10^{-4}	6.42×10^{-10} 1.31×10^{-6}	1.13×10^{-7} 2.13×10^{-7}	5.28×10^{-6} 1.58×10^{-2}	1.50×10^{-3} 2.50×10^{-3}	3.07×10^{-6} 4.29×10^{-5}	1.32×10^{-8} 1.85×10^{-7}	9.33×10^{-8} 1.37×10^{-7}	3.12×10^{-5} 3.54×10^{-3}	1.30×10^{-3} 1.80×10^{-3}
Cd	5.20×10^{-11} 2.53×10^{-6}	7.80×10^{-10} 3.80×10^{-5}	8.61×10^{-6} 1.19×10^{-5}			3.98×10^{-8} 1.08×10^{-6}	5.97×10^{-7} 1.62×10^{-5}	4.62×10^{-6} 8.80×10^{-6}		
Cr	1.19×10^{-7} 3.84×10^{-4}	4.86×10^{-6} 1.58×10^{-2}	1.45×10^{-3} 2.48×10^{-3}			3.27×10^{-7} 8.56×10^{-5}	1.34×10^{-5} 3.51×10^{-3}	8.45×10^{-4} 1.80×10^{-3}		
Pb	7.90×10^{-8} 4.58×10^{-5}	3.32×10^{-9} 1.92×10^{-6}	4.25×10^{-7} 5.97×10^{-7}			2.17×10^{-7} 1.53×10^{-5}	9.13×10^{-9} 6.41×10^{-7}	2.36×10^{-7} 4.00×10^{-7}		
Ni	2.02×10^{-11} 3.37×10^{-5}	1.84×10^{-11} 3.49×10^{-5}	4.20×10^{-6} 6.39×10^{-6}			6.17×10^{-7} 1.35×10^{-5}	5.62×10^{-7} 1.23×10^{-5}	3.22×10^{-6} 6.62×10^{-6}		

The research in e-waste dismantling sites in India reported that LCR of carcinogenic metal include As, Cd, Cr, Ni and Pb as 2.34×10^{-9}, 2.65×10^{-8}, 1.47×10^{-8}, 6.01×10^{-9} and 2.79×10^{-8} in PM_{10} inhale of e-waste workers, which were lower than

this present study, similarly to non- carcinogenic metals (Singh et al.,2018). Fang et al. (2018) evaluated the values of LCR and reported as 1.36×10^{-4}, 6.56×10^{-6}, 2.03×10^{-6}, and 9.93×10^{-7} for Cr, Ni, Cd, and Pb, respectively. The values of LCR of Cd and Cr in this present study were higher than the study of Fang et al. (2018), while LCR of Pb was lower than this study. The values of LCR of Ni in both studies were similar.

There was some uncertainty for the risk assessment method used in this study. For example, the slope factor of Cr (VI) was used to calculate LCR of Cr that could not be identified whether Cr (III) or Cr (VI). As a result, lifetime cancer risk (LCR) would be overestimated. To reduce the health risk of cancer from heavy metals exposure via inhalation, the high efficiency of personal protective equipment must be used to decrease the chance of inhalation with heavy metals emitted from an e-waste dismantling. Furthermore, proper procedures for wearing personal protective equipment should be suggested through risk communication activities to maximize protection for the workers.

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research aimed to study about the concentration of heavy metals (As, Cd, Cr, Cu, Pb, Ni, Mn and Zn) in dust and heavy metals in urine of electronic waste dismantling workers in Buriram province, Thailand, and to estimate health risk of electronic waste dismantling workers exposed to heavy metal in dust using urinary heavy metals as a biomarker. The personal inhalation exposure samples were collected at the e-waste dismantling site in Daengyai sub-district, Banmaichaiyapot district and Banpao sub-district, Phutthaisong district and non-e-waste dismantling workers in Village No.1 Daengyai sub-district, Buriram province, Thailand during January to February 2019. All the obtained results could be concluded as follows:

5.1.1 Heavy metals concentrations in PM_{10}

1) The average concentration of heavy metals in PM_{10} of electronic waste dismantling workers (exposure group) was higher than that at non-electronic waste dismantling workers (control group), in exception for Zinc. The result shows that Cu and Pb in PM_{10} of exposure and control groups were significantly different (p = 0.014, p = 0.019), respectively.

2) All of the heavy metal concentrations of non-e-waste dismantling workers and electronic waste dismantling workers lower than the standard of ACGIH and TLVs 2019.

5.1.2 Heavy metals concentrations in urine

1) The average concentration of heavy metals in the urine of electronic waste dismantling workers (exposure group) was higher than that at non-electronic waste dismantling workers (control group) except for Nickel and Zinc. The result

showed that Cd, Pb and Ni in the urine of exposure and control groups was significantly different (p = 0.003, p = 0.000, and p = 0.033), respectively.

2) The concentration of As, Cu, Mn, and Zn in the urine of some dismantling workers exceeded the ACGIH standard which accounted for 70%, 8%, 21%, and 4% of the total, respectively, and those of 48.4%, 9.7%, 19.4% and 3.2% for non-electronic waste dismantling workers.

5.1.3 Associated factors of the heavy metal presence in urine

1) For general characteristics, the Chi-square test (χ^2) showed that the significantly associated factor related to the Pb in urine was the occupation of e-waste (p = 0.002) and that for As in urine was alcohol drinking (p = 0.042) at 95% confidence level.

2) For occupational characteristics, e-waste burning and grove&mask using were determined as the significant associated factors of As (p = 0.046) and Pb (p = 0.012) in urine at a 95% confidence level, respectively.

3) The Spearman correlation tests showed the positive relationship between concentrations of Pb in urine and concentrations of Pb in PM_{10} of e-waste and non-e-waste dismantling workers at a 95% confidence level.

5.1.4 Health risk assessment of the non- and e-waste dismantling workers exposed to heavy metals via inhalation

1) The 95% confidence intervals (95%CI) of Hazard Quotient (HQ) of e-waste dismantling workers exposed to heavy metals in PM_{10} of at e-waste dismantling sites were in the range of 16.727-28.642, 0.008-0.011, 3.367-5.306, 0.046-0.066, 0.289-0.452, and 4.233-5.512 for As, Cd, Cr, Cu, Ni and Mn, respectively. There were 75, 65, 4, 77 participants from the total of 83 who had the HQ of As, Cr, Ni, and Mn exceed the acceptable risk (>1). For non-e-waste dismantling workers, the 95% CI ranged from 12.648-18.508, 0.004-0.007, 1.804-3.832, 0.020-0.045, 0.206-0.424, and 2.811-4.470 for As, Cd, Cr, Cu, Mn and Ni, respectively. There were 20, 16, and 18 participants from a total of 20 who had the HQ of As, Cr, and Mn exceeds the

acceptable risk. For Hazard Index or HI, the 95% CI of e-waste dismantling workers and non-e-waste workers were in the range of 25.4-39.1 and 18. 7-26.1, respectively, and those of 81 and 20 participants from the total were higher than the acceptable criteria in respectively.

2) The 95% CI of lifetime cancer risk (LCR) of e-waste dismantling workers exposed to heavy metals in PM_{10} at the e-waste dismantling sites ranged from 1.14×10^{-7}-2.18×10^{-7}, 1.45×10^{-3}-2.48×10^{-3}, 4.25×10^{-7}-5.97×10^{-7}, and 4.20×10^{-6}-6.39×10^{-6} as for As, Cd, Cr, Pb and Ni, respectively. There were 39, 80, 1, and 10 participants from the total of 83 who had the LCR of Cd, Cr, Pb and Ni exceed the acceptable risk ($>10^{-6}$). For non-e-waste dismantling workers, the 95% CI ranged from 9.33×10^{-8}-1.37×10^{-7}, 4.62×10^{-6}-8.80×10^{-6}, 8.45×10^{-4}-1.80×10^{-3}, 2.36×10^{-7}-4.0×10^{-7}, and 3.22×10^{-6}-6.62×10^{-6} as for As, Cd, Cr, Pb and Ni, respectively. There were 5, 20, and 3 participants from the total of 20 who had the risk level of Cd, Cr and Ni over the acceptable risk. The 95% CI of total lifetime cancer risk (TLCR) of e-waste dismantling workers were ranged from $1.5\text{-}2.5\times10^{-3}$ and 82 participants from the total subjects were found to have the risk over the acceptable criteria. Whilst, those of the non-e-waste dismantling workers ranged from $1.3\text{-}1.8\times10^{-3}$ and 20 participants showed the TLCR values higher than the acceptable risk.

5.2 Recommendations and suggestions

Due to the high level of unacceptable risk of exposure to heavy metals via inhalation, the people should have their health surveillance. Moreover, the local administrative organization should set the plan to protect the worker's health in the consequences of electronic waste dismantling, and also control the pollution emitted into the environment. These findings further indicate the need for automatic machines in the recycling of e-waste to protect e-waste dismantling workers. Furthermore, more studies of associated factors from informal e-waste dismantling workers in combination with exposure monitoring will be needed for encouraging the worker's awareness to prevent their exposure to heavy metals from e-waste dismantling as well as to minimize their adverse health risks.

REFERENCES

Akerstrom, M., Barregard, L., Lundh, T., Sallsten, G. J. J. o. E. S., & Epidemiology, E. (2014). Variability of urinary cadmium excretion in spot urine samples, first morning voids, and 24 h urine in a healthy non-smoking population: implications for study design. *24*(2), 171.

Asante, K. A., Agusa, T., Biney, C. A., Agyekum, W. A., Bello, M., Otsuka, M., . . . Tanabe, S. E. (2012). Multi-trace element levels and arsenic speciation in urine of e-waste recycling workers from Agbogbloshie, Accra in Ghana. *Science of the Total, 424*, 63-73.

Azuka, A. I. J. L. E. t., & J., D. (2009). The influx of used electronics into Africa: a perilous trend. *5*, 90.

Balde, C., Kuehr, R., Blumenthal, K., Gill, S. F., Kern, M., Micheli, P., . . . Huisman, J. (2015). E-waste statistics: Guidelines on classifications, reporting and indicators. *The Global E-waste Monitor 2017*.

Ballatori, N., Cherian, M., Dawson, D., Delnomdedieu, M., Druet, P., Fisher, B., . . . Imura, N. (2012). *Toxicology of metals: biochemical aspects* (Vol. 115): Springer Science & Business Media.

Bolden, D. (2017). *Labcorp: The DNA of a Corporation*: Chapel Hill Press.

Bureau, P. R. (2008). Use of Biomarkers in Predicting Health and Mortality. *Today's Research on Aging, 14*, 1-6.

Canfield, R. L., Henderson Jr, C. R., Cory-Slechta, D. A., Cox, C., Jusko, T. A., & Lanphear, B. P. J. N. E. j. o. m. (2003). Intellectual impairment in children with blood lead concentrations below 10 μg per deciliter. *348*(16), 1517-1526.

Cann, M. (2005). *Environmental chemistry*: Macmillan.

Ceballos, D. M., & Dong, Z. J. E. i. (2016). The formal electronic recycling industry: Challenges and opportunities in occupational and environmental health research. *95*, 157-166.

Chan, J. K., Xing, G. H., Xu, Y., Liang, Y., Chen, L. X., Wu, S. C., . . . technology. (2007). Body loadings and health risk assessment of polychlorinated dibenzo-p-dioxins and dibenzofurans at an intensive electronic waste recycling site in China. *41*(22), 7668-7674.

Chang, H.-X., Brown, P. J., Lipka, A. E., Domier, L. L., & Hartman, G. L. J. B. g. (2016). Genome-wide association and genomic prediction identifies associated loci and predicts the sensitivity of Tobacco ringspot virus in soybean plant introductions. *17*(1), 153.

Chen, J., Wang, X., Steemers, K. J. E., & Buildings. (2013). A statistical analysis of a residential energy consumption survey study in Hangzhou, China. *66*, 193-202.

Chiba, M., & Masironi, R. J. B. o. t. W. H. O. (1992). Toxic and trace elements in tobacco and tobacco smoke. *70*(2), 269.

Cohen, J. (1988). Statisiical power analysis for the behavioral sci-ences . New York: Academic.

Deng, W., Zheng, J., Bi, X., Fu, J., & Wong, M. H. J. E. I. (2007). Distribution of PBDEs in air particles from an electronic waste recycling site compared with Guangzhou and Hong Kong, South China. *33*(8), 1063-1069.

Falcon-Rodriguez, C. I., Osornio-Vargas, A. R., Sada-Ovalle, I., & Segura-Medina, P. J. F. i. i. (2016). Aeroparticles, composition, and lung diseases. *Frontiers in*

Immunology, 7, 3.

Fang, W., Yang, Y., Xu, Z. J. E. s., & technology. (2013). PM10 and PM2. 5 and health risk assessment for heavy metals in a typical factory for cathode ray tube television recycling. *47*(21), 12469-12476.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. J. B. r. m. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *41*(4), 1149-1160.

Finlayson-Pitts, B. J., & Pitts Jr, J. N. (1999). *Chemistry of the upper and lower atmosphere: theory, experiments, and applications*: Elsevier.

Galażyn-Sidorczuk, M., Brzóska, M. M., Moniuszko-Jakoniuk, J. J. E. m., & assessment. (2008). Estimation of Polish cigarettes contamination with cadmium and lead, and exposure to these metals via smoking. *137*(1-3), 481-493.

Gangwar, C., Singh, A., Kumar, A., Chaudhry, A., Tripathi, A. J. S. V., & Metal, P. S. o. H. (2016). Appraisement of Heavy Metals in Respirable Dust (PM 10) Around E-waste Burning and Industrial Sites of Moradabad: Accentuation on Spatial Distribution. *10*(6), 14-21.

Gimeno-García, E., Andreu, V., & Boluda, R. J. E. p. (1996). Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. *92*(1), 19-25.

Goudarzi, G., Alavi, N., Geravandi, S., Idani, E., Behrooz, H. R. A., Babaei, A. A., . . . Mohammadi, M. J. J. I. j. o. b. (2018). Health risk assessment on human exposed to heavy metals in the ambient air PM 10 in Ahvaz, southwest Iran. *62*(6), 1075-1083.

Gu, Z., Feng, J., Han, W., Wu, M., Fu, J., & Sheng, G. J. C. (2010). Characteristics of organic matter in PM2. 5 from an e-waste dismantling area in Taizhou, China. *80*(7), 800-806.

Gullett, B. K., Linak, W. P., Touati, A., Wasson, S. J., Gatica, S., King, C. J. J. J. o. M. C., & Management, W. (2007). Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations. *9*(1), 69-79.

Guo, Y., Huo, X., Li, Y., Wu, K., Liu, J., Huang, J., . . . Wang, Y. J. S. o. t. t. e. (2010). Monitoring of lead, cadmium, chromium and nickel in placenta from an e-waste recycling town in China. *408*(16), 3113-3117.

Harpole, M., Davis, J., & Espina, V. J. E. r. o. p. (2016). Current state of the art for enhancing urine biomarker discovery. *13*(6), 609-626.

Horng, C.-J., Tsai, J.-L., Horng, P.-H., Lin, S.-C., Lin, S.-R., & Tzeng, C.-C. J. T. (2002). Determination of urinary lead, cadmium and nickel in steel production workers. *56*(6), 1109-1115.

Ibanez, J. G., Carreon-Alvarez, A., Barcena-Soto, M., Casillas, N. J. J. o. f. c., & analysis. (2008). Metals in alcoholic beverages: A review of sources, effects, concentrations, removal, speciation, and analysis. *21*(8), 672-683.

Julander, A., Lundgren, L., Skare, L., Grandér, M., Palm, B., Vahter, M., & Lidén, C. (2014). Formal recycling of e-waste leads to increased exposure to toxic metals: an occupational exposure study from Sweden. *Environment international*

73, 243-251.

Kiddee, P., Naidu, R., & Wong, M. H. J. W. m. (2013). Electronic waste management approaches: An overview. *33*(5), 1237-1250.

Kolias, K., Hahladakis, J. N., & Gidarakos, E. J. W. m. (2014). Assessment of toxic metals in waste personal computers. *34*(8), 1480-1487.

Leung, A. O., Duzgoren-Aydin, N. S., Cheung, K., & Wong, M. H. (2008). Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in southeast China. *Environmental science technology*

42(7), 2674-2680.

Lim, S.-R., & Schoenung, J. M. J. W. M. (2010). Toxicity potentials from waste cellular phones, and a waste management policy integrating consumer, corporate, and government responsibilities. *30*(8-9), 1653-1660.

Nathalie, D. J. U. G. (2012). A comparative overview of commonly used food security indicators, case study in the Limpopo Province, South Africa.

Needhidasan, S., Samuel, M., Chidambaram, R. J. J. o. E. H. S., & Engineering. (2014). Electronic waste–an emerging threat to the environment of urban India. *12*(1), 36.

Oguri, T., Suzuki, G., Matsukami, H., Uchida, N., Tue, N. M., Viet, P. H., . . . Takigami, H. J. S. o. t. T. E. (2018). Exposure assessment of heavy metals in an e-waste processing area in northern Vietnam. *621*, 1115-1123.

Pereira, P. A. d. P., Lopes, W. A., Carvalho, L. S., da Rocha, G. O., de Carvalho Bahia, N., Loyola, J., . . . de Andrade, J. B. (2007). Atmospheric concentrations and dry deposition fluxes of particulate trace metals in Salvador, Bahia, Brazil. *Atmospheric Environment*

41(36), 7837-7850.

Pookkasorn, S., & Sharp, A. (2016). The Management of Waste from Electrical and Electronic Equipment (WEEE) in Bangkok, Thailand. *6th International Conference on Biological, Chemical & Environmental Sciences*.

Prakash, S., Manhart, A., Amoyaw-Osei, Y., Agyekum, O. O. J. Ö.-I. e. i. c. w. G. E. P. A., Green Advocacy Ghana, M. o. H., Spatial Planning, & the Environment, V.-I. (2010). Socio-economic assessment and feasibility study on sustainable e-waste management in Ghana.

Qingbin Song, J. L. (2014). Environmental effects of heavy metals derived from the e-waste recycling activities in China: A systematic review. *Waste Management, 34*(12), 2587-2594.

Restrepo, E., Widmer, R., & Schluep, M. (2016). *A critical review of recycling and disposal options for leaded glass from cathode ray tubes (CRTs).* Paper presented at the 2016 Electronics Goes Green 2016+(EGG).

Riyad, A., Hassan, K. M., Iqbal, M. J., Rahim, M. A., & Uddin, S. (2014). E-waste recycling practices in Bangladesh. *Int. J. Renew. Energy Environ. Eng*

2, 193-200.

Roberts, J. W., Wallace, L. A., Camann, D. E., Dickey, P., Gilbert, S. G., Lewis, R. G., & Takaro, T. K. (2009). Monitoring and reducing exposure of infants to pollutants in house dust. In *Reviews of Environmental Contamination and Toxicology Vol 201* (pp. 1-39): Springer.

Robinson, B. H. J. S. o. t. t. e. (2009). E-waste: an assessment of global production and environmental impacts. *408*(2), 183-191.

Saravanabhavan, G., Werry, K., Walker, M., Haines, D., Malowany, M., Khoury, C. J. I. j. o. h., & health, e. (2017). Human biomonitoring reference values for metals

and trace elements in blood and urine derived from the Canadian Health Measures Survey 2007–2013. *220*(2), 189-200.

Silva, J. C. P. d., Soler, Z. A. S. G., & DominguesWysocki, A. J. R. d. E. d. E. d. U. (2017). Associated factors to urinary incontinence in women undergoing urodynamic testing. *51*.

Singh, M., Thind, P. S., & John, S. J. C. (2018). Health risk assessment of the workers exposed to the heavy metals in e-waste recycling sites of Chandigarh and Ludhiana, Punjab, India. *203*, 426-433.

Singh, R. B., Takahashi, T., Nagib-Elkilany, G. E., Hristova, K., Singh, A., Pal, R., . . . Shastun, S. J. W. H. J. (2015). The ambient air pollution and the heart. *7*(4), 165.

Sivaramanan, S. (2013). E-Waste Management, Disposal and Its Impacts on the Environment. *Journal of Environmental Research Technology*

3(5).

Srigboh, R. K., Basu, N., Stephens, J., Asampong, E., Perkins, M., Neitzel, R. L., & Fobil, J. (2016). Multiple elemental exposures amongst workers at the Agbogbloshie electronic waste (e-waste) site in Ghana. *Chemosphere*

164, 68-74.

Srithawirat, T., Latif, M. T., & Sulaiman, F. R. J. A. (2016). Indoor PM10 and its heavy metal composition at a roadside residential environment, Phitsanulok, Thailand. *29*(4), 311-322.

Strimbu, K., & Tavel, J. A. (2010). What are biomarkers? *Current opinion in HIV and AIDS, 5*(6), 463-466. doi:10.1097/COH.0b013e32833ed177

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. In *Molecular, clinical and environmental toxicology* (pp. 133-164): Springer.

UNEP. (2005). the hidden side of IT equipment's manufacturing and use. Chapter 5—Early warning on emerging environmental threats. DEWA/GRID.

Van Loon, J. C. (1982). *Chemical analysis of inorganic constituents of water*: CRC Press, Inc.

Vassanadumrongdee, S., Manomaivibool, P., Jitwiwat, S., & Rachakornkij, M. . (2015). Electronic waste: a severe hazard in the high-tech date. *Royal Thai Navy Medical Journal, 41*(3), 65-74.

Wang, H., Han, M., Yang, S., Chen, Y., Liu, Q., & Ke, S. (2011). Urinary heavy metal levels and relevant factors among people exposed to e-waste dismantling. *Environment International, 37*(1), 80-85.

Wei, L., & Liu, Y. J. P. E. S. (2012). Present status of e-waste disposal and recycling in China. *16*, 506-514.

WHO. (2019). *Preventing disease through healthy environments: exposure to lead: a major public health concern*. Retrieved from

Wongsasuluk, P., Chotpantarat, S., Siriwong, W., & Robson, M. (2018). Using urine as a biomarker in human exposure risk associated with arsenic and other heavy metals contaminating drinking groundwater in intensively agricultural areas of Thailand. *Environmental geochemistry health*

40(1), 323-348.

World Health Organization, w. w. i. i. f. c. p. (2010). Exposure to cadmium: a major public health concern. Geneva, Switzerland.

Xing, G. H., Chan, J. K. Y., Leung, A. O. W., Wu, S. C., & Wong, M. H. J. E. i. (2009). Environmental impact and human exposure to PCBs in Guiyu, an electronic waste recycling site in China. *35*(1), 76-82.

Xue, M., Yang, Y., Ruan, J., Xu, Z. J. E. s., & technology. (2011). Assessment of noise and heavy metals (Cr, Cu, Cd, Pb) in the ambience of the production line for recycling waste printed circuit boards. *46*(1), 494-499.

Yu, E. A., Akormedi, M., Asampong, E., Meyer, C. G., & Fobil, J. N. J. G. h. p. (2017). Informal processing of electronic waste at Agbogbloshie, Ghana: workers' knowledge about associated health hazards and alternative livelihoods. *24*(4), 90-98.

Zheng, J., Chen, K.-h., Yan, X., Chen, S.-J., Hu, G.-C., Peng, X.-W., . . . safety, e. (2013). Heavy metals in food, house dust, and water from an e-waste recycling area in South China and the potential risk to human health. *96*, 205-212.

Zheng, L., Wu, K., Li, Y., Qi, Z., Han, D., Zhang, B., . . . Chen, S. J. E. r. (2008). Blood lead and cadmium levels and relevant factors among children from an e-waste recycling town in China. *108*(1), 15-20.

APPENDIX A
STATISTICAL RESULTS FROM SPSS PROGRAM

Statistical analysis for exposure concentration of particulate matter of the workers via inhalation

Table A1 Tests of Normality of Heavy Metals in PM_{10}

Heavy Metals ($\mu g/m^3$)	Exposure group			Control group		
	Mean ± SD	Median	p-value	Mean ± SD	Median	p-value
As-PM_{10}	1.165±1.304	0.876	0.002	0.731±0.294	0.813	0.403*
Cd-PM_{10}	0.021±0.013	0.018	0.000	0.012±0.009	0.011	0.274*
Cr-PM_{10}	1.521±1.384	1.148	0.000	0.927±0.664	0.609	0.098*
Cu-PM_{10}	0.374±0.285	0.280	0.026	0.204±0.169	0.132	0.000
Pb-PM_{10}	0.368±0.222	0.336	0.001	0.218±0.107	0.226	0.431*
Ni-PM_{10}	0.176±0.175	0.129	0.001	0.148±0.109	0.132	0.078*
Mn-PM_{10}	0.771±0.453	0.683	0.494*	0.599±0.250	0.648	0.080*
Zn-PM_{10}	1018.311 ±776.673	884.394	0.000	913.831 ±340.500	897.537	0.366*

* = Kolmogorov-Smirnov test ,(Normal Distribution, p-value > 0.05)

Statistical analysis for exposure concentration of urine of the workers

Table A2 Tests of normality of heavy metals in urine

Heavy Metals (µg/g creatinine)						
	Mean ± SD	**Median**	**p-value**	**Mean ± SD**	**Median**	**p-value**
As-U	55.229±34.906	47.70	0.018	46.021±36.856	32.04	0.000
Cd-U	0.895±0.47	0.77	0.000	0.722±0.533	0.55	0.000
Cr-U	2.547±2.466	1.685	0.000	1.946±1.305	1.61	0.000
Cu-U	25.469±16.483	19.895	0.000	23.167±17.608	15.49	0.000
Pb-U	8.194±6.126	6.355	0.000	4.377±3.32	3.97	0.000
Ni-U	3.452±2.971	2.68	0.001	4.305±2.714	3.67	0.058*
Mn-U	1.978±1.324	1.755	0.001	2.069±1.173	1.72	0.030
Zn-U	351.111±253.954	280.00	0.000	363.20±204.754	320.00	0.002

* = Kolmogorov-Smirnov test ,(Normal Distribution, p-value > 0.05)

Table A3 Spearman correlation test of heavy metals in urine and PM_{10} of non- and e-waste dismantling workers in SPSS program

Correlations

			As_U	As_Pm
Spearman's rho	As_U	Correlation Coefficient	1.000	-.046
		Sig. (2-tailed)	.	.652
		N	97	97
	As_Pm	Correlation Coefficient	-.046	1.000
		Sig. (2-tailed)	.652	.
		N	97	97

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Cd_U	Cd_Pm
Spearman's rho	Cd_U	Correlation Coefficient	1.000	.050
		Sig. (2-tailed)	.	.620
		N	102	102
	Cd_Pm	Correlation Coefficient	.050	1.000
		Sig. (2-tailed)	.620	.
		N	102	102

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Cr_U	Cr_Pm
Spearman's rho	Cr_U	Correlation Coefficient	1.000	-.201*
		Sig. (2-tailed)	.	.042
		N	103	103
	Cr_Pm	Correlation Coefficient	-.201*	1.000
		Sig. (2-tailed)	.042	.
		N	103	103

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Cu_U	Cu_Pm
Spearman's rho	Cu_U	Correlation Coefficient	1.000	-.102
		Sig. (2-tailed)	.	.316
		N	98	98
	Cu_Pm	Correlation Coefficient	-.102	1.000
		Sig. (2-tailed)	.316	.
		N	98	98

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Pb_U	Pb_Pm
Spearman's rho	Pb_U	Correlation Coefficient	1.000	.203*
		Sig. (2-tailed)	.	.045
		N	98	98
	Pb_Pm	Correlation Coefficient	.203*	1.000
		Sig. (2-tailed)	.045	.
		N	98	98

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

			Mn_U	Mn_Pm
Spearman's rho	Mn_U	Correlation Coefficient	1.000	.092
		Sig. (2-tailed)	.	.356
		N	102	102
	Mn_Pm	Correlation Coefficient	.092	1.000
		Sig. (2-tailed)	.356	.
		N	102	102

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.9 General characteristic of participants exposed to Arsenic

General characteristic	Total n=131	As - Urine		p-value
		High > Med cut point n= 65 (49.6%)	Low ≤ Med cut point n= 66 (50.4%)	
Gender				
Male	62 47.30%	32 51.6%	30 48.4%	0.665
Female	69 52.7%	33 47.8%	36 52.2%	
Seafood consumption				
Yes	105 80.2%	52 49.5%	53 50.5%	0.965
No	26 19.8%	13 50.0%	13 50.0%	
Smoking behavior				
Yes	35 26.70%	20 57.1%	15 42.9%	0.298
No	96 73.30%	45 46.9%	51 53.1%	
Secondhand smoke				
Yes	50 38.20%	27 54.0%	23 46.0%	0.431
No	81 61.80%	38 46.9%	43 53.1%	
Alcohol drinking				
Yes	73 55.70%	42 57.5%	31 42.5%	**0.042***
No	58 44.30%	23 39.7%	35 60.3%	
Fertilizer using				
Yes-within 1 year	76 58.00%	40 52.6%	36 47.4%	0.417
No	55 42.00%	25 45.5%	30 54.5%	
Age				
high	63 48.10%	30 47.6%	33 52.4%	0.660
low	68 51.90%	35 51.5%	33 48.5%	
Height				
high	48 36.60%	21 43.7%	27 56.3%	0.307
low	83 63.40%	44 53.0%	39 47.0%	
Weight				
high	62 47.30%	30 48.4%	32 51.6%	0.789
low	69 52.70%	35 50.7%	34 49.3%	
BMI				
high	65 49.60%	30 46.2%	35 53.8%	0.431
low	66 50.40%	35 53.0%	31 47.0%	
Occupation of e-waste				
Yes	100 76.30%	53 53.0%	47 47.0%	0.164
No	31 23.70%	12 38.7%	19 61.3%	

* = Chi-square test , (p-value < 0.05)

Table 4.10 General characteristic of participants exposed to cadmium

General characteristic	Total n=131	Cd - Urine		p-value
		High > Med cut point n= 62 (47.3%)	Low ≤ Med cut point n= 69 (52.7%)	
Gender				
Male	62 47.30%	24 38.71%	38 61.29%	0.061
Female	69 52.7%	38 55.07%	31 44.93%	
Seafood consumption				
Yes	105 80.2%	52 49.52%	53 50.48%	0.312
No	26 19.8%	13 38.46%	13 61.54%	
Smoking behavior				
Yes	35 26.70%	17 48.57%	18 51.43%	0.863
No	96 73.30%	45 46.88%	51 53.13%	
Secondhand smoke				
Yes	50 38.20%	26 52.00%	24 48.00%	0.400
No	81 61.80%	36 44.44%	45 55.56%	
Alcohol drinking				
Yes	73 55.70%	32 43.84%	41 56.16%	0.369
No	58 44.30%	30 51.72%	28 48.28%	
Fertilizer using				
Yes-within 1 year	76 58.00%	33 43.42%	43 56.58%	0.292
No	55 42.00%	29 52.73%	26 47.27%	
Age				
high	63 48.10%	26 41.27%	37 58.73%	0.181
low	68 51.90%	36 52.94%	32 47.06%	
Height				
high	48 36.60%	26 54.17%	22 45.83%	0.233
low	83 63.40%	36 43.37%	47 56.63%	
Weight				
high	62 47.30%	34 54.84%	28 45.16%	0.103
low	69 52.70%	28 40.58%	41 59.42%	
BMI				
high	65 49.60%	26 40.00%	39 60.00%	0.095
low	66 50.40%	36 54.55%	30 45.45%	
Occupation of e-waste				
Yes	100 76.30%	54 54.00%	46 46.00%	**0.006***
No	31 23.70%	8 25.81%	23 74.19%	

* = Chi-square test , (p-value < 0.05)

Tale 4.11 General characteristic of participants exposed to chromium

General characteristic	Total n=131	Cr - Urine		p-value
		High > Med cut point n=63 (48.1%)	Low ≤ Med cut point n=68 (51.9%)	
Gender				
Male	62 47.30%	29 46.77%	33 53.23%	0.775
Female	69 52.7%	34 49.28%	35 50.72%	
Seafood consumption				
Yes	105 80.2%	50 47.62%	55 52.38%	0.828
No	26 19.8%	13 50.00%	13 50.00%	
Smoking behavior				
Yes	35 26.70%	18 51.43%	17 48.57%	0.644
No	96 73.30%	45 46.88%	51 53.13%	
Secondhand smoke				
Yes	50 38.20%	20 40.00%	30 60.00%	0.145
No	81 61.80%	43 53.09%	38 46.91%	
Alcohol drinking				
Yes	73 55.70%	33 45.21%	40 54.79%	0.458
No	58 44.30%	30 51.72%	28 48.28%	
Fertilizer using				
Yes-within 1 year	76 58.00%	37 48.68%	39 51.32%	0.873
No	55 42.00%	26 47.27%	29 52.73%	
Age				
high	63 48.10%	27 42.86%	36 57.14%	0.248
low	68 51.90%	36 52.94%	32 47.06%	
Height				
high	48 36.60%	23 47.92%	25 52.08%	0.976
low	83 63.40%	40 48.19%	43 51.81%	
Weight				
high	62 47.30%	31 50.00%	31 50.00%	0.679
low	69 52.70%	32 46.38%	37 53.62%	
BMI				
high	65 49.60%	33 50.77%	32 49.23%	0.543
low	66 50.40%	30 45.45%	36 54.55%	
Occupation of e-waste				
Yes	100 76.30%	51 51.00%	49 49.00%	0.231
No	31 23.70%	12 38.71%	19 61.29%	

* = Chi-square test , (p-value < 0.05)

Table A4.4 General characteristic of participants exposed to copper

General characteristic	Total n=131	Cu - Urine		p-value
		High > Med cut point n= 65 (49.6%)	Low ≤ Med cut point n= 66 (50.4%)	
Gender				
Male	62 47.30%	32 51.61%	30 48.39%	0.665
Female	69 52.70%	33 47.83%	36 52.17%	
Seafood consumption				
Yes	105 80.2%	51 48.57%	54 51.43%	0.630
No	26 19.8%	14 53.85%	12 46.15%	
Smoking behavior				
Yes	35 26.70%	13 37.14%	22 62.86%	0.085
No	96 73.30%	52 54.17%	44 45.83%	
Secondhand smoke				
Yes	50 38.20%	28 56.00%	22 44.00%	0.251
No	81 61.80%	37 45.68%	44 54.32%	
Alcohol drinking				
Yes	73 55.70%	34 46.58%	39 53.42%	0.435
No	58 44.30%	31 53.45%	27 46.55%	
Fertilizer using				
Yes-within 1 year	76 58.00%	33 43.42%	43 56.58%	0.095
No	55 42.00%	32 58.18%	23 41.82%	
Age				
high	63 48.10%	35 55.56%	28 44.44%	0.191
low	68 51.90%	30 44.12%	38 55.88%	
Height				
high	48 36.60%	22 45.83%	26 54.17%	0.510
low	83 63.40%	43 51.81%	40 48.19%	
Weight				
high	62 47.30%	31 50.00%	31 50.00%	0.934
low	69 52.70%	34 49.28%	35 50.72%	
BMI				
high	65 49.60%	32 49.23%	33 50.77%	0.930
low	66 50.40%	33 50.00%	33 50.00%	
Occupation of e-waste				
Yes	100 76.30%	53 53.00%	47 47.00%	0.164
No	31 23.70%	12 38.71%	19 61.29%	

* = Chi-square test , (p-value < 0.05)

Table A4.5 General characteristic of participants exposed to lead

General characteristic	Total n=131	Pb - Urine		p-value
		High > Med cut point n=65 (49.6%)	Low ≤ Med cut point n=66 (50.4%)	
Gender				
Male	62 47.30%	35 56.45%	27 43.55%	0.138
Female	69 52.70%	30 43.48%	39 56.52%	
Seafood consumption				
Yes	105 80.2%	52 49.52%	53 50.48%	0.965
No	26 19.8%	13 50.00%	13 50.00%	
Smoking behavior				
Yes	35 26.70%	16 45.71%	19 54.29%	0.589
No	96 73.30%	49 51.04%	47 48.96%	
Secondhand smoke				
Yes	50 38.20%	24 48.00%	26 52.00%	0.771
No	81 61.80%	41 50.62%	40 49.38%	
Alcohol drinking				
Yes	73 55.70%	33 45.21%	40 54.79%	0.257
No	58 44.30%	32 55.17%	26 44.83%	
Fertilizer using				
Yes-within 1 year	76 58.00%	38 50.00%	38 50.00%	0.918
No	55 42.00%	27 49.09%	28 50.91%	
Age				
high	63 48.10%	35 55.56%	28 44.44%	0.191
low	68 51.90%	30 44.12%	38 55.88%	
Height				
high	48 36.60%	22 45.83%	26 54.17%	0.510
low	83 63.40%	43 51.81%	40 48.19%	
Weight				
high	62 47.30%	32 51.61%	30 48.39%	0.665
low	69 52.70%	33 47.83%	36 52.17%	
BMI				
high	65 49.60%	32 49.23%	33 50.77%	0.930
low	66 50.40%	33 50.00%	33 50.00%	
Occupation of e-waste				
Yes	100 76.30%	57 57.00%	43 43.00%	**0.002***
No	31 23.70%	8 25.81%	23 74.19%	

* = Chi-square test , (p-value < 0.05)

Table A4.6 General characteristic of participants exposed to nickel

General characteristic	Total n=131	Ni - Urine		p-value
		High > Med cut point n= 65 (49.6%)	Low ≤ Med cut point n= 66 (50.4%)	
Gender				
Male	62 47.30%	28 45.16%	34 54.84%	0.333
Female	69 52.70%	37 53.62%	32 46.38%	
Seafood consumption				
Yes	105 80.2%	55 52.38%	50 47.62%	0.204
No	26 19.8%	10 38.46%	16 61.54%	
Smoking behavior				
Yes	35 26.70%	16 45.71%	19 54.29%	0.589
No	96 73.30%	49 51.04%	47 48.96%	
Secondhand smoke				
Yes	50 38.20%	25 50.00%	25 50.00%	0.945
No	81 61.80%	40 49.38%	41 50.62%	
Alcohol drinking				
Yes	73 55.70%	34 46.58%	39 53.42%	0.435
No	58 44.30%	31 53.45%	27 46.55%	
Fertilizer using				
Yes-within 1 year	76 58.00%	37 48.68%	39 51.32%	0.802
No	55 42.00%	28 50.91%	27 49.09%	
Age				
high	63 48.10%	31 49.21%	32 50.79%	0.928
low	68 51.90%	34 50.00%	34 50.00%	
Height				
high	48 36.60%	27 56.25%	21 43.75%	0.248
low	83 63.40%	38 45.78%	45 54.22%	
Weight				
high	62 47.30%	28 45.16%	34 54.84%	0.333
low	69 52.70%	37 53.62%	32 46.38%	
BMI				
high	65 49.60%	33 50.77%	32 49.23%	0.794
low	66 50.40%	32 48.48%	34 51.52%	
Occupation of e-waste				
Yes	100 76.30%	45 45.00%	55 55.00%	0.058
No	31 23.70%	20 64.52%	11 35.48%	

* = Chi-square test, (p-value < 0.05)

Table A4.7 General characteristic of participants exposed to manganese

General characteristic	Total n=131	Mn – Urine		p-value
		High > Med cut point n= 65 (49.6%)	Low ≤ Med cut point n= 66 (50.4%)	
Gender				
Male	62 47.30%	29 46.77%	33 53.23%	0.537
Female	69 52.70%	36 52.17%	33 47.83%	
Seafood consumption				
Yes	105 80.2%	53 50.48%	52 49.52%	0.693
No	26 19.8%	12 46.15%	14 53.85%	
Smoking behavior				
Yes	35 26.70%	15 42.86%	20 57.14%	0.350
No	96 73.30%	50 52.08%	46 47.92%	
Secondhand smoke				
Yes	50 38.20%	25 50.00%	25 50.00%	0.945
No	81 61.80%	40 49.38%	41 50.62%	
Alcohol drinking				
Yes	73 55.70%	34 46.58%	39 53.42%	0.435
No	58 44.30%	31 53.45%	27 46.55%	
Fertilizer using				
Yes-within 1 year	76 58.00%	37 48.68%	39 51.32%	0.802
No	55 42.00%	28 50.91%	27 49.09%	
Age				
high	63 48.10%	30 47.62%	33 52.38%	0.660
low	68 51.90%	35 51.47%	33 48.53%	
Height				
high	48 36.60%	26 54.17%	22 45.83%	0.428
low	83 63.40%	39 46.99%	44 53.01%	
Weight				
high	62 47.30%	31 50.00%	31 50.00%	0.934
low	69 52.70%	34 49.28%	35 50.72%	
BMI				
high	65 49.60%	30 46.15%	35 53.85%	0.431
low	66 50.40%	35 53.03%	31 46.97%	
Occupation of e-waste				
Yes	100 76.30%	50 50.00%	50 50.00%	0.875
No	31 23.70%	15 48.39%	16 51.61%	

* = Chi-square test, (p-value < 0.05)

Table A4.8 General characteristic of participants exposed to zinc

General characteristic	Total n=131	Zn - Urine		p-value
		High > Med cut point n=64 (48.9%)	Low ≤ Med cut point n= 67 (51.1%)	
Gender				
Male	62 47.30%	30 48.39%	32 51.61%	0.919
Female	69 52.70%	34 49.28%	35 50.72%	
Seafood consumption				
Yes	105 80.2%	55 52.38%	50 47.62%	0.105
No	26 19.8%	9 34.62%	17 65.38%	
Smoking behavior				
Yes	35 26.70%	18 51.43%	17 48.57%	0.722
No	96 73.30%	46 47.92%	50 52.08%	
Secondhand smoke				
Yes	50 38.20%	22 44.00%	28 56.00%	0.382
No	81 61.80%	42 51.85%	39 48.15%	
Alcohol drinking				
Yes	73 55.70%	36 49.32%	37 50.68%	0.906
No	58 44.30%	28 48.28%	30 51.72%	
Fertilizer using				
Yes-within 1 year	76 58.00%	36 47.37%	40 52.63%	0.689
No	55 42.00%	28 50.91%	27 49.09%	
Age				
high	63 48.10%	31 49.21%	32 50.79%	0.938
low	68 51.90%	33 48.53%	35 51.47%	
Height				
high	48 36.60%	21 43.75%	27 56.25%	0.374
low	83 63.40%	43 51.81%	40 48.19%	
Weight				
high	62 47.30%	28 45.16%	34 54.84%	0.423
low	69 52.70%	36 52.17%	33 47.83%	
BMI				
high	65 49.60%	34 52.31%	31 47.69%	0.433
low	66 50.40%	30 45.45%	36 54.55%	
Occupation of e-waste				
Yes	100 76.30%	50 50.00%	50 50.00%	0.638
No	31 23.70%	14 45.16%	17 54.84%	

* = Chi-square test, (p-value < 0.05)

Table A4.9 Occupational characteristic of participants exposed to arsenic

Occupational characteristic	Total n=100	As - Urine		p-value
		High > Med cut point n=50 (50.0%)	Low ≤ Med cut point n=50 (50.0%)	
E-waste burning				
Yes	50 50.00%	30 60.0%	20 40.0%	**0.046***
No	50 50.00%	20 40.0%	30 60.0%	
Grove&mask using				
Yes	23 23.00%	11 47.8%	12 52.2%	0.812
No	77 77.00%	39 50.6%	38 49.4%	
Grove using				
Yes	75 75.00%	38 50.7%	37 49.3%	0.817
No	25 25.00%	12 48.0%	13 52.0%	
Mask using				
Yes	2 2.00%	1 50.0%	1 50.0%	1.000
No	98 98.00%	49 50.0%	49 50.0%	
Workhour				
High	4 4.00%	3 75.0%	1 25.0%	0.617
Low	96 96.00%	47 49.0%	49 51.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.10 Occupational characteristic of participants exposed to cadmium

Occupational characteristic	Total n=100	Cd - Urine		p-value
		High > Med cut point n=49 (49.0%)	Low ≤ Med cut point n=51 (51.0%)	
E-waste burning				
Yes	50 50.00%	21 42.0%	29 58.0%	0.161
No	50 50.00%	28 56.0%	22 44.0%	
Grove&mask using				
Yes	23 23.00%	13 56.5%	10 43.5%	0.411
No	77 77.00%	36 46.8%	41 53.2%	
Grove using				
Yes	75 75.00%	35 46.7%	40 53.3%	0.419
No	25 25.00%	14 56.0%	11 44.0%	
Mask using				
Yes	2 2.00%	1 50.0%	1 50.0%	1.000
No	98 98.00%	48 49.0%	50 51.0%	
Workhour				
High	4 4.00%	1 25.0%	3 75.0%	0.618
Low	96 96.00%	48 50.0%	48 50.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.11 Occupational characteristic of participants exposed to chromium

Occupational characteristic	Total n=100	Cr - Urine		p-value
		High > Med cut point n=49 (49.0%)	Low ≤ Med cut point n=51 (51.0%)	
E-waste burning				
Yes	50	25	25	
	50.00%	50.0%	50.0%	0.841
No	50	24	26	
	50.00%	48.0%	52.0%	
Grove&mask using				
Yes	23	12	11	
	23.00%	52.2%	47.8%	0.729
No	77	37	40	
	77.00%	48.1%	51.9%	
Grove using				
Yes	75	35	40	
	75.00%	46.7%	53.3%	0.419
No	25	14	11	
	25.00%	56.0%	44.0%	
Mask using				
Yes	2	2	0	
	2.00%	100.0%	0.0%	0.238
No	98	47	51	
	98.00%	48.0%	52.0%	
Workhour				
High	4	0	4	
	4.00%	0.0%	100.0 %	0.118
Low	96	49	47	
	96.00%	51.0%	49.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.12 Occupational characteristic of participants exposed to copper

Occupational characteristic	Total n=100	Cu - Urine		p-value
		High > Med cut point n=50 (50.0%)	High ≤ Med cut point n=50 (50.0%)	
E-waste burning				
Yes	50	22	28	
	50.00%	44.0%	56.0%	0.230
No	50	28	22	
	50.00%	56.0%	44.0%	
Grove&mask using				
Yes	23	10	13	
	23.00%	43.5%	56.5 %	0.476
No	77	40	37	
	77.00%	51.9%	48.1%	
Grove using				
Yes	75	39	36	
	75.00%	52.0%	48.0%	0.488
No	25	11	14	
	25.00%	44.0%	56.0%	
Mask using				
Yes	2	1	1	
	2.00%	50.0%	50.0%	1.000
No	98	49	49	
	98.00%	50.0%	50.0%	
Workhour				
High	4	1	3	
	4.00%	25.0%	75.0%	0.617
Low	96	49	47	
	96.00%	51.0%	49.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.13 Occupational characteristic of participants exposed to lead

Occupational characteristic	Total n=100	Pb - Urine		p-value
		High > Med cut point n=49 (49.0%)	Low ≤ Med cut point n=51 (51.0%)	
E-waste burning				
Yes	50	21	29	0.161
	50.00%	42.0%	58.0%	
No	50	28	22	
	50.00%	56.0%	44.0%	
Grove&mask using				
Yes	23	6	17	
	23.00%	26.1%	73.9%	**0.012***
No	77	43	34	
	77.00%	55.8%	44.2%	
Grove using				
Yes	75	41	34	
	75.00%	54.7%	45.3%	0.051
No	25	8	17	
	25.00%	32.0%	68.0%	
Mask using				
Yes	2	2	0	
	2.00%	100.0%	0.0%	0.238
No	98	47	51	
	98.00%	48.0%	52.0%	
Workhour				
High	4	2	2	
	4.00%	50.0%	50.0%	0.967
Low	96	47	49	
	96.00%	49.0%	51.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.14 Occupational characteristic of participants exposed to nickel

Occupational characteristic	Total n=100	Ni - Urine		p-value
		High > Med cut point n=50 (50.0%)	High ≤ Med cut point n=50 (50.0%)	
E-waste burning				
Yes	50	24	26	0.689
	50.00%	48.0%	52.0%	
No	50	26	24	
	50.00%	52.0%	48.0%	
Grove&mask using				
Yes	23	10	13	
	23.00%	43.5%	56.5%	0.476
No	77	40	37	
	77.00%	51.9%	48.1%	
Grove using				
Yes	75	38	37	
	75.00%	50.7%	49.3%	0.817
No	25	12	13	
	25.00%	48.0%	52.0%	
Mask using				
Yes	2	2	0	
	2.00%	100.0%	0.0%	0.495
No	98	48	50	
	98.00%	49.0%	51.0%	
Workhour				
High	4	2	2	
	4.00%	50.0%	50.0%	1.000
Low	96	48	48	
	96.00%	50.0%	50.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.15 Occupational characteristic of participants exposed to manganese

occupational characteristic	Total n=100	Mn - Urine		p-value
		High > Med cut point n=50 (50.0%)	Low ≤ Med cut point n=50 (50.0%)	
E-waste burning				
Yes	50	23	27	0.424
	50.00%	46.0%	54.0%	
No	50	27	23	
	50.00%	54.0%	46.0%	
Grove&mask using				
Yes	23	11	12	
	23.00%	47.8%	52.2%	0.812
No	77	39	38	
	77.00%	50.6%	49.4%	
Grove using				
Yes	75	38	37	
	75.00%	50.7%	49.3%	0.817
No	25	12	13	
	25.00%	48.0%	52.0%	
Mask using				
Yes	2	1	1	
	2.00%	50.0%	50.0%	1.000
No	98	49	49	
	98.00%	50.0%	50.0%	
Workhour				
High	4	1	3	
	4.00%	25.0%	75.0%	0.617
Low	96	49	47	
	96.00%	51.0%	49.0%	

* = Chi-square test, (p-value < 0.05)

Table A4.16 Occupational characteristic of participants exposed to zinc

Occupational characteristic	Total n=100	Zn - Urine		p-value
		High > Med cut point n=50 (50.0%)	Low ≤ Med cut point n=50 (50.0%)	
E-waste burning				
Yes	50	28	22	
	50.00%	56.0%	44.0%	0.230
No	50	22	28	
	50.00%	44.0%	56.0%	
Grove&mask using				
Yes	23	9	14	
	23.00%	39.1%	60.9%	0.235
No	77	41	36	
	77.00%	53.2%	46.8%	
Grove using				
Yes	75	40	35	
	75.00%	53.3%	46.7%	0.248
No	25	10	15	
	25.00%	40.0%	60.0%	
Mask using				
Yes	2	1	1	
	2.00%	50.0%	50.0%	1.000
No	98	49	49	
	98.00%	50.0%	50.0%	
Workhour				
High	4	1	3	
	4.00%	25.0%	75.0%	0.617
Low	96	49	47	
	96.00%	51.0%	49.0%	

* = Chi-square test, (p-value < 0.05)

APPENDIX B

TABLES OF RESULT SUMMARY

Table B1 Main e-waste group found in this dismantling site

E-waste groups	**Participants (n=100)**	**Possible metals found in e-waste**
1. Fans	26 (26.0%)	Cu, Pb, Cd, As, Ni, Zn
2. TV monitors	19 (19.0%)	Pb, Cu, Cr, As, Ni, Zn
3. Computer monitors	12 (12.0%)	Pb, Cu, Cr, As, Zn

Table B2 The percentage of the non- and e-waste dismantling workers who have non-carcinogenic risk and higher than acceptable risk

	HQ		**HI**	
HMs	Exposure group > acceptable risk (n=83)	Control group > acceptable risk (n=20)	Exposure group > acceptable risk (n=83)	Control group > acceptable risk (n=20)
As	75 (90.4%)	20 (100%)	81 (97.6%)	20 (100%)
Cd	0 (0.0%)	0 (0.0%)		
Cr	65 (78.3%)	16 (80.0%)		
Cu	0 (0.0%)	0 (0.0%)		
Ni	4 (4.8%)	0 (0.0%)		
Mn	77 (92.8%)	18 (90.0%)		

Table B3 The percentage of the non- and e-waste dismantling workers who have carcinogenic risk and higher than acceptable risk

	LCR		**TLCR**	
HMs	Exposure group > acceptable risk (n=83)	Control group > acceptable risk (n=20)	Exposure group > acceptable risk (n=83)	Control group > acceptable risk (n=20)
As	0 (0.0%)	0 (0.0%)	82 (98.8%)	20 (100%)
Cd	39 (47.0%)	5 (25.0%)		
Cr	80 (96.4%)	20 (100%)		
Pb	1 (1.2%)	0 (0.0%)		
Ni	10 (12.0%)	3 (15.0%)		

VITA

NAME	Panvarong Wongsabsakul
DATE OF BIRTH	30 May 1994
PLACE OF BIRTH	Sukhothai
INSTITUTIONS ATTENDED	Bachelor degree of environmental science at Silpakorn university
HOME ADDRESS	13/19 Soi Krom thang, Jarod Vitti Thong Road Mueang Sawankhalok, Amphoe Sawankhalok, Sukhothai 64110, Thailand 64110
PUBLICATION	A paper entitled "Heavy Metal Levels in Urine of E-waste Dismantling Workers in Buriram Province, Thailand at the International Conference on Medical, Pharmaceutical and Health Sciences (ICMPH) held in Tokyo, Japan on 5th-6th November 2019. Paper ID: GS-ICMPH-TKYO-05119-1719