Health risk assessment of Burmese related to heavy metal contamination in ginger from local markets in Myanmar and Thailand

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การประเมินความเสี่ยงต่อสุขภาพชาวเมียนมาร์จากโลหะหนักปนเปื้อนในขิง ในประเทศเมียนมาร์และประเทศไทย

น.ส.เมย์ โก โก

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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By	Miss May Ko Ko
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Thesis Advisor	POKKATE WONGSASULUK, Ph.D.

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เมย์ โก โก : การประเมินความเสี่ยงต่อสุขภาพชาวเมียนมาร์จากโลหะหนักปนเปื้อนในขิง ในประเทศเมียนมาร์และประเทศไทย. (Health risk assessment of Burmese related to heavy metal contamination in ginger from local markets in Myanmar and Thailand) อ.ที่ปรึกษาหลัก : ปกเกศ วงศาสุลักษณ์

โลหะหนักปนเปื้อนในดินนั้น พบทั่วไปในดินตามธรรมชาติ แต่กิจกรรมที่เกี่ยวกับธรณีวิทยาต่างๆของมนุษย์นั้นสามารถเพิ่มการปนเปื้อนของโลหะหนักในดิน ถึงระดับที่เป็นอันตรายต่อทั้งพืชและสัตว์ได้ การศึกษานี้ จึงมีวัตถุประสงค์ 1) เพื่อหาความเข้มข้นของโลหะหนัก (As, Cu, Ni, Cd, Cr และ Pb) ในขิง (Zingiber officinale Roscoe) จากตลาดค้าส่งในกรุงเทพฯ ประเทศไทย และจากย่างกุ้ง เมียนมาร์ 2) เพื่อประเมินความเสี่ยงผลกระทบต่อสุขภาพ จากการเกิดมะเร็งและไม่ใช่มะเร็ง ของชาวพม่า ที่บริโภคขิงปนเปื้อนโลหะหนัก มีการใช้แบบสอบถามออนไลน์เพื่อรวบรวมข้อมูลส่วนบุคคลและอัตราการบริโภคขิง ตรวจสอบการปนเปื้อน As, Cu, Ni, Cd, Cr และ Pb ในขิง โดย ICP-MS ผลการศึกษาพบว่า โลหะหนักส่วนใหญ่ในขิงจากกรุงเทพฯและย่างกุ้ง ต่ำกว่ามาตรฐานความปลอดภัยของ WHO ยกเว้น Pb ในขิงของกรุงเทพฯ As และ Pb ในขิงของย่างกุ้ง ที่สูงความระดับความปลอดภัยต่อการบริโภค อัตราการบริโภคขิงโดยเฉลี่ยในกรุงเทพฯ อยู่ที่ 44.08± 6.54 กรัม/วัน และ 44.61± 7.91 กรัม/วัน ในย่างกุ้ง ผลการประเมินความเสี่ยงด้านสุขภาพในกรุงเทพฯ พบว่า Hazard Quotient (HQs) ของ As, Cd, Cr, Cu, Ni และ Pb เท่ากับ 0.0166, 0.0038, 0.0322, 0.0265, 0.0080, และ 0.0211 ตามลำดับ Hazard Index (HI) เท่ากับ 0.1082 ซึ่งอยู่ในระดับที่ไม่มีความเสี่ยงต่อสุขภาพ สำหรับย่างกุ้ง พบว่าค่าเฉลี่ย HQs ของ As, Cd, Cr, Cu, Ni และ Pb คือ 0.1228, 0.0003, 0.0724, 0.0196, 0.0078 และ 0.0311 ตามลำดับ HI คือ 0.2552 อย่างไรก็ตาม Cancer Risk (CR) ของ As, Cd และ Pb คือ 0.810×10^{-6}, 0.157×10^{-6}, 0.068×10^{-6} สำหรับกรุงเทพฯ และ 18.449×10^{-6}, 0.038×10^{-6}, 0.309×10^{-6}สำหรับย่างกุ้ง ตามลำดับ ความเสี่ยงในการเกิดมะเร็งโดยรวม (TCR) ของ As, Cd และ Pb เท่ากับ 1.035×10^{-6} ในกรุงเทพฯ และ 18.796×10^{-6} ในย่างกุ้ง ซึ่งทั้งสองนั้น สูงกว่าระดับที่ยอมรับได้ที่ 1×10^{-6} จึงสรุปได้ว่า ความเข้มข้นของโลหะหนักในขิงจากประเทศพม่า สูงกว่าโลหะหนักในขิงจากประเทศไทย และชาวพม่าที่อาศัยอยู่ในประเทศพม่า มีความเสี่ยงต่อมะเร็งจากการบริโภคขิง มากกว่าชาวพม่าที่อาศัยอยู่ในประเทศไทย

สาขาวิชา	การจัดการสารอันตรายและสิ่งแวดล้อม	ลายมือชื่อนิสิต ....
ปีการศึกษา	2564	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

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May Ko Ko : Health risk assessment of Burmese related to heavy metal contamination in ginger from local markets in Myanmar and Thailand. Advisor: POKKATE WONGSASULUK, Ph.D.

Heavy metals are naturally present in the soil, but geologic and anthropogenic activities raise their concentrations to harmful levels for both plants and animals. This study aims 1) to determine the concentrations of heavy metals (As, Cu, Ni, Cd, Cr, and Pb) in ginger (Zingiber officinale Roscoe) from the wholesale markets of Bangkok, Thailand, and from Yangon, Myanmar, and 2) to access cancer and noncancer risks of Burmese related to the consumption of heavy metal contaminated ginger. The online questionnaire was used to collect personal information and consumption rate. ICP-MS was used to investigate As, Cu, Ni, Cd, Cr, and Pb contaminations in ginger. Most of the heavy metals in ginger from Bangkok and Yangon were lower than the WHO permissible limits, except for Pb in the ginger of Bangkok, As and Pb in the ginger of Yangon were exceeded. The average consumption rate of ginger in Bangkok was 44.08± 6.54 g/day, and 44.61± 7.91 g/day in Yangon. The health risk assessment results showed the average hazard quotient (HQs) of As, Cd, Cr, Cu, Ni, and Pb were 0.0166, 0.0038, 0.0322, 0.0265, 0.0080, and 0.0211 respectively, the hazard index (HI) was 0.1082, indicating acceptable risks for non-cancer for Thailand. Regarding Yangon, Myanmar, the HQs of As, Cd, Cr, Cu, Ni, and Pb were 0.1228, 0.0003, 0.0724, 0.0196, 0.0078, and 0.0311 respectively, the HI was 0.2552. However, the cancer risk (CR) of As, Cd, and Pb were 0.810×10^{-6}, $0.157 \text{ x } 10^{-6}$, and 0.068×10^{-6} for Bangkok, and were 18.449×10^{-6}, 0.038×10^{-6}, and 0.309×10^{-6} for Yangon respectively. The total carcinogenic risk (TCR) of As, Cd, and Pb was 1.035×10^{-6} in Bangkok, and 18.796×10^{-6} in Yangon. Both were higher than the acceptable level of 1×10^{-6}. In conclusion, the heavy metal concentrations in ginger from Myanmar were higher than in ginger from Thailand, besides, Burmese living in Myanmar have greater lifetime cancer risks related to ginger consumption than Burmese living in Thailand.

Field of Study:	Hazardous Substance and Environmental Management	Student's Signature ....
Academic Year:	2021	Advisor's Signature ....

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May Ko Ko

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

USEPA	United States Environmental Protection Agency
ICP-MS	Inductively coupled plasma mass spectrometry
LD 50	Lethal dose 50
NOAEL	No-observed-adverse-effect level
LOAEL	Lowest-observed-adverse-effect level
UF	Uncertainty factors
RfD	Reference dose
ADD	Average daily dose
C	Contaminant concentration in food
IR	Daily vegetable consumption
EF	Exposure factor
ED	Exposure duration
BW	Body weight
AT	Averaging time
HQ	Hazard quotient
HI	Hazard Index
As	Arsenic
Cd	Cadmium
Fe	Iron
Cu	Copper
Zn	Zinc
Ni	Nickel
Cr	Chromium
Pb	Lead

CHAPTER I INTRODUCTION

1.1. Background and Rationale

1.1.1. Heavy metal contamination

Heavy metals are naturally found in the earth's crust and are used for a variety of industrial and economic reasons. Heavy metals in the natural environment mainly include cobalt, nickel, arsenic, cadmium, chromium, copper, iron, mercury, manganese, lead, and zinc (Hawkes 1997). Heavy metal contamination has spread across the globe, causing environmental disruption and posing major health risks to humans (Rai, Lee et al. 2019). Heavy metals are naturally present in the soil, but geologic and anthropogenic activity raise their concentrations to levels that are detrimental to both plants and animals. Mining and smelting of metals, burning of fossil fuels, usage of fertilizers and pesticides in agriculture, manufacturing of batteries and other metal products in industries, sewage sludge, and municipal waste disposal are only a few of these activities (Chibuike and Obiora 2014). The rapid pace of urbanization, land-use changes, and industrialization, especially in emerging nations with extraordinarily large populations, are often believed to be the main causes of heavy metals pollution (Rai, Lee et al. 2019). Due to the recent economic growth, ASEAN countries are increasingly witnessing heavy metal pollution (Hart, Jones et al. 2001).

Heavy metal pollution can occur in different media including soil, water, air, and vegetables grown in polluted soil. Industrial and consumer waste, as well as acidic rain that breaks down soils and releases heavy metals into streams, lakes, rivers, and groundwater, can all contribute to heavy metal contamination of water supplies. Soil pollution is also a result of heavy metal pollution of surface and subsurface water sources. In the soil environment, heavy metals can accumulate and mobilize. When agricultural soils are polluted, these metals are taken up by plants and accumulate in their tissues and cause heavy metal contamination in vegetables. The composition of the soil, pollution levels, and harvesting season may all influence the concentration of heavy metals in plants (Shaheen, Irfan et al. 2016). Atmospheric deposition, livestock manure, traffic emissions, and industrial waste can cause heavy metal pollution in agricultural soil; moreover, irrigation with wastewater or polluted water, usage of pesticides or herbicides, phosphate-based fertilizers, and sewage sludge-based amendments are the primary sources of heavy metal concentration in crops and vegetables (Rai, Lee et al. 2019). Through the eating of heavy metal contaminated vegetable and crops, dietary exposure to heavy metals such as cadmium (Cd), lead (Pb), zinc (Wyszkowska, Boros-Lajszner et al.), and copper (Cu) has been found as a concern to human health (Kachenko and Singh 2006). Among the various herbs and spices, ginger is one of the spices which is particularly susceptible to heavy metal contamination. Heavy metals such as As, Cu, Ni, Cd, Cr, and Pb are commonly detected in ginger, according to prior studies from different countries, and these heavy metal contaminations must be addressed since they can cause cancer and non-cancer risks to people who consume contaminated ginger.

1.1.2. Heavy metal exposure

Toxic heavy metal emissions can contaminate surface water, groundwater, agricultural soils, and food crops, posing health concerns to people through a variety of routes. Humans can come into direct contact with heavy metals via eating contaminated foods, drinking contaminated water, inhaling polluted air as dust fumes, or being exposed to heavy metals at work (Engwa, Ferdinand et al. 2019). Ingestion of fruits, vegetables, and spices is the most common route for humans to be exposed to heavy metals since humans consume them daily. For example, about 70% of Cd intake is contributed via oral consumption (Nabulo, Young et al. 2010). The presence of essential metals in food like iron, copper, nickel, and zinc are very useful for the healthy growth of the body; however, metals like mercury, lead, and cadmium are toxic even at very low concentrations.

1.1.3. Heavy metal pollution in agricultural soil in Thailand

Thailand uses approximately 3,920,000 tonnes of fertilizer and 198,000 tonnes of pesticides each year (Kladsomboon, Jaiyen et al. 2020).Unpurified fertilizers and pesticides typically contain several impurities, particularly heavy metals. Chemical fertilizers, pesticides, and fungicides usually contain As, Cu, Zn, Cd, Hg, and Pb (Gimeno-García, Andreu et al. 1996).The use of these products allows toxic substances to enter the environment and contaminate soil, surface water, and vegetables.

Heavy metal contamination in vegetables and agricultural soil in Thailand has also been a serious problem. Many research has been conducted on heavy metal contamination in water, air, soil, agricultural areas, and vegetables in Thailand and found out that some research areas have serious heavy metal contamination, causing cancer and non-cancer risks to the residents. (Kayee, Seksitkan et al. 2018) reported that the levels of Hg and As in crop samples exceed the permissible limits set by the Ministry of Public Health, Thailand (Notification of Ministry of Public Health,1986) and Codex; (FAO/WHO, 2015) respectively. Heavy metal contaminated vegetables are also an alarming issue that needs to be focused on to prevent the potential human health risk since ingestion of food is the main exposure route for heavy metal concentration in human organs. Therefore, attention should be given to the daily consumed vegetables and spices which can be polluted with hazardous heavy metals from the environment.

Thailand has the best climate for growing ginger in the world, and Thai ginger is prized for its great quality and distinct aroma. Thailand's ginger is grown in 12 of the country's 76 provinces, and these provinces contribute ginger to the wholesale markets and other vegetable markets around Thailand (Kirkthanasatit, 2021). Thai cuisine is frequently spiced with ginger and Thai people think it has significant medical effects, both as a digestive aid and as a stomach acid-reducing agent (Geoff Thomas, 2012). Ginger is usually consumed raw or cooked in Thailand; in addition, it is commonly used as a topping in congee, steamed fish, and Chinese vinegar-based sauces. This demonstrates why this rhizome is so important in Thai cooking. However, some researchers have found that heavy metals in the agricultural soil can accumulate in ginger and reach humans via ingestion and cause potential human health problems (Nkansah and Amoako 2010).

1.1.4. Heavy metal pollution in agricultural soil in Myanmar

The agricultural sector plays a significant role in the economy of Myanmar and contributes 32 % to the country's gross domestic product (GDP). The current extent of the agricultural area in Myanmar is approximately 12 million hectares, occupying 18% of total cultivated land resources. Ginger (Zingiber officinale Roscoe) is one of the export crops in Myanmar with an annual production volume of 66,085 tons from an approximate cultivation area of 4,985 hectares. It is grown by smallholder farmers and offers major economic opportunities for more than 6,000 households in the Southern Shan State of Myanmar (Phoo, 2019).

However, the increasing number of industries, and mining areas in Myanmar and the use of pesticides and chemical fertilizer in agricultural areas cause hazardous substances and heavy metal pollution in soil and lead to the accumulation of these in vegetables and crops. Those metals are dangerous since they are capable of decreasing crop production and have the risk of bioaccumulation and biomagnification in the food chain. Some research has been done on heavy metal contents in plants in irrigated farmlands in Myanmar and considered the potential human health risks due to consumption.

1.1.5. Consumption of Ginger in Thailand and Myanmar

The use of spices and other herbs has markedly increased mainly because of their medicinal values in most regions of the world including Europe and North America. Many common spices have outstanding antimicrobial effects; however, they can also contain toxic substances accumulated from the environment. Both fresh and dried ginger rhizomes are used worldwide as a spice, and ginger extracts are used extensively in the food, beverage, and confectionery industries in the production of products such as marmalade, pickles, chutney, liquors, biscuits, and other bakery products (Wagesho and Chandravanshi 2015). In Thailand and Myanmar, it is among the most important spices used in every kitchen to flavor stew, curry, bread, and local tea**.** For both Thai and Burmese in the areas covered in this research, ginger is a common spice in food per day and a known medicinal remedy, especially during this pandemic. However, heavy metals in soil can significantly affect the growth of ginger. Since the edible portion, known as the rhizome, grows in direct contact with the soil, ginger is particularly susceptible to heavy metal contamination**.**

As people directly consume ginger as spice and medicine, some heavy metals as well as trace elements in ginger that could cause health damage, in the long run, may be taken indirectly and may result in the accumulation of these metals in human organs and lead to different health troubles(Goroya, Mitiku et al. 2019). In Thailand and Myanmar, spices have varied uses; however, there is little information available about the safety of these spices concerning heavy metal contamination. Monitoring the levels of heavy metal toxicity in spices would help ascertain the health impact of taking these spices, and provide relevant data on spices in the studied countries (Nkansah and Amoako 2010). Thus, monitoring the levels of heavy metal concentration in ginger would aid in assessing the health effects of consuming them, as well as providing useful information on the significant and widely used spice ginger in the studied countries.

1.2. Research Questions

1. What are the concentrations of heavy metals (As, Cu, Ni, Cd, Cr, and Pb) in ginger from the local markets in Thailand and Myanmar?
2. Do the participants in this research have cancer risks and/or non-cancer risks related to heavy metals due to the oral ingestion of ginger?

1.3. Research Objectives

Main Objectives

- To investigate the human health risk assessment related to heavy metal contamination in ginger.

Sub-objectives

- To determine the concentrations of heavy metals (As, Cu, Ni, Cd, Cr, and Pb) in ginger (Zingiber officinale Roscoe) from local markets of Thailand and Myanmar.
- To access cancer and noncancer risks related to the consumption of heavy metal contaminated ginger in Thailand and Myanmar.
- To compare the heavy metal contamination in ginger from Thailand and Myanmar.
- To compare the health risks related to the consumption of heavy metal contaminated ginger grown in Thailand and Myanmar.

1.4. Research Hypothesis

- The concentration of heavy metals in ginger from Thailand and Myanmar exceeds the standard guideline values for food safety of the WHO.
- There are cancer and noncancer risks related to the consumption of heavy metal contaminated ginger grown in Thailand and Myanmar.

1.5. Scope of the study

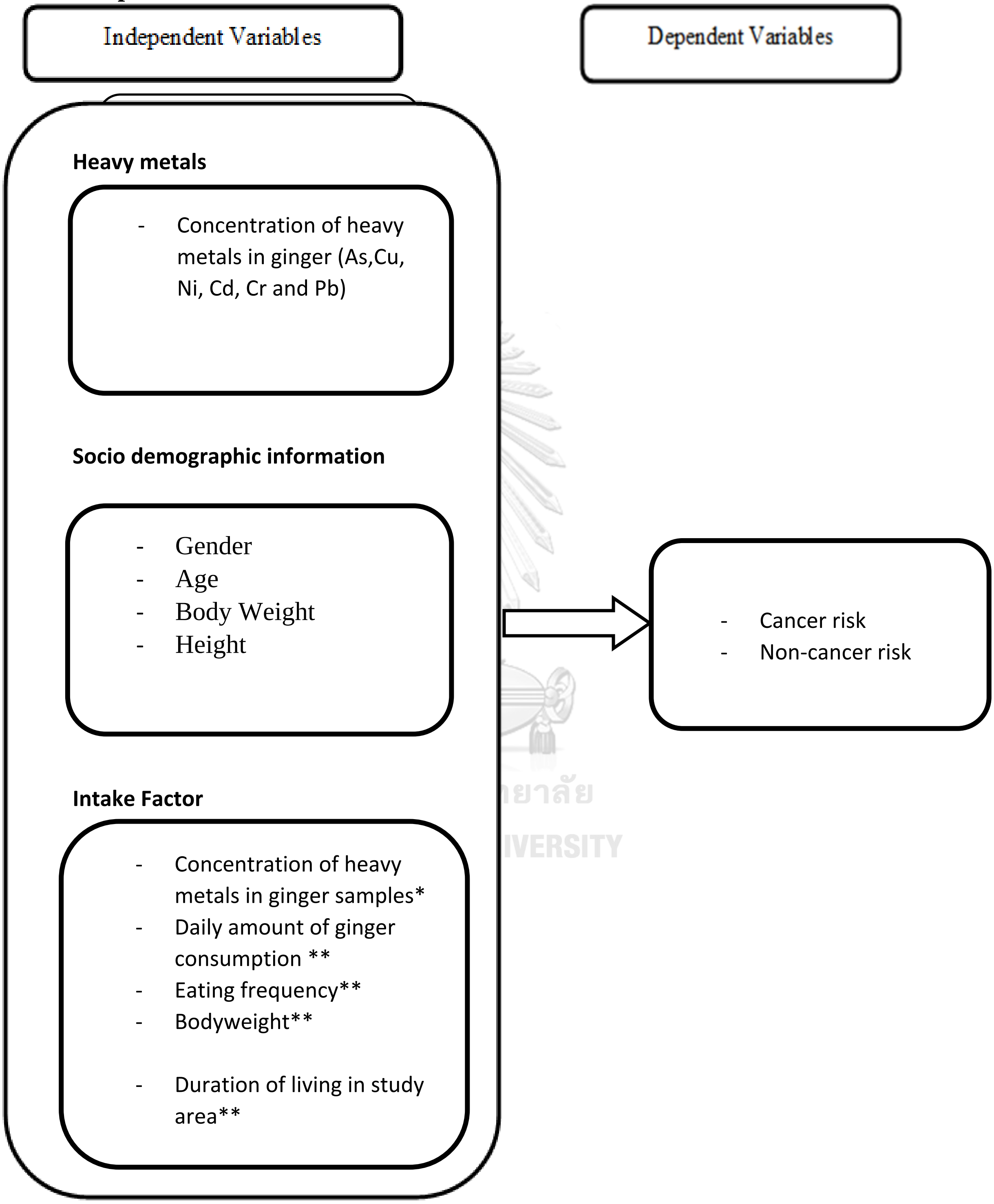
The scope of the study is as follows:

- This is a cross-sectional study that took place from January to March of 2022.
- The proposed study areas were Simummuang Market, a wholesale fresh market in Pathum Thani province, Bangkok, Thailand, and Thiri Mingalar Market, the biggest wholesale vegetable market in Yangon, Myanmar.
- This study included the subjects between the ages of 18 and 60, who have been living in the study areas for at least 1 year as well as those who are

willing and able to participate in the studied markets in Pathum Thani, Bangkok, Thailand, and Yangon, Myanmar.

- Ginger samples were collected from the wholesale markets in Thailand and Myanmar and Microwave digestion Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine the heavy metal contents in ginger.
- Online Questionnaires and face-to-face interviews with Burmese participants in Myanmar and online questionnaires to Burmese in Thailand were done to obtain personal information regarding socio-demographic information, intake factors, and eating habits.
- Evaluation of cancer and non-cancer risks of participants in these study areas who are exposed to the heavy metals via their ingestion of ginger were conducted by following the four fundamental steps of a risk assessment.

1.6 .Conceptual Framework



*Data was obtained from laboratory analysis

** Data was obtained from online and face-to-face interview questionnaires

CHAPTER II LITERATURE REVIEW

2.1. Characteristics of Heavy Metals

Heavy metals are defined as metallic elements with an unusually high density when compared to water (Ferguson 1990). They are naturally occurring substances that can be found in the earth's crust, water, air, and food. Anthropogenic activities such as mining and smelting operations, industrial production, and the use of agricultural pesticides containing metals and metal compounds have resulted in increased levels of heavy metals in the environment, resulting in environmental contamination and human toxicity(Goyer and Clarkson 1996). Heavy metal toxicity has shown to be a significant hazard, with many health risks linked with it. Few metals, such as aluminum, may be eliminated by normal bodily functions, whereas others accumulate in the body and food chain, causing chronic effects. Sources of heavy metals in plants are rainfall in atmospheric polluted areas, traffic density, use of oil or fossil fuels for heating, atmospheric dust, plant protection agents, and fertilizers which could be adsorbed through leaf blades and trace metals as farmers wash them with wastewater before bringing them into the market (Sobukola, Adeniran et al. 2010). Non-essential metals are ranked among the most hazardous toxic substances owing to their persistence in the environment and absorption in the food chain. Generally, most heavy metals are not biodegradable, have long biological half-lives, and have the potential for accumulation in the different body organs if they are ingested with food (Radwan and Salama 2006).

With the current emphasis on eating more healthy diets that are low in fat and salt, people are turning to various herbs and spices to flavor their food. Culinary herbs and spices are obtained from a plant's bark, buds, flowers, leaves, fruit, seeds, rhizome, or roots and are used to improve the flavor of vegetables, soups, stir-fries, and pasta meals (Nkansah and Amoako 2010). Furthermore, they are said to have a variety of medical and pharmacological qualities, and as a result, they are used in the creation of a variety of medicines(Parthasarathy, Chempakam et al. 2008). The presence of essential metals in food like iron, copper, nickel, and zinc are very useful for the healthy growth of the body; however, metals like mercury, lead, and cadmium are toxic even at very low concentrations (Nkansah and Amoako 2010). These metals may reach and contaminate plants, vegetables, fruits, and canned foods through the air, water, and soil during cultivation, industrial processing, and packaging (Ozores-Hampton, Hanlon et al. 1997). Therefore, identifying the potentially dangerous effects of these heavy metals in spices, as well as conducting health risk evaluations, are critical (Nkansah and Amoako 2010).

2.2. Heavy metal contamination

Ginger is a spice that can be found in candies, beverages, liqueurs, ice cream, baked products, curry powder blends, sauces, and a variety of condiments. Herbal medicine makes use of it as well. Between 2004 and 2014, 27,447 goods with ginger as an ingredient were launched around the world (Boquiren, M., Infante Villarroel, M., Than Htay, T., & Myaing Htay, A. (2018). Asia region including Thailand and Myanmar has a long history of using some of the most wonderful vegetables, herbs, and spices grown for medicinal purposes. The brilliant colors, aromas, and flavors of Thai cuisine are well-known. The use of various fresh herbs and spices by Thai people in their recipes is what distinguishes this food as a delicacy. Many Thai herbs and spices can be found in meals from restaurants to street food all around the country.

Thai cuisine is frequently spiced with ginger and Thai people think it has significant medical effects, both as a digestive aid and as a stomach acid-reducing agent (Geoff Thomas, 2012). Ginger can be consumed raw or cooked. Raw ginger goes well with *naem*, a fermented sausage that must always be served with shallots and chilies. The fermented pork in the sausage is thought to cause stomach distress, and the ginger counters this effect (Geoff Thomas, 2012). The sweet and spicy flavors of ginger are used in a variety of Thai dishes, including desserts, cocktails, and marinades. *Tom som pla*, for example, is a traditional Thai dish that can be made with either saltwater or freshwater fish. Its flavor mixes the sourness of sour tamarind, the sweetness of palm sugar, and the saltiness of *nam pla*; however, this combination of tastes must be dominated by the aroma and flavor of ginger. Moreover, ginger is sometimes mashed into a paste and used to marinate meat or poultry dishes. It is also used in soup, either whole or in thin slices: young ginger is served with chicken and beef meals, as well as in *Tom Yum* (Geoff Thomas, 2012). *Gai pat khing* is a stir-fried chicken dish with shredded ginger and other seasonings. This traditional Thai meal can be served with either cooked rice or *khao tom* (rice soup). When people are unwell in Thailand, they often have no appetite for anything other than *khao tom*. Ginger is also required in *Pla kraphong jien* (fried barramundi fish with salted plums and a sweet sauce). The stronger the ginger taste and aroma in the sauce, the better. *Pet yang* (grilled duck), *moo daeng yang* (grilled Chinese red pork), and *kha moo yat sai* are some of the other foods that would lose their attractiveness if ginger was removed (Geoff Thomas, 2012). Moreover, ginger is required for the preparation of *tao huay*, a soft tofu snack. To achieve the desired powerful flavor, this broth must be cooked with large, mature chunks of ginger. It highlights the significance of this rhizome in Thai cuisine.

Similarly, Myanmar people pay close attention to meals because eating is an important social activity here. In Myanmar, food can be roasted, stewed, boiled, fried, steamed, baked, grilled, or any combination of these processes, depending on the recipe (Jeffrey Hays, 2008). Ginger is one of the most important and basic spices used in most Burmese curries to overwhelm the fishy smell and provide flavor. Burmese chicken curry, for example, is a delightful combination of chicken, green onions, turmeric, garlic, ginger, sweet paprika, and lemongrass (Alix and Hugo, 2021). Burmese cuisine also features a variety of salads (a thoke), each centered on a single main component, such as rice, wheat and rice noodles, glass noodles, and vermicelli, as well as potato, ginger, tomato, kaffir lime, lahphet (pickled tea leaves), and ngapi (fish paste). Among Burmese salads, ginger salad is very popular in Myanmar and raw ginger is eaten with other ingredients such as pumpkin seeds, fried split peas or chickpeas, roasted peanuts, lightly toasted sesame seeds, dried shrimp powder, and cherry tomatoes. Most Burmese dishes would be incomplete without ginger, which is one of the most common spices in Burmese cookery and can be found in every Myanmar kitchen. In addition, especially during cold and flu season, Burmese drink spicy herbal tea mixed with fresh ginger juice and honey. This pure dried ginger is caffeine-free and is commonly drunk to enhance the immune system. Therefore, ginger is very important in both Myanmar and Thai cooking and making herbal tea. In this study, the health risks of consumers who are exposed to As, Cu, Ni, Cd, Cr, and Pb via the consumption of contaminated ginger were assessed as these heavy metals are mostly found in ginger (Wagesho and Chandravanshi 2015). These heavy metals are also widely occurred in the natural environment and also have the potential to bio-accumulate in people, organisms, and the environmental media along with water, soil, sediment, or food crops (WHO, 2007). Therefore, once these heavy metals enter the body through oral, dermal, and inhalation routes, they can go across the body through the bloodstream and accumulate in the target organs. Some studies had conducted cancer and non-cancer risk assessment of oral exposure to these heavy metals.

(Sobukola, Adeniran et al. 2010) found the levels of Lead, Cadmium, Copper, Zinc, Cobalt, and Nickel for the leafy vegetables respectively ranged from 0.09±0.01 to 0.21±0.06, 0.03±0.01 to 0.09±0.00, 0.02±0.00 to 0.07±0.00, 0.01±0.00 to 0.10±0.00, 0.02±0.00 to 0.36±0.00, and 0.05±0.04 to 0.24±0.01 mg/kg and the values obtained are comparable with those available in the literature and within tolerable limits of some regulatory authorities. In all sampled vegetables presented in (Guerra, Trevizam et al. 2012)'s research, average concentrations of Cd and Ni were lower than the permissible limits established by the Brazilian legislation; however, Pb and Cr exceeded the limits in 44 % of the analyzed samples. (Wang, Gao et al. 2021) collected 18 ginger samples with root-soil from a ginger-planting area in the Jing River Basin and described that Zn content was the highest (2.36 mg/kg), and Hg content was the lowest (0.0015 mg/kg) in the ginger of that study. Based on the bioconcentration factor, Cd and Zn have a high potential for enrichment in ginger and the average concentrations of heavy metals in ginger followed the order: Zn > Cu > Ni > Cr > Pb > As > Cd. (Obi-Iyeke 2019) also measured the heavy metal concentrations in street-vending fruits and vegetables in Warri, Delta State, Nigeria, and the result indicated that the concentration of Cd, Cu, Ni, Mn, and Zn were within the permissible limits of the WHO,2015, while the concentration of Pb in most samples were above the WHO,2015 limit, posing a toxicological risk. The trend of trace metals concentration in ginger samples from selected districts of Central Gondar Zone, Ethiopia was reported by (Getaneh, Guadie et al. 2021) as follows: Fe > Cu > Zn > Ni > Cd > Cr. The Cd concentration was found in the range of 4.63± 0.16 mg/kg to 5.43±0.14 mg/kg in ginger samples collected from East Dembia and Gondar Zuria, respectively, and its Cd levels were slightly higher than the results reported from India, Poland, Iraq, and Ethiopia. The results showed that ginger contained the highest amount of Fe followed by Cu, Zn, Ni, Cd, and Cr at all study sites. The health index (HI) values were slightly higher than unity, which implies that there are significant health effects to the population from consuming ginger in the study (Getaneh, Guadie et al. 2021). (Sultana, Chamon et al. 2021) also collected the most popular vegetables and fruits and their corresponding soil from the sub-urban industrial area of Bangladesh and determined the concentration of carcinogenic (Pb, As, and Cd) and non-carcinogenic (Fe, Co, V, Cu, Cr, Zn, Mn, and Ni) heavy metals. That research found that the probability of an adult developing cancer from the consumption of studied vegetables was greater than the US-EPA threshold risk limit ($>10^{-4}$) for As and Cd. In addition, the cumulative cancer risk (∑ILCR) of all the studied vegetables and fruits exceeded the limit for fruit, root, and leafy vegetables. It suggested that the study area is unsuitable for growing leafy and root vegetables due to the risk of higher intakes of heavy metals which affect the food safety. (Sultana, Chamon et al. 2021) have also reported the concentration of chromium (Nabulo, Young et al.), cadmium (Cd), lead (Pb), nickel (Ni), copper (Cu), zinc (Wyszkowska, Boros-Lajszner et al.), iron (Fe) and manganese (Mn) in four stem vegetables such as potato, ginger, garlic and onion from fresh vegetable market of Dhaka city of Bangladesh. Average daily intake (ADI), hazard quotient (HQ) and hazard index (HI) were also estimated to assess the human health risks posed by heavy metals from the consumption of the studied vegetables. Mean concentration of maximum permissible limit (MPL) exceeded in ginger for Fe, Ni and Mn. Hazard quotient of Mn for dietary intake of ginger (3.152) and hazard indices of ginger (4.626), garlic (1.183) and onion (1.069) exceeded unity, signifying potential health risks from the dietary intake of these vegetables. Therefore, (Sultana, Chamon et al. 2021) suggested regular monitoring of heavy metals in vegetables to avoid the potential health hazards on human. Furthermore, other studies also conducted non-cancer and cancer risk assessment of oral exposure to the heavy metals in ginger and other spices, and potential non-cancer and cancer risks had also been reported. Table 1 shows the concentrations of heavy metals in ginger in the aforementioned countries.

Table 1 Concentrations of heavy metals found in ginger from different countries

Countries	Sampling sites	Cd	Cr	Cu	Ni	As	Pb	References
Central Gondar Zone, Ethiopia	Cultivation sites (from six markets)	4.63 to 5.43	2.17 to 4.44	62.52 to 65.14	6.49 to 7.58	NG	ND	(Getaneh, Guadie et al. 2021)
Ethiopia	From ginger producing model farmers	ND	NG	NG	0.15-0.21	NG	ND	(Goroya, Mitiku et al. 2019)
Nigeria	From the local markets	7.450±0.021	5.650±0.019	13.500±0.027	3.417±0.01	NG	2.700±0.011	(Gaya and Ikechukwu 2016)
India	From industrial city	0.92-2.27	NG	3.06-14.56	ND	NG	0.5-12.0	(Jagrati, Nitin et al. 2011)
Iraq	From local markets	1.32	16.0±0.1	15.2	NG	NG	7.2	(I Ibrahim, M Hassan et al. 2012)
Poland	From local markets	0.02-0.04	NG	2.35-8.32	NG	NG	0.21-0.78	(Krejpcio, Krol et al. 2007)
Ghana	From central market	NG	NG	0.089	0.433	NG	1.153	(Nkansah and Amoako 2010)
Ethiopia	From four	0.38–0.97	6.02–10.8	1.10–4.78	5.46–8.40	NG	ND	(Wagesho and Chandravanshi 2015)

	major ginger producing areas in Ethiopia							
North China	From standardized ginger planting area	0.0096	0.52	0.84	0.55	NG	0.04	(Wang, Gao et al. 2021)
Ogun State, South west, Nigeria	From Seasonings sold in some major highway	0.01	NG	0.4	NG	NG	0.001	(Makanjuola and OSINFADE 2016)
Bangladesh	From vegetable market	0.13	1.93	6.73	NG	NG	NG	(Sultana, Chamon et al. 2021)
Thailand	food crops collected from Nakhon Pathom province	0.001-0.028	NG	NG	NG	0.001-0.156	0.001-0.094	(Choprathumma, Thongkam et al. 2021)
WHO permissible limits for heavy metals inplant		0.1mg/kg	1.3mg/kg	73.3mg/kg (Mensah, Kyei-Baffour et al. 2009)	67.9mg/kg (Mensah, Kyei-Baffour et al. 2009)	0.1mg/kg	0.1mg/kg	(FAO/WHO)

ND – Not detected in heavy metal analysis, NG – Not given in their research

2.2.1. Cadmium

Cadmium Cd is widely found in the earth's crust (Faroon, Ashizawa et al. 2013), and it is a soft, very malleable, ductile, lustrous, and silver-white metal and has a bluish tinge surface (Masindi and Muedi 2018). Cd levels in the environment are typically low, but they can rise due to natural processes such as weathering, erosion, and volcanic eruptions. Furthermore, it can also be increased through human activities such as mining, smelting, and refining of non-ferrous metals, tobacco smoking, incineration of municipal waste, fossil fuel combustion, phosphate fertilizers manufacturing, recycling of cadmium-plated steel scrap, and electric and electronic waste (WHO, 2010). Cd is one of the most toxic heavy metals (Jaishankar, Tseten et al. 2014), and it can be exposed through oral, dermal, and inhalation routes. Once cadmium is taken up into the body, the bloodstream can transport the Cd throughout the body, and then it can accumulate in various organs and tissues. After that, it can impact human health depending on the duration and magnitude of exposure, lifestyle, and demographic factors. Symptoms resulting from exposure to Cd are weakness, fever, headache, sweating, aching pain in the back and limbs, and muscular pain. Cd poisoning, on the other hand, can harm the kidneys and liver, as well as the brain, central nervous system, heart, lungs, stomach, skeletal system, testes, and placenta (Faroon, Ashizawa et al. 2013). WHO permissible limit of Cd in plants is 0.1 mg/kg (FAO/WHO, 2015), and exposure to levels higher than this can cause health concerns.

2.2.2. Chromium Cr

Chromium (Nabulo, Young et al.) is found in the earth's crust and seawater and is a naturally occurring heavy metal in industrial processes (Tchounwou, Yedjou et al. 2012). Cr has multiple oxidation states ranging from −2 to + 6, in which the trivalent and hexavalent forms are the most common stable forms (Shekhawat, Chatterjee et al. 2015). Cr (VI) is related to a series of diseases and pathologies, while Cr (III) is required in trace amounts for natural lipid and protein metabolism and also as a cofactor for insulin action (Havel 2004). Based on the International Agency for Research on Cancer (IARC) report (2018), hexavalent chromium Cr (VI) has been classified as a group I occupational carcinogen (Balali-Mood, Naseri et al. 2021). Metallurgical, refractory, and chemical industries release a large amount of Cr into the soil, groundwater, and air which causes health issues in humans, animals, and marine life (Balali-Mood, Naseri et al. 2021). Bioaccumulation of chromium in the human body can result in a range of disorders. This includes anything from dermal, renal, neurological, and gastrointestinal disorders to the development of tumors in the lungs, throat, bladder, kidneys, testicles, bone, and thyroid (Balali-Mood, Naseri et al. 2021). Exposure to extremely high doses of chromium (VI) compounds in humans can result in severe cardiovascular, respiratory, hematological, gastrointestinal, renal, hepatic, and neurological effects and possibly death. In vivo and in vitro studies have revealed that chromate chemicals can cause DNA damage in a variety of ways, including the creation of DNA adducts, chromosomal abnormalities, replication sister chromatid exchange modifications, and DNA transcription (Engwa, Ferdinand et al. 2019). As a result, there is strong evidence that chromium promotes human carcinogenicity, as animals and humans exposed to chromium(VI) in drinking water have developed more stomach tumors (Engwa, Ferdinand et al. 2019). WHO permissible limit of Cr in plants is 1.3 mg/kg and exposure to above this amount can cause health problems (WHO, 1996).

2.2.3. Copper Cu

Copper is a trace dietary mineral that is required by all living creatures since it is a component of the respiratory enzyme complex cytochrome c oxidase (med.libretexts.org). Copper is a component of the blood pigment hemocyanin in mollusks and crustaceans, but it is replaced by iron-complexed hemoglobin in fish and other vertebrates. Copper is primarily found in the liver, muscle, and bone in humans, and copper levels in adults range between 1.4 and 2.1 milligrams per kilogram of body weight (Araya, Olivares et al. 2007). According to the National Institutes of Health (NIH), adults should not consume more than 10 mg of copper per day. Excessive amounts of this metal can lead to adverse health effects. People rarely develop copper toxicity; however, it can occur when a person ingests high levels of the substance from contaminated water, food, or air. A person can develop copper toxicity if they eat food served on or prepared with corroded copper cookware, dishes, or utensils. Stomach pain, nausea, vomiting, diarrhea, blue or green colored feces, headache, dizziness, exhaustion, aching muscles, and severe thirst are all symptoms of copper toxicity. It can also cause neurological and psychological symptoms such as mood swings, sadness or anxiety symptoms, irritability or overexcitement, and difficulties in concentrating. Furthermore, it might cause serious health problems such as renal failure, heart failure, red blood cell loss, and liver damage (Jamie Eske, 2020). WHO permissible limit for copper in plants is 73.3mg/kg (Mensah, Kyei-Baffour et al. 2009).

2.2.4. Lead Pb

Pb is a soft, blue-gray metal that occurs naturally in the earth's crust in combination with other metals (Abadin, Ashizawa et al. 2007). It can be found in the form of an inorganic and organic compound, which has no nutritional value for the human body. Pb can be released into the environment through natural activities such as soil erosion and atmospheric deposition. Natural deposits of Pb generally occur together with Zn, Cu, silver, gold, As, antimony (Sb), and Cd (Lansdown 2013). Much of Pb is released into the environment because of human activities such as mining, burning fossil fuels, production of paint and gasoline, recycling operations and lead-contaminated consumer products, and other manufacturing (Belle, J. v., Conway, M., Knetsch, G.-J., Putten, E. v., & Ramlal, R. (2010). Pb is one of the most toxic heavy metals, and it can enter the human body through oral, dermal, and inhalation routes. Once it enters the body, it can accumulate into different tissues and organs of the body through the transportation of the bloodstream. Therefore, it can affect almost every organ and system of the human body based on the duration and magnitude of exposure (Castro-González and Méndez-Armenta 2008). The most sensitive targets for exposure to Pb are the nervous system, the hematological and cardiovascular systems, and the kidney. The symptoms of Pb poisoning include irritability, abdominal pain, headache, and various symptoms, which are related to the nervous system (Järup, 2003,(Sparling 2016). Pb toxicity can produce drowsiness, irritability, vomiting, low attention span, forgetfulness, coma, and death in long-term exposure. Children are more sensitive to Pb toxicity, and exposure to Pb can result in learning difficulties, behavioral issues, and mortality in youngsters (Belle et al., 2010; Castro-Gonzalez & Mendez-Armenta, 2008). The maximum allowable levels of lead in vegetables, according to the (FAO/WHO, 2015) is 0.1 mg/kg.

2.2.5. Nickel Ni

Nickel, a well-known heavy metal, is prevalent in the environment at extremely low amounts. It may be found in many types of soils and meteorites, as well as erupting from volcanic eruptions. Nickel is primarily bound with oxygen or sulfur in the environment, forming oxides or sulfides in the earth's crust (Das, Reddy et al. 2019). Nickel's ubiquitous industrial use, recycling, and disposal have resulted in significant environmental damage. It is released into the atmosphere by nickel mining or other industrial activities such as power plants or incinerators, rubber and plastic industries, nickel-cadmium battery industries, and electroplating industries. Therefore, nickel's widespread use in various industries, as well as occupational exposure, has a significant negative influence on human health (Das, Reddy et al. 2019). Man's main source of nickel intake has been discovered to be food. The highest quantities of nickel were detected in the canned vegetables, sweets, preserves, and bread and cereals food groups, implying a contribution from food processing equipment and, presumably, food cans (Smart and Sherlock 1987). The route of exposure, dosage, and solubility of the nickel influence nickel toxicity in humans. For nickel-induced toxicity, inhalation is the most common route of exposure, however; nickel can also be absorbed through the skin or swallowed. The kidneys and lungs are the principal organs targeted (Cameron, Buchner et al. 2011). Other organs, such as the liver, spleen, heart, and testes, may be affected to a lesser extent. Although an allergic reaction is the most prevalent side effect, research has shown that nickel can cause cancer in humans (Cameron, Buchner et al. 2011). The maximum allowable level of Nickel in vegetables is 67.9 mg/kg (FAO/WHO).

2.2.6. Arsenic As

Arsenic is a naturally occurring metalloid that can be found in soil, air, water, plants, and animals. It has been used for a long time, either as a metalloid or as a medical compound. Arsenic exists in the forms of metalloid (As^0), inorganic (As^{3+} and As^{5+}), organic, and arsine (AsH_3) (Balali-Mood, 2021). In its inorganic form, it is extremely poisonous. Drinking contaminated water, utilizing polluted water in food preparation and irrigation of food crops, industrial activities, eating contaminated food, and smoking tobacco all expose people to high doses of inorganic arsenic (WHO, 2018). At very high levels**,** arsenic is hazardous and has substantial and rapid health consequences. Depending on the species, plants absorb varying levels of arsenic from the soil and transport it to different parts (Trustees of Dartmouth College). The small intestine is the primary source of As absorption into the body. Other routes of exposure include skin contact and inhalation, which are then distributed to a variety of tissues and organs throughout the body, including the lungs, heart, kidneys, liver, muscles, and neural tissue. Chronic arsenic poisoning can be caused by long-term exposure to inorganic arsenic, which is mostly acquired through drinking water and food. As toxicity, both acute and chronic, is linked to the malfunction of many important enzymes. Like the other heavy metals, As can inhibit enzymes that contain a sulfhydryl group, causing them to malfunction (Balali-Mood, 2021). Arsenic is associated with skin damage, increased risk of cancer, and problems with the circulatory system and it is one of WHO's 10 chemicals of major public health concern. The current recommended limit of arsenic in drinking water is 10 μg/L, and the maximum allowable daily level of arsenic in foodstuff is taken as 0.02 mg/kg (FAO/WHO, 2017).

2.3 Heavy Metals Exposure

These heavy metals widely occur in the natural environment and some are not important to organisms and have significant toxicity to humans and animals. They also have the potential to bio-accumulate in people, organisms, and in the environmental media along with water, soil, sediment, or food crops (WHO, 2007). Therefore, once these heavy metals enter the body through oral, dermal, and inhalation routes, they can go across the body through the bloodstream and accumulate in the target organs. Various public health measures have been undertaken to control, prevent and treat metal toxicity occurring at various levels, such as occupational exposure, accidents, and environmental factors. Metal toxicity depends upon the absorbed dose, the route of exposure, and the duration of exposure, i.e. acute or chronic. This can lead to various disorders and can also result in excessive damage due to oxidative stress induced by free radical formation (Jaishankar, Tseten et al. 2014). Excessive content of Pb and Cd metals in food is associated with many diseases especially cardiovascular, kidney, nervous as well as bone diseases (WHO, 1992). Copper toxicity induces iron deficiency, lipid peroxidation, and destruction of membranes (Zaidi, Asrar et al. 2005). A high level of Nickel may also result in Zn or Fe deficiency as well as enzymic malfunctioning. Some metals and their compounds may cause cancer if exposed to them repeatedly over time (Sobukola, Adeniran et al. 2010) . Some studies had conducted cancer and non-cancer risk assessment of oral exposure to these heavy metals.

2.4 Health Impacts of heavy metals

Toxic effects of heavy metals on humans include vomiting, diarrhea, headache, irritability, hypertension, heart, lung, kidney, liver, and intellectual problems, and cancer (Shah, Ara et al. 2012). Heavy metal toxicity can reduce energy levels and harm the brain, lungs, kidneys, liver, blood composition, and other vital organs. Long-term exposure can cause physical, muscular, and neurological degeneration that imitate multiple sclerosis, Parkinson's disease, Alzheimer's disease, and muscular dystrophy (Jaishankar, Tseten et al. 2014). Toxicity of heavy metals can occur as a result of a single, severe exposure or a series of exposures over time. The severity of the symptoms varies according to the metal, the amount absorbed, and the age of the person who was exposed. With their long biological half-lives, nonbiodegradability, and ability to chronically accumulate in different parts of the body, such as the kidneys and liver, heavy metals are extremely harmful (Wagesho and Chandravanshi 2015). Reduced growth and development, cancer, organ damage, nervous system damage, and, in the worst-case scenario, deaths are among them.

2.5 Risk assessment

Since around 1970, the area of risk assessment has piqued the interest of both scientific and administrative communities (Shah, Ara et al. 2012). The process of determining the kind and likelihood of negative health effects that may arise following exposure to a hazardous substance is known as risk assessment (Brecher 1997). A human health risk assessment is a procedure for determining the nature and likelihood of adverse health consequences in individuals who may be exposed to chemicals in polluted environmental media in the present or future (USEPA, 2016). The goal of the risk assessment method is to assign an objective risk measurement to a specific exposure so that decisions about chemical exposure are based on logic rather than fear, prejudice, or the ability of interested parties to manipulate the media or exert political pressure (Sullivan and Krieger 2001). It's also referred to as a tool that decision-makers use to assess the risk of harmful human health impacts from the exposure to contaminants at a particular site (Jacobs 1999). Risk assessment consists of four fundamental steps: (1) Hazard identification, (2) Dose-response assessment,(3) Exposure assessment, and (4) Risk characterization (USEPA, 2016).

2.5.1. Hazard identification

The first phase in the risk assessment process is hazard identification, which aims to qualitatively identify and examine any probable incidence or degree of adverse health effects caused by a chemical, as well as the exposure circumstances that cause public health damage, injury, or disease (Asante-Duah 2002). The available scientific data for a particular chemical is analyzed in this process, and then a weight of evidence is established to show the link between the adverse health effects and the chemical. Toxicologists use both humans and animals as data sources to carry out testing. Statistically controlled clinical studies on humans can produce the best evidence for the relationship between the negative health effects and the specific chemical, whereas the results from epidemiological studies by conducting a statistical assessment of human populations have a weakness. When data from human studies are unavailable because of having significant ethical issues, the study on animals (e.g. rats, mice, rabbits, etc.) are more often conducted at various life stages and for an increasing duration of time ranging from a single acute exposure, a short-term exposure and a chronic (lifetime) exposure. After that, the relevant toxic endpoints are used in the risk assessment (USEPA, 2016). In this study, published literature regarding diseases caused due to heavy metals exposure and oral studies were the sources used to identify the hazards of the public who eat the heavy metal contaminated ginger.

2.5.2. Dose-response Assessment

Dose-response assessment is the process that quantitatively estimates a relationship between the amount of exposure to a substance and the possibility of adverse health effects or diseases (Robson and Toscano 2007). Appropriate toxicity values can be calculated from the quantitative dose-response relationship, and these are then used to estimate the occurrence of adverse effects in populations at risk for various exposure levels (Asante-Duah 2002). From the quantitative dose-response relationship, appropriate toxicity values can be derived, and this is subsequently used to estimate the incidence of adverse effects occurring in populations at risk for different exposure levels (Asante-Duah 2002). Dose-response is generally carried out by use of in vitro tests, in silico studies, and studies in animals, particularly in rodents and also in other species to use in humans (Adamson, 2016). The acute lethal dose 50 (LD 50) toxicity test is carried out in rodents to assess the safety of a chemical based on the amount of LD 50. The amount of LD 50 for a chemical is statistically derived, and it is anticipated to cause death in 50% of the animals when given through a specified route as a single dose and the animals determined for a specific period (Hayes, 2007). While LD 50 can offer some useful information regarding the lethal effects of a chemical, most chemicals do not cause deleterious effects until they reach at a certain amount of dose called threshold dose (USEPA, 2018). The highest exposure level at which no significant increase in the frequency or severity of adverse health effects is observed between the exposed population and its appropriate control is called the 'no-observed-adverse-effect level (NOAEL). NOAEL is the starting point for the calculation of the final reference dose (RfD), which is used to calculate non-cancer risks. If NOAEL cannot be identified for the human effect relevant to the duration, frequency, and route of exposure in the test animals, the NOAEL is divided by the safety or uncertainty factors, UFs, (e.g., to account for species variation or study duration) to calculate the RfD. If NOAEL does not occur in a study, a 'lowest-observe adverse-effects-level' (LOAEL) will be displayed. The NOAEL generally lie between zero and the LOAEL at which significant adverse health effect occurs. Thus, a UF (generally 10 but sometimes 3 or 1) is applied to the LOAEL to derive a nominal NOAEL (Ricci, 2006). According to the USEPA, the cancer slope factor (CSF) is defined as "an upper bound, approximating a 95%

confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg-day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to a risk less than 1 in 100 (USEPA, 2018).” In the case of cancer risk, there is no threshold dose, and the CSF is generally multiplied by the exposure estimate to generate and estimated the risk. Thus, if CSF is zero, the risk is also zero (Ricci, 2006).

In this study, the non-cancer and cancer risks of consumers who ingest the heavy metals in the ginger were assessed. CSF and RfD of the heavy metals for oral exposure route that is provided by USEPA were used in the evaluation of risks, and the cancer slope factor for As is 1.5 (mg/kg/day)-1 , for Cd was 0.38 (mg/kg/day)-1, for Pb was 0.0085 (mg/kg/day)-1 and RfD for As, Cd, Cr, Cu, Ni, and Pb are 0.0003, 0.001, 0.003, 0.042, 0.02, and 0.0035(mg/kg-day) respectively (USEPA, 1989).

2.5.3. Exposure Assessment

Exposure assessment is defined as “the identification and evaluation of the human population exposed to a toxic agent, describing its composition and size, as well as the type, magnitude, frequency, route, and duration of exposure” (USEPA, 2018; WHO, 2004). It involves quantitative and qualitative evaluation of the contact, and it is applied to estimate the rate of chemical absorption by potential receptors. As most potential receptors expose to a toxic agent from different sources or special environmental media, the realistic data for total chemical intake from different sources or media may be critical to determine in a multi-pathway exposure assessment (Paustenbach 2015). Exposure assessment can be conducted in one of two ways: (1) direct exposure assessment methods and (2) indirect exposure assessment methods. In a direct exposure assessment way, monitoring the concentration of the pollutants that are exposed by an individual in his daily activities is provided. By conducting this way, real exposure to pollutants by an individual can be observed. Regarding indirect exposure assessment way, monitoring the microenvironment, or areas or activities that have similar and relatively homogeneous exposures to toxic agents is carried out

(Robson and Toscano 2007). The later way is a relatively more commonly estimated way that is conducted by consideration of measured concentrations in the environment as well as estimations of human intake over time (USEPA, 2016). The exposure assessment in this study was an occupational setting involving consumers who eat heavy metal contaminated ginger. The route of exposure that was evaluated for non-cancer and cancer risk assessment was the oral route. Calculation of the mean daily intakes was conducted according to USEPA (USEPA, 1989).

2.5.4. Risk Characterization

Risk characterization is the final phase in the risk assessment process, and it combines and integrates the data from the previous three steps to establish cancer and non-cancer risk levels qualitatively and/or statistically (Asante-Duah 2002). It is a description of the type and amount of the health risk associated with exposure to a chemical substance or a mixture of chemicals in the environment to human health, other living forms, or the environment, including the accompanying uncertainty (Robson and Toscano 2007). In this research, the characterization of non-cancer and cancer risks of the participants were calculated according to the USEPA guidance documents.

CHAPTER III RESEARCH METHODOLOGY

3.1 Research Design

The study was designed as a cross-sectional study. A face-to-face interview and online questionnaire were used to explore the information of the participants, and ginger samples were collected from Simummuang market, Thailand, and Thiri Mingalar Market, Yangon, Myanmar. The heavy metal concentrations in ginger samples were measured and compared with the guideline values from the WHO. Then, questionnaires to the ginger consumers in the studied areas were conducted, and cancer and non-cancer risks of the participants were calculated according to the USEPA guidelines. In addition, the heavy metal contaminations in the ginger of Thailand and Myanmar and the cancer and non-cancer risks of the participants in two study areas were compared.

3.2 Study area

3.2.1. Study Area 1

The research was conducted in Simummuang Market, a wholesale fresh market in Pathum Thani Province, Thailand. This market is located in Pathum Thani which is the capital of the Pathum Thani Province, Thailand, and is situated in central Thailand, directly north of the capital city, Bangkok (Figure 1). Its address is 355/115-116 Moo 15, Phahonyothin Road, Lam Luk Ka District, Pathum Thani 12130 (Boards of directors, Pattana Wittaya School, 2019). Simummuang Market, which opened in 1983, is the country's largest wholesale market for fruits and vegetables, and there are over 30,000 continuous customers per day. This market is investing over 4 billion baht intending to become Asia's most customer-centric agricultural distribution hub, where customers may trade any standardized and high-quality products at a reasonable price. Simummuang Market now has a total area of 724,283 square meters (453 rai) and has an annual transaction value of 100 billion Baht (3 Billion USD) (Simummuang's public profile on Linkedin). The market serves as a hub for local and imported fresh produce trading, as well as providing critical services that benefit to local farmers and other stakeholders. It distributes fruits, vegetables, and spices to many small markets around Thailand and Bangkok.

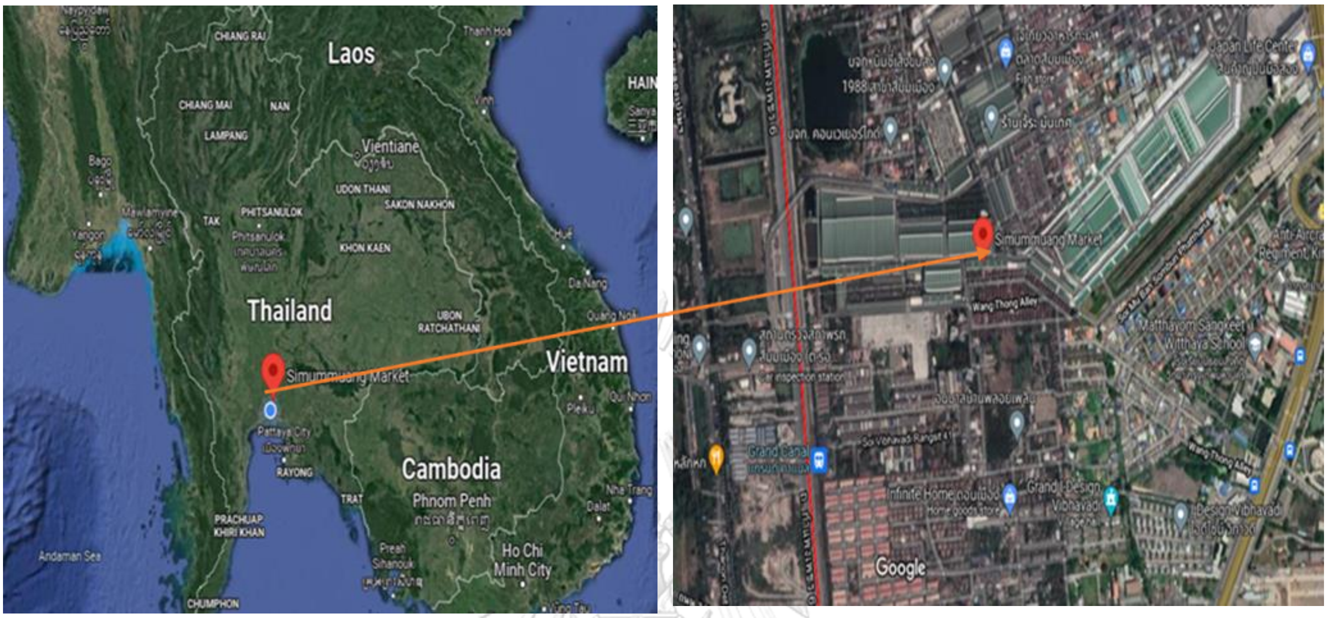


Figure 1 Map of the study area 1
Source: Imagery ©2021 CNES / Airbus, Maxar Technologies, Map data ©2021

3.2.2. Study Area 2

Study area 2 is Thiri Mingalar Market, the biggest wholesale vegetable market in Yangon, Myanmar. It is a Flea & Street Markets place which is located in Bayint Naung Road, Mayangone Township, Yangon (Rangoon), Yangon Region, Myanmar (Burma). Thiri Mingalar Market is situated in West Central Yangon, Yangon (Rangoon), Myanmar with GPS coordinates of 1° 00' 0.0" N and 1° 00' 0.0" E (Trip Express, 2021) (Figure 2). Thiri Mingalar Market, which was built in 1997, has been used for over 20 years and is located just outside the city's core. The local fruits and vegetables which are transported from different parts of Myanmar can be seen in this market; moreover, it is also the main market for fruits and vegetables to be distributed all over Myanmar. All kinds of vegetables, fish, rice, and different commodities are supplied to the other fresh markets of Yangon from this market. Therefore, this study can give a representative result of vegetables found in other vegetable markets of Yangon, Myanmar. The ginger samples were collected from these two biggest wholesale vegetable markets which distribute to many small markets around Thailand and Myanmar. So, the samples from these markets can give the representative result of ginger grown in Thailand and Myanmar.

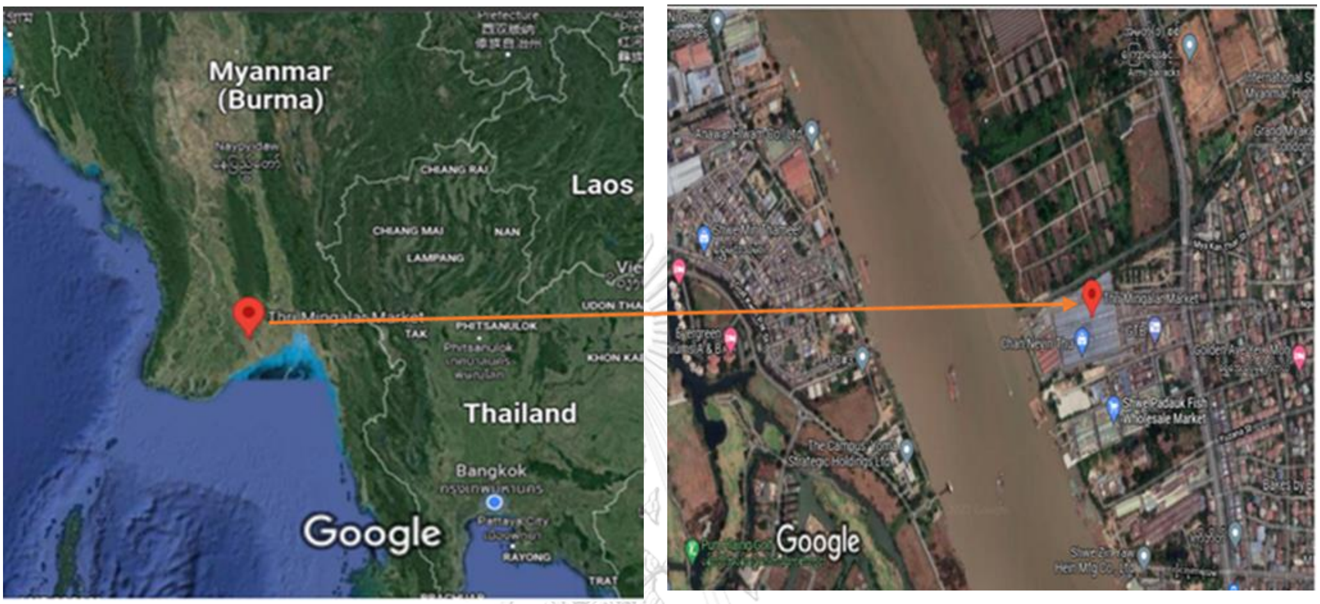


Figure 2 Map of the study area 2
Source: imagery ©2021 CNES / Airbus, Maxar Technologies, Map data ©2021

3.3 Subjects (Inclusion and Exclusion Criteria)

Burmese who eat ginger or drink ginger tea and have lived in this study region for at least a year were the subjects in study area 1. Similarly, the study area 2's subjects were Burmese who chew ginger or drink ginger tea and have lived in the area for at least a year.

3.3.1 Sample size calculation

3.3.1.1. Sample size for study area 1 (Simummuang Market, Pathum Thani, Bangkok, Thailand)

According to the Office of Migrant Workers Administration, The Ministry of Labor: 2015, Pathum Thani province has 125,626 registered migrant workers, compared to 1,074,058 Thai residents (Pathum Thani Provincial Statistical Office: 2015). Therefore, it can be said that Pathum Thani has more than 10% of migrant workers in the province (Thatsanai 2020). Burmese migrant workers make up most of the workforce. Therefore, 125,626 were used as the Burmese population for this study area. The Taro Yamane method for sample size calculation was used to estimate the number of subjects to be conducted for a survey in this research. The required sample size for study area 1 was calculated by using the following equation:

Yamane's Formula

$$n = \frac{N}{1+N\,(e)^2} \quad \text{(Yamane 1967)}$$

where :

e= precision level

N= population size

n= Yamane's sample size recommendation.

If there will be 5 percent-plus or minus-precision (e = 0.05) and 125,625 people in this study area, we would calculate

$$\frac{125625}{1 + 125625\,(0.05)^2} = 400$$

So, a random sample of 400 participants in our target population was enough for this research.

3.3.1.2. Sample size for study area 2 (Thiri Mingalar Market, Yangon, Myanmar)

According to the Myanmar Population and Housing Census 2014, 343,270 people are residing in Shwepyithar township, where the Thiri Mingalar market is located. By using Yamane's formula and 5 percent-plus or minus-precision (e= 0.05), the sample size for study area 2 was calculated as follows:

Yamane's Formula

$$n = \frac{N}{1+N\,(e)^2} \quad \text{(Yamane 1967)}$$

where :

e= precision level (allowable level %)

N= population size

n= Yamane’s sample size recommendation

$$\frac{343{,}270}{1+343{,}270\,(0.05)^2} = 400$$

Therefore, 400 participants from our target population were the sample size in this study area 2.

3.3.2 Inclusion criteria

- Participants within the age range of 18-60 years were the subjects of this research.
- Subjects who have been living in these study areas for at least 1 year.
- Subjects who eat ginger at least 1 time per week.
- Subjects who are willing to participate and give information in the study.
- Participants who can communicate in Burmese.

3.3.3. Exclusion criteria

People who were not considered participants in this research were

- Subjects who have an allergy to ginger or ginger food products.
- Subjects who have psychological problems.

3.4 Sampling method (Questionnaire, and Sample collection)

3.4.1. Research Instrument for Data Collection (Questionnaire)

The questionnaire contained the following four parts :

Part 1: Socio-demographic information of the consumers, namely: gender, age, height, and weight were obtained.

Part 2: Information on exposure determinants such as intake frequency, amount of consumption, duration of living in the study areas, and body weight were used as input parameters in calculating the daily intake of heavy metals via ginger consumption.

Part 3: Beliefs about ginger consumption (why do they eat ginger?) Even though they are Burmese, their eating habits and beliefs about ginger consumption could vary depending on the country where they live. Therefore, Burmese living in these two countries may have different health risks related to the consumption of heavy metal contaminated ginger.

Part 4: Adverse health symptoms were obtained to assess any health problems potentially associated with chronic exposure to heavy metals. Because these health symptoms might be related to ingestion of heavy metal contaminated ginger.

An online survey was undertaken for the subjects in Simummuang Market in Pathum Thani, Bangkok, Thailand, to obtain socio-demographic information as well as eating habits, frequency, and intake amount of ginger.

Similarly, for the subjects in Thiri Mingalar Market in Yangon, Myanmar, an online questionnaire and face-to-face interview were carried out to get the socio-demographic information and eating habits, frequency, and intake amount of ginger. Before asking questions to the respondents in both study areas, screening questions were asked first, based on the inclusion and exclusion criteria, and only those who meet the inclusion criteria were permitted to respond to the actual questionnaire. Before completing the questionnaire, they were explained the purpose of the study clearly, and information sheets, written both in English, and Myanmar were provided. Following that, each participant received a questionnaire that last approximately 10 minutes. Subjects participated in this study only one time during the data collection period.

3.4.2. Sample collection

Ginger samples were bought from Simummuang Market, a wholesale fresh market in Pathum Thani, Bangkok, Thailand, and Thiri Mingalar Market, the biggest wholesale vegetable market in Yangon, Myanmar. Ginger samples with a diameter and length of around 4 inches and an age of around 10-12 months were purchased at random from each ginger selling shop in these markets. Four pieces of ginger (four inches in diameter and length, 10-12 months old, and weighing approximately 70 grams per piece) were collected from each shop, with five shops per market. The shops were also randomly selected. As a result, 20 pieces of ginger were collected from randomly selected 5 vegetable shops in each market for this study. For ginger from Myanmar, they were collected from Thiri Mingalar Market in Yangon, Myanmar and transported to Bangkok, Thailand for heavy metal analysis.

3.5 Sample analysis

3.5.1. Sample preparation and Analysis of heavy metals in ginger samples

The ginger samples were dried in the oven (carbolated fusion furnace) at a temperature of 105°C for 24 h to have a dry mass basis (Wagesho and Chandravanshi 2015). The dried samples were powdered in a stainless-steel mill till obtaining fine particles that pass through a 0.5 mm mesh and were kept dry in a cleaned polyethylene bag until digestion. Association of Analytical Communities (AOAC) official method (2019) was used for the analysis of As, Cd, Cr, Cu, Ni and Pb in ginger samples. All vessels and containers were soaked in 10% HNO_3 for 24 hours and rinsed with Milli-Q water and air-dried before use. 0.3g of ginger sample (dry basis) was added into decontaminated decomposition vessel and 5 ml of concentrated nitric acid HNO_3 (analytical grade) and 2 mL 30% H_20_2 were added and digested at 150 °C for 2 h. The digested solution was transferred to 25 ml volumetric flask and diluted with 4 ml of deionized water. After that, the concentrations of As, Cd, Cr, Cu, Ni, and Pb in the digested samples were determined using atomic absorption spectrophotometer and blanks were treated in the same way as tests.

3.5.2. Quality Control and Assurance

The samples were analyzed for quality control and assurance. Each sample was analyzed in duplicate. All chemicals and reagents were analytical grades. All the solutions were prepared with Milli-Q water, and nitric acid and hydrogen peroxide were used for the digestion of the samples. Ultra high-purity or equivalent acids were used in the preparation of standards and for sample processing (USEPA 6020B). The essential reagents, standards, and analytical sample processing and dilution were all prepared with double distilled water (DDW). Calibration curves were produced for each investigated heavy metal. Blanks were also examined regularly to ensure that the analytical quality was maintained. Throughout the analysis, DDW was used to wash the equipment at regular intervals to avoid contamination. The recovery percentages of these six heavy metals ranged from 91.19 to 103.321% and the relative standard deviation was 0.197- 0.58%. For every 10 samples, the control was analyzed for accuracy checking. The analysis results of ginger samples reported in dry weight.

In the risk assessment of heavy metals, selecting and implementing an appropriate analytical method among a variety of analytical methods is vital. Several studies have utilized ICP-MS to quantify the concentrations of heavy metals (Luo et al., 2010) since ICP-MS is a very sensitive technique for most elements and has more advantages than other metal-analysis techniques. It can also handle both simple and complex sample matrices, and it has exceptionally low detection limits that range from parts per billion (ppb) to trillions (ppt) (Jignesh et al., 2012). Therefore, the digested ginger samples were evaluated using an inductively coupled plasma mass spectrometry (ICP-MS) to measure the concentrations of As, Cd, Cr, Cu, Ni, and Pb in the ginger samples.

3.6. Data Calculation and Analysis

After analyzing the samples through ICP-MS, the concentrations of each heavy metal in ginger samples were subjected to mean ± standard deviation (SD), minimum and maximum concentrations of these metals. The values of heavy metals in samples were compared to the values of the quality standards from the guidelines by

FAO/WHO. After that, the analyzed concentrations of each heavy metal were used in the calculation of non-cancer and cancer risks of the participants who are exposed to these heavy metals via the oral route. SPSS® Statistics and Microsoft Excel® were used to analyze the statistical data.

3.7. Health risk assessment and exposure parameters

The health risk assessment model was provided by USEPA and allowed for quantitative assessment of the human health risks via exposure to dangerous chemicals and substances. There are four steps in risk assessment and include (1) Hazard identification, (2) Dose-response assessment, (3) Exposure assessment, and (4) Risk characterization (USEPA, 2016). As the first step of risk assessment, the hazard of heavy metals in ginger samples was identified. In this study, the concentrations of heavy metals (As, Cu, Ni, Cd, Cr, and Pb) in ginger samples were measured, and calculated their associated health risks. Among these heavy metals, Arsenic (As), Cadmium (Cd), Lead (Pb), Copper (Cu), Nickel (Ni), and Chromium (Nabulo, Young et al.) are known to have non-cancer risks, whereas Arsenic (As), Cadmium (Cd), and Lead (Pb) can cause both cancer and non-cancer risks.

In the second step of risk assessment, the mean daily dose (ADD) was used to measure the amount of daily heavy metal intake associated with the participants' ginger consumption. Using the average amount of ginger consumed (44.08g/day by Burmese in Bangkok, Thailand and 44.61g/day by Burmese in Yangon, Myanmar; data from questionnaire), the absorption rate or chronic daily intake of heavy metals from ginger consumption was computed using the following equation.

$$\textbf{ADD (mg/kg. d)} = \frac{C \times IR \times EF \times ED}{BW \times AT} \quad \text{…………………. (1)} \quad \textbf{(USEPA, 1989)}$$

Where:

C = heavy metal concentration in ginger (mg/kg)

IR = the daily vegetable consumption of the subject (kg/person/day)

EF = the exposure frequency (365 days/year)

ED = the exposure duration (years) (duration of living in the study area)

BW = the body weight (kg) of the participants

AT = the mean exposure time

For carcinogens, 365 × life expectancy (USEPA, 2017) was used as the mean exposure time (AT). For non-carcinogenic risk, the mean exposure time (AT) is 365 × ED (USEPA,2017).

Life expectancy in Myanmar: males (64.3 years), females (70.3 years), Average = 67years (The world bank,2020)

In calculating the cancer risks of Burmese participants in Myanmar and Thailand, life expectancy (67 years – average life expectancy of Burmese) was used and didn't calculate the cancer risks for males and females separately using their respective life expectancy because this research intended to cover only the mean cancer risks of the general Burmese in both study areas.

In the exposure assessment, the non-carcinogenic health risks and carcinogenic health risks were calculated. The non-carcinogenic health risk of participants who are exposed to heavy metals via consumption of contaminated ginger was expressed as the hazard quotient (HQ). The hazard quotient is a ratio of the average daily dose of a contaminant to the oral reference dose and it was computed by using the following equation:

Non-carcinogenic risk characterization

HQ =ADD/ RfD …………………(2) (USEPA,1991)

Where ;

HQ = Hazard Quotient

ADD = Average daily dose of the subject (mg/kg.day)

RfD = Reference dose

HQ > 1, adverse lifetime non-carcinogenic effects were concerned.

HQ ≤ 1 means an acceptable level.

The RfD is an estimation of daily oral exposure to the human population that is possible to be without a significant risk of harmful effects during life, and the hazard quotient (HQ) is an indicator of risks associated with health effects. After HQ is calculated, the Hazard Index (HI) was calculated to estimate the potential human health risks when more than one heavy metal is consumed. The hazard index (HI) for the noncarcinogen risk of a variety of heavy metals was calculated by using the following equation:

Hazard Index (HI)= $\sum$ HQi .... (3) (USEPA,1991)

Where;

HI = The sum of hazard quotients

HQ = Hazard quotient

HQi = Summation of all the HQ for non-carcinogens

HI > 1, adverse lifetime non-carcinogenic effects were concerned.

HI ≤ 1 means acceptable level.

The sum of the HQs is called the hazard index (HI) which assumes that the effects of the different compounds and effects are additive. The reference dose (RfD) and cancer slope factor (CSF) of heavy metals involved in this study are shown in table 2.

Table 2 List of Reference dose and cancer slope factor for heavy metals

Heavy metals	Non-cancer Reference Dose (RfD) (mg/kg-day)	Cancer Slope Factor (CSF) $(mg/kg\text{-}day)^{-1}$	Reference Source
Arsenic	0.0003	1.5	(USEPA,1988)
Cadmium	0.001	0.38	(USEPA 2011)
Copper	0.042	-	USEPA IRIS 2011

Nickel	0.02	-	USEPA IRIS 2011
Chromium	0.003	-	IRIS 2008
Lead	0.0035	0.0085	(USEPA,1989)

For the calculation of the cancer risks of participants who are orally exposed to As, Pb, and Cd in ginger, the following equation was used:

Carcinogenic risk characterization

Cancer risk, CR = $\sum_{i=1}^{n}(ADD_i \times SF_i)$………….. (4) (USEPA,1991)

Where:

SF = Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$

ADD = Average daily dose (mg/kg-day)

The final step of risk assessment is risk characterization, in which cancer and non-cancer risks of the participants who orally ingested heavy metal contaminated ginger were characterized according to the U.S EPA guidance documents (USEPA,1991). If the Hazard Index (HI) is greater than 1, there may have the potential for adverse systemic health concerns in the exposed individuals. If HI is less than or equal to 1, there may not have significant adverse health effects (USEPA, 1991). According to the USEPA, the acceptable range for lifetime cancer risk is expressed as 1×10^{-4} to 1×10^{-6}, that is, one in ten thousand to one in one million can cause cancer cases. However, 1×10^{-6} was used as an acceptable cancer risk and the cancer risks greater than that value were assumed as having potential carcinogenic risks because cancer risks of the consumers for ingestion exposure to the heavy metals contaminated ginger were considered in this study. Unlike the reference dose for non- carcinogenic health risks, the cancer slope factor (CSF) that exposed to any amount of a carcinogen produce the cancer risk, i.e. there is no threshold dosage. ((Fowle and Dearfield 2000); USEPA,1991).

3.8 Ethical/Legal Consideration

- This study was approved by the Research Ethics Review Committee for Research Involving Human Research Participants, Group 1, Chulalongkorn University, Thailand, with a Certificate of Approval (COA) No.084/65.
- Before conducting the questionnaire, the purpose of the study was explained to the participants clearly.
- The collected data and information were used for the research's purpose only.
- The information of the participants was kept confidential.

CHAPTER IV RESULTS

This study was a cross-sectional study that was conducted in Simummuang market, Pathum Thani, Thailand and Thiri Mingalar Market, Yangon, Myanmar. The total subjects in this study were 800 Burmese participants. 400 participants including both males and females were asked face-to-face questions and online questionnaires in Yangon, Myanmar and online questionnaire were done to 400 Burmese participants in Bangkok, Thailand. In the questionnaire, there were four parts: socio-demographic information; exposure determinants; exposure factors; and adverse health symptoms.

This chapter provides a detailed description of the results obtained from both questionnaire and concentrations of the heavy metals in ginger samples. The variables are described as simple percentages, mean, standard deviation, and range.

4.1. Bangkok, Thailand

4.1.1 Socio-demographic characteristics of Burmese participants in Bangkok, Thailand

400 Burmese participants (170 males and 230 females) from Bangkok, Thailand were asked the online questionnaire. The number of female participants was higher than that of male participants, with 57.5 % as opposed to 42.5%. The sociodemographic characteristics of the participants in Bangkok, Thailand are shown in table 3.

The results show that the age of the Burmese participants in Bangkok, Thailand ranged from 18 to 58 years of age; a median was 29 years of age and the mean ± SD age was 30.7± 8.35 years. To be more specific the age regarding gender, the ages of male participants ranged from 18 to 53 years with a mean ± SD age of 31.07± 8.51years, whereas the ages of female participants ranged from 18 to 58 years and the mean ± SD age was 30.43 ± 8.23 years. Overall, among the participants, there were 206 (51.5%) participants in the age range of 18-30 years of age; 158 (39.5%) participants in the age range of 31-43 years; and 36 (9%) participants were 44-58 years.

The height of the participants in this study area ranged from 147.32 to 188cm with a median of 165 cm and the mean ± SD height was 164.14 ± 6.46 cm. Bodyweights of the participants ranged from 44 to 82 kg with a median of 61 kg, and the mean ± SD was 61.02 ± 7.51 kg. For male participants, the mean ± SD height was 172.16 ± 5.63 cm with a range of 156 to 186 cm, and the mean ± SD weight was 62.69 ± 7.27 kg with a range of 45 to 82 kg. For female participants, the mean ± SD height was 159.34 ± 5.86 cm with a range of 147.32 to 180 cm and the mean ± SD weight was 59.47 ± 7.63kg with a range of 44 to 77 kg.

Regarding their educational level, there were no participants whose education was lower than primary school, 14.5% of them attended secondary school and 44% of them had gone to high school, 41.5% had a bachelor's or higher degree. To be more specific, 14.7% of male participants attended secondary school and 45.9% had high school education, and 39.4% had a bachelor's or higher degree. Of female participants, 14.8% received a secondary school education, 42.6% attended high school, and 42.6% had a bachelor's or higher degree.

In terms of smoking behavior, 13.8 percent of the 400 participants in Bangkok, Thailand reported being smokers, 80.5 percent were nonsmokers, and 5.8 percent were ex-smokers. In the case of alcohol drinking behavior among 400 participants, 19% of them reported as drinkers, 74.8% of them were non-drinkers, and 6.3 % were ex-drinkers. To be more specific, 27.1% of the male participants were smokers, 61.2% were non-smokers, and 11.8 % of them were ex-smokers. On the other hand, only 3.9% of female participants were reported as smokers and 95.2% were non-smokers, and 0.9% were reported as ex-smokers. Regarding alcohol drinking habits, 37.6% of male participants were drinkers, 47.6% of them were non-drinkers, and 14.7% were ex-drinkers. However, only 5.2% of female participants were found as drinkers, and 94.8% of them were non-drinkers. Since smoking and alcohol drinking behaviors can elevate the levels of As, Cd, and Pb in the bloodstream, the smokers and drinkers in this study may receive non-cancer and cancer risks even if they might not have risks from ingestion of heavy metals contaminated ginger.

Regarding the ginger eating frequency, 37.3% (149 participants) consume ginger every day, one time a day, 27% (108 participants) reported that they eat ginger 5-6 times a week, 24% (96 participants) eat ginger every day, twice a day, 6% (24 participants) eat 2-4 times a week, and 5.8% (23 participants) consume ginger every day, more than twice a day.

Table 3 Socio-demographic characteristics of sampling population (n= 400) in Bangkok, Thailand

Characteristics		**Participants (%)**
Gender		
Male		170 (42.5%)
Female		230 (57.5%)
Age (years)		
18-30		206 (51.5%)
31-43		158 (39.5%)
44-60		36 (9%)
Mean ± SD	30.70±8.35	
Median	29	
Range	18-58	
Bodyweight (kg)		
Male participants (n=170)		
Mean ± SD	62.69 ± 7.27	
Median	63.82	
Range	45 - 82	
Female participants **(n=230)**		
Mean ± SD	59.47 ± 7.63	
Median	60	
Range	44 - 77	
All participants (n=400)		
Mean ± SD	61.02 ± 7.51	

Median	61	
Range	44 - 82	
Height (cm)		
Male participants (n=170)		
Mean ± SD	172.16 ± 5.63	
Median	174	
Range	156 - 186	
Female participants(n=230)		
Mean ± SD	159.33 ± 5.86	
Median	160.02	
Range	147.32 - 180	
All participants (n=400)		
Mean ± SD	164.14 ± 6.46	
Median	165	
Range	147.32 - 188	
Education level(n=400)		
Primary school		0
Secondary school		58 (14.5%)
High school		176 (44%)
Bachelor or higher degree		166 (41.5%)
Smoking behavior		
All participants		
Smoker		55 (13.8%)
Non-smoker		322 (80.5%)
Ex-smoker		23 (5.8%)

Drinking behavior		
All participants		
Drinker		76 (19%)
Non-drinker		299 (74.8%)
Ex-drinker		25 (6.3%)
Occupation		
All participants		
Student		133 (33.33%)
Employee		158 (39.5%)
State enterprise		109 (27.3%)
Exposure factors		
Amount of ginger consumption(g/day)		
All participants (n=400)		
Mean ± SD	44.08 ± 6.54	
Median	41	
Range	34 - 70	
Exposure frequency (days/yr)		
Mean ± SD	365±0	
Duration of living in the study area (years)		
All participants(n=400)		
Mean ± SD	7.38± 4.58	
Median	6	
Range	1 - 21	

Times of ginger consumption		
2-4 times a week		24 (6%)
5-6 times a week		108 (27%)
Every day, one time a day		149 (37.3%)
Every day, twice a day		96 (24%)
Every day, more than twice a day		23 (5.8%)

4.1.1.1 Exploration of Adverse Health Symptoms of Burmese in Bangkok, Thailand

As exposure to the As, Cd, Cr, Cu, Ni, and Pb can result in non-carcinogenic and carcinogenic diseases, the signs, and symptoms of both acute and chronic toxic effects after exposure to the heavy metals were explored. In this study, Burmese participants were asked about the signs and symptoms which may be related to the ingestion of heavy metals during the last 3 months and 12 months separately.

Regarding the signs and symptoms of participants during the last 3 months in Bangkok, Thailand, it was found that some participants have more than one symptom. The most frequent signs and symptoms from these participants were joint pains (85 participants), pain in the back and limbs (71 participants), forgetfulness (171 participants), muscular pain (98 participants), hair loss (166 participants), headache (122 participants), skin rashes (39 participants) and weakness (73 participants), nervousness (41 participants), irritability (27 participants), shyness (27 participants), vomiting (9 participants) and diarrhea (71 participants) as shown in figure 3.

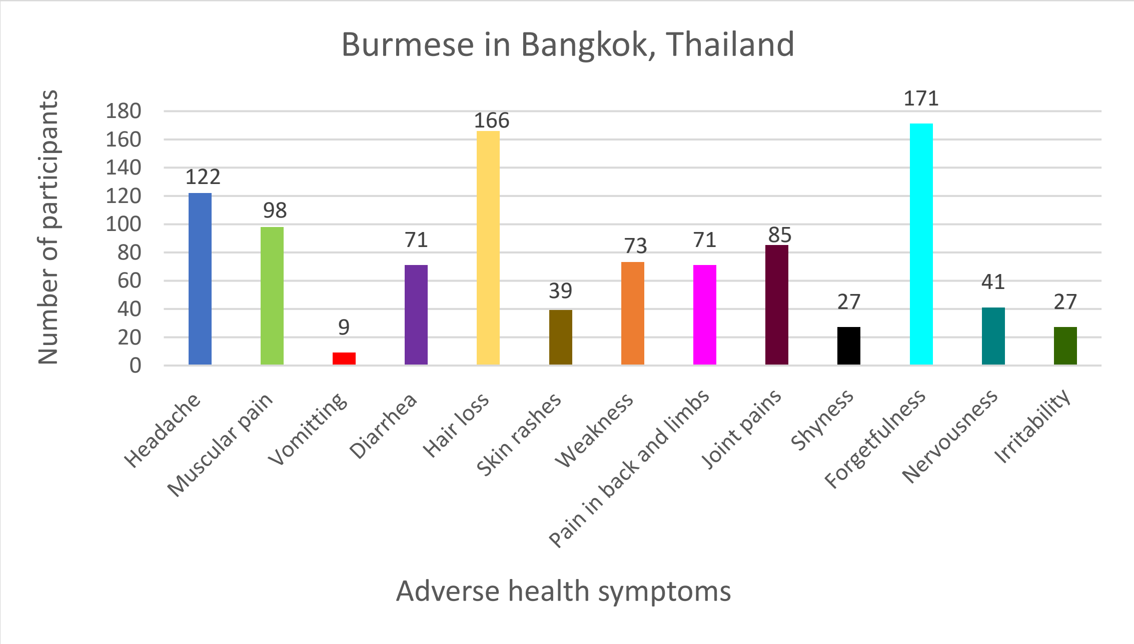


Figure 3 Symptoms reported by Burmese during the last 3 months in Bangkok, Thailand

In the case of the signs and symptoms during the last 12 months, some signs and symptoms were reported by the same participants in the last 3 months. These same signs and symptoms were joint pains (89 participants), pain in the back and limbs (70 participants), forgetfulness (180 participants), muscular pain (116 participants), hair loss (165 participants), and shyness (30 participants), headache (126 participants), skin rashes (57 participants), and weakness (64 participants), vomiting (9 participants), diarrhea (57 participants), nervousness (26 participants), and irritability (20 participants). Figure 4 indicates the number of Burmese participants from Bangkok, Thailand who are suffering the different health symptoms during the last twelve months.

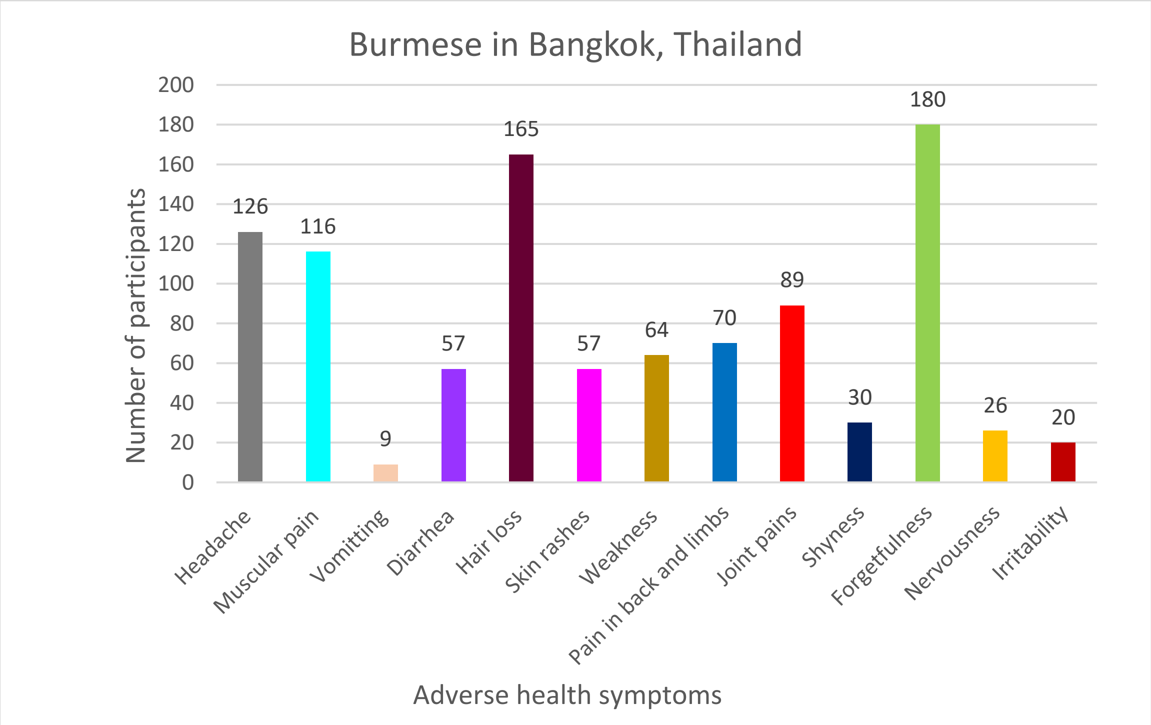


Figure 4 Symptoms reported by Burmese during the last 12 months in Bangkok, Thailand

4.1.2. Concentrations of the Heavy Metals in ginger samples from Bangkok, Thailand

The concentrations of the heavy metals in ginger samples from Simummuang Market, Pathum Thani, Bangkok, Thailand are shown in table 4 and it presents the mean ± SD, median, range, and minimum and maximum concentrations of heavy metals in ginger samples.

In the ginger samples from Simummuang Market, Pathum Thani, Bangkok, Thailand, the mean ± SD concentration of As was 0.0068 ± 0.011 mg/kg and the median was 0.002mg/kg with the range from 0.001mg/kg to 0.026 mg/kg. The mean ± SD concentration of Cd was 0.0052 ± 0.004 mg/kg with the range from 0.000 mg/kg to 0.013 mg/kg. The mean ± SD concentration of Cr was 0.1316 ± 0.075 mg/kg and the median was 0.108 mg/kg with the range from 0.058 mg/kg to 0.253 mg/kg. In the case of Cu, the mean ± SD concentration was 1.4996 ±0.142 mg /kg and the median were

1.522 mg/kg with the range from 1.271 mg/kg to 1.629 mg/kg. For Ni, the mean ± SD concentration was 0.2162 ±0.085 mg/kg and the median was 0.236 mg/kg with the range from 0.116mg/kg to 0.32mg/kg. The mean ± SD concentration of Pb was 0.1008 ± 0.075 mg/kg, the median was 0.114 mg/kg with the range from 0.019 mg/kg to 0.190 mg/kg.

Table 4 Concentrations of the heavy metals found in ginger samples (Simummuang Market, Bangkok, Thailand)

	Concentration (mg/kg)					
	As	Cd	Cr	Cu	Ni	Pb
	Simummuang Market, Thailand					
Mean ± SD	0.0068±0.011	0.0052±0.004	0.1316±0.075	1.4996±0.142	0.2162±0.085	0.1008±0.075
Median	0.002	0.004	0.108	1.522	0.236	0.114
Min- Max	<0.145	<0.020	0.058-0.253	1.271-1.629	0.116-0.320	0.019-0.190
Limit of detection (LOD)	0.145	0.020	0.005	0.100	0.005	0.005
Guideline values (FAO/WHO,2019)	0.1	0.1	1.3	73.3	67.9	0.1
Thai standard	2[a]	0.1[a]	1[c]	20[c]	NA	0.1[a]
EU standard	0.15[b]	0.1[b]	1[b]	NA	NA	0.2[b]

[a] Permissible values of the Ministry of Public Health in Thailand (2020)

[b] Food standard Australia New Zealand

[c] National Food Institute, Thailand

NA- Not available

4.1.3. Exposure assessment and risk characterization

This part was separated into 2 parts: (1) non-carcinogenic risk and (2) carcinogenic risk. Exposure factors such as eating frequency, exposure duration, and body weight were obtained by questionnaires. The mean eating frequency for Burmese participants was 365 days per year. The mean ± SD exposure duration (duration of living in Bangkok, Thailand) was 7.38 ± 4.58 years, and the median was 6 with a range from 1 to 21 years as shown in table 5.

Table 5 Exposure factors of Burmese participants in Bangkok, Thailand

	Sampling population (n=400)					
	Age (yrs)	Weight(kg)	Height (cm)	Duration (yrs)	Amount of consumption (g/day)	Exposure frequency (days/yr)
Mean ± SD	30.7 ± 8.35	61.02 ± 7.51	164.14 ± 6.46	7.38 ±4.58	44.08 ± 6.54	365 ±0
Median	29	61	165	6	41	365
Min - Max	18 - 58	44 - 82	147.32 – 188	1 – 21	34 - 70	365

In the case of the weight of the participants in Bangkok, Thailand, the mean ± SD weight for all the participants was 61.02 ± 7.51 kg and the median was 61 kg with the range from 44 to 82 kg. Regarding the height, the mean ± SD height for all the participants was 164.14 ± 6.46 cm and the median was 165 cm with the range from 147.32 to 188 cm.

The exposure factors of Burmese obtained from the questionnaire as shown in table 5 were used for the calculations of the mean daily intake for ingestion exposure (ADD) to the heavy metals for the participants. By using the eq (1) from section 3.7, ADD for both non-cancer and cancer risks was calculated for the participants based on their socio-demographic and ingestion factors attained from questionnaires. Furthermore, the concentration of heavy metals in ginger samples was used as the input concentration in the ADD calculation of Burmese participants in Bangkok, Thailand.

4.1.3.1. Non-cancer risk characterization

Firstly, the mean daily dose (ADD) for ingestion exposure to each heavy metal such as As, Cd, Cr, Cu, Ni, and Pb in ginger from Bangkok, Thailand for non-cancer risks was calculated for the participants through equation (1) from section 3.7. The average daily dose (ADD) of the heavy metals via ginger consumption was shown in table 6. After that, the hazard quotient (HQ) and hazard index (HI) of each heavy metal (As, Cd, Cr, Cu, Ni, and Pb) were calculated for the participants through equations (2) and (3) from section 3.7 respectively. The mean HQs of each heavy metal were calculated for each Burmese participant in Bangkok, Thailand, and the results are shown in table 7.

Table 6 Average daily dose (ADD) for As, Cd, Cr, Cu, Ni, and Pb in Bangkok, Thailand (n= 400)

Participants	Average daily dose (ADD) (mg/kg.day)					
	As	Cd	Cr	Cu	Ni	Pb
Mean	4.986×10^{-6}	3.813×10^{-6}	96.497×10^{-6}	$1{,}111.000 \times 10^{-6}$	160.171×10^{-6}	73.913×10^{-6}
SD	9.584×10^{-6}	7.329×10^{-6}	18.549×10^{-6}	310.000×10^{-6}	44.632×10^{-6}	14.207×10^{-6}
Median	4.772×10^{-6}	3.649×10^{-6}	92.351×10^{-6}	52.000×10^{-6}	151.719×10^{-6}	70.737×10^{-6}
Minimum	3.264×10^{-6}	2.496×10^{-6}	63.168×10^{-6}	720.000×10^{-6}	103.776×10^{-6}	48.384×10^{-6}
Maximum	8.596×10-6	6.573×10^{-6}	166.362×10^{-6}	$5{,}624.000 \times 10^{-6}$	810.750×10^{-6}	127.426×10^{-6}

Table 7 Hazard quotient (HQ) for As, Cd, Cr, Cu, Ni, and Pb in Bangkok, Thailand (n= 400)

Participants	Hazard Quotient (HQ)					
	As	Cd	Cr	Cu	Ni	Pb
Mean	0.01662	0.00381	0.03217	0.02645	0.00801	0.02112

SD	0.00319	0.00073	0.00618	0.00737	0.00223	0.00406
Median	0.01591	0.00365	0.03078	0.02506	0.00759	0.02021
Minimum	0.01088	0.00249	0.02106	0.01714	0.00519	0.01382
Maximum	0.02865	0.00657	0.05545	0.13389	0.04054	0.03641

According to table 7, the total mean ± SD HQ of As in Bangkok, Thailand was 0.01662 ± 0.00319 with the range from 0.01088 to 0.02865. In the case of Cd, the total mean ± SD HQ of Cd in Bangkok, Thailand was 0.00381 ± 0.00073 with the range from 0.00249 to 0. 00657. Regarding Cr, the total mean± SD HQ of Cr in Bangkok, Thailand was 0.03217 ±0.00618 with the range from 0.02106 to 0.05545. For Cu, the total mean ± SD HQ of Cu in this study area was 0.02645 ± 0.00737 with the range from 0.01714 to 0.13389. For Ni, the total mean ± SD HQ of Ni was 0.00801 ± 0.00223 with the range from 0.00519 to 0.04054. In the case of Pb, the total mean ± SD HQ of Pb in ginger of Bangkok, Thailand was 0.02112 ± 0.00406 with the range from 0.01382 to 0.03641.

After that, hazard quotients (HQ) for all heavy metals were combined to obtain the hazard index (HI) of the participants. The calculated mean ± SD HI of Burmese in Bangkok, Thailand was 0.10817 ± 0.02185 with the range from 0.07058 to 0.24648 which is less than the acceptable non-cancer risk level (HI=1), and the median was 0.10319 as shown in table 8. Therefore, no participant might have non-cancer risks in this study because of the ingestion exposure to As, Cd, Cr, Cu, Ni, and Pb in the ginger from Bangkok, Thailand.

Table 8 Hazard index (HI) for non-cancer risks of Burmese in Bangkok, Thailand (n=400)

Participants (n=400)	Hazard Index (HI) (HI= $\sum$ HQi)
Mean	0.10817
SD	0.02185

Median	0.10319
Minimum	0.07058
Maximum	0.24648

4.1.3.2. Cancer risks characterization

The cancer risks of ingestion exposure to arsenic, cadmium, and lead in the ginger samples were assessed in this study. The average daily dose (ADD) for lifetime cancer risks was calculated by using socio-demographic data and exposure durations which were obtained from questionnaires, and lifetime cancer risks were calculated by using the default life expectancy (67 years) average life expectancy in Myanmar (The world bank,2020). The ADD for carcinogenic risks for Burmese participants in Bangkok, Thailand was calculated by using the equation (1) from section (3.7) and the results are shown in table 9.

Table 9 Average daily dose ADDs of Arsenic (As), Cadmium (Cd), and lead (Pb)

Participants (n=400)	Average daily dose (ADD) for lifetime cancer risks		
	ADD As	ADD Cd	ADD Pb
Mean	0.540×10^{-6}	0.413×10^{-6}	8.006×10^{-6}
SD	0.345×10^{-6}	0.263×10^{-6}	5.116×10^{-6}
Median	0.418×10^{-6}	0.320×10^{-6}	6.207×10^{-6}
Minimum	0.062×10^{-6}	0.048×10^{-6}	0.926×10^{-6}
Maximum	1.898×10^{-6}	1.452×10^{-6}	28.149×10^{-6}

4.1.3.2.1. Lifetime cancer risks of As for the participants in Bangkok, Thailand

The lifetime cancer risks of As for Burmese participants in Bangkok, Thailand were calculated based on their socio-demographic and exposure parameters obtained from questionnaires. The mean ± SD cancer risks of As was $0.810\times10^{-6} \pm 0.518\times10^{-6}$ and the median was 0.628×10^{-6} ranging from 0.094×10^{-6} to 2.848×10^{-6} which is higher than the acceptable cancer risk of 1×10^{-6}. 127 (31.75%) out of 400 Burmese participants in Bangkok, Thailand were greater than acceptable cancer risks of 1×10^{-6}; therefore, they might have cancer risks because of the ingestion exposure to As in the ginger from Bangkok, Thailand. Table 10 shows the results of the lifetime cancer risk of As in Bangkok, Thailand.

Table 10 Lifetime cancer risk of As in Bangkok, Thailand

Participants (n=400)	Cancer risk As
Mean	0.810×10^{-6}
SD	0.518×10^{-6}
Median	0.628×10^{-6}
Minimum	0.094×10^{-6}
Maximum	2.848×10^{-6}

4.1.3.2.2. Lifetime cancer risks of Cd for the participants in Bangkok, Thailand

The lifetime cancer risk of Cd for each Burmese participant in Bangkok, Thailand was calculated step by step. The results showed that the mean ± SD cancer risks of Cd for all the participants was $0.157\times10^{-6} \pm 0.100 \times10^{-6}$ and the median was 0.122×10^{-6} ranging from 0.018×10^{-6} to 0.552×10^{-6} that is lower than the acceptable cancer risk level of 1×10^{-6}. Therefore, these participants from Bangkok, Thailand might not have lifetime cancer risks due to the ingestion exposure to Cd in the ginger. Table

11 presents the results of the lifetime cancer risks of Cd of the Burmese participants by consuming ginger from Bangkok, Thailand.

Table 11 Lifetime cancer risk of Cd in Bangkok, Thailand

Participants (n=400)	Cancer risk Cd
Mean	0.157×10^{-6}
SD	0.100×10^{-6}
Median	0.122×10^{-6}
Minimum	0.018×10^{-6}
Maximum	0.552×10^{-6}

4.1.3.2.3. Lifetime cancer risks of Pb for the participants in Bangkok, Thailand

Similarly, the lifetime cancer risk of Pb for each Burmese participant in Bangkok, Thailand was calculated step by step. The results presented that the mean ± SD cancer risks of Pb for all the participants was $0.068 \times 10^{-6} \pm 0.043 \times 10^{-6}$ and the median was 0.053×10^{-6} ranging from 0.008×10^{-6} to 0.239×10^{-6} which is lower than the acceptable cancer risk value of 1×10^{-6}. Therefore, these participants from Bangkok, Thailand might not have lifetime cancer risks due to the exposure to Pb in the ginger. Table 12 describes the results of the lifetime cancer risks of Pb of Burmese participants by consuming ginger from Bangkok, Thailand.

Table 12 Lifetime cancer risk of Pb in Bangkok, Thailand

Participants (n=400)	Cancer risk Pb
Mean	0.068×10^{-6}
SD	0.043×10^{-6}
Median	0.053×10^{-6}

Minimum	0.008×10^{-6}
Maximum	0.239×10^{-6}

4.1.3.2.4. Total cancer risks from the ingestion of As, Cd, and Pb in ginger samples from Bangkok, Thailand

The lifetime cancer risks of Arsenic (As), Cadmium (Cd), and Lead (Pb) were summarized to obtain the total cancer risks of the participants in Bangkok, Thailand. The mean ± SD total cancer risks for all Burmese participants in Bangkok, Thailand was $1.035\times10^{-6} \pm 0.661\times10^{-6}$ and the median was 0.803×10^{-6} ranging from 0.119×10^{-6} to 3.639×10^{-6} that is a little higher than the acceptable cancer risk of 1×10^{-6}. To summarize the lifetime cancer risks for all participants, 157 (39.25%) out of 400 Burmese participants in Bangkok, Thailand were greater than acceptable cancer risks of 1×10^{-6} and might have lifetime cancer risks due to ginger consumption. Table 13 shows the results of the lifetime cancer risks of Burmese participants by consuming ginger from Bangkok, Thailand.

Table 13 Total lifetime cancer risk of Burmese participants in Bangkok, Thailand

Participants (n=400)	Total lifetime cancer risk
Mean	1.035×10^{-6}
SD	0.661×10^{-6}
Median	0.803×10^{-6}
Minimum	0.119×10^{-6}
maximum	3.639×10^{-6}

4.2. Yangon, Myanmar

4.2.1 Socio-demographic Characteristics of Burmese in Yangon, Myanmar

In this part, 400 participants (187 males and 213 females) from Thiri Mingalar Market, Yangon, Myanmar were asked the interview questions both face-to-face and online questionnaire. The number of female participants was higher than the male participants, with 53.2 % as opposed to 46.8%. The sociodemographic characteristics of Burmese participants in Yangon, Myanmar are shown in table 14.

The results show that the age of Burmese participants from Yangon, Myanmar ranged from 18 to 60 years of age; a median was 36 years of age and the mean ± SD age was 36.94 ± 12.14 years. To be more specific the age regarding gender, the ages of male participants ranged from 18 to 60 years with the mean ± SD age of 38.53±12.18 years, whereas the ages of female participants ranged from 18 to 60 years and the mean ± SD age was 35.5 ± 11.93 years. Overall, among the participants, there were 143 (35.75%) participants in the age range of 18-30 years of age; 131(32.75%) participants in the age range of 31-43 years; and 126 (31.5%) participants were between 44 and 60 years old.

The height of the participants in Yangon, Myanmar ranged from 147.32 to 180.34cm with a median of 162.56 cm and the mean ± SD height was 163.13 ± 7.20 cm. The body weights of the participants ranged from 45 to 79 kg with a median of 61 kg, and the mean ± SD was 60.79 ± 7.47 kg. For male participants, the mean ± SD height was 168.24 ± 5.12 cm with a range of 152.4 to 180.34 cm and the mean weight ± SD was 62.09 ± 6.98 kg with the range of 45 to 79 kg. For female participants, the mean ± SD height was 158.59 ± 5.48 cm with a range of 147.32 to 175.26 cm and the mean ± SD weight was 59.64 ± 7.71kg with a range of 45 to 77 kg.

Regarding their educational level, there were no participants whose education was lower than primary school, 0.8% of them attended primary school education, 6% of them attended secondary school and 40 % of them had gone to high school, 53.2% had bachelor's or higher degree. To be more specific, 0.5 % of male participants had primary school education, 4.8% attended secondary school and 40.6% attended high school, and 54% had a bachelor's or higher degree. Of female participants, 0.9% received a primary school education, 7% had gone to secondary school, 39.4% attended high school, and 52.6%% had a bachelor's or higher degree.

For smoking behavior, among 400 participants in this study, 14.3% of Burmese participants reported as smokers, 80% of them were non-smokers, and 5.8% of them were ex-smokers. In the case of alcohol drinking behavior among 400 participants, 20.5% of them reported as drinkers, 73.3% of them were non-drinkers, and 6.3 % were ex-drinkers. To be more specific, 29.9% of the male participants were smokers, 57.8% were non-smokers, and 12.3 % of them are ex-smokers. On the other hand, only 0.5% of female participants reported as smokers and 99.5% were non-smokers. Regarding alcohol drinking habits, 42.2% of male participants were drinkers, 44.4% of them were non-drinkers, and 13.4% were ex-drinkers. However, only 1.4% of female participants were found as drinkers, and 98.6% of them were non-drinkers.

Regarding the ginger eating frequency, 32.5% (130 participants) reported that they eat ginger 5-6 times a week, 27.8% (111 participants) consume ginger every day, one time a day, 25.5% (102 participants) eat ginger every day, twice a day, 8.3% (33 participants) eat 2-4 times a week, and 6% (24 participants) consume ginger every day

Table 14 Socio-demographic characteristics of sampling population (n= 400) in Yangon, Myanmar

Characteristics	Participants	Percentage (%)
Gender		
Male		187 (46.8%)
Female		213 (53.2%)
Age (years)		
18-30		143 (35.75%)
31-43		131 (32.75%)
44-60		126 (31.5%)
Mean ± SD	36.94±12.14	

Median	36	
Range	18 - 60	
Bodyweight (kg)		
Male participants (n=187)		
Mean ± SD	62.09± 6.98	
Median	62	
Range	45 - 79	
Female participants (n=213)		
Mean ± SD	59.64 ±7.71	
Median	60	
Range	45 - 77	
All participants (n=400)		
Mean ± SD	60.79 ± 7.47	
Median	61	
Range	45 - 79	
Height (cm)		
Male participants (n=187)		
Mean ± SD	168.24 ± 5.12	
Median	167.64	
Range	152.4 - 180.34	
Female participants(n=213)		
Mean ± SD	158.59 ± 5.48	
Median	160.02	
Range	147.32 - 175.26	
All participants (n=400)		

Mean ± SD	163.13 ± 7.2	
Median	162.56	
Range	147.32 to 180.34	
Education level(n=400)		
Primary school		3(0.8%)
Secondary school		24 (6%)
High school		160 (40%)
Bachelor or higher degree		213 (53.3%)
Smoking behavior		
All participants		
Smoker		57 (14.2%)
Non-smoker		320 (80%)
Ex-smoker		23 (5.8%)
Drinking behavior		
All participants		
Drinker		82 (20.5%)
Non-drinker		293 (73.3%)
Ex-drinker		25 (6.3%)
Occupation		
All participants		
Student		62 (15.5%)
Government officer		65 (16.3%)
Employee		157 (39.32%)
farmer		8(2%)
State enterprise		108 (27%)

Exposure factors		
Amount of ginger consumption(g/day)		
All participants (n=400)		
Mean ± SD	44.61 ± 7.91	
Median	40	
Range	30 - 70	
Exposure frequency (days/yr)		
Mean ± SD	365±0	
Duration of living in the study area (years)		
All participants(n=400)		
Mean ± SD	23.19 ± 19.66	
Median	20	
Range	1 - 60	
Times of ginger consumption		
2-4 times a week		33 (8.3%)
5-6 times a week		130 (32.5%)
Every day, one time a day		111(27.8%)
Every day, twice a day		102 (25.5%)
Every day, more than twice a day		24 (6%)

4.2.1.1 Exploration of Adverse Health Symptoms of Burmese Participants in Yangon, Myanmar

As exposure to the As, Cd, Cr, Cu, Ni, and Pb can result in non-carcinogenic and carcinogenic diseases, the signs, and symptoms of both acute and chronic toxic effects after exposure to the heavy metals were explored. In this study, the participants were asked about the adverse health symptoms which might be related to the ingestion of heavy metals from ginger in Yangon, Myanmar during the last 3 months and 12 months separately.

Regarding the signs and symptoms during the last 3 months in Yangon, Myanmar, it was found that some participants have more than one symptom. The most frequent signs and symptoms from Burmese participants in Yangon, Myanmar were joint pains (80 participants), pain in the back and limbs (67 participants), forgetfulness (158 participants), muscular pain (99 participants), hair loss (158 participants), headache (113 participants), skin rashes (37 participants) and weakness (71 participants), nervousness (34 participants), irritability (26 participants), shyness (27 participants), vomiting (7 participants), and diarrhea (73 participants). The results are shown in figure 5.

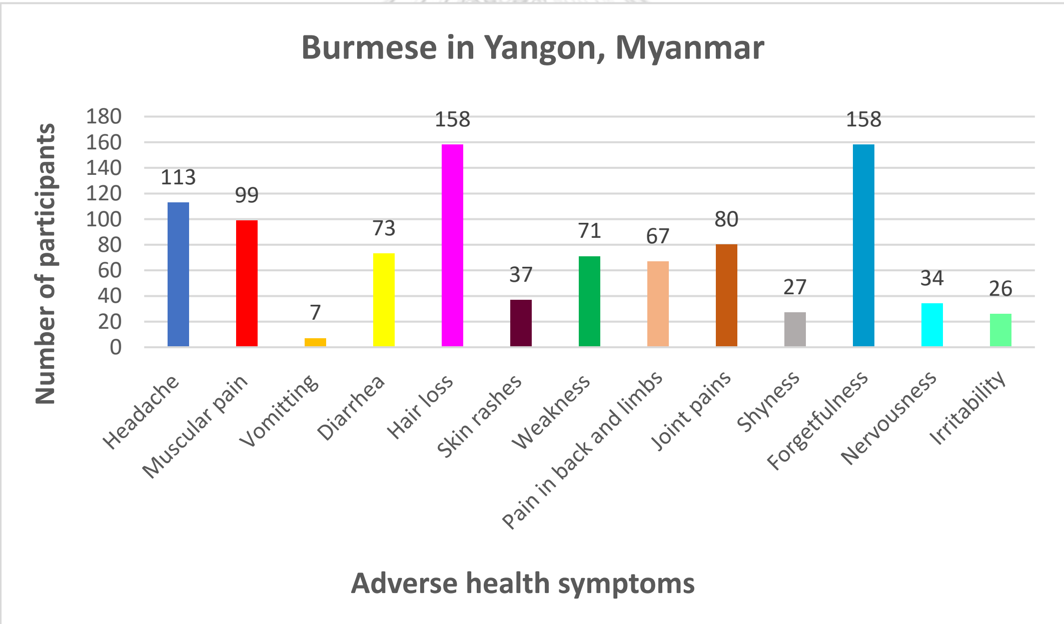


Figure 5 Symptoms reported by Burmese for the last 3 months in Yangon, Myanmar

In the case of the signs and symptoms during the last 12 months in Yangon, Myanmar, some signs, and symptoms were reported by the same participants in the last 3 months. These same signs and symptoms were joint pains (83 participants), pain in the back and limbs (65 participants), forgetfulness (168 participants), muscular pain (112 participants), hair loss (156 participants), and shyness (29 participants), headache

(117 participants), skin rashes (55 participants), and weakness (64 participants), vomiting (9 participants), diarrhea (55 participants), nervousness (24 participants), and irritability (21 participants). The results are shown in figure 6.

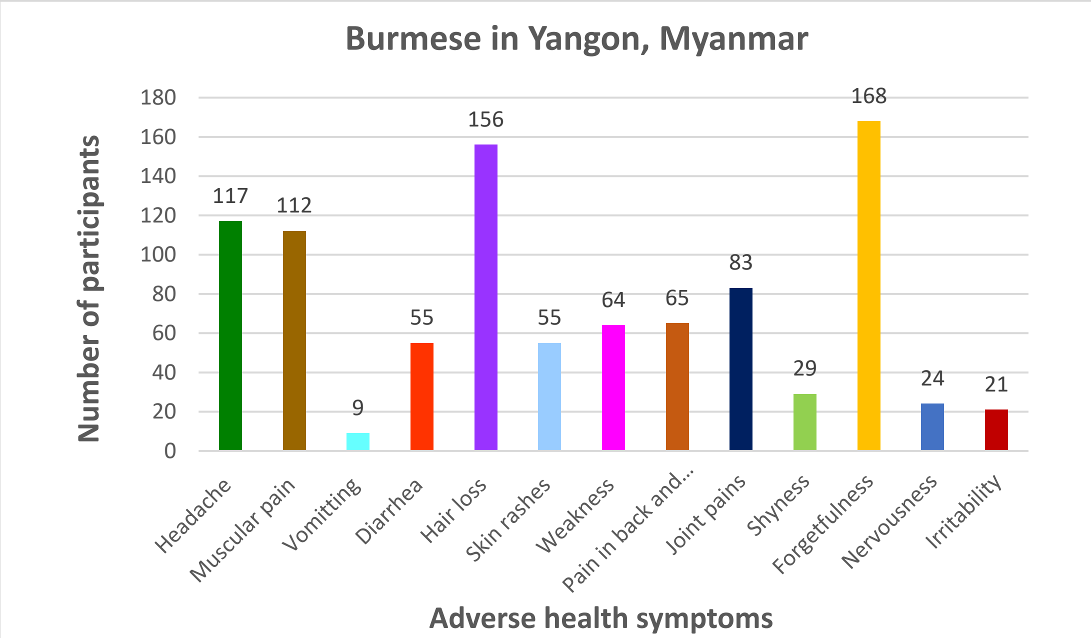


Figure 6 Symptoms reported by Burmese for the last 12 months in Yangon, Myanmar

4.2.2 Concentrations of the Heavy Metals in ginger samples from Yangon, Myanmar

The concentrations of the heavy metals in ginger samples from Yangon, Myanmar are shown in table 15, and the mean ± SD, median, and range of heavy metal concentrations in ginger samples from Yangon, Myanmar were presented.

In Yangon, Myanmar, the mean ± SD concentration of As in ginger samples was 0.0494 ± 0.024 mg/kg and the median was 0.047mg/kg with the range from 0.024mg/kg to 0.086 mg/kg. The mean ± SD concentration of Cd was 0.0004 ± 0.0005 mg/kg with the range from 0.000 mg/kg to 0.001 mg/kg. In the case of Cr, the mean ± SD concentration was 0.2958 ± 0.105 mg/kg and the median was 0.247 mg/kg with the range from 0.194 mg/kg to 0.419 mg/kg. For Cu, the mean ± SD concentration of Cu was 1.1058 ± 0.153 mg/kg and the median was 1.091 mg/kg with the range from 0.962mg/kg to 1.345mg/kg. Regarding the concentration of Ni, the mean ± SD concentration was

0.2086 ± 0.011 mg/kg, and the median was 0.211mg/kg with the range from 0.197mg/kg to 0.22mg/kg. The mean ± SD concentration of Pb was 0.1460 ± 0.063 mg/kg, the median was 0.138 mg/kg with the range from 0.080 mg/kg to 0.245 mg/kg.

Table 15 Concentrations of heavy metals found in ginger samples (Thiri Mingalar market, Yangon,Myanmar)

	Concentration (mg/kg)					
	As	Cd	Cr	Cu	Ni	Pb
	Thiri Mingalar Market, Yangon, Myanmar					
Mean ± SD	0.0494±0.024	0.0004±0.0005	0.2958±0.106	1.1058±0.154	0.2086±0.011	0.1460±0.063
Median	0.047	0.000	0.247	1.091	0.211	0.138
Min- Max	<0.145	<0.020	0.194-0.419	0.962-1.345	0.197-0.220	0.080-0.245
Limit of detection (LOD)	0.145	0.020	0.005	0.100	0.005	0.005
Guideline values (FAO/WHO,2019)	0.1	0.1	1.3	73.3	67.9	0.1
Thai standard	2[a]	0.1[a]	1[c]	20[c]	NA	0.1[a]
EU standard	0.15[b]	0.1[b]	1[b]	NA	NA	0.2[b]

[a] Permissible values of the Ministry of Public Health in Thailand

[b] Food standard Australia New Zealand

[c] National Food Institute, Thailand

NA- Not available

4.2.3 Exposure assessment and risk characterization

This part was separated into 2 parts: (1) non-carcinogenic risk and (2) carcinogenic risk. Exposure factors such as eating frequency, exposure duration, height, and body weight were obtained by questionnaires. The mean eating frequency for Burmese participants in Yangon, Myanmar was 365 days per year. The mean ± SD exposure duration (duration of living in Yangon, Myanmar) was 23.19 ± 19.66 years, and the median was 20 with a range from 1 to 60 years as shown in table 16.

Table 16 Exposure factors of Burmese participants in Yangon, Myanmar

	Sampling population (n= 400)					
	Age(yrs)	Weight (kg)	Height(cm)	Duration(yrs)	Amount of consumption (g/day)	Exposure frequency (days/yr)
Mean ± SD	36.94 ± 12.14	60.79 ±7.47	163.14±7.20	23.19±19.66	44.61 ±7.91	365±0
Median	36	61	162.56	20	40	365
Min – Max	18 – 60	45 - 79	147.32– 180.34	1 - 60	30 - 70	365

In the case of the weight of the participants, the mean ± SD weight for all the participants was 60.79 ± 7.47 kg and the median was 61 kg with the range from 45 to 79 kg. Regarding the height, the mean ± SD height for all the participants was 163.13 ± 7.20 cm and the median was 162.56 cm with the range from 147.32 to 180.34 cm.

The exposure factors obtained from the questionnaires, as shown in table 16, were used to calculate the participants' mean daily intake for ingestion exposure (ADD) to heavy metals. ADD for both non-cancer and cancer risks were calculated for the participants using eq (1) from section 3.7 based on their socio-demographic and ingestion factors obtained from questionnaires. Moreover, the concentration of heavy metals in ginger samples was used as the input concentration in the ADD calculation for Burmese participants in Yangon, Myanmar.

4.2.3.1 Non-cancer risk characterization

To begin, the participants' mean daily dose (ADD) to each heavy metal, such as As, Cd, Cr, Cu, Ni, and Pb in ginger from Yangon, Myanmar for non-cancer risks was calculated using equation (1) from section 3.7. The average daily dose of the heavy metals via ginger consumption was shown in table 17. After that, the hazard quotient (HQ) and hazard index (HI) of each heavy metal (As, Cd, Cr, Cu, Ni, and Pb) were calculated for the participants through equations (2) and (3) from section 3.7 respectively. The mean HQs of each heavy metal for each Burmese participant in Yangon, Myanmar were calculated, and the results are shown in table 18.

Table 17 Average daily dose (ADD) for As, Cd, Cr, Cu, Ni, and Pb in Yangon, Myanmar (n= 400).

Participants	Average daily dose (ADD) (mg/kg.day)					
	As	Cd	Cr	Cu	Ni	Pb
Mean	36.851×10^{-6}	0.298×10^{-6}	220.659×10^{-6}	825.000×10^{-6}	155.610×10^{-6}	108.912×10^{-6}
SD	8.137×10^{-6}	0.066×10^{-6}	49.182×10^{-6}	184.000×10^{-6}	34.683×10^{-6}	24.275×10^{-6}
Median	34.666×10^{-6}	0.281×10^{-6}	207.579×10^{-6}	776.000×10^{-6}	146.386×10^{-6}	102.456×10^{-6}
Minimum	22.454×10^{-6}	$0.182\times10\text{-}^{6}$	134.455×10^{-6}	503.000×10^{-6}	94.818×10^{-6}	66.364×10^{-6}
Maximum	65.245×10^{-6}	0.528×10^{-6}	390.679×10^{-6}	$1,460.000\times10^{-6}$	275.509×10^{-6}	192.830×10^{-6}

Table 18 Hazard quotient (HQ) for As, Cd, Cr, Cu, Ni, and Pb in Yangon, Myanmar (n= 400).

Participants	Hazard Quotient (HQ)					
	As	Cd	Cr	Cu	Ni	Pb
Mean	0.12284	0.00029	0.07236	0.01964	0.00778	0.03112
SD	0.02738	0.00006	0.01639	0.00438	0.00173	0.00694

Median	0.11556	0.00028	0.06919	0.01847	0.00732	0.02927
Minimum	0.07485	0.00018	0.04482	0.01197	0.00474	0.01896
Maximum	0.21748	0.00053	0.13023	0.03478	0.01378	0.05509

According to table 18, the total mean ± SD HQ of As in Yangon, Myanmar was 0.12284± 0.02738 with the range from 0.07485 to 0.21748. In the case of Cd, the total mean ± SD HQ of Cd in Yangon, Myanmar was 0.00029 ±0.00006 with the range from 0.00018 to 0.00053. Regarding Cr, the total mean± SD HQ of Cr was 0.07236 ±0.01639 with the range from 0.04482 to 0.13023. For Cu, the total mean ± SD HQ of Cu in Yangon, Myanmar was 0.01964 ± 0.00438 with the range from 0.01197 to 0.03478. For Ni, the total mean ± SD HQ of Ni in Yangon, Myanmar was 0.00778 ± 0.00173 with the range from 0.00474 to 0.01378. In the case of Pb, the total mean ± SD HQ of Pb in Yangon, Myanmar was 0.03112 ± 0.00694 with the range from 0.01896 to 0.05509.

Afterward, the calculated hazard quotients (HQs) for As, Cd, Cr, Cu, Ni, and Pb were summarized to obtain the hazard index (HI). The mean ± SD HI of Burmese participants in Yangon, Myanmar was 0.25523 ± 0.05689 with the range from 0.15552 to 0.45188 that is less than the acceptable non-cancer risk level (HI=1), and the median was 0.24009. The results are shown in table 19. Therefore, no participant might have non-cancer risks in this study because of the ingestion exposure to As, Cd, Cr, Cu, Ni, and Pb in the ginger from Yangon, Myanmar.

Table 19 Hazard index (HI) for non-cancer risks of the participants in Yangon, Myanmar (n=400)

Participants (n=400)	Hazard Index (HI) (HI= ∑ HQi)
Mean	0.25523
SD	0.05689
Median	0.24009

Minimum	0.15552
Maximum	0.45188

4.2.3.2 Cancer risks characterization

This study looked at the cancer risks of ingesting arsenic, cadmium, and lead from ginger samples. The average daily dose (ADD) for lifetime cancer risks of Burmese in Yangon, Myanmar was calculated using socio-demographic data and exposure durations obtained from questionnaires, and lifetime cancer risks were calculated using Burmese's default life expectancy (67 years) (The world bank,2020) The ADD of participants for carcinogenic risks was calculated using the equation (1) from section (3.7), and the results are shown in table 20.

Table 20 Average daily dose ADDs of Arsenic (As), Cadmium (Cd), and lead (Pb)

Participants (n=400)	Average daily dose (ADD) for lifetime cancer risk		
	ADD As	ADD Cd	ADD Pb
Mean	12.299×10^{-6}	0.038×10^{-6}	36.351×10^{-6}
SD	10.548×10^{-6}	0.032×10^{-6}	31.177×10^{-6}
Median	11.719×10^{-6}	0.036×10^{-6}	34.637×10^{-6}
Minimum	0.423×10^{-6}	0.001×10^{-6}	1.249×10^{-6}
Maximum	42.684×10^{-6}	0.131×10^{-6}	126.153×10^{-6}

4.2.3.2.1 Lifetime cancer risks of As for the participants in Yangon, Myanmar

The lifetime cancer risks of As of the participants in Yangon, Myanmar were calculated based on their socio-demographic and exposure parameters obtained from questionnaires. The mean ± SD cancer risks of As for all the participants was 18.449 $\times10^{-6}$ ± 15.823 $\times10^{-6}$ and the median was 17.579 $\times10^{-6}$ ranging from 0.634 $\times10^{-6}$ to 64.027 $\times10^{-6}$ which is higher than the acceptable cancer risk, 1×10^{-6}. Therefore, some participants in this study might have cancer risks because of the ingestion exposure to As in the ginger from Yangon, Myanmar. The lifetime cancer risks of As for 384 (96%) out of 400 participants in Yangon, Myanmar were greater than the acceptable cancer risks of 1×10^{-6}. Table 21 shows the detailed results of the cancer risks of As for the participants.

Table 21 Lifetime cancer risk of As in Yangon, Myanmar

Participants (n=400)	Cancer risk As
Mean	18.449 $\times10^{-6}$
SD	15.823 $\times10^{-6}$
Median	17.579 $\times10^{-6}$
Minimum	0.634 $\times10^{-6}$
Maximum	64.027 $\times10^{-6}$

4.2.3.2.2 Lifetime cancer risks of Cd for the participants in Yangon, Myanmar

The mean ± SD cancer risks of Cd for all the participants was 0.038×10^{-6} ± 0.032×10^{-6}, and the median was 0.036 $\times10^{-6}$ ranging from 0.001×10^{-6} to 0.131×10^{-6} that is lower than the acceptable cancer risks, 1×10^{-6}. Therefore, these Burmese participants from Yangon, Myanmar might not have lifetime cancer risks due to the exposure to Cd in the ginger. Table 22 presents the results of the lifetime cancer risks of Cd of the participants by consuming ginger in Yangon, Myanmar.

Table 22 Lifetime cancer risk of Cd in Yangon, Myanmar

Participants (n=400)	Cancer risk Cd

Mean	0.038×10^{-6}
SD	0.032×10^{-6}
Median	0.036×10^{-6}
Minimum	0.001×10^{-6}
Maximum	0.131×10^{-6}

4.2.3.2.3 Lifetime cancer risks of Pb for the participants in Yangon, Myanmar

The mean ± SD current cancer risks of Pb for all the participants in this study area was $0.309 \times 10^{-6} \pm 0.265 \times 10^{-6}$, and the median was 0.294×10^{-6} ranging from 0.011 $\times 10^{-6}$ to 1.072×10^{-6} and some of the participants have a little higher risk than the acceptable cancer risk level. In details, the lifetime cancer risks of Pb for 2 (0.5%) out of 400 participants were greater than the acceptable cancer risks of $1 \times 10^{-6.}$ Therefore, some Burmese participants from Yangon, Myanmar might have lifetime cancer risks due to the exposure to Pb in the ginger. Table 23 presents the results of the lifetime cancer risks of Pb of the participants by consuming ginger from Yangon, Myanmar.

Table 23 Lifetime cancer risk of Pb in Yangon, Myanmar

Participants (n=400)	Cancer risk Pb
Mean	0.309×10^{-6}
SD	0.265×10^{-6}
Median	0.294×10^{-6}
Minimum	0.011×10^{-6}
Maximum	1.072×10^{-6}

4.2.3.2.4 Total cancer risks from the ingestion of As, Cd, and Pb in ginger samples

The lifetime cancer risks of Arsenic (As), Cadmium (Cd), and Lead (Pb) were summarized to obtain the total cancer risks of the participants in Yangon, Myanmar. The mean ± SD total cancer risks for all the participants in Yangon, Myanmar was $18.796 \times 10^{-6} \pm 16.121 \times 10^{-6}$ and the median was 17.910×10^{-6} ranging from 0.646×10^{-6} to 65.231×10^{-6} that is higher than the acceptable cancer risks of 1×10^{-6}. To summarize the total lifetime cancer risks for the participants, the lifetime cancer risks of 384 (96%) out of 400 participants were greater than the acceptable cancer risks of 1×10^{-6}. Table 24 displays the results of the participants' lifetime cancer risks from the consumption of ginger from Yangon, Myanmar.

Table 24 Total lifetime cancer risk of the participants in Yangon, Myanmar

Participants (n=400)	Total lifetime cancer risk
Mean	18.796×10^{-6}
SD	16.121×10^{-6}
Median	17.910×10^{-6}
Minimum	0.646×10^{-6}
Maximum	65.231×10^{-6}

4.3 Comparison between Bangkok, Thailand and Yangon, Myanmar

The concentration of heavy metals in ginger samples and the means of each exposure parameter such as the body weights of the participants, amount of consumption, exposure frequency, and duration of living in the study areas were used to compare cancer and non-cancer risks of the participants from ingestion of heavy metals contaminated ginger in these two study areas.

4.3.1 Comparison of concentrations of heavy metals in ginger samples of two study areas

When comparing the concentrations of heavy metals in ginger samples of two study areas, the mean concentration of As in Yangon, Myanmar was considerably higher than that of As in Bangkok, Thailand, with 0.0494 mg/kg as opposed to 0.0068mg/kg. However, the concentration of As in Bangkok, Thailand and the amount of As in Yangon, Myanmar were lower than the guideline values (WHO) of 0.1 mg/kg. On the other hand, a higher concentration of Cd was found in the ginger of Bangkok, Thailand than that of Cd in the ginger of Yangon, Myanmar, with 0.0052 mg/kg as against 0.0004 mg/kg. However, the concentrations of Cd in both study areas were lower than the permissible limit of 0.1mg/kg. Similarly, the amount of Cr in both study areas was smaller than that of recommended value by WHO (1.3mg/kg), with 0.1316mg/kg in Bangkok, Thailand and 0.2958mg/kg in Yangon, Myanmar respectively. Regarding the Cu concentration in ginger samples, 1.4996mg/kg of Cu was found in the ginger of Bangkok, Thailand, while 1.1058mg/kg of Cu was measured in the ginger of Yangon, Myanmar, and the concentrations of Cu in both study areas were significantly lower than that of standard values by WHO whose value was 73.3mg/kg. In the case of Ni, a higher amount was found in the ginger of Bangkok, Thailand than that of ginger from Yangon, Myanmar, with 0.2162mg/kg in contrast to 0.2086 mg/kg, and the amounts are considerably lower than the acceptable value (67.9mg/kg). Concerning Pb concentrations, 0.1008 mg/kg of Pb was found in the ginger of Bangkok, Thailand, in comparison with ginger of Yangon, Myanmar whose figure was 0.146mg/kg. Moreover, the concentration of Pb in Yangon, Myanmar was higher than the permissible limit of Pb by FAO/WHO, with 0.146 mg/kg against 0.1mg/kg; similarly, the amount of Pb in ginger of Bangkok, Thailand was also a little higher than that of acceptable value, with 0.1008 mg/kg as opposed to 0.1 mg/kg. Overall, the majority of the heavy metal concentrations found in ginger samples of Bangkok, Thailand were lower than the WHO permissible limits, except for Pb, which was slightly higher than the acceptable limit. Regarding Yangon, Myanmar, most of the heavy metal concentrations found in the ginger samples were lower than the WHO permissible limits, except for Pb which were higher than the standard value. Figure 7 compares the heavy metal concentrations of two study areas with the WHO permissible limits.

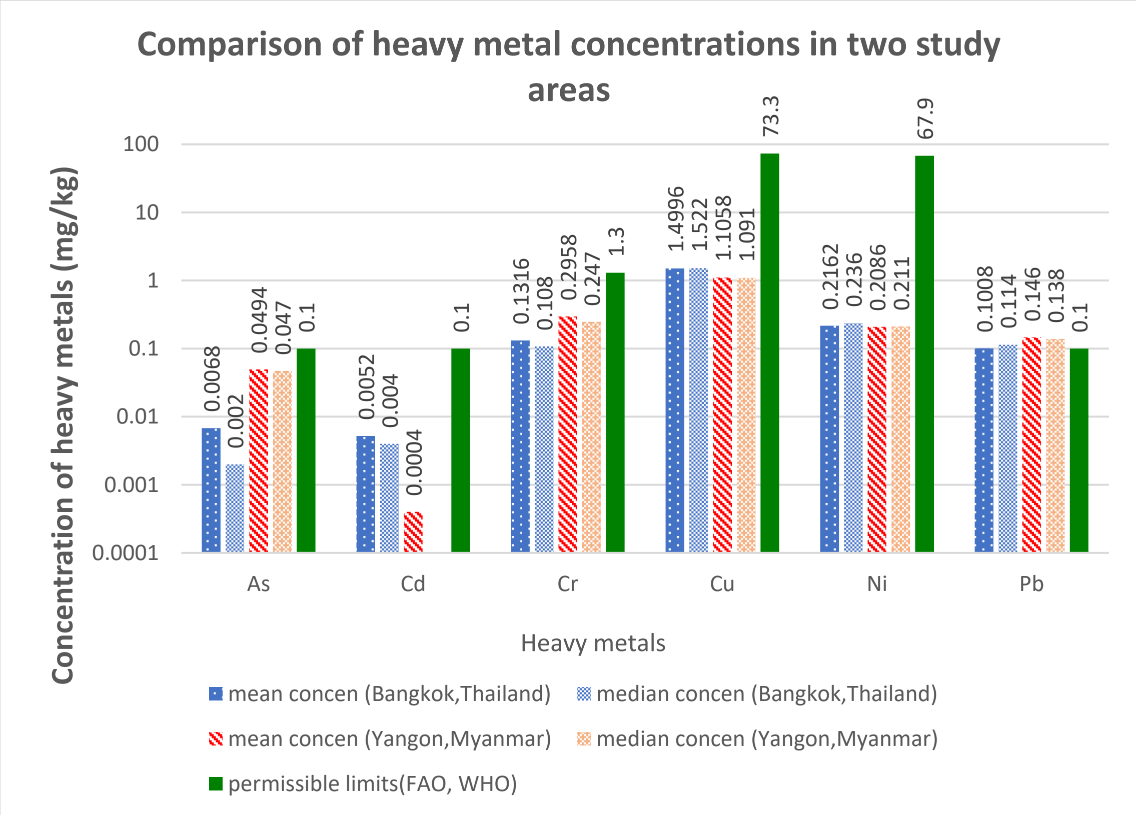


Figure 7 Comparison of mean and median heavy metal concentrations in ginger from two study areas

Results of Quality Control

In-house method TE-CH-134 based on the Association of Analytical Community (AOAC) (2019) by ICP-MS technique was chosen by the laboratory for heavy metal analysis and quality control for ginger samples. Reagents used in the digestion process were analaR grade that meets the requirements of the American Chemical Society Committee on Analytical Reagent. The limit of detection (LOD) of As, Cd, Cr, Cu, Ni, and Pb were 0.145 mg/kg, 0.020 mg/kg, 0.005 mg/kg, 0.100 mg/kg, 0.005 mg/kg, and 0.005 mg/kg respectively, and the results of most of heavy metals analysis in this study were above the respective LOD, except for As and Cd whose concentrations are lower than the LOD values. Each of the samples was analyzed in duplicates, and blank solutions were analyzed to account for any contamination through the acids used in the digestion before analyzing each of the heavy metals. The relative standard deviations (RSD) of the heavy metals were < 5%.

4.3.2 Comparison between the characteristics of Burmese participants in Bangkok, Thailand and Yangon, Myanmar

4.3.2.1 Comparison of mean height, weight, and duration of living in the study area of 2 groups of participants from Bangkok, Thailand and Yangon, Myanmar

Since the data from both study areas are normally distributed, independent samples T-test were used to compare the mean, height, weight, and duration of living years in the study area for 2 groups of Burmese participants in Bangkok, Thailand and Yangon, Myanmar. Since the p-value for the mean height of Burmese from two study areas is 0.039 which is less than 0.05 as shown in table 26, there is significant evidence to support that the mean height of the two Burmese groups from Bangkok, Thailand and Yangon, Myanmar are different. By looking at the means, Burmese participants from Thailand have greater mean height than those from Myanmar as shown in table 25.

Table 25 Comparisons of the mean height, weight, and duration of living areas of participants from Bangkok, Thailand and Yangon, Myanmar

	Participants	Mean	Std.deviation	Std.Error Mean
Height (cm)	Burmese participants from Bangkok, Thailand	164.14	6.46	0.32
	Burmese participants from Yangon, Myanmar	163.13	7.20	0.36
Weight(kg)	Burmese participants from Bangkok, Thailand	61.02	7.51	0.37
	Burmese participants from Yangon, Myanmar	60.79	7.47	0.37

Duration of living year(yrs)	Burmese participants from Bangkok, Thailand	7.38	4.58	0.23
	Burmese participants from Yangon, Myanmar	23.19	19.66	0.98

Table 26 Independent sample T-test for the mean height, weight, and duration of living areas of participants from Bangkok, Thailand and Yangon, Myanmar

Variables	P-value	Mean difference	Std.Error difference	95% Confidence interval of the difference	
				Lower	Upper
Height	0.039*	1.00170	0.48374	0.05214	1.95126
Weight	0.666	0.229	0.530	-0.811	1.269
Duration of living years	0.000*	-15.808	1.010	-17.792	-13.823

*Significant different at p-value <0.05

The p-value for the mean weight of Burmese from two study areas is 0.666, which is greater than 0.05, as shown in table 26; therefore, the mean weights of the two groups do not differ significantly. Looking at the means, we can see that the mean weights of the two Burmese groups are similar, with 61.02 kg for Burmese participants in Bangkok, Thailand, and 60.79 kg for Burmese participants in Yangon, Myanmar, as shown in table 25.

On the other hand, the p-value for participants' mean duration of living in these study areas is 0.000, which is less than 0.05 as shown in table 26. As a result, the mean durations of living years in two study areas differ significantly between the two Burmese groups from Bangkok, Thailand and Yangon, Myanmar. Looking at the mean duration of living years, Burmese in Bangkok, Thailand have shorter living years than Burmese in Yangon, Myanmar, with 7 years compared to 23 years as shown in table 25.

4.3.2.2 Comparison between the amount of consumption, frequency of consumption, and beliefs towards ginger consumption in two study areas

Regarding the amount of ginger consumption in two study areas according to the data from the questionnaire, the average amount of ginger consumption per day in Bangkok, Thailand was 44.08 ±6.54 g/day ranging from 34 g to 70g per day, and the average consumption of ginger in Yangon, Myanmar was 44.61 ±7.91 g/day ranging from 30 g to 70 g per day. Therefore, the amount of daily ginger consumption by Burmese in Yangon, Myanmar was a little higher than that of ginger consumed by Burmese in Bangkok, Thailand, with 44.61g/day as opposed to 44.08g/day as shown in figure 8.

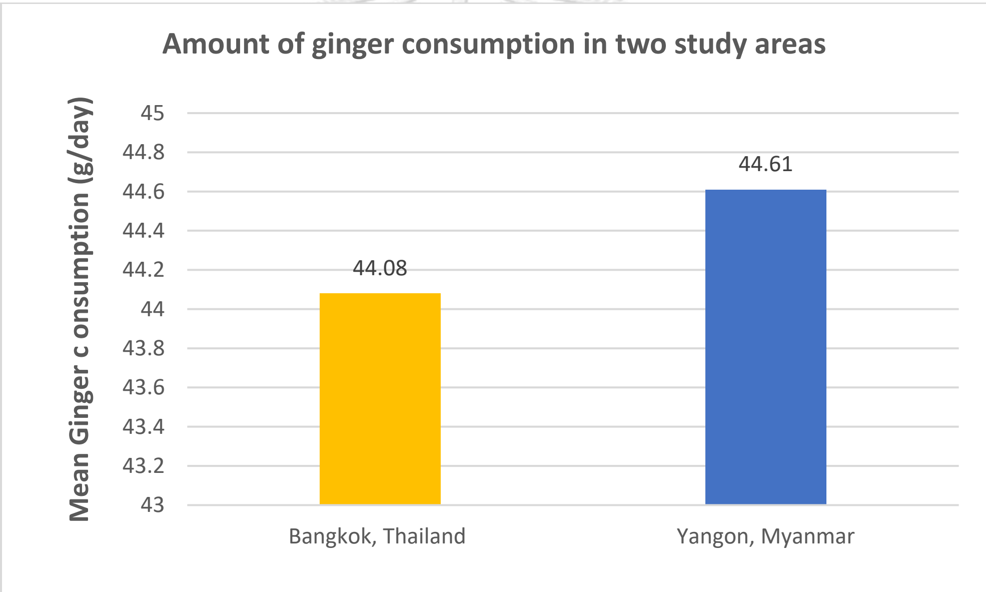


Figure 8 Amount of ginger consumption in two study areas

Regarding the ginger eating frequency as shown in figure 9, 37.3% (149 participants) of Bangkok, Thailand consume ginger every day, one time a day, while there were 27.8% (111 participants) of Yangon, Myanmar consume this rate. Then, 27% (108 participants) of Bangkok, Thailand as opposed to 32.5% (130 participants) in Yangon, Myanmar reported that they eat ginger 5-6 times a week. Similarly, there was a higher percentage of participants in Yangon, Myanmar than that of participants in Bangkok, Thailand who eat ginger every day, twice a day, with 25.5% (102 participants) compared to 24% (96 participants). In Bangkok, Thailand, 6% (24 participants) eat ginger 2-4 times a week, while 8.3% (33 participants) eat ginger 2-4 times a week in Yangon, Myanmar. In addition, 5.8% (23 participants) in Bangkok, Thailand consume ginger every day, more than twice a day, whereas 6% (24 participants) in Yangon, Myanmar consume this rate as shown in figure 9.

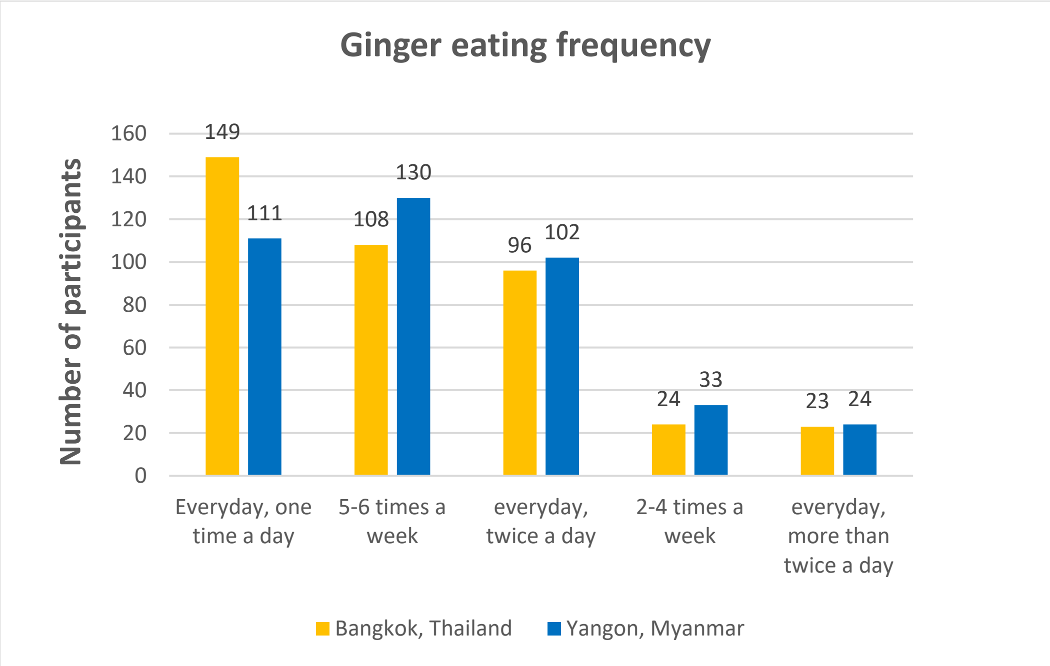


Figure 9 Ginger eating frequency of participants in two study areas

Regarding the beliefs towards ginger consumption in two study areas, only 0.25% (10 participants) from Bangkok, Thailand said that they eat ginger as a source of nutrient, while 15.55% (62 participants) of Yangon, Myanmar consume ginger as a source of nutrient. In Bangkok, Thailand, 45.5% (182 participants) said that they eat ginger since they believe that consumption of ginger can improve health, whereas 64.75% (259 participants) of Yangon, Myanmar consume ginger to improve health, especially during this COVID-19 pandemic. On the other hand, 7.5% (30 participants) in Bangkok, Thailand said that they eat ginger with the belief that ginger can prevent cancer, heart disease, stroke, and obesity, as compared to 29% (116 participants) in Yangon, Myanmar. Moreover, 35% (140 participants) from Bangkok, Thailand answered that they believe that ginger consumption can keep them from getting sick while 40.5% (162 participants) from Yangon, Myanmar reported the same answer. In addition, a high proportion of participants in Bangkok, Thailand and Yangon, Myanmar answered that ginger can make food tasty, with 76.75% (307 participants) against 87.5% (350 participants). Figure 10 compares the beliefs towards ginger consumption in two study areas.

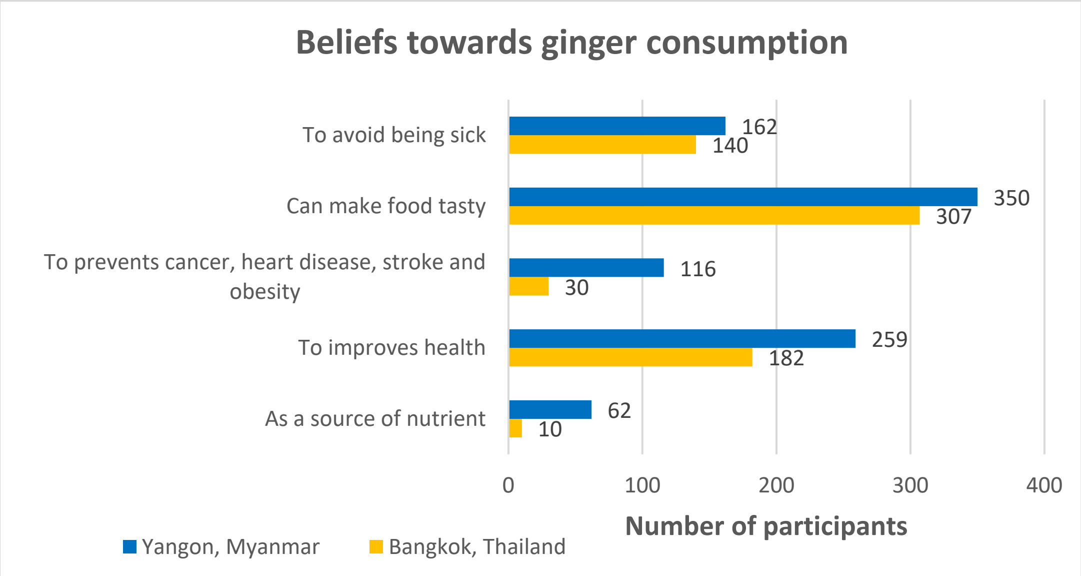


Figure 10 Beliefs towards ginger consumption in two study areas

4.3.2.3 Comparison of adverse health symptoms in two study areas

Regarding the signs and symptoms during the last 3 months, the most frequent signs and symptoms from the participants in both study areas were joint pains (85participants) in Bangkok, Thailand and (80 participants) in Yangon, Myanmar, pain in the back and limbs (71 participants) in Bangkok, Thailand compared to (67 participants) in Yangon, Myanmar, forgetfulness (171 participants) as opposed to (158 participants) in Bangkok, Thailand and Yangon, Myanmar respectively, muscular pain (98 participants) in Bangkok, Thailand against (99 participants) in Yangon, Myanmar, hair loss (166 participants) in Bangkok, Thailand in contrast to (158 participants) in Yangon, Myanmar, headache (122 participants) in Bangkok, Thailand compared to (113 participants) in Yangon, Myanmar, skin rashes (39 participants) in Bangkok, Thailand compared with (37participants) in Yangon, Myanmar, and weakness (73 participants) in Bangkok, Thailand as opposed to (71participants) in Yangon, Myanmar, nervousness (41 participants) in Bangkok, Thailand against (34 participants) in Yangon, Myanmar ,and 27 participants and 26 participants in Bangkok, Thailand and Yangon, Myanmar reported that they are suffering irritability respectively. In addition, the same number of participants in both study areas reported that they were suffering from shyness, with (27 participants) in each. Moreover, symptoms of diarrhea were reported by (71 participants) in Bangkok, Thailand and by (73 participants) in Yangon, Myanmar. The lowest number of participants in both study areas reported vomiting symptoms, with (9 participants) in Bangkok, Thailand and (7 participants) in Yangon, Myanmar respectively as shown in figure 11.

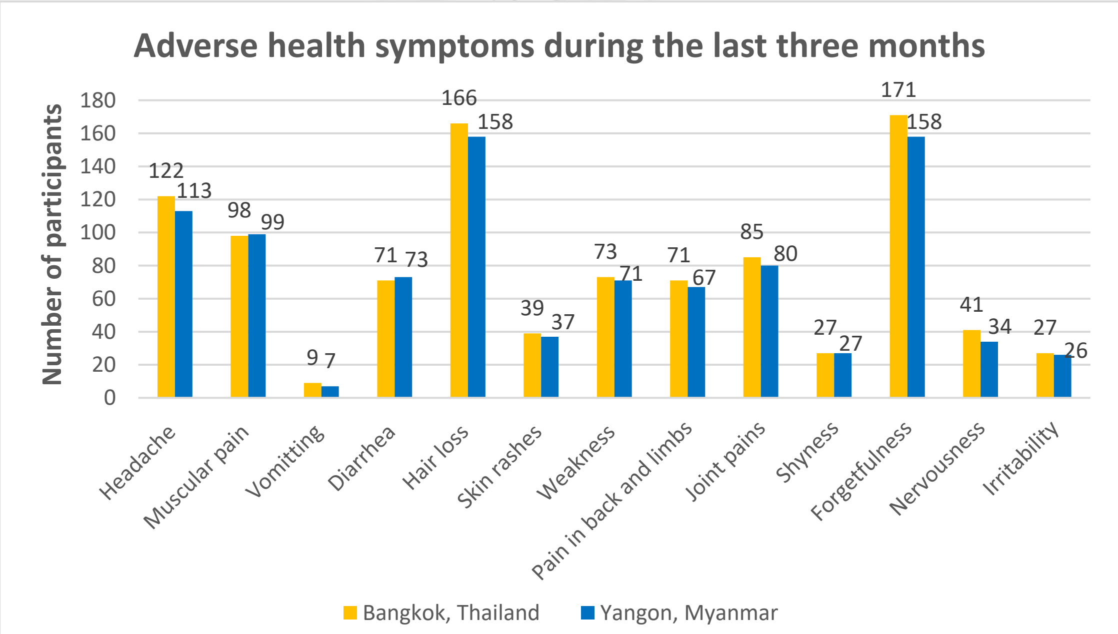


Figure 11 Comparison of adverse health symptoms of participants during the last three months in Bangkok, Thailand and Yangon, Myanmar

In the case of the signs and symptoms during the last 12 months in both study areas, some signs and symptoms were reported by the same participants within the last 3 months. These same signs and symptoms were joint pains (89 participants) in Bangkok, Thailand as opposed to (83participants) in Yangon, Myanmar, pain in the back and limbs (70 participants) in Bangkok, Thailand compared to (65participants) in Yangon, Myanmar, forgetfulness (180 participants) in Bangkok, Thailand against (168 participants) in Yangon, Myanmar, muscular pain (116 participants) in Bangkok, Thailand in contrast to (112 participants) in Yangon, Myanmar, hair loss (165 participants) as opposed to (156participants) in Bangkok, Thailand and Yangon, Myanmar respectively, shyness (30 participants)in Bangkok, Thailand compared to (29participants) in Yangon, Myanmar, headache (126 participants) in Bangkok, Thailand against (117participants) in Yangon, Myanmar, and skin rashes were reported by (57 participants) in Bangkok, Thailand and by (55 participants) in Yangon, Myanmar. Moreover, the same proportion of participants in both study areas reported that they were suffering from weakness and vomiting, with (64 participants) and (9 participants) each. In addition, the symptom of diarrhea was reported by more participants in Bangkok, Thailand than that in Yangon, Myanmar, with (57 participants) compared to (55 participants). Similarly, (26 participants) in Bangkok, Thailand reported that they were suffering from nervousness, while (24 participants) in Yangon, Myanmar reported the same symptom. Moreover, a similar number of participants in Bangkok, Thailand and Yangon, Myanmar said that they were suffering irritability, with (20 participants) and (21participants) respectively. Figure 12 indicates the number of participants in both study areas who are suffering different health symptoms during the last 12 months.

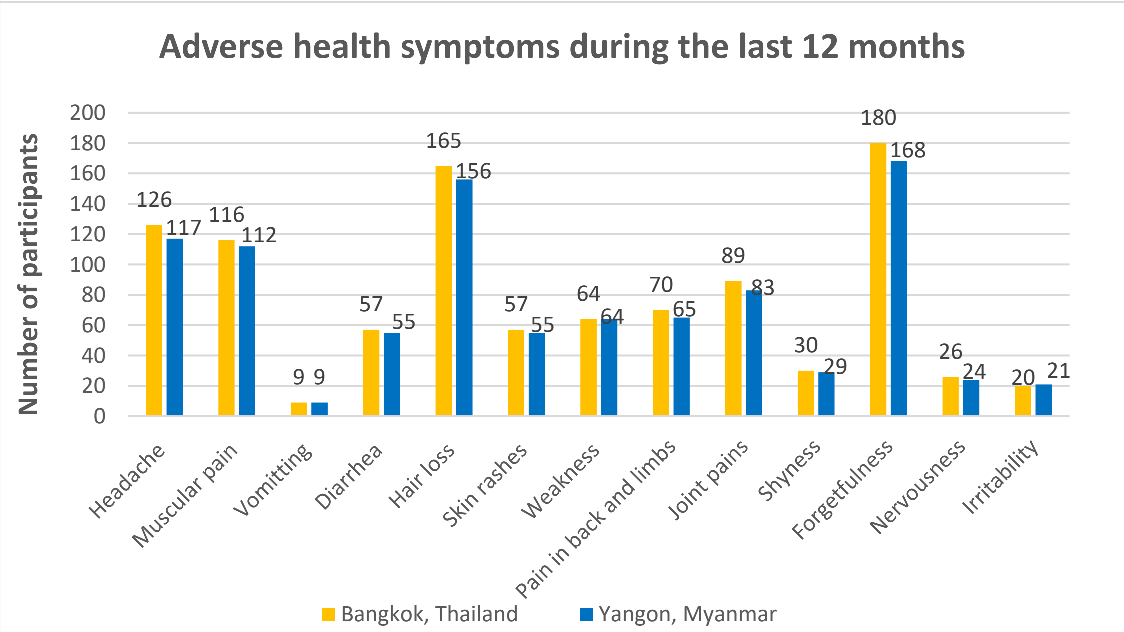


Figure 12 Comparison of adverse health symptoms of participants in both study areas during the last twelve month

4.3.3 Comparison of health risks between Burmese participants in Bangkok, Thailand and Yangon, Myanmar

4.3.3.1 Comparison of average daily dose (ADDs) of As, Cd, Cr, Cu, Ni, and Pb in two study areas

The mean daily dose (ADD) for ingestion exposure to each heavy metal such as As, Cd, Cr, Cu, Ni, and Pb in ginger from Bangkok, Thailand and Yangon, Myanmar for non-cancer risks were calculated through equation (1) from section 3.7. The average daily dose (ADDs) of the heavy metals via ginger consumption in both study areas were compared in figure 13. The results show that the average daily dose (ADD) of As via ginger consumption in Bangkok, Thailand was 4.99×10^{-6} mg/kg.day which was lower than the ADD of As in Yangon, Myanmar at 3.69×10^{-5} mg/kg.day. However, the average daily dose (ADD) of Cd from ginger in Bangkok, Thailand was higher than the average daily dose (ADD) of Cd from ginger in Yangon, Myanmar with 3.81×10^{-6} mg/kg.day as opposed to 2.98×10^{-7} mg/kg.day. In the case of Cr, the average daily dose (ADD) of Cr via ginger consumption in Bangkok, Thailand was 9.65×10^{-5} mg/kg. day, while the average daily dose (ADD) of Cr in Yangon, Myanmar was 2.21×10^{-4} mg/kg.day. Concerning the average daily dose (ADD) of Cu, the amount was higher in Bangkok, Thailand than that of Yangon, Myanmar, with 1.11×10^{-3} mg/kg.day compared to 8.25×10^{-4} mg/kg.day. Similarly, 1.6×10^{-4} mg/kg.day of Ni was daily consumed via ginger eating in Bangkok, Thailand, while 1.56×10^{-4} mg/kg.day of Ni was daily eaten from ginger consumption in Yangon, Myanmar. However, a lower amount of the average daily dose (ADD) of Pb, accounting for 7.39×10^{-5} mg/kg.day was reported in Bangkok, Thailand than the average daily dose (ADD) of Pb in Yangon, Myanmar, representing 1.09×10^{-4} mg/kg.day.

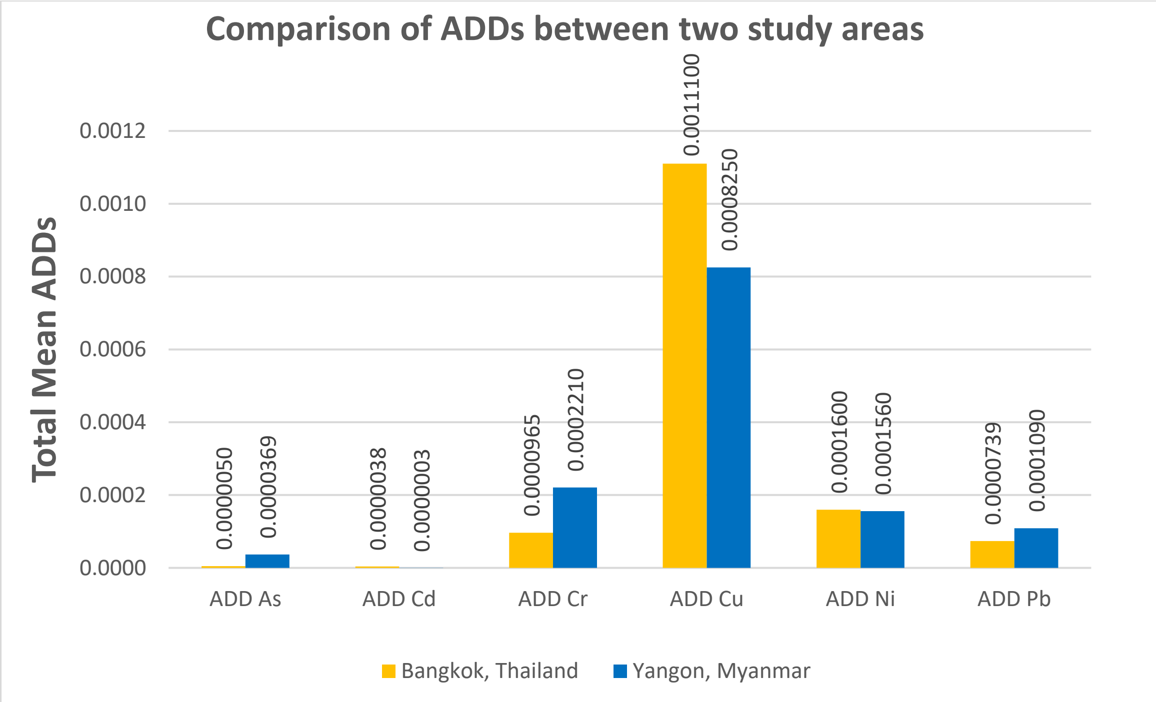


Figure 13 Comparison of average daily dose (ADDs) of heavy metals via ginger consumption in both study areas

4.3.3.2 Comparison of Hazard Quotients (HQs) of As, Cd, Cr, Cu, Ni, and Pb in two study areas

The hazard quotient (HQ) and hazard index (HI) of each heavy metal (As, Cd, Cr, Cu, Ni, and Pb) in both study areas were calculated for the participants through equations (2) and (3) from section 3.7 respectively and the results are shown in figure 14. The mean HQ of As in Bangkok, Thailand was 0.01662 which was lower than the mean HQ of As in Yangon, Myanmar at 0.12284. In contrast, the mean HQ of Cd in Bangkok, Thailand was higher than that of Cd in Yangon, Myanmar, with 0.00381 as opposed to 0.00029. In the case of Cr, a higher value of mean HQ was found in Yangon, Myanmar than in Bangkok, Thailand, with 0.07236 and 0.03217 respectively. Regarding Cu, the mean HQ of Cu in Bangkok, Thailand was 0.02645, while the mean HQ of Cu in Yangon, Myanmar was 0.01964. In addition, the calculated mean HQ of Ni in Bangkok, Thailand was 0.00801 which was slightly higher than the mean HQ of Ni in Yangon, Myanmar at 0.00778. The mean HQ value of Pb in Bangkok, Thailand, representing 0.02112 was lower than in Yangon, Myanmar whose mean HQ value of Pb was 0.03112.

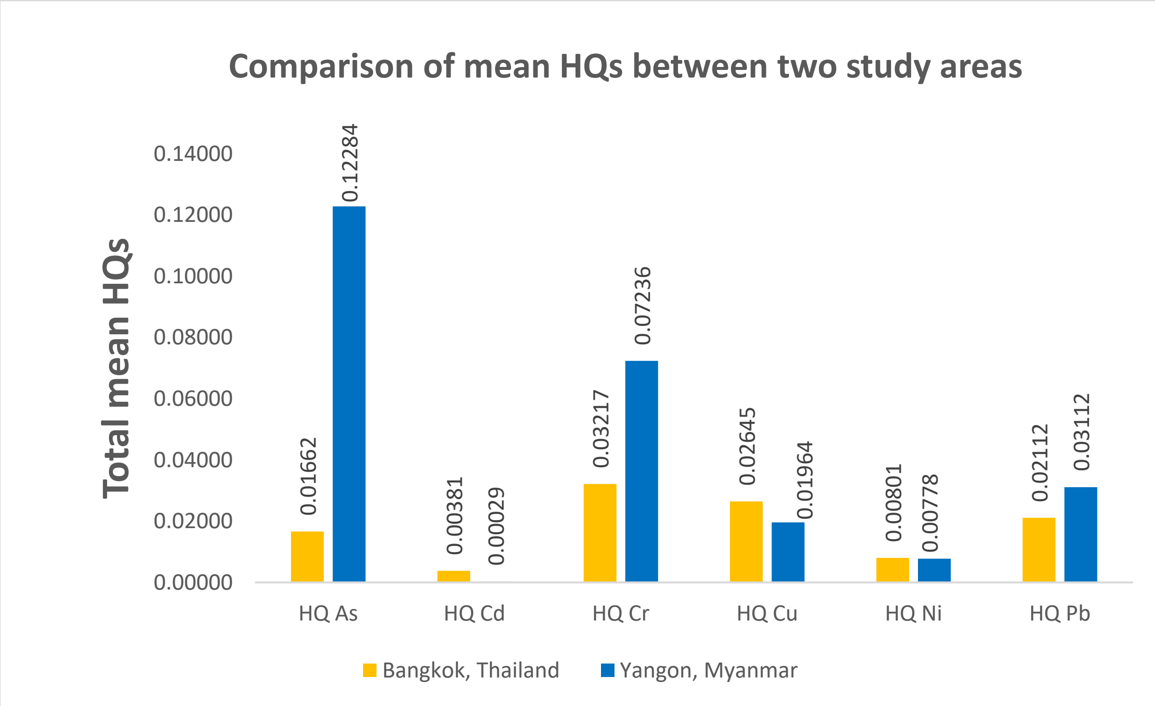


Figure 14 Comparison of mean HQs of As, Cd, Cr, Cu, Ni, and Pb in two study areas (use decimal 5 digits)

4.3.3.3 Comparison of Hazard Index (HI) between two study areas

The calculated hazard quotients (HQs) for As, Cd, Cr, Cu, Ni, and Pb were summarized to obtain the hazard index (HI) in both study areas. The calculated mean ± SD HI of the participants in Bangkok, Thailand was 0.10818 ± 0.02185 with the range from 0.07058 to 0.24648 which is less than the calculated mean ± SD HI of the participants in Yangon, Myanmar whose value was 0.25523 ± 0.05689 with the range from 0.15552 to 0.45188. Additionally, both the mean hazard index (HI) of the two study areas were less than the acceptable non-cancer risk level (HI=1), and the results are shown in figure 15. Therefore, there were no participants who might have non-cancer risks because of the ingestion exposure to As, Cd, Cr, Cu, Ni, and Pb in the ginger of both study areas.

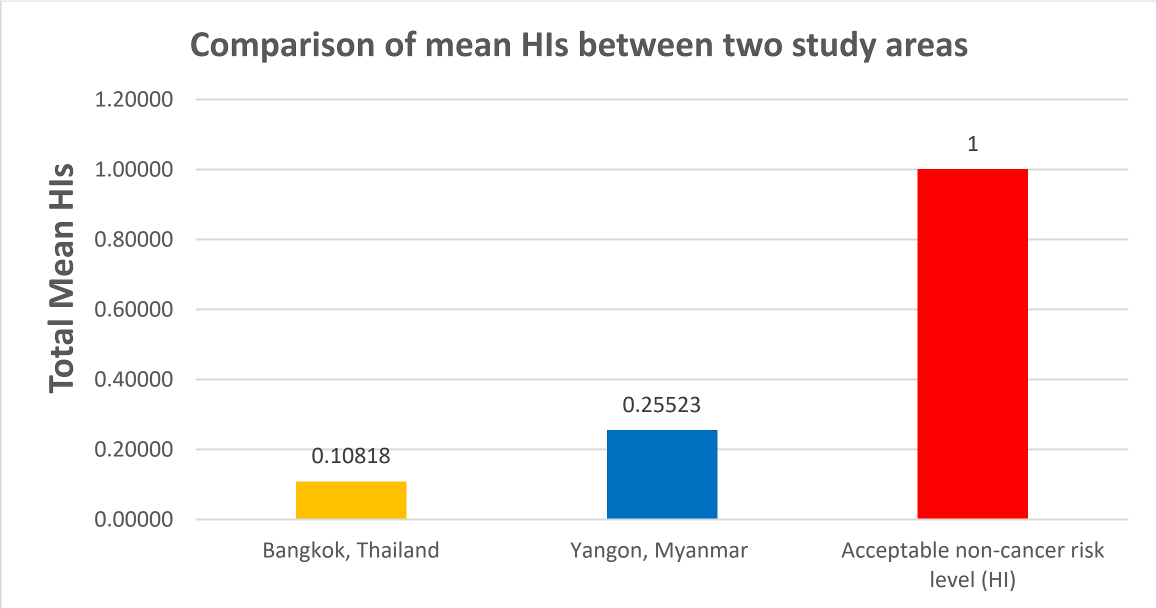


Figure 15 Comparison of mean HIs with acceptable non-cancer risk level in two study areas

4.3.3.4 Comparison of lifetime cancer risks of As, Cd, and Pb in two study areas

According to USEPA, ingestion of As, Cd, and Pb can cause cancer cases in the long term. Therefore, the lifetime cancer risks of As, Cd, and Pb of the participants in Bangkok, Thailand and Yangon, Myanmar were calculated based on their socio-demographic and exposure parameters obtained from questionnaires. The mean cancer risks of the participants from ingestion of As, Cd, and Pb via ginger consumption were calculated to compare the lifetime cancer risks of participants in two study areas. The results showed that the mean lifetime cancer risk of As for all the participants in Bangkok, Thailand was 0.810×10^{-6} which was less than that of As in Yangon, Myanmar at 18.449×10^{-6}. Regarding the lifetime cancer risks of Cd, the results indicated that 0.157×10^{-6} in Bangkok, Thailand and 0.038×10^{-6} in Yangon, Myanmar. A higher lifetime cancer risk of Pb via ginger consumption was found in Yangon, Myanmar than in Bangkok, Thailand, with 0.309×10^{-6} as opposed to 0.068×10^{-6}. Among all the lifetime cancer risks of heavy metals, the highest mean lifetime cancer risk was found in the ingestion of As in Yangon, Myanmar at 18.449×10^{-6}. Figure 16 shows the detailed results of the mean lifetime cancer risks of As, Cd, and Pb for the participants in both study areas.

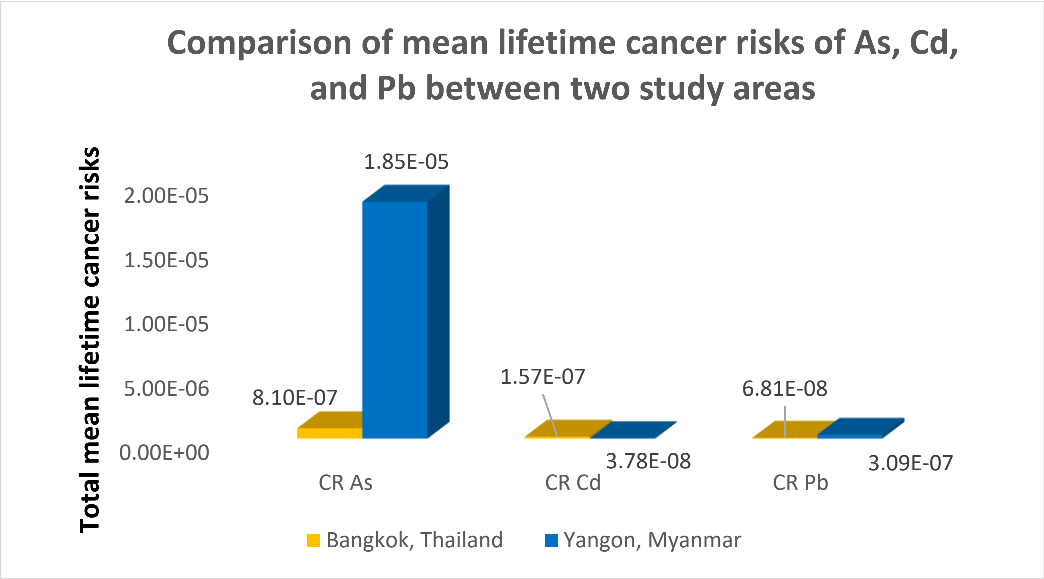


Figure 16 Comparison of mean lifetime cancer risks of As, Cd, and Pb in two study areas

4.3.3.5 Comparison of total lifetime cancer risks of participants in two study areas

The lifetime cancer risks of Arsenic (As), Cadmium (Cd), and Lead (Pb) were summarized to obtain the total cancer risks of the participants in both study areas. Figure 17 presents the results of the total cancer risks of the participants by consuming ginger from Bangkok, Thailand and Yangon, Myanmar. The mean total cancer risks for all the participants in Bangkok, Thailand was 1.035×10^{-6} which is a little higher than the acceptable cancer risk level of 1×10^{-6}. However, the mean total cancer risks for all the participants in Yangon, Myanmar was 18.796×10^{-6} which is significantly higher than the acceptable cancer risk level of 1×10^{-6}. In summary, when the total cancer risks of each participant in Bangkok, Thailand were calculated, 157 (39.25%) out of 400 participants were greater than acceptable cancer risks of 1×10^{-6} and might have lifetime cancer risks. On the other hand, the lifetime cancer risks of 384 (96%) out of 400 participants in Yangon, Myanmar were greater than the acceptable cancer risk level of 1×10^{-6}.

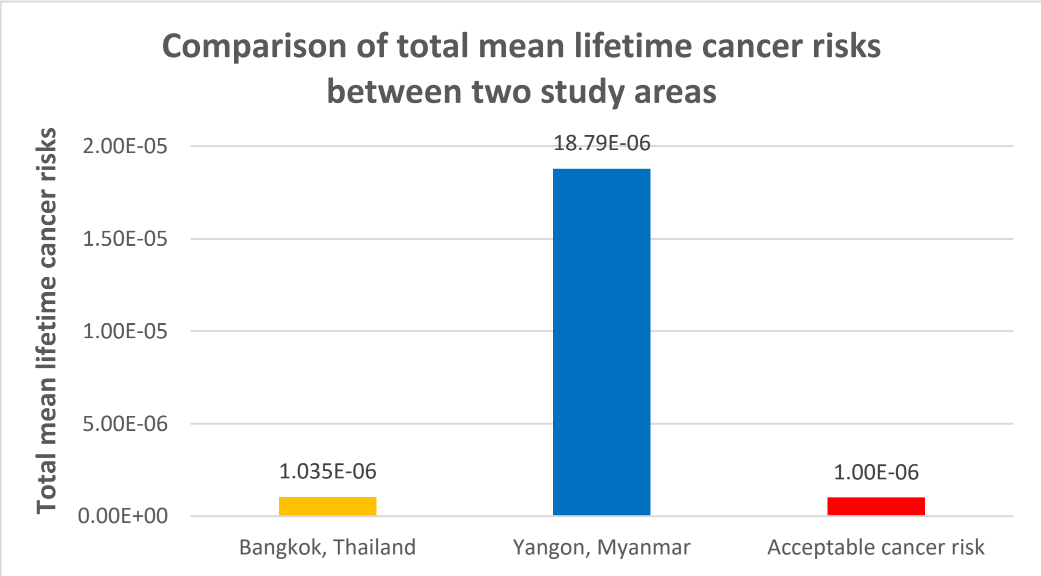


Figure 17 Comparison of total mean lifetime cancer risks of all participants in two study areas

CHAPTER V DISCUSSION

5.1 Comparison of the characteristics of Burmese participants in Bangkok, Thailand with other research

The height of Burmese participants in Bangkok, Thailand ranged from 147.32 to 188cm with a median of 165 cm and the mean ± SD height was 164.14 ± 6.46 cm. Bodyweights of the participants ranged from 44 to 82 kg with a median of 61 kg, and the mean ± SD was 61.02 ± 7.51 kg. According to WorldData.info, the mean height and weight of Burmese in Myanmar were 166 cm and 61.1 kg for males and 154 cm and 54.70 kg for females. However, the mean height and weight of male and female participants in this study were a little different from the values of (WorldData.info, 2022). For male participants, the mean ± SD height was 172.16 ± 5.63 cm with a range of 156 to 186 cm, and the mean ± SD weight was 62.69 ± 7.27 kg with a range of 45 to 82 kg. For female participants, the mean ± SD height was 159.34 ± 5.86 cm with a range of 147.32 to 180 cm and the mean ± SD weight was 59.47 ± 7.63kg with a range of 44 to 77 kg.

5.2. Comparison of the concentrations of heavy metals in ginger from Bangkok, Thailand with other research

The concentration of heavy metals in ginger samples from Bangkok, Thailand was mainly compared with the recommended guideline values for food safety of WHO and with other research findings. The concentration of As in the ginger samples from Bangkok, Thailand was 0.001 to 0.026 mg/kg which was not different from that of As found in food crops collected from Nakhon Pathom province, Thailand (0.001 to 0.156 mg/kg) (Choprathumma, Thongkam et al. 2021). In the case of Cd, its concentration was 0.0052 ± 0.004 mg/kg which was significantly lower than the concentration of Cd found in four spices groups from local markets in Nigeria (7.45± 0.02 mg/kg) (Gaya and Ikechukwu 2016), that of Cd found in herbal plant leaves from an industrial city in India (0.92 – 2.27 mg/kg)(Jagrati, Nitin et al. 2011), that of Cd found in four ginger producing areas in Ethiopia (0.38-0.97 mg/kg) (Wagesho and Chandravanshi 2015), the concentration of Cd found in standardized ginger planting area in North China (0.0096 mg/kg) (Wang, Gao et al. 2021), and that of Cd in commonly sold stem vegetables from a vegetable market in Bangladesh (0.13 mg/kg) (Sultana, Chamon et al. 2021). Similarly, the concentration of Cr in ginger from Bangkok, Thailand was 0.1316 ± 0.075 mg/kg which was lower than the concentration of Cr found in ginger from local markets of Nigeria (5.65±0.019 mg/kg) (Gaya and Ikechukwu 2016), local markets in Iraq (16 ±0.1 mg/kg) (I Ibrahim, M Hassan et al. 2012), and stem vegetables sold in the vegetable market of Bangladesh (1.93 mg/kg) (Sultana, Chamon et al. 2021). However, Cu concentration in ginger of Bangkok, Thailand was 1.271 mg/kg to 1.629 mg/kg which was higher than the concentration of Cu found in common spices from the central market of Ghana (0.089 mg/kg) (Nkansah and Amoako 2010), standardized ginger planting area in North China (0.84 mg/kg) (Wang, Gao et al. 2021), and seasoning sold in some major highways of Ogun state, West Nigeria (0.4 mg/kg) (Makanjuola and OSINFADE 2016). In the case of Ni, its concentration was 0.116mg/kg to 0.32mg/kg, which was higher than the concentration of Ni found in ginger producing model farmers in Ethiopia (0.15 to 0.21 mg/kg)(Goroya, Mitiku et al. 2019) but lower than that of Ni in common spices from the central market in Ghana (0.433 mg/kg)(Nkansah and Amoako 2010) and standardized ginger planting area in North China (0.55 mg/kg) (Wang, Gao et al. 2021). The concentration of Pb in ginger samples from Bangkok, Thailand was 0.019 mg/kg to 0.19 mg/kg, which was lower than the concentrations of Pb found in different medicinal plants from industrial city in India (0.5 to 12 mg/kg) (Jagrati, Nitin et al. 2011), local market in Iraq (7.2 mg/kg) (I Ibrahim, M Hassan et al. 2012), spices and herbs available on Polish market (0.21 to 0.78 mg/kg)(Krejpcio, Krol et al. 2007), but higher than the concentrations of Pb found in food crops collected from Nakhon Pathom province, Thailand (0.001 to 0.094 mg/kg) (Choprathumma, Thongkam et al. 2021). Most of the heavy metal concentrations found in ginger from Bangkok, Thailand were lower than that of FAO/WHO guideline values, except Pb whose concentration was a little higher than the acceptable limit.

5.3 Ingestion rate of ginger in Bangkok, Thailand and Yangon, Myanmar

According to the WHO 'fruit and vegetable promotion' campaign launched in 2003, an individual should eat at least 5 servings or 400 g of fruit and vegetables daily (Who and Consultation 2003). However, many people have lower intakes, both in high-income and low-income countries (Pomerleau, Lock et al. 2004). In many Southeast Asian countries, large proportions of the population had a low intake (Hall, Moore et al. 2009). As defined by the World Health Report (WHO, 2002) for low fruit and vegetable intake, the average vegetable consumption is 240g/person/day. According to the national food consumption data based on dietary surveys in Europe, the mean vegetable intake (including pulses and nuts) in Europe is 220 g per day and mean fruit intake is 166 g per day, implying that the average consumption of fruit and vegetables is 386 g per day (EUFIC,2012). From the survey of 6,991 adults in 2020 in Thailand, on average, the study participants consumed 336.9 g (median = 295.7) of fruits and vegetables per day (Phulkerd, Thapsuwan et al. 2020). From this research, the daily amount of ginger consumption by Burmese participants in both Bangkok, Thailand and Yangon, Myanmar was around 44 g per day which was lower than the ingestion rate of tomato and onion by the residents from the district of Jhansi in Uttar Pradesh State of India in which the consumption rate is regarded as 65 g/person/ day for tomato, 60 g/person/day for onion, and 35 g/person/day for coriander (survey from local residents)(Gupta, Yadav et al. 2022).

5.4 Comparison of non-carcinogenic risks and carcinogenic risks of Burmese participants from Bangkok, Thailand with other findings

The mean HQs of As, Cd, Cr, Cu, Ni, and Pb from heavy metal contaminated ginger consumption in Bangkok, Thailand were 0.01662, 0.00381, 0.03217, 0.02645, 0.00801, 0.02112 respectively. The non-cancer risks of As, Cd, Cr, Cu, Ni, and Pb which can contribute to adverse effects on the liver, kidney, and immune system were expressed as the HI and the cumulative HI of these 6 heavy metals in ginger samples from this study area was 0.10817, which was lower than the HI value from the study of (Bian, Lin et al. 2016) in which most of the plants had HI value greater than 1, presenting high non-carcinogenic risks to the local adults and the high risks were associated with As, Pb and Cd, and suggested that residents would be at risk by consuming plants in that study area. Moreover, non-carcinogenic risk (HI value) from our study in Bangkok, Thailand was less than the total non-carcinogenic risks of As and Pb from food plants and grasshoppers in Greece whose HI value was greater than 1, suggesting significant health risks. In addition, the health index (HI) from the consumption of ginger from Bangkok, Thailand was significantly lower than the HI value due to the intake of toxic metals from the consumption of tomato and cabbage in Ethiopia , with HI values of 7.205 for tomato and 15.078 for cabbage consumption, respectively (Gebeyehu and Bayissa 2020). This clearly suggested the possible adverse health effects to adult population from the consumption of tomato and cabbage from the study area.

Regarding the carcinogenic risks due to the consumption of heavy metal contaminated ginger from Bangkok, Thailand, the lifetime cancer risks of As, Cd, and Pb for Burmese participants in Bangkok, Thailand were 0.810×10^{-6}, $0.157 \text{ x } 10^{-6}$, and 0.068×10^{-6} and total cancer risk (TCR) was 1.035×10^{-6}, that is a little higher than the acceptable cancer risk of 1×10^{-6}. Similarly, in the health risk assessment of heavy metals in soil-plant system amended with biogas slurry in Taihu basin, China, the mean total target cancer risk (TCR) values for As, Cd and Cr of crops were 2.02×10^{-3}, 6.28×10^{-4} and 3.39×10^{-3}, respectively. The total cancer risks resulting from the heavy metals in that study were significantly higher than the acceptable level of 1×10^{-6}, which indicated that the cancer risks pertaining to As, Cd and Cr were also high in all crops in the study area(Bian, Lin et al. 2016). Moreover, the total cancer risks from our study in Bangkok, Thailand was less than the potential carcinogenic risk level from the study of vegetables and associated health risks in Mojo area, Ethiopia in which the cancer risk of As, Pb, and Cd from tomato consumption was 9.1×10^{-4}, 9.70×10^{-6}, and 6.69×10^{-5} while the cancer risk of As, Pb, and Cd from cabbage consumption was 2.7×10^{-3}, 2.02×10^{-5}, and 1.86×10^{-4}(Gebeyehu and Bayissa 2020). Therefore, it revealed that there would be a significant carcinogenic health risk to the consumers associated with the consumption of cabbage and tomato being cultivated in Mojo area.

5.5 Comparison of the characteristics of Burmese participants in Yangon, Myanmar with another research

The height of Burmese participants in Yangon, Myanmar from this study ranged from 147.32 to 180.34cm with a median of 162.56 cm and the mean ± SD height was 163.13 ± 7.20 cm which was following the findings of the average height of Burmese in placer small scale gold mining sites in Myanmar (Tun, Wongsasuluk et al. 2020), in which the mean ± SD height of the Burmese participants ranged from 146 to 180 cm with a median of 165 cm and mean ± SD height was 163 ± 9 cm. The body weights of the participants from Yangon, Myanmar in this study ranged from 45 to 79 kg with a median of 61 kg, and the mean ± SD weight was 60.79 ± 7.47 kg, which was compatible with the body weight of participants from (Tun, Wongsasuluk et al. 2020) research, which ranged from 46 to 75 kg with a median of 59 kg, and the mean ± SD weight was 59 ± 7 kg.

5.6 Comparison of the concentrations of heavy metals in ginger from Yangon, Myanmar with other research finding

The concentration of As in the ginger samples from Yangon, Myanmar was 0.0494 ± 0.024 mg/kg which was higher than that of As found in food crops collected from Nakhon Pathom province, Thailand (0.001 to 0.028 mg/kg) (Choprathumma, Thongkam et al. 2021). In the case of Cd, its concentration was 0.000 to 0.001mg/kg which was significantly lower than the concentration of Cd in different medicinal plants from an industrial city in India (0.92 – 2.27 mg/kg) (Jagrati, Nitin et al. 2011), some common spices from local markets in Iraq (1.32 mg/kg) (I Ibrahim, M Hassan et al. 2012), spices and herbs available on the polish market (0.02-0.04 mg/kg) (Krejpcio, Krol et al. 2007), four ginger producing areas in Ethiopia (0.38-0.97 mg/kg) (Wagesho and Chandravanshi 2015), standardized ginger planting area in North China (0.0096 mg/kg) (Wang, Gao et al. 2021), seasonings sold in some major highways in Ogun state, Nigeria (0.01 mg/kg) (Gaya and Ikechukwu 2016), and commonly sold stem vegetables in Bangladesh (0.13 mg/kg)(Sultana, Chamon et al. 2021). Similarly, the concentration of Cr in ginger from Yangon, Myanmar was 0.194 to 0.419 mg/kg which was lower than that of Cr found in the ginger of central Gondar zone, Ethiopia

(2.17 to 4.44 mg/kg) (Getaneh, Guadie et al. 2021), selected spices from local markets in Nigeria (5.65±0.019 mg/kg) (Gaya and Ikechukwu 2016), common spices from Iraq (16 ±0.1 mg/kg) (I Ibrahim, M Hassan et al. 2012), and stem vegetables in Bangladesh (1.93 mg/kg) (Sultana, Chamon et al. 2021). However, Cu concentration in ginger from Yangon, Myanmar was 0.962 to 1.345 mg/kg, which was higher than the concentration of Cu in some common spices from the central market of Ghana (0.089 mg/kg) (Nkansah and Amoako 2010), that of Cu found in standardized ginger planting area in North China (0.84 mg/kg) (Wang, Gao et al. 2021), that of Cu in seasoning sold in some major highways of Ogun state, West Nigeria (0.4 mg/kg) (Makanjuola and OSINFADE 2016). In the case of Ni, its concentration was 0.197 to 0.22 mg/kg, which was higher than that of Ni found in ginger from Ethiopia (0.15 to 0.21 mg/kg) (Goroya, Mitiku et al. 2019) but lower than Ni concentration found in some spices from the central market in Ghana (0.433 mg/kg)(Nkansah and Amoako 2010), and local markets in Nigeria (3.417±0.01 mg/kg)(Gaya and Ikechukwu 2016). The concentration of Pb in ginger samples from this study area was 0.08 to 0.245 mg/kg, which was lower than the concentrations of Pb found in medicinal plants from an industrial city in India (0.5 to 12 mg/kg) (Jagrati, Nitin et al. 2011), that of Pb found in spices and herbs from local markets in Poland (0.21 to 0.78 mg/kg) (Krejpcio, Krol et al. 2007), in some common spices from the central market in Ghana (1.153 mg/kg)(Nkansah and Amoako 2010) but higher than the concentrations of Pb found in food crops collected from Nakhon Pathom province, Thailand (0.001 to 0.156 mg/kg) (Choprathumma, Thongkam et al. 2021). Most of the heavy metal concentrations found in ginger from Yangon, Myanmar were lower than that of FAO/WHO guideline values, except Pb whose concentrations was higher than the acceptable limits.

5.7 Comparison of non-carcinogenic risks and carcinogenic risks of Burmese participants from Yangon, Myanmar with other findings

From the calculation of non-carcinogenic risks and carcinogenic risks by USEPA risk assessment model for Burmese participants in Yangon, Myanmar, the mean HQs of As, Cd, Cr, Cu, Ni, and Pb from heavy metal contaminated ginger consumption were 0.12284, 0.00029, 0.07236, 0.01964, 0.00778, and 0.03112 respectively. After that, the non-cancer risks of As, Cd, Cr, Cu, Ni, and Pb were expressed as the HI, and the cumulative HI of these 6 heavy metals in ginger samples from this study area was 0.25523, that is less than the acceptable non-cancer risk level (HI=1). Similarly, in the study of heavy metal accumulation in vegetables and health risk to humans from their consumption in Uttar Pradesh State of India**,** the hazard quotient (HQ) of all analyzed heavy metals in coriander, onion, and tomato was under the safe value of 1, indicating that the vegetable consumption in that area will not have any significant non-carcinogenic effects on humans (Gupta, Yadav et al. 2022). However, the cumulative HI value in coriander from that study was slightly higher than the safe limit of 1 at some sampling sites and needs urgent attention to lower the heavy metals concentration in those sites; otherwise, it may pose serious health hazards to humans in the near future. The cumulative hazard index (HI) from our study in Yangon, Myanmar was significantly lower than the study of the probabilistic health risk assessment of salad vegetables sold in Tabriz ciy, Iran (Khezerlou, Dehghan et al. 2021) in which the hazard quotient (HQ) of Pb, Cd, and Cr was more than 1 in all the salad vegetables for both males and females. The cumulative hazard index (HI) of lettuce, cabbage, tomatoes, cucumbers, carrots, and radish in that study was 14.1, 14.33, 13.05, 12.94, 10.77, and 11.2, respectively, for male, while it was 15.97, 16.1, 14.72, 14.54, 12.1, and 12.59, respectively, for females. Among the selected vegetables, the highest HI was 14.33 for cabbage and 14.1 for lettuce in both males and females which were considerably higher than the HI value for ginger consumption in Yangon, Myanmar.

Concerning the carcinogenic risks due to the consumption of heavy metal contaminated ginger from Yangon, Myanmar, the lifetime cancer risks of As, Cd, and Pb for Burmese participant in Yangon, Myanmar were 18.449×10^{-6}, 0.038×10^{-6}, and 0.309×10^{-6} and total cancer risk (TCR) was 18.796×10^{-6} that is higher than the acceptable cancer risks of 1×10^{-6}. However, the total lifetime cancer risks from our study were significantly lower than the lifetime cancer risks from the consumption of lettuce, cabbage, tomatoes, cucumber, carrots, radish in Tabriz, Iran, in which the lifetime cancer risk of Pb due to the consumption of these vegetables was 0.187 for males and 0.22 for females while the lifetime cancer risk of As in that study was 0.03 for males and 0.032 for females, and indicated that the ingestion of these vegetables has high potential cancer risk to the consumers in the study area (Khezerlou, Dehghan et al. 2021). Similarly, in the study of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica, the total lifetime cancer risks (TCR) of As from the consumption of Jamaican-grown food crops is 2.00×10^{-4} which exceed the threshold value of 1×10^{-6} and estimated the potential carcinogenic risks (Antoine, Fung et al. 2017). In addition, lifetime cancer risk of Burmese participants from Yangon, Myanmar was compatible with the study of health risks from heavy metals via consumption of cereals and vegetables in Isfahan Province, Iran which showed that the total combined cancer risk for As is 1×10^{-4} (children) and $1.3 \times 10^{-4} – 8.4 \times 10^{-4}$ for adults, which is higher than an acceptable risk (1×10^{-6}), showing that inhabitants of Isfahan Province may experience the adverse health risk via consumption of wheat, rice, and onions (Salehipour, Ghorbani et al. 2015).

CHAPTER VI CONCLUSION

6.1 Conclusion

This study was conducted to investigate the concentrations of 6 heavy metals in the ginger of Bangkok, Thailand and Yangon, Myanmar to assess the non-cancer and cancer risks of Burmese participants because of ingestion exposure to these heavy metals by consuming contaminated ginger. The questionnaire was used to collect socio-demographic information, exposure determinants, exposure factors, and adverse health symptoms. The study population was focused on 800 Burmese participants who have been living in Bangkok, Thailand and Yangon, Myanmar. Online questionnaire was done to 400 Burmese participants in Bangkok, Thailand and both face-to-face interviews and online questionnaires were conducted with 400 participants in Yangon, Myanmar.

6.1.1 Characteristics of Burmese participants in Bangkok, Thailand

The Burmese participants in Bangkok, Thailand were females (57.5%) and males (42.5%). The mean ± SD age of male participants was 31.07 ± 8.51 years with the range from 18 to 53 years; whereas the mean ± SD age of female participants was 30.43 ± 8.23 years with the range from 18 to 58 years. The body weights of the participants ranged from 44 to 82 kg with a median of 61 kg, and the mean ± SD was 61.02 ± 7.51 kg. Regarding the smoking and drinking behaviors, (13.8%) of the participants in this study area were smokers, and (19%) of the participants drank alcohol.

6.1.2 Concentration of heavy metals in ginger from Bangkok, Thailand

The concentration of As, Cd, Cu, Cr, Ni, and Pb were analyzed from the ginger samples of Simummuang Market, Pathum Thani, Bangkok, Thailand. Regarding the mean concentrations of heavy metals in ginger samples in this study area, the mean ± SD concentration of As was 0.0068 ± 0.011 mg/kg, of Cd was 0.0052 ± 0.004 mg/kg, of Cr was 0.1316 ± 0.075 mg/kg, of Cu was 1.4996 ±0.142 mg /kg, of Ni was 0.2162

±0.085 mg/kg, and of Pb was 0.1008 ± 0.075 mg/kg. Moreover, the concentration of Pb in ginger from Bangkok, Thailand was a little higher than the WHO guideline values for food safety (0.1008 mg/kg compared to 0.1mg/kg); however, other heavy metals concentrations were lower than the permissible limits.

6.1.3 Average daily dose (ADD), non-cancer and cancer risks of Burmese participants in Bangkok, Thailand

The average daily consumption (ADD) of ginger by the participants in Bangkok, Thailand was as follows: Cu> Ni> Cr> Pb > As> Cd mg/kg.day. Based on the average consumption data from the questionnaire, which showed that Burmese in the study area consumed 44.08 g of ginger every day, the highest HQ through ginger consumption in Bangkok, Thailand was found in Cr at 0.03217. The total HQs of As, Cd, Cr, Cu, Ni, and Pb from heavy metals contaminated ginger consumption in this study area were 0.01662, 0.00381, 0.03217, 0.02645, 0.00801, and 0.02112. Through considering the hazard quotient (HQ) of heavy metals, Cr accounts for (29.74%) of the HI followed by Cu (24.45%), Pb (19.52%), As (15.36%), Ni (7.4%), and Cd (3.52%).

The mean ± SD non-cancer risks (HI) for all Burmese participants in Bangkok, Thailand was 0.10817± 0.02185 with the range from 0.07058 to 0.24648 which is less than the acceptable non-cancer risk level (HI=1), and the median was 0.10319. Therefore, all the participants in this study area might not have the potential to get any significant adverse health effects because of the ingestion exposure to heavy metals in ginger.

The lifetime cancer risks of Arsenic (As), Cadmium (Cd), and Lead (Pb) were summarized to obtain the total cancer risks of the participants in Bangkok, Thailand, and the cancer risks of heavy metals decreased in the order of As > Cd > Pb. The mean ± SD total cancer risks for all the participants was $1.035\times10^{-6} \pm 0.661\times10^{-6}$, and the median was 0.803×10^{-6} ranging from 0.119×10^{-6} to 3.639×10^{-6}. Regarding the lifetime cancer risks of participants in Bangkok, Thailand, 157 (39.25%) out of 400 participants in this study area were greater than the acceptable cancer risks of 1×10^{-6}. Therefore, Burmese participants in Bangkok, Thailand might receive carcinogenic diseases if they keep consuming this contaminated ginger for 67 years.

6.1.4 Characteristics of Burmese participants in Yangon, Myanmar

Concerning Burmese participants in Yangon, Myanmar, most of the participants in this study area were female (53.2%), and (46.8%) were males. The mean ± SD age of male participants was 38.53 ± 12.18 years with the range from 18 to 60 years; whereas the mean ± SD age of female participants was 35.50 ± 11.93 years with the range from 18 to 60 years. The body weights of the participants ranged from 45 to 79 kg with a median of 61 kg, and the mean ± SD weight was 60.79 ± 7.47 kg. 14.3% of the participants in Yangon, Myanmar were smokers and 20.5% of participants drank alcohol.

6.1.5 Concentration of heavy metals in ginger from Yangon, Myanmar

In the ginger samples from Thiri Mingalar Market, Yangon, Myanmar, the mean ± SD concentration of As was 0.0494 ± 0.024 mg/kg, of Cd was 0.0004 ± 0.0005 mg/kg, of Cr was 0.2958± 0.105 mg/kg, of Cu was 1.1058 ± 0.153mg/kg, of Ni was 0.2086 ± 0.011 mg/kg, and of Pb was 0.1460 ± 0.063 mg/kg. Most of the heavy metal concentrations in ginger samples in this study area were lower than WHO/FAO guideline values, except for Pb whose concentrations was higher than the guideline limits.

6.1.6 Average daily dose (ADD), non-cancer and cancer risks of Burmese participants in Yangon, Myanmar

The average daily consumption (ADD) of ginger by the participants in Yangon, Myanmar was as follows: Cu> Cr> Ni> Pb > As > Cd mg/kg.day. Based on the average consumption data from the questionnaire, which showed that Burmese in this study area consumed 44.61 g of ginger every day, the highest HQ through ginger consumption in Yangon, Myanmar was found in As at 0.12284. The total HQs of As, Cd, Cr, Cu, Ni, and Pb from heavy metals contaminated ginger consumption in this study were 0.12284, 0.00029, 0.07236, 0.01964, 0.00778, and 0.03112. Taking into account the hazard quotient (HQ) of heavy metals, As accounts for (48.36%) of the HI followed by Cd (0.11%), Cr (28.48%), Cu (7.73%), Ni (3.06%), and Pb (12.25%).

Concerning Burmese participants in Yangon, Myanmar, the mean ± SD non-cancer risks (HI) for all the participants in Yangon, Myanmar was 0.25523 ± 0.05689 with the range from 0.15552 to 0.45188 which is less than the acceptable non-cancer risk level (HI=1), and the median was 0.24009. As a result, all Burmese participants in this study area may not experience any significant adverse health effects because of the ingestion exposure to heavy metals in ginger.

Regarding the lifetime cancer risks of Burmese participants due to the consumption of heavy metal contaminated ginger from Yangon, Myanmar, the lifetime cancer risks of Arsenic (As), Cadmium (Cd), and Lead (Pb) were summarized to obtain the total cancer risks of the participants in this study area, and the cancer risks of heavy metals decreased in the order of As > Pb >Cd. The mean ± SD total cancer risks for all the participants was $18.796 \times 10^{-6} \pm 16.121 \times 10^{-6}$ and the median was 17.910×10^{-6} ranging from 0.646×10^{-6} to 65.231×10^{-6}. Overall, 384 (96%) out of 400 participants from this study were greater than the acceptable cancer risks of 1×10^{-6}. As a result, if Burmese participants in Yangon, Myanmar continue to consume this contaminated ginger for the next 67 years, they may develop carcinogenic diseases.

6.1.7 Comparison of lifetime cancer risks of participants in Bangkok, Thailand and Yangon, Myanmar

The higher non-cancer and cancer risks were found in Burmese participants from Yangon, Myanmar as the heavy metal concentrations in ginger from this area were relatively higher than that of ginger from Bangkok, Thailand.

According to the comparison of lifetime cancer risks in two study areas, Burmese participants who consumed contaminated ginger from Yangon, Myanmar had the highest lifetime cancer risks. The lifetime cancer risks of participants in Yangon, Myanmar were 18.796×10^{-6}, which means that 18 people in a million could develop cancer because of eating heavy metal contaminated ginger from the area. In contrast, the lifetime cancer risks of Burmese participants in Bangkok, Thailand was 1.035×10^{-6}, which means that 1 person in a million may develop the carcinogenic disease if they consume heavy metals polluted ginger from this study area for a long period. Burmese mostly consume ginger since they believe that eating ginger or drinking ginger herbal tea can prevent them from the diseases and getting the fever. Therefore, during this covid-19 pandemic, they eat more ginger than ever before. However, ginger consumption may have decreased after the covid pandemic, and the calculated total lifetime cancer risks from our study may also be reduced.

6.2 Recommendation

6.2.1 Personal Level

The participants who eat ginger from the studied markets of Bangkok, Thailand and Yangon, Myanmar should be given awareness about the potential health risks due to the consumption of heavy metal contaminated vegetables and crops. Based on the baseline data from this research, residents in these study areas can be suggested to limit the amount of ginger they should eat and how often they should not consume. Furthermore, participants in these study areas should reduce smoking and drinking, as these can also increase the likelihood of health problems in addition to heavy metal toxicity.

6.2.2 Community and organization level

In terms of community level, regular monitoring of heavy metal concentrations in the farming sites should be done to prevent the contamination of hazardous metals in the agricultural soils and food crops. In addition, the negative health effects and diseases associated with heavy metal pollution in soil and crops should be constantly monitored.

6.2.3 Government or nationality level

The government should establish pollution control policies for farming sites, as well as guideline values for heavy metals in agricultural soil and vegetables grown on it. Furthermore, the local government should organize campaigns and health promotion to educate the public about the potential health risks associated with heavy metal contamination.

6.2.4 Recommendation for future research

- This study provides baseline information for future studies on heavy metal pollution in the widely used herb, ginger in Myanmar and Thailand, and its associated health risks to the participants.

- This study focused only on 6 heavy metals, namely As, Cd, Cu, Cr, Ni, and Pb in the ginger from local markets of Myanmar and Thailand; however, other associated heavy metals were not investigated. Further research should concern more heavy metals such as (Zinc and Iron) in mostly consumed vegetables or spices as well.

- This is just a cross-sectional study that took place from January to March 2022 and conducting the questionnaire and measuring concentrations of heavy metals in ginger samples were done only one time during this study. Therefore, regular monitoring of heavy metal contamination in vegetables and crops in these study areas should be done to avoid the potential health risks.

- Moreover, further research should be conducted to determine the correlation between heavy metal contamination in water, soil, and crops in these study areas.

REFERENCES

Abadin, H., et al. (2007). A framework to guide public health assessment decisions at lead sites. Toxicological Profile for Lead, Agency for Toxic Substances and Disease Registry (US).

Alix and Hugo (2021). "Burmese Chicken Curry (Panthe Kaukswe)", ahedgehoginthekitchen.com Accessed 29 October 2021 from https://ahedgehoginthekitchen.com/burmese-chicken-curry-turmeric-ginger/

Araya, M., et al. (2007). "Copper in human health." International Journal of Environment and Health **1**(4): 608-620.

Asante-Duah, D. K. (2002). Public health risk assessment for human exposure to chemicals, Springer.

Balali-Mood, M., et al. (2021). "Toxic mechanisms of five heavy metals: Mercury, Lead, Chromium, Cadmium, and Arsenic." Frontiers in pharmacology **12**.

Belle, J. v., Conway, M., Knetsch, G.-J., Putten, E. v., & Ramlal, R. (2010). Lead pollution and poisioning crisis, Environmental emergency response Mission, Zamfara State, Nigeria. Retrieved 08 January 2022 from http://www.unocha.org/publication/lead-pollution-andpoisoning-crisis-environmental-emergency-response-mission-zamfar

Board of directors, Pattana Wittaya School (2019) "Simummuang Market", Accessed 30 November 2021 from https://www.simummuangmarket.com/en

Boquiren, M., Infante Villarroel, M., Than Htay, T., & Myaing Htay, A. (2018). "A case study of drivers and constraints for occupational safety and health improvement in the ginger global value chain from Myanmar".ISBN: 978-92-2-031285-8 (web pdf)

Brecher, R. W. (1997). "Risk assessment." Toxicologic pathology **25**(1): 23-26.

Cameron, K. S., et al. (2011). "Exploring the molecular mechanisms of nickel-induced genotoxicity and carcinogenicity: a literature review."

Castro-González, M. and M. Méndez-Armenta (2008). "Heavy metals: Implications associated to fish consumption." Environmental toxicology and pharmacology **26**(3): 263-271.

Chibuike, G. U. and S. C. Obiora (2014). "Heavy Metal Polluted Soils: Effect on Plants and Bioremediation Methods." Applied and Environmental Soil Science **2014**: 752708.

Choprathumma, C., et al. (2021). "Determination of toxic heavy metal contaminated in food crops in Nakhon Pathom province, Thailand." วารสาร แก่น เกษตร **47**(1): 83-94.

Das, K. K., et al. (2019). "Primary concept of nickel toxicity–an overview." Journal of Basic and Clinical Physiology and Pharmacology **30**(2): 141-152.

Engwa, G. A., et al. (2019). "Mechanism and health effects of heavy metal toxicity in humans." Poisoning in the modern world-new tricks for an old dog **10**.

FAO/WHO (Food and Agriculture Organization/World Health Organization) (2019). General Standard for Contaminants and Toxins in Food and Feed. Codex Alimentarius Commission. Available: http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXS%2B193-1995%252FCXS_193e.pdf.

Faroon, O., et al. (2013). "Toxicological profile for cadmium."

Ferguson, J. E. (1990). The heavy elements: chemistry, environmental impact and health effects.

Fowle, J. R. and K. L. Dearfield (2000). Risk characterization handbook, Science Policy Council, US Environmental Protection Agency.

Gaya, U. and S. Ikechukwu (2016). "Heavy metal contamination of selected spices obtained from Nigeria." Journal of Applied Sciences and Environmental Management **20**(3): 681-688.

Geoff Thomas (2012). “Ginger and Cooking in Thailand.”, CTN News Chiang Rai Times, Accessed 27 October 2021 from https://www.chiangraitimes.com/food/ginger-and-cooking-in-thailand/

Getaneh, A., et al. (2021). "Levels of heavy metals in ginger (Zingiber officinale Roscoe) from selected districts of Central Gondar Zone, Ethiopia and associated health risk." Heliyon **7**(4): e06924.

Gimeno-García, E., et al. (1996). "Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils." Environmental pollution **92**(1): 19-25.

Goroya, K. G., et al. (2019). "Determination of concentration of heavy metals in ginger using flame atomic absorption spectroscopy." African Journal of Plant Science **13**(6): 163-167.

Goyer, R. A. and T. W. Clarkson (1996). "Toxic effects of metals." Casarett & Doull's Toxicology. The Basic Science of Poisons, Fifth Edition, Klaassen, CD [Ed]. McGraw-Hill Health Professions Division **23**: 813-858.

Guerra, F., et al. (2012). "Heavy metals in vegetables and potential risk for human health." Scientia Agricola **69**: 54-60.

Hart, B. T., et al. (2001). "Transboundary water quality issues in the Mekong River Basin." Water Studies Centre, Monash University, Melbourne, Australia.

Havel, P. J. (2004). "A scientific review: the role of chromium in insulin resistance." Diabetes Educator **30**(3 SUPPL.): 1-14.

Hawkes, S. J. (1997). "What is a" heavy metal"?" Journal of Chemical Education **74**(11): 1374.

I Ibrahim, G., et al. (2012). "Effect of heavy metal content of some common spices available in local markets in Erbil city on human consumption." Rafidain Journal of Science **23**(5): 106-114.

Jacobs, B. (1999). "Guidance for Conducting Risk Assessments and Related Risk Activities for the DOE-ORO Environmental Management Program." BJC/OR-271, Oak Ridge, TN.

Jagrati, A., et al. (2011). "Determination of heavy metal contents in samples of different medicinal plants." International Journal of Chemical Sciences **9**(3): 1126-1132.

Jaishankar, M., et al. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol 7: 60–72.

Järup, L. (2003). Hazards of heavy metal contamination. British Medical Bulletin, 68(1), 167-182

Jeffrey Hays (2008). "Burmese Cuisine And Food In Myanmar", Accessed 28 October 2021 from https://factsanddetails.com/southeast-asia/Myanmar/sub5_5c/entry-3067.html

Jignesh, S., Vineeta, K., Abhay, S., & Vilasrao, K. (2012). Analytical methods for estimation of metals. Int. J. Res. Pharm. Chem, 2(1), 146-163.

Kachenko, A. G. and B. Singh (2006). "Heavy Metals Contamination in Vegetables Grown in Urban and Metal Smelter Contaminated Sites in Australia." Water, Air, and Soil Pollution **169**(1): 101-123.

Kayee, P., et al. (2018). "Heavy metals residues in soil and vegetables from agricultural area in Wangkanai District, Kanchanaburi Province, Thailand." Journal of Engineering and Applied Sciences **13**: 177-180.

Kladsomboon, S., et al. (2020). "Heavy metals contamination in soil, surface water, crops, and resident blood in Uthai District, Phra Nakhon Si Ayutthaya, Thailand." Environmental geochemistry and health **42**(2): 545-561.

Krejpcio, Z., et al. (2007). "Evaluation of Heavy Metals Contents in Spices and Herbs Available on the Polish Market." Polish Journal of Environmental Studies **16**(1).

Lansdown, A. B. (2013). The carcinogenicity of metals: human risk through occupational and environmental exposure, Royal Society of Chemistry.

Makanjuola, O. M. and B. OSINFADE (2016). "Detection of Heavy Metals in Some Seasonings Sold in Some Major Highways in Ogun State, South West, Nigeria." International Journal of Research Studies in Biosciences (IJRSB) **4**(9): 21-24.

Masindi, V. and K. L. Muedi (2018). "Environmental contamination by heavy metals." Heavy metals **10**: 115-132.

Mensah, E., et al. (2009). Influence of Human Activities and Land Use on Heavy Metal Concentrations in Irrigated Vegetables in Ghana and Their Health Implications**:** 9-14.

Ministry of Public Health in Thailand. 2017. Standard of Contaminated Food. Ministry of Public Health in Thailand. Available: http:// www.fda.moph.go.th/sites/food/Standard/ Shared%20Documents/Foodlaw_Book/ food_ law.pdf.

Nabulo, G., et al. (2010). "Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils." Science of the Total Environment **408**(22): 5338-5351.

Nkansah, M. A. and C. O. Amoako (2010). "Heavy metal content of some common spices available in markets in the Kumasi metropolis of Ghana." American Journal of Scientific and Industrial Research **1**(2): 158-163.

Obi-Iyeke, G. (2019). "Heavy metal concentrations in street-vended fruits and vegetables in Warri, Delta State, Nigeria." Journal of Applied Sciences and Environmental Management **23**(3): 443-447.

Ozores-Hampton, M., et al. (1997). "Cadmium, copper, lead, nickel and zinc concentrations in tomato and squash grown in MSW compost-amended calcareous soil." Compost Science & Utilization **5**(4): 40-45.

Parthasarathy, V. A., et al. (2008). Chemistry of spices, Cabi.

Paustenbach, D. J. (2015). Human and Ecological Risk Assessment: Theory and Practice (Wiley Classics Library), John Wiley & Sons.

Phoo (2019). “Upgrading options for Myanmar Fresh Ginger Value Chains”, Accessed 24 November,2021fromhttps://mro.massey.ac.nz/bitstream/handle/10179/15531/PhooMAgriCommerceThesis.pdf

Radwan, M. A. and A. K. Salama (2006). "Market basket survey for some heavy metals in Egyptian fruits and vegetables." Food and chemical toxicology **44**(8): 1273-1278.

Rai, P. K., et al. (2019). "Heavy metals in food crops: Health risks, fate, mechanisms, and management." Environment International **125**: 365-385.

Robson, M. G. and W. A. Toscano (2007). Risk assessment for environmental health, John Wiley & Sons.

Ricci, P. (2006). Environmental and health risk assessment and management: principles and practices (Vol. 9): Springer Science & Business Media.
Robson, M. G. and W. A. Toscano (2007). Risk assessment for environmental health, John Wiley & Sons.

Shah, M., et al. (2012). "Health risk assessment via surface water and sub-surface water consumption in the mafic and ultramafic terrain, Mohmand agency, northern Pakistan." Journal of Geochemical Exploration **118**: 60-67.

Shaheen, N., et al. (2016). "Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh." Chemosphere **152**: 431-438.

Shekhawat, K., et al. (2015). "Chromium toxicity and its health hazards." International Journal of Advanced Research **3**(7): 167-172.

Smart, G. and J. Sherlock (1987). "Nickel in foods and the diet." Food Additives & Contaminants **4**(1): 61-71.

Sobukola, O., et al. (2010). "Heavy metal levels of some fruits and leafy vegetables from selected markets in Lagos, Nigeria." African Journal of food science **4**(6): 389-393.

Sparling, D. W. (2016). Ecotoxicology essentials: environmental contaminants and their biological effects on animals and plants, Academic Press.

Sullivan, J. B. and G. R. Krieger (2001). Clinical environmental health and toxic exposures, Lippincott Williams & Wilkins.

Sultana, R., et al. (2021). "Heavy metal concentration in commonly sold stem vegetables in Dhaka city market and probable health risk." Dhaka University Journal of Biological Sciences **30**(2): 221-232.

Tchounwou, P. B., et al. (2012). "Heavy metal toxicity and the environment." Exp Suppl **101**: 133-164.

Thatsanai, R. (2020). "The Comparing of Promoting Factor for Co-existence between Thais and Migrant Workers: A Case Study Pathum Thani Province, Thailand." PSAKU International Journal of Interdisciplinary Research **8**.

The world bank (2020), life expectancy in Myanmar, Accessed 04 June,2022. Retrived from ://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=MM.

Trip Express (2021) “Thiri Mingalar Market”, Accessed 29 November 2021 from https://www.tripexpress.org/attraction-thiri-mingalar-market-7336902/

Trustees of Dartmouth College (2021) “Arsenic And You” Information on Arsenic in Food, Water & Other Sources, Accessed 23 November 2021 from(https://sites.dartmouth.edu/arsenicandyou/arsenic-in-fruits-juices-and-vegetables/)

Tun, A., et al. (2020). "Heavy Metals in the Soils of Placer Small-Scale Gold Mining Sites in Myanmar." Journal of Health and Pollution **10**: 200911.

USEPA. (1989). Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A): United State Environmental Protection Agency.

USEPA. (1991). Risk assessment guidance for superfund, volume II: Human health evaluation manual, supplemental guidance, "Standard default exposure factors": United States Environmental Protection Agency

Wagesho, Y. and B. S. Chandravanshi (2015). "Levels of essential and non-essential metals in ginger (Zingiber officinale) cultivated in Ethiopia." SpringerPlus **4**: 107-107.

Wang, S., et al. (2021). "Source and Health Risk Assessment of Heavy Metals in Soil–Ginger System in the Jing River Basin of Shandong Province, North China." International Journal of Environmental Research and Public Health **18**(13): 6749.

World Health Organisation (WHO), 1989. Report of 33rd meeting, Joint FAO/WHO Joint Expert Committee on Food Additives, Toxicological evaluation of certain food additives and contaminants No. 24, International Programme on Chemical Safety, WHO, Geneva.

WHO. (2007). Health risks of heavy metals from long-range transboundary air pollution. World Health Organization.

WHO. (2010). Exposure to cadmium: a major public health concern. In. World Health Organization Geneva.

FAO-WHO. 2015. General standard for contaminants and toxins in food and feed (GSCTFF). Codex Alimentarius Commission. Available: www.fao. org/input/download/standards/17/ CXS_193e_2015. pdf

WorldData.info. (2022). Average sizes of men and women. Accessed 14 June 2022 from https://www.worlddata.info/averagebodyheight.phphttps://www.worlddata.info/average-bodyheight.php

Yamane, T. (1967). Statistics: An introductory analysis.

Zaidi, M. I., et al. (2005). "The heavy metal concentration along roadside trees of Quetta and its effects on public health." Journal of Applied Sciences **5**(4): 708-711.

"สถิติทางการทะเบียน" [Registration statistics]. *bora.dopa.go.th*. Department of Provincial Administration (DOPA). December 2019. Retrieved 22 September 2020. Download จำนวนประชากร ปี พ.ศ.2562 - Download population year 2019

APPENDICES

Appendix A : Schedule of the study

<table>
<tr><th colspan="13">Time Frame (Month)</th></tr>
<tr><th rowspan="2">Project procedure</th><th colspan="5">2021</th><th colspan="7">2022</th></tr>
<tr><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>June</th><th>July</th></tr>
<tr><td>1.Literature review and writing Thesis proposal</td><td bgcolor="#FFC000"></td><td bgcolor="#FFC000"></td><td bgcolor="#FFC000"></td><td bgcolor="#FFC000"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.Proposal exam</td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.Ethic consideration from Chulalongkorn University</td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td><td bgcolor="#FFC000"></td><td bgcolor="#FFC000"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.Research tool (Set-up and Pre-test)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td><td></td><td></td><td></td></tr>
<tr><td>5.Data collection</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td><td></td><td></td></tr>
<tr><td>6.Data analysis</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td><td bgcolor="#FFC000"></td><td></td></tr>
<tr><td>7.Discussion report writing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td><td></td></tr>
<tr><td>8.Thesis defense</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td></tr>
<tr><td>9.Thesis submission</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="#FFC000"></td></tr>
</table>

Appendix B : Certificate of Approval

The Research Ethics Review Committee for Reseach Involving Human Research Participants, Group I, Chulalongkorn University

Chamchuri 1 Building, 2nd Floor, 254 Phayathai Road, Pathumwan, Bangkok 10330 Thailand

Telephone: 02-218-3202, 02-218-3049 Email: eccu@chula.ac.th

COA No. 084/65

Certificate of Approval

Study Title No. 650030 : HEALTH RISK ASSESSMENT OF BURMESE RELATED TO HEAVY METALS CONTAMINATION IN GINGER FROM LOCAL MARKETS IN MYANMAR AND THAILAND

Principal Investigator : Ms. May Ko Ko

Place of Proposed Study/institution : Graduate School, Chulalongkorn University

The Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University, Thailand, has approved constituted in accordance with Belmont Report 1979, Declaration of Helsinki 2013, Council for International Organizations of Medical Sciences (CIOM) 2016, Standards of Research Ethics Committee (SREC) 2017, and National Policy and guidelines for Human Research 2015.

Signature Prida Tasanapradit

(Associate Prof. Prida Tasanapradit)

Chairman

Signature Raveenan Mingpakanee

(Assistant Prof. Dr. Raveenan Mingpakanee)

Secretary

Date of Approval : 4 April 2022

Approval Expire date : 3 April 2023

The approval documents including:

1. Participant Information Sheet and Consent Form
2. Research proposal
3. Researcher
4. Research instruments/tools

Conditions

The approved investigator must comply with the following conditions:

1. It's unethical to collect data of research participants before the project has been approved by the committee.

2. The research/project activities must end on the approval expired date. To renew the approval, it can be applied one month prior to the expired date with submission of progress report.

3. Strictly conduct the research/project activities as written in the proposal.

4. Using only the documents that bearing the RECCU's seal of approval: research tools, information sheet, consent form, invitation letter for research participation (if applicable).

5. Report to the RECCU for any serious adverse events within 5 working days.

6. Report to the RECCU for any amendment of the research project prior to conduct the research activities.

7. Report to the RECCU for termination of the research project within 2 weeks with reasons.

8. Final report (AF 01-15) and abstract is required for a one year (or less) research/project and report within 30 days after the completion of the research/project.

9. Research project with several phases; approval will be approved phase by phase, progress report and relevant documents for the next phase must be submitted for review.

10. The committee reserves the right to site visit to follow up how the research project being conducted.

11. For external research proposal the dean or head of department oversees how the research being conducted

The Research Ethics Review Committee for Research Involving Human Research Participants Group I

Digital Certificate

Study Title No. 650030

Date of Approval 04 Apr 2022

Approval Expire date 03 Apr 2023

Appendix C: Questionnaire (English version)

Screening Questions (English Version)

Participant Code …………….

1. Are you a participant within the age range of 18-60 years?
   ☐ YES ☐ NO

2. Can you read and write in Burmese?
   ☐ YES ☐ NO

3. Are you willing to participate in this survey?
   ☐ YES ☐ NO

4. Do you eat ginger?
   ☐ YES ☐ NO

5. Do you have any allergies to ginger or goods that contain ginger?
   ☐ YES ☐ NO

6. Do you eat ginger at least 1 time per week?
   ☐ YES ☐ NO

7. Have you lived here for at least 1 year?
   ☐ YES ☐ NO

8. Do you have a mental illness?
   ☐ YES ☐ NO

The Research Ethics Review Committee for Research Involving Human Research Participants Group 1

Project Number 650030
Date of approval 04 Apr 2022
Expire date 03 Apr 2023
1

Questionnaire (English Version)

Participant Code:…………

Part I : Socio-demographic information

1. Gender ☐ Male ☐ Female
2. Age ……………….. years
3. Body weight ……………. Kilogram (kg)
4. Height ………………….. Centimeters (cm)
5. Education level (check only one item)
    - Lower than primary school
    - Primary school
    - Secondary school
    - High school
    - Bachelor or Higher Degree

6. How many family members in your family?

    ……………. persons

7. Occupation

☐ Student ☐ Government officer ☐ Employee ☐ Farmer ☐ State enterprise

8. Do you smoke?
    - ☐ Yes
    - ☐ No
    - ☐ Ex-smoker

9. Do you drink alcoholic beverages?
    - ☐ Yes
    - ☐ No
    - ☐ Ex- drinker

10. How long have you been living here?

…………………… year(s)

Part II Consumption of ginger

11. How often do you usually eat ginger?

☐ 2-4 times a week

☐ 5-6 times a week

☐ Every day, one time a day

☐ Every day, twice a day

☐ Every day, more than twice a day

12. How do you usually eat ginger?

☐ Raw (without any addition)

☐ As an ingredient in curry cooking

☐ Ginger salad

☐ Juices/beverages/smoothies

☐ Ginger tea

☐ In a hot meal/soup

13. How many grams of ginger do you eat a day?

……… gram(s)

1piece of ginger (around 4 inches) approximately 70g

1piece of ginger (around 3 inches) approximately 50g

1piece of ginger (around 2 inches) approximately 40g

14. How many grams of ginger do you usually add to one curry?

……………gram (s)

1piece of ginger (around 4 inches) approximately 70g

1piece of ginger (around 3 inches) approximately 50g

1piece of ginger (around 2 inches) approximately 40g

Part III Belief towards consumption of ginger

15.	YES	NO	NOT SURE
Ginger as a source of nutrients	☐	☐	☐
Consumption of ginger improves health	☐	☐	☐
Consumption of ginger prevents cancer, heart disease, stroke and obesity	☐	☐	☐
Eating them along with meals is delightful and can make the food tasty	☐	☐	☐
When I'm sick, I consume ginger to get better and avoid being sick.	☐	☐	☐

Part IV. Adverse Health Symptoms

16. Have you ever experienced the following diseases during the last 3 months?

Acute Health Symptoms	Chronic Health Symptoms
☐ Headache	☐ Weakness
☐ Muscular Pain	☐ Pain in back and limbs
☐ Vomiting	☐ Joint pains
☐ Diarrhea	☐ Shyness
☐ Hair loss	☐ Forgetfulness
☐ Skin rashes	☐ Nervousness
	☐ Irritability

17. Have you ever experienced the following diseases during the last 12 months?

Acute Health Symptoms	Chronic Health Symptoms
□ Headache	□ Weakness
□ Muscular Pain	□ Pain in back and limbs
□ Vomiting	□ Joint pains
□ Diarrhea	□ Shyness
□ Hair loss	□ Forgetfulness
□ Skin rashes	□ Nervousness
	□ Irritability

Appendix D : Questionnaire (Myanmar version)

Screening Questions (Myanmar Version)

သုတေသနတွင် ပါဝင်သူ၏ ကုတ်နံပါတ်.............

၁။ သင်သည် အသက် 18 မှ 60 နှစ် အတွင်း ပါဝင်သူလား။

☐ ဟုတ်ပါသည် ။ ☐ မဟုတ်ပါ။

၂ ။ မြန်မာဘာသာဖြင့် ရေးနိုင်ဖတ်နိုင်ပါသလား။

☐ လုပ်နိုင်ပါသည် ။ ☐ မလုပ်နိုင်ပါ ။

၃ ။ ဤစစ်တမ်းတွင် သင်ပါဝင်ရန် ဆန္ဒရှိပါသလား။

☐ ရှိပါသည် ။ ☐ မရှိပါ ။

၄ ။ သင် ဂျင်းစားလား။

☐ စားပါသည်။ ☐ မစားပါ ။

၅ ။ သင့်တွင် ဂျင်း သို့မဟုတ် ဂျင်းပါဝင်သော ပစ္စည်းများနှင့် ဓာတ်မတည့်မှု တစ်ခုခုရှိပါသလား။

☐ ရှိပါသည် ။ ☐ မရှိပါ ။

၆ ။ သင်တစ်ပတ်ကို အနည်းဆုံး တစ်ကြိမ် ဂျင်းစားလား ။

☐ စားပါသည် ။ ☐ မစားပါ ။

၇။ သင်သည် ဤနေရာမှာ အနည်းဆုံး ၁ နှစ် နေထိုင်သူ ဖြစ်ပါသလား။

☐ ဖြစ်ပါသည် ။ ☐ မဖြစ်ပါ ။

Questionnaire (Myanmar Version)

မေးခွန်းလွှာ (မြန်မာ)

သုတေသနတွင် ပါဝင်သူ၏ ကုတ်နံပါတ်..........

အပိုင်း (၁) လူမှုရေးရာဆိုင်ရာ သတင်းအချက်အလက်

၁။ လိင်အမျိုးအစား ☐ ကျား ☐ မ

၂။ အသက် .... နှစ်

၃။ကိုယ်အလေးချိန် .... ကီလိုဂရမ် (kg)

၄။ အရပ်အမြင့် .... စင်တီမီတာ (cm)

၅။ ပညာအရည်အချင်း (အောက်ပါတို့မှ တစ်ခုကိုသာ အမှန်ခြစ်ပါ။)

- ☐ မူလတန်းအောက်
- ☐ မူလတန်း
- ☐ အလယ်တန်း
- ☐ အထက်တန်း
- ☐ ဘွဲ့ရ

၆ ။ သင့်မိသားစုဝင် ဘယ်နှစ်ယောက် ရှိပါသလဲ ။

.... ဦး

၇ ။ အလုပ်အကိုင်

☐ ကျောင်းသား ☐ အစိုးရဝန်ထမ်း ☐ ကုမ္ပဏီဝန်ထမ်း ☐လယ်သမား

☐နိုင်ငံပိုင်လုပ်ငန်း

၈ ။ သင်ဆေးလိပ်သောက်ပါသလား ။

- သောက်ပါသည် ။
- မသောက်ပါ ။
- အရင်က သောက်ပါသည် ။

၉ ။ သင်အရက်သောက်ပါသလား ။

- သောက်ပါသည် ။
- မသောက်ပါ ။
- အရင်က သောက်ပါသည် ။

၁၀။ သင်ဒီမှာနေတာ ဘယ်လောက်ကြာပြီလဲ။

.... နှစ်

အပိုင်း (၂) ဂျင်းစားသုံးမှု

၁၁ ။ သင် ဂျင်းကို ဘယ်နှစ်ကြိမ်စားလေ့ရှိလဲ။

- တစ်ပတ်လျှင် တစ်ကြိမ်အောက် စားပါသည် ။
- တစ်ပတ်လျှင် ၂-၄ ကြိမ် စားပါသည် ။
- တစ်ပတ်လျှင် ၅-၆ ကြိမ် စားပါသည် ။
- နေ့တိုင်း၊ တစ်နေ့တစ်ကြိမ် စားပါသည် ။
- နေ့တိုင်း၊ တစ်နေ့နှစ်ကြိမ် စားပါသည် ။
- နေ့တိုင်း၊ တစ်နေ့နှစ်ကြိမ် ထက်မက စားပါသည် ။

၁၂ ။ သင် ဂျင်းကို ဘယ်လိုစားလေ့ရှိလဲ။

- အစိမ်းစား ပါသည်။

- ဟင်းချက်ရာတွင် ပါဝင်ပစ္စည်းအဖြစ် သုံးပါသည် ။
- ဂျင်းသုပ် အဖြစ် စားပါသည်။
- ဖျော်ရည် အဖြစ်လုပ်စားပါသည် ။
- ဂျင်းလက်ဖက်ရည် အဖြစ်သောက်ပါသည် ။
- ပူပူနွေးနွေးအစားအစာ / ဟင်းချိုထဲမှာ ထည့်စားပါသည် ။

၁၃။ တစ်နေ့ကို ဂျင်းဘယ်လောက် စားလဲ။

.... ဂရမ်

ဂျင်း ၁ စိတ် (၄ လက်မဝန်းကျင်) ~ ၇၀ ဂရမ်

ဂျင်း ၁ စိတ် (၃ လက်မ ဝန်းကျင်) ~ ၅၀ ဂရမ်

ဂျင်း ၁ စိတ် (၂ လက်မ ဝန်းကျင်) ~ ၄၀ ဂရမ်

၁၄ ။ ဟင်းတစ်ခွက်မှာ ဂျင်းဘယ်နှစ်ဂရမ် ထည့်လေ့ရှိလဲ။

......................ဂရမ်

ဂျင်း ၁ စိတ် (၄ လက်မဝန်းကျင်) ~ ၇၀ ဂရမ်

ဂျင်း ၁ စိတ် (၃ လက်မ ဝန်းကျင်) ~ ၅၀ ဂရမ်

ဂျင်း ၁ စိတ် (၂ လက်မ ဝန်းကျင်) ~ ၄၀ ဂရမ်

အပိုင်း (၃) ဂျင်းစားသုံးမှုနှင့် ပတ်သက်သော ယုံကြည်ချက်

၁၅။	မှန်ပါသည်	မဟုတ်ပါ
အာဟာရအဖြစ် ဂျင်းကို စားပါသည်။		
ဂျင်းကို စားသုံးခြင်းက ကျန်းမာရေးကို		

တိုးတက်စေပါတယ်။

ဂျင်းစားသုံးခြင်းသည် ကင်ဆာ၊ နှလုံးရောဂါ၊

လေဖြတ်ခြင်းနှင့် အဝလွန်ခြင်းတို့ကို ကာကွယ်ပေးသည်။

ဂျင်းကို အစားအစာများနှင့်အတူ စားသုံးခြင်းသည်

နှစ်သက်ဖွယ်ကောင်းပြီး အစားအစာကို အရသာရှိစေနိုင်သည်။

နေမကောင်းတဲ့အခါ ဂျင်းကို နေကောင်းအောင် စားသုံးပါတယ်။

အပိုင်း (၄) ဆိုးရွားသောကျန်းမာရေးလက္ခဏာများ

၁၆ ။ ပြီးခဲ့သော ၃ လအတွင်း အောက်ပါရောဂါများကို သင်ကြုံတွေ့ဖူးပါသလား။

ပြင်းထန်သောကျန်းမာရေးလက္ခဏာများ	နာတာရှည်ကျန်းမာရေးလက္ခဏာများ
☐ ခေါင်းကိုက်ခြင်း။ ☐ ကြွက်သားနာကျင်မှု ။ ☐ အန်ခြင်း။ ☐ ဝမ်းလျှောခြင်း။ ☐ ဆံပင်ကျွတ်ခြင်း။ ☐ အရေပြားအဖုများဖြစ်ခြင်း ။	☐ အားနည်းနုံးခွေခြင်း။ ☐ နောက်ကျောတက်ခြင်းနှင့်ခြေလက်များတွင်နာကျင်မှု။ ☐ အဆစ်အမြစ်များနာကျင်ကိုက်ခဲခြင်း။ ☐ ရှက်ကြောက်လွယ်ခြင်း။ ☐ သတိမေ့လျော့ခြင်း ။ ☐ စိုးရိမ်ပူပန်လွယ်ခြင်း ။ ☐ စိတ်ဂဏာမငြိမ်ဖြစ်ခြင်း ။

၁၇။ ပြီးခဲ့သော ၁၂ လအတွင်း အောက်ပါရောဂါများကို သင်ကြုံတွေ့ဖူးပါသလား။

ပြင်းထန်သောကျန်းမာရေးလက္ခဏာများ	နာတာရှည်ကျန်းမာရေးလက္ခဏာများ
□ ခေါင်းကိုက်ခြင်း။ □ ကြွက်သားနာကျင်မှု ။ □ အန်ခြင်း။ □ ဝမ်းလျှောခြင်း။ □ ဆံပင်ကျွတ်ခြင်း။ □ အရေပြားအဖုများဖြစ်ခြင်း ။	□ အားနည်းနုံးခွေခြင်း။ □ နောက်ကျောတက်ခြင်းနှင့်ခြေလက်များတွင်နာကျင်မှု။ □ အဆစ်အမြစ်များနာကျင်ကိုက်ခဲခြင်း။ □ ရှက်ကြောက်လွယ်ခြင်း။ □ သတိမေ့လျော့ခြင်း ။ □ စိုးရိမ်ပူပန်လွယ်ခြင်း ။ □ စိတ်ဂဏာမငြိမ်ဖြစ်ခြင်း ။

Appendix E : Research Participant Information Sheet and Consent Form (English version)

Research Participant Information Sheet and Consent Form

Title of research project : "Health risk assessment of Burmese related to heavy metals contamination in ginger from local markets in Myanmar and Thailand"

Principal researcher's name: Ms. May Ko Ko Position: Master student

Office address : International Program in Hazardous Substance and Environmental Management, CU Research Building, 9th Floor, Chulalongkorn University, Phayathai Rd, Wang Mai, Pathumwan, Bangkok 10330 Thailand

Home address : Ratchaprarop Tower Mansion (room 1018), 99 Ratchaprarop 14, Makkasan, Bangkok 10400

Telephone (office) .... Telephone (home) ....

Cell phone : 0640965793 E-mail: maykoko203@gmail.com

Sponsor/Funding organization (if any)..

1. Introduction

My name is May Ko Ko, a master's degree student at Chulalongkorn University in Bangkok, Thailand. As a requirement to fulfill the academic requirements of the university, we are required to do research and submit a thesis. I am interested in human health risks related to environmental pollution, so I decided to do a health risk assessment of Burmese related to heavy metal contamination in ginger from local markets in Myanmar and Thailand.

You are cordially invited to take part in this study, which will involve 800 Burmese participants from Thailand and Myanmar who are 18 to 60 years old, can communicate in Burmese, eat ginger at least once a week, and are currently residing in the study areas. Furthermore, your responses are kept private.

You can continue reading this information sheet and, after balancing the benefits and potential risks, you can decide whether or not to continue with the study. Please do not hesitate to ask the researcher anything before, during, or after the study if you have any questions.

2. Objectives of the research

   i. To determine the concentrations of heavy metals (As, Cu, Ni, Cd, Cr, and Pb) in ginger (Zingiber officinale Roscoe) from local markets of Thailand and Myanmar.

   ii. To assess the health risks of the participants who were orally exposed to the heavy metals in ginger from Thailand and Myanmar.

3. Contents of the questionnaire

The research involves filling out an online questionnaire related to ginger consumption which will take about 5-10 minutes. There are four sections of the questionnaire which are (1) socio-demographic factors, (2) frequency and amount of ginger consumption, (3) Belief towards consumption of ginger, and (4) Adverse Health Symptoms. The whole questionnaire uses filling numbers, answering yes/no, ticking the right answers in multiple-choice questions for the ease of the participants in response to the questionnaire. Furthermore, your responses are kept private.

The participants need to pass the screening procedure before answering the real questionnaire. In the screening process, they will be asked questions about whether they eat ginger or if they are between the ages of 18 and 60. Those who do not meet the required standards after the screening process can no longer answer the questionnaire.

4. **There is no risk or harm in participating in this research questionnaire. Participants' responses will be kept anonymous. However, some individuals may be hesitant to respond to the questions asking about the adverse health symptoms that could be linked to the consumption of heavy metals contaminated ginger. Please do not feel worry for those questions concerning negative health symptoms; it doesn't mean that you're in any danger. I appreciate you taking the time to complete the questionnaire.**

5. Procedure of taking consent

After reading the information about the research at the beginning of the online questionnaire and receiving further explanation on the unclear part of the questionnaire from the researcher, if necessary, the participant will be required to give informed consent if they are older than 18 years old and willing to participate in the study.

If you do not want to participate in this study, you do not need to give consent and you do not need to explain anything as a reason. You can withdraw from the study at any time as you wish with no need to give a reason and it will not have any negative impact upon the participants.

6. **Benefits**

The study may not provide direct benefit to you; however, this will contribute valuable information regarding the health risks related to the consumption of heavy metal contaminated vegetables or herbs.

7. **Confidentiality**

Any information that is linked to you will be kept confidential. Your names or other identifying information will not be mentioned in the report or summaries of the study. The final report can be available from the researcher and this report will be used for only fulfillment of the academic requirement of the Master's degree. All the data will be kept confidential and will not disclose to anyone. Once the study is completed, all data and participant information will be destroyed.

There is nothing to give participants for taking part in this research other than heartfelt thanks. Your cooperation will be extremely beneficial to my research.

Participation in this study is **voluntary** and the participant has the **right to deny** and/or **withdraw** from the study at any time, no need to give any reason, and there will be no bad impact upon that participant. The researcher can be reached at any time at this address (Ratchaprarop Tower Mansion, room 1018, 99 Ratchaprarop 14, Makkasan, Ratchathewi, Bangkok 10400, telephone: 0640965793, and email: maykoko203@gmail.com) if you have any questions or would like additional information. If the researcher has new information regarding benefit on risk/harm, participants will be informed as soon as possible. If the researcher does not perform upon participants as indicated in the participant information sheet and consent form, participants can report the incident to the Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University (RECCU) Jamjuree 1 Bldg., 254 Phyathai Rd., Patumwan district, Bangkok 10330, Thailand, Tel./Fax. 0-2218-3202, 0-2218-3049 E-mail: eccu@chula.ac.th.

The Research Ethics Review Committee for Research Involving Human Research Participants
Group 1

Project Number 650030
Date of approval 04 Apr 2022
Expire date 03 Apr 2023

I have read the objectives of this research, what I will engage in details, the benefits, and risk (if there is any) of this research, and the rights and duties of the participants. I have been given the contact details of the researcher. I have read the information sheet and the researcher has explained me and guaranteed to act as indicated in the information sheet. I clearly understand with satisfaction. I willingly agree to participate in this research and respond to the questionnaire which focuses on frequency and amount of ginger consumption which will take about 5-10 minutes and will not contain any name or identifying information of me.

I have the right to withdraw from the research at any time as I wish with no need to give any reason. This withdrawal will not have any negative impact on me.

If I am not treated as indicated in the information sheet, I can report to the Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University (RECCU) Jamjuree 1 Bldg., 254 Phyathai Rd., Patumwan district, Bangkok 10330, Thailand, Tel./Fax. 0-2218-3202, 0-2218-3049 E-mail: eccu@chula.ac.th.

I have been explained by researcher and understand all the details provided. And I voluntarily signed my name to enroll in this project and receive a copy of this document.

Sign..	Sign..
(May Ko Ko)	(..)
Principal investigator	Research participant
Date.....23../......03......./.......2022............	Date......./............/..................
Sign..	Sign..
(..)	(..)
Witness	Parent or guardian of participant (If needed)
Date......./............/..................	Date......./............/..................

The Research Ethics Review Committee for Research Involving Human Research Participants Group I

Project Number 650030
Date of approval 04 Apr 2022
Expire date 03 Apr 2023

Appendix F : Research Participant Information Sheet and Consent Form (Myanmar version)

သုတေသနပါဝင်သူအချက်အလက်စာရွက်နှင့်သဘောတူညီချက်ပုံစံ

ခေါင်းစဉ် - မြန်မာနိုင်ငံနှင့် ထိုင်းနိုင်ငံရှိ ပြည်တွင်းဈေးကွက်များမှ ဂျင်းတွင် သတ္တု ညစ်ညမ်းမှုနှင့် ပတ်သက်သည့် ကျန်းမာရေးအန္တရာယ် အကဲဖြတ်ချက်

သုတေသန ပြုလုပ်သူ - မေကိုကို **ရာထူး- မဟာကျောင်းသား**

ရုံးလိပ်စာ : International Program in Hazardous Substance and Environmental Management, CU Research Building, 9th Floor, Chulalongkorn University, Phayathai Rd, Wang Mai, Pathumwan, Bangkok 10330 Thailand

အိမ်လိပ်စာ : Ratchaprarop Tower Mansion (room 1018) , 99 Ratchaprarop 14, Makkasan, Bangkok 10400

ဖုန်း- +၆၆၆၀၆၄၀၉၆၅၇၉၃ **အီးမေးလ်:** maykoko203@gmail.com

<u>၁ ။ နိဒါန်း</u>

ကျွန်မသည် ထိုင်းနိုင်ငံ ဘန်ကောက်မြို့ ချူလာလောင်ကွန်း တက္ကသိုလ်တွင် မဟာဘွဲ့ ကို ဆည်းပူးနေသော ကျောင်းသူ တစ်ယောက် ဖြစ်ပါသည်။ တက္ကသိုလ်၏ ပညာရေးဆိုင်ရာ လိုအပ်ချက်များကို ဖြည့်ဆည်းရန် လိုအပ်ချက်တစ်ခုအနေဖြင့် သုတေသနတစ်ခုပြုလုပ်ပြီး စာတမ်းတစ်ခုတင်သွင်းရန် လိုအပ်ပါသည်။ သဘာဝပတ်ဝန်းကျင် ညစ်ညမ်းမှုနှင့် ပတ်သက်သော လူသားတို့၏ ကျန်းမာရေး အန္တရာယ်များကို ကျွန်ုပ် အမှန်တကယ် စိတ်ဝင်စားပါသည်၊ ထို့ကြောင့် ကျွန်မ၏ ဘွဲ့ရရန် ပြုစုနေသော မဟာကျမ်းမှာ မြန်မာနိုင်ငံနှင့် ထိုင်းနိုင်ငံရှိ ပြည်တွင်းဈေးကွက်များမှ ဂျင်းများတွင် သတ္တုအမြောက်အများ ညစ်ညမ်းမှုနှင့် ပတ်သက်သည့် ကျန်းမာရေးအန္တရာယ် အကဲဖြတ်မှု အကြောင်း ဖြစ်ပါသည်။

အသက် ၁၈ နှစ်မှ၆၀ နှစ်ကြားရှိ မြန်မာဘာသာဖြင့် ပြောဆိုဆက်ဆံနိုင်ပြီး တစ်ပတ်လျှင် အနည်းဆုံး တစ်ကြိမ် ဂျင်းစားသုံးနိုင်ပြီး ထိုင်းနိုင်ငံနှင့် မြန်မာနိုင်ငံမှာ လက်ရှိနေထိုင်လျက်ရှိသော မြန်မာနိုင်ငံသား ၈၀၀ ပါဝင်မည့် ဤလေ့လာမှုတွင် ပါဝင်ရန် လေးစားစွာ ဖိတ်ကြားအပ်ပါသည်။ ထို့အပြင်

သင်၏တုံ့ပြန်မှုများကို လျှို့ဝှက်ထားမည်ဖြစ်သည်။ အောက်တွင် ဆက်လက်ဖော်ပြမည့် အချက်အလက်များကို ဖတ်ပြီး မရှင်းလင်းသည်ကို မေးမြန်းနိုင်ပါသည်။ ဤသုတေသနတွင် ပါဝင်/မပါဝင် လွတ်လပ်စွာ ဆုံးဖြတ်နိုင်ပါသည်။

<u>၂။ သုတေသန၏ရည်ရွယ်ချက်များ</u>

၁ ။ ထိုင်းနှင့်မြန်မာပြည်တွင်းဈေးကွက်များမှ ဂျင်း (Zingiber officinale Roscoe) တွင် သတ္တုများ (As, Cu, Ni, Cd, Cr, and Pb) ၏ ပါဝင်မှုပမာဏကို ဆုံးဖြတ်ရန်။

၂။ ထိုင်းနိုင်ငံနှင့် မြန်မာနိုင်ငံတို့မှ ဂျင်းတွင် ရောနှောပါဝင်နေသော သတ္တုဓာတ်များကို စားသုံးမိသူများ၏ ကျန်းမာရေးအန္တရာယ်များကို အကဲဖြတ်ရန်။

<u>၃။ မေးခွန်းလွှာပါ အကြောင်းအရာများ</u>

သုတေသနတွင် ဂျင်းစားသုံးမှုနှင့် ပတ်သက်သည့် မေးခွန်းလွှာကို ဖြည့်သွင်းရန် ၅ မိနစ်မှ ၁၀ မိနစ်ခန့် ကြာနိုင်သည်။ မေးခွန်းလွှာတွင် ပါရှိသော အပိုင်းလေးပိုင်းမှာ (၁) လူမှုဘဝဆိုင်ရာအချက်များ၊ (၂) ဂျင်းစားသုံးမှုပမာဏနှင့် အကြိမ်အရေအတွက်၊ (၃) ဂျင်းစားသုံးမှုအပေါ် ယုံကြည်ချက်နှင့် (၄) ဆိုးရွားသော ကျန်းမာရေး လက္ခဏာများဖြစ်သည်။ မေးခွန်းလွှာတစ်ခုလုံးတွင် နံပါတ်များကို ဖြည့်သွင်းခြင်း၊ ဟုတ်/မဟုတ် ဖြေဆိုခြင်း၊ ရွေးချယ်မှုမျိုးစုံသောမေးခွန်းများတွင် မှန်ကန်သောအဖြေများကို အမှတ်အသားပြုရသည်များ ပါဝင်ပါသည် ။မေးခွန်းလွှာကိုဖြေဆိုရာတွင် ပါဝင်သူများလွယ်ကူစေရန်အတွက် သင့်အဖြေများသည် အမည်မသိဖြစ်သည်။

ပါဝင်သူများသည် မေးခွန်းလွှာကို မဖြေဆိုမီ စိစစ်ခြင်းလုပ်ငန်းစဉ်ကို ကျော်လွှန်ရန်လိုအပ်ပါသည်။ စိစစ်ရေးလုပ်ငန်းစဉ်တွင် ၎င်းတို့သည် ဂျင်းစားခြင်းရှိမရှိ သို့မဟုတ် အသက် ၁၈ နှစ်မှ၆၀ နှစ်ကြားရှိမရှိ မေးခွန်းများမေးမြန်းမည်ဖြစ်သည်။ စိစစ်မှုလုပ်ငန်းစဉ်ပြီးနောက် လိုအပ်သည့်စံနှုန်းများနှင့် မကိုက်ညီသူများသည် မေးခွန်းလွှာကို ဖြေဆိုနိုင်တော့မည်မဟုတ်ပေ။

၄။ ဤသုတေသနမေးခွန်းလွှာတွင် ပါဝင်ရာတွင် အန္တရာယ် သို့မဟုတ် ထိခိုက်မှု မရှိပါ။ ပါဝင်သူများ၏ တုံ့ပြန်ချက်များကို အမည်ဝှက်ထားပါမည်။ သို့သော် အချို့သောလူများသည် မသန့်ရှင်းသော ဂျင်းကို စားသုံးခြင်းနှင့် ဆက်စပ်နိုင်သည့် ဆိုးရွားသော ကျန်းမာရေး လက္ခဏာများအကြောင်း မေးမြန်းသည့် မေးခွန်းများကိုတုံ့ပြန်ရန်ချီတုံချတုံဖြစ်နိုင်ပါသည်။ကျန်းမာရေးလက္ခဏာများနှင့်ပတ်သက်သော အဆိုပါမေးခွန်းများအတွက် စိတ်မပူပါနှင့်။ သင်သည် မည်သည့်အန္တရာယ်မှ ကျရောက်နေသည်ဟု မဆိုလိုပါ။ မေးခွန်းလွှာကို ဖြေဆိုရန် အချိန်ပေး၍ ကျေးဇူးတင်ပါသည်။

<u>၅။ သဘောတူညီချက် ရယူခြင်း</u>

ဤ အသိ ပေးစာတွင် ပါဝင်သော အချက်အလက်များနှင့် မေးခွန်းများကို ဖတ်ပြီးနောက် သင်သည် အသက် ၁၈ နှစ်ပြည့်ပြီးသူဖြစ်ပါက ဤသုတေသန တွင် ပါဝင်ရန် သဘောတူကြောင်း လက်မှတ်ထိုးရပါမည်။ မပါဝင်လိုပါကလည်း မည့်သည့် အကြောင်းပြချက်မျှ ပေးစရာ မလိုဘဲ မပါဝင်နိုင်ပါသည်။ ထို့အတွက် မည်သို့မျှ အကျိုးသက်ရောက် မည် မဟုတ်ပါ။

<u>၆။ သုတေသန၏ အကျိုးကျေးဇူးများ</u>

ဤလေ့လာမှုသည် သင့်အတွက် တိုက်ရိုက်အကျိုးရှိမည်မဟုတ်သော်လည်း အန္တရာယ်ရှိသော သတ္တုများ ပါဝင်နေသော ဟင်းသီးဟင်းရွက် သို့မဟုတ် ဟင်းခတ်အပင်များ စားသုံးမှုနှင့် ဆက်စပ်သော ကျန်းမာရေးအန္တရာယ်များနှင့် စပ်လျဉ်းသည့် အဖိုးတန်အချက်အလက်များကို ပံ့ပိုးပေးမည်ဖြစ်သည်။

၇။ အချက်အလက်များကို လျှို့ဝှက် ထိန်းသိမ်းထားမှုများ

ဤ သုတေသနတွင် ဖြေဆိုထားသော အချက်အလက်များကို သုတေသန ပြုလုပ်သူမှလွဲ၍မည်သူ့ကိုမျှ ဖော်ပြသွားမည် မဟုတ်ပါ။ ဤ သုတေသနတွင်လည်း သင်၏ နာမည်နှင့် သင်ဟု ဖော်ပြနိုင်သော အချက်အလက်များကို ဖော်ပြသွားမည် မဟုတ်ပါ။ လေ့လာမှုပြီးသည်နှင့် ဒေတာနှင့် ပါဝင်သူ အချက်အလက်အားလုံးကို ဖျက်ဆီးပစ်မည်ဖြစ်သည်။

ဤသုတေသနတွင် ပါဝင်ခဲ့ကြသည့် ပါဝင်သူများကို စေတနာဖြင့် ကျေးဇူးတင်ရှိမှတပါး အခြားဘာမျှပေးစရာမရှိပါ။ သင်၏ပူးပေါင်းဆောင်ရွက်မှုသည် ကျွန်ုပ်၏သုတေသနအတွက် အလွန်အကျိုးရှိမည်ဖြစ်သည်။

ဤလေ့လာမှုတွင် ပါဝင်ခြင်းမှာ ဆန္ဒအလျောက်ဖြစ်ပြီး ပါဝင်သူသည် လေ့လာမှုမှ အချိန်မရွေး ငြင်းပယ်ခြင်းနှင့်/သို့မဟုတ် နုတ်ထွက်ခွင့်၊ မည်သည့်အကြောင်းပြချက်ကိုမျှ ပေးဆောင်ရန်မလိုအပ်ဘဲ နှုတ်ထွက်နိုင်ပါသည်။သုတေသီအား မေးမြန်းလိုသည်များရှိပါက၊ ဤလိပ်စာဖြင့် (Ratchapraprop Tower Mansion၊ အခန်း 1018၊ 99 Ratchaprarop 14၊ Makkasan၊ Ratchathewi၊ Bangkok 10400၊ တယ်လီဖုန်း- 0640965793၊ နှင့် email: maykoko203@gmail.com) အချိန်မရွေး ဆက်သွယ်နိုင်ပါသည်။ အကယ်၍ သုတေသီသည် သုတေသနနှင့် ပတ်သက်သည့် အချက်အလက်အသစ်များရှိပါက ပါဝင်သူများကို တတ်နိုင်သမျှ အမြန်ဆုံး အကြောင်းကြားပါမည်။ အကယ်၍ သုတေသီသည် ပါဝင်သူအချက်အလက်စာရွက်နှင့် သဘောတူညီချက်ပုံစံတွင် ဖော်ပြထားသည့်အတိုင်း မလုပ်ဆောင်ပါက၊ ပါဝင်သူများသည် အဆိုပါဖြစ်ရပ်အား သုတေသနဆိုင်ရာ ကျင့်ဝတ်ပြန်လည်သုံးသပ်ရေးကော်မတီ၊ Group I၊ Chulalongkorn University (RECCU) Jamjuree 1 Bldg.၊ 254 Phyathai Rd., Patumwan District, Bangkok 10330, Thailand, Tel./Fax. 0-2218-3202, 0-2218-3049 E-mail: eccu@chula.ac.th သို့ဆက်သွယ် တိုင်ကြားနိုင်ပါသည်။

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ကျွန်ုပ်သည် ဤသုတေသနနှင့် ပတ်သက်သော ရည်ရွယ်ချက် အသေးစိတ်လုပ်ငန်းစဉ်၊ ကောင်းကျိုး၊ ဆိုးကျိုးများ ၊ အခွင့်အရေးများ နှင့် တာဝန်များကို သိရှိပြီး ဖြစ်ပါသည်။ ကျွန်ုပ်သည် သုတေသနပြုလုပ်သူ၏ ဆက်သွယ်ရန် အချက်အလက် များနှင့် အသိပေးစာကို သိရှိပြီး ဖြစ်ပါ သည်။ သုတေသနပြုလုပ်သူသည် ထိုအသိပေးစာကို ရှင်းပြ ပြီး ထိုစာတွင် ဖော်ပြထားသည့်အတိုင်း လိုက်နာပါမည်ဟု ကတိပြုပါသည်။ ကျွန်ုပ် သည် သေသေချာချာနားလည်ပြီး ဤ သုတေသနတွင် လိုလိုလားလားပါဝင်ပါမည်။ဤသုတေသနတွင်ပါဝင်သောမေးခွန်းများသည်ဂျင်းစားသုံးမှုအကြိမ်ရေနှင့် ပမာဏအကြောင်း အဓိကထား၍ မေးထားပြီး ကျွန်ုပ်၏ နာမည်နှင့် အခြား ကျွန်ုပ်ဖြစ်ကြောင်း ဖော်ပြနိုင်သော အချက်အလက်များ လုံးဝမပါဝင်ပါ။ မေးခွန်းများကို ဖြေဆိုချိန် ၅-၁၀ မိနစ်ခန့် ကြာမြင့်နိုင်ပါသည်။

ကျွန်ုပ်သည် ဤ သုတေသနမှ အချိန်မရွေး မည်သည့် အကြောင်းပြချက်မှ ပေးစရာ မလိုဘဲ နှုတ်ထွက်နိုင် ပြီး ထိုသို့ နှုတ်ထွက်ခြင်းသည် ကျွန်ုပ် အပေါ် မကောင်းသော အကျိုးသက်ရောက်မှု မရှိစေပါ။ အကယ်၍ ကျွန်ုပ်သည် အသိပေးစာတွင် ဖော်ပြထားသည့် အတိုင်း ဆောင်ရွက်ခြင်း မရှိသည်ကို တွေ့ရှိပါက ထိုင်းနိုင်ငံ ဘန်ကောက်မြို့ ချူလာလောင်ကွန်း တက္ကသိုလ်ရှိ သုတေသန ကျင့်ဝတ် စိစစ်ရေး ကော်မတီသို့ တယ်လီဖုန်းနံပါတ် ၀-၂၂၁၈-၃၂၀၂ email – eccu@chula.ac.th ကိုဆက်သွယ်တိုင်ကြားနိုင်သည် ။ ကျွန်ုပ် သည် ဤ အသိပေးသဘောတူညီချက်တွင် ပါသော အချက်အလက်များကို ဖတ်ပြီး၍ အသိပေးစာနှင့် သဘောတူညီချက် မိတ္တူကိုလက်ခံရရှိ ပါသည်။ ကျွန်ုပ်သည် ဤသုတေသနတွင် ပါဝင်ရန် အောက်တွင် လက်မှတ်ထိုး၍ သဘောတူပါသည်။

I have been explained by researcher and understand all the details provided. And I voluntarily signed my name to enroll in this project and receive a copy of this document.

Sign..	Sign..
(May Ko Ko)	(..)
Principal investigator	Research participant
Date.....23.../......03......./.......2022............	Date......../............./..................
Sign..	Sign..
(..)	(..)
Witness	Parent or guardian of participant (If needed)
Date......../............./..................	Date......../............./..................

The Research Ethics Review Committee for Research Involving Human Research Participants Group 1

Project Number 650030
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Appendix G : Statistics Analysis Output

Concentration of heavy metals in ginger samples from Simummuang Market, Pathumthani, Bangkok, Thailand

Statistics

		As	Cd	Cr	Cu	Ni	Pb
N	Valid	5	5	5	5	5	5
	Missing	0	0	0	0	0	0
Mean		.00680	.00520	.13160	1.49960	.21620	.10080
Median		.00200	.00400	.10800	1.52200	.23600	.11400
Std. Deviation		.010803	.004764	.075029	.142217	.085213	.075991
Range		.025	.013	.195	.358	.204	.171
Minimum		.001	.000	.058	1.271	.116	.019
Maximum		.026	.013	.253	1.629	.320	.190

Exposure factors of Burmese participants in Bangkok, Thailand

Statistics

		gender	age	weight	height	duration	amount_of_consumption	exposure_frequency
N	Valid	400	400	400	400	400	400	400
	Missing	0	0	0	0	0	0	0
Mean		1.58	30.70	61.02	164.1409	7.38	44.08	365.00
Median		2.00	29.00	61.00	165.0000	6.00	41.00	365.00
Std. Deviation		.495	8.352	7.514	6.46104	4.589	6.545	.000
Variance		.245	69.753	56.463	41.745	21.058	42.843	.000
Range		1	40	38	40.68	20	36	0
Minimum		1	18	44	147.32	1	34	365
Maximum		2	58	82	188.00	21	70	365

Concentrations of heavy metals found in ginger samples from Thiri Mingalar market, Yangon,Myanmar

Statistics

		As	Cd	Cr	Cu	Ni	Pb
N	Valid	5	5	5	5	5	5
	Missing	0	0	0	0	0	0
Mean		.04940	.00040	.29580	1.10580	.20860	.14600
Median		.04700	.00000	.24700	1.09100	.21100	.13800
Mode		.024[a]	.000	.194[a]	.962[a]	.197	.080[a]
Std. Deviation		.024603	.000548	.105687	.153560	.011104	.063336
Variance		.001	.000	.011	.024	.000	.004
Range		.062	.001	.225	.383	.023	.165
Minimum		.024	.000	.194	.962	.197	.080
Maximum		.086	.001	.419	1.345	.220	.245

a. Multiple modes exist. The smallest value is shown

Exposure factors of Burmese participants in Yangon, Myanmar

Statistics

		gender	age	weight	height	duration	amount_of_consumption	exposure_frequency
N	Valid	400	400	400	400	400	400	400
	Missing	0	0	0	0	0	0	0
Mean		1.53	36.94	60.79	163.1392	23.19	44.61	365.00
Median		2.00	36.00	61.00	162.5600	20.00	40.00	365.00
Std. Deviation		.500	12.148	7.475	7.20124	19.664	7.910	.000
Variance		.250	147.573	55.877	51.858	386.684	62.575	.000
Range		1	42	34	33.02	59	40	0
Minimum		1	18	45	147.32	1	30	365
Maximum		2	60	79	180.34	60	70	365

Comparisons of the mean height of Burmese participants from Bangkok, Thailand and Yangon, Myanmar

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Height	Group 1(Thailand)	400	164.1409	6.46104	.32305
	Group 2(Myanmar)	400	163.1392	7.20124	.36006

Independent sample test for the mean height of participants from Bangkok, Thailand and Yangon, Myanmar

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Height	Equal variances assumed	5.873	.016	2.071	798	.039	1.00170	.48374	.05214	1.95126
	Equal variances not assumed			2.071	788.793	.039	1.00170	.48374	.05212	1.95128

Comparison of the mean weight of participants from Bangkok, Thailand and Yangon, Myanmar

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Weight	Group 1(Thailand)	400	61.02	7.514	.376
	Group 2(Myanmar)	400	60.79	7.475	.374

Independent sample test for the mean weight of participants from Bangkok, Thailand and Yangon, Myanmar

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Weight	Equal variances assumed	.095	.758	.432	798	.666	.229	.530	-.811	1.269
	Equal variances not assumed			.432	797.978	.666	.229	.530	-.811	1.269

Comparison of participants' mean duration of living in Bangkok, Thailand and Yangon, Myanmar

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
duration	Group 1(Thailand)	400	7.38	4.589	.229
	Group 2(Myanmar)	400	23.19	19.664	.983

Independent sample test for the mean duration of participants from Bangkok, Thailand, and Yangon, Myanmar

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
duration	Equal variances assumed	881.523	.000	-15.657	798	.000	-15.808	1.010	-17.789	-13.826
	Equal variances not assumed			-15.657	442.329	.000	-15.808	1.010	-17.792	-13.823

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